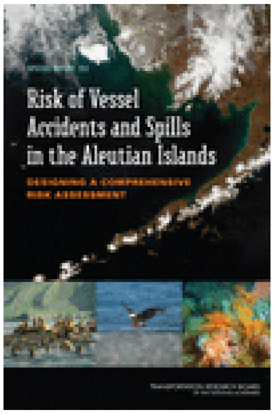
# Free Executive Summary




**Risk of Vessel Accidents and Spills in the Aleutian Islands: Designing a Comprehensive Risk Assessment - Special Report 293**

Committee for Risk of Vessel Accidents and Spills in the Aleutian Islands: A Study to Design a Comprehensive Risk Assessment

ISBN: 978-0-309-11332-8, 202 pages, 8 1/2 x 11, paperback (2008)



*TRB Special Report 293, Risk of Vessel Accidents and Spills in the Aleutian Islands: Designing a Comprehensive Risk Assessment, provides guidance for a comprehensive risk assessment of vessel accidents and spills in the Aleutian Islands. The report examines data related to the risk of oil, chemical, and other hazardous cargo spills from vessel traffic through the Aleutian Islands and identifies key information needed to conduct a comprehensive risk assessment.*

# Summary

Risk assessment is a systematic approach used to evaluate the level of safety of a complex system or operation and to recommend appropriate safety improvement measures. It is an established engineering discipline with application in many industrial enterprises for which safety is a paramount concern, such as nuclear reactors, large chemical plants, and the airline industry. Risk assessment is also widely used in the marine industry by government and private authorities to help manage safe shipping operations. Assessing risk involves addressing three key questions: What can go wrong? How likely is it? and What are the impacts? These questions are organized systematically into discrete steps that involve identifying hazards (or creating risk scenarios), determining the likelihood of their occurrence, and identifying their consequences. The present study applies such classic fundamentals of risk assessment to the question of how to minimize vessel accidents and spills in the Aleutian Islands and recommends an appropriate framework for conducting a comprehensive risk assessment for such events.

The Aleutian Islands are a 1,200-mile chain of small volcanic islands in the North Pacific stretching westward from the Alaska Peninsula to Russia. In addition to their biological, cultural, and ecological significance, these islands have long been politically and economically important. The Aleutians are located along the shortest transportation route for commercial vessels traveling between northwestern North America and Asia. More than 4,500 large commercial vessels annually now traverse Unimak Pass at the eastern end of the Aleutians—a number that has steadily risen in recent years and is anticipated to continue to grow with increases in vessel traffic between Asia and North America, including the Arctic as well as the Aleutians Islands.

In December 2004, the grounding and breakup of the bulk carrier M/V *Selendang Ayu* during a severe storm focused public attention on the oil spill risks posed by vessels transiting the Aleutians. The accident caused the death of six crew members when a U.S. Coast Guard (USCG) rescue helicopter crashed. It also resulted in a spill of 336,000 gallons of heavy fuel oil near the shore of Unimak Island. While this incident was particularly severe, other accidents, spills, and near misses have taken place and continue to occur in the region. The court settlement following the M/V *Selendang Ayu* accident specified that funds be allocated for a comprehensive risk assessment of ship accidents and spills in the Aleutians and for conduct of projects identified by the risk assessment.

This study, conducted by a committee empaneled by the Transportation Research Board of the National Academies, was initiated to provide guidance for the conduct of that assessment. The charge to the committee was to examine available data and evidence about the risk of spills from vessels transiting the Aleutian Islands, determine the information needed to conduct a comprehensive risk assessment, recommend a framework for the most appropriate and scientifically rigorous risk assessment approach possible given available data and modeling capability, and identify how the risk assessment could be conducted in a logical sequence of discrete steps.

The risk posed to people and the environment by shipping in the Aleutians is greatly influenced by the region's unique setting, harsh environment, and difficult operating conditions. Such factors as geography, climate, regulatory regime, population and its cultural base, ecology, and industrial activities all combine to define this special operating environment. Assessing the risk in this environment requires a full understanding of these conditions and factors as they are at present and as they may change over time.

This report reviews and evaluates available information on the current system and operating environment for shipping in the Aleutian Islands. It presents the committee's proposed design for a comprehensive risk assessment for the evaluation of vessel accidents and spills in the Aleutians and recommendations for an appropriate framework for the conduct of that assessment. These recommendations identify a logical sequence of building blocks that can be used to conduct the assessment in discrete steps so that early decisions can be made regarding the most important safety improvements and risk mitigation options can be considered in the order of their priority.

## STUDY CONTEXT

### *The Aleutian Islands: Resources and Infrastructure*

Central to the public concern about improving the safety of shipping in the Aleutian Islands are the unique and valuable natural resources in the region that could suffer damage from vessel accidents. Indeed, history has shown that oil spill accidents in the Aleutians are not uncommon, in large part because of the frequent and sudden storms, high winds, and severe sea conditions to which the region is subject. Response to these events is often ineffective as a result of the severe weather conditions and a lack of adequate salvage and spill response infrastructure (for example, there are no large rescue-capable tugs).

The Aleutian region is home to natural resources found nowhere else in the world. Because of the vast diversity of species over a broad area, most of the Aleutian Island chain has been designated as a national wildlife refuge. Few marine areas in the world match the Aleutians in marine productivity, and Dutch Harbor is the leading U.S. fishing port in tonnage landed.

Large commercial vessels engaged in the substantial and growing maritime trade between northwestern North America and northern Asia travel the North Pacific Great Circle Route that traverses the Aleutian Islands. The 4,500 vessels that transit Unimak Pass annually are a mix of large containerships, bulk carriers, car carriers, tankers, and others—the majority foreign flagged and on "innocent passage" through these waters. These vessels carry large quantities of fuel oil and various cargoes, including chemicals and other hazardous materials. The spill risk they pose will grow as their traffic volume increases and as new shipping routes emerge to serve future resource development in Alaska and other Arctic regions.

The volume of vessel traffic through Unimak Pass is roughly double that calling on all ports in the 17th USCG District (Alaska). Vessels entering those major ports are subject to a set of controls, whereas similar vessels traveling on innocent passage through the Aleutians need not meet comparable requirements.

### *Vessel Accidents and Spills*

In the region near Dutch Harbor, large commercial ship traffic is concentrated in and near Unimak Pass, and the local fishing fleet, tugs and barges, ferries, and other small vessels often cross the large-ship traffic lanes. Farther out in the Aleutian chain, the traffic is more dispersed, but hazards are always present. Since 2005, because of new automatic identification system (AIS) carriage requirements and the installation of AIS stations in the area, the Marine Exchange of Alaska has been collecting data on ship transits through Unimak Pass for USCG. These data identify and characterize each vessel transit, and the annual reports produced from the data can be combined with incident/accident reports to determine historical patterns.

Historical data on accidents and spills near the Aleutian Islands show that fishing vessels account for the majority of the accidents, most of these resulting in small spills, while the large commercial fleet has experienced only a few major accidents but with much larger spill volumes. Over the past 20 years, about 20 fishing vessel accidents with spills in excess of 1,000 gallons were recorded, while just two commercial cargo vessel accidents (the M/V *Selendang Ayu* in 2004 and the M/V *Kuroshima* in 1997) spilled 336,000 and 40,000 gallons, respectively.

Data for the past 20 years on response to spills in the Aleutians have also shown that almost no oil has been recovered during events in which recovery attempts have been made by the responsible parties or government agencies and that in many cases, weather and other conditions have prevented any response at all. This evidence and other data on the difficulty of recovering oil from the sea in open ocean environments and severe weather conditions lead the committee to suggest that accident and spill prevention be given high priority in considering risk reduction options.

### *Safety Infrastructure*

The 1,200-mile-long Aleutian Island chain is remote and sparsely populated. It has few sizable harbors and minimal maritime infrastructure—especially with respect to the ability to respond to vessels in distress. Given this limited infrastructure and the harsh climate and other hazards to shipping that characterize the region, mariners are challenged to maintain safe operations. The committee therefore reviewed the existing infrastructure and safety measures (such as practices on board and in port, regulations, and the use of vessel monitoring and tracking systems) to identify key areas for improvement that should be considered in assessing the risk of vessel accidents and spills in the Aleutian Islands.

Reliable communications are vital to safe shipping, and the committee found that there are significant gaps in coverage within the Aleutian study area. Moreover, several accident reports cite poor communications as a factor contributing to a chain of events leading to serious problems. Vessel monitoring and tracking systems also can enhance safe operations. The advent of AIS technology has improved traffic management capabilities and offers the potential for active monitoring and early identification of problems. Beginning January 1, 2009, vessel tracking capability will be further improved by International Maritime Organization (IMO) regulations requiring cargo ships above 300 gross tons to transmit long-range identification and tracking technology (LRIT) data.

When vessels at sea do experience problems, it is important to have an effective response capability. Tug capability for assisting large vessels in distress does not exist in the Aleutians. Only small harbor tugs are stationed in Dutch Harbor, and they are not rescue-capable. While Dutch Harbor authorities have prepared Emergency Towing System packages that represent an important step toward improving shipping safety in and near the harbor, their coverage is primarily local; other areas in the Aleutians remain more vulnerable. None of the existing measures are adequate for responding to large vessels under severe weather conditions, and the substantial funding normally required for such a capability has not been identified.

## RECOMMENDATIONS

### *Risk Assessment Framework*

The committee developed a risk assessment framework for analyzing the commercial shipping system in the Aleutian region, both in its current state and projected into the future, with respect to accidents and spills resulting in harm to people and the environment. The proposed framework can be used to evaluate hazards, identify current levels of risk, investigate risk reduction measures, analyze the costs and benefits of those measures, and justify safety improvements to the system.

**The committee recommends that a structured risk assessment be performed with two major phases—a Phase A Preliminary Risk Assessment and a Phase B Focused Risk Assessment.** This process would include a specific, stepped approach to collecting and categorizing available data; development of a logical sequence of events defining key scenarios; and use of a risk matrix for an initial qualitative evaluation of risk levels.

**The Phase A Preliminary Risk Assessment should begin with semiquantitative studies aimed at traffic characterization and projections, spill estimates, and identification of the highest risks. This information should then be used for a qualitative assessment and prioritization of risk reduction options.**

**The Phase B Focused Risk Assessment should entail detailed, in-depth assessments of individual risk reduction options** in order of priority. The time and resources dedicated to Phase A should be limited to ensure that it is completed in a timely manner and that sufficient resources have been reserved for Phase B. Phase B should be accomplished in discrete steps as necessary in accordance with the priority of measures to be investigated and the level of risk reduction possible. The committee believes that this framework would enable risks to be evaluated effectively and efficiently within the resources available. It would also allow for explicit and comparative evaluations of risk reduction measures using more analytical techniques, such as modeling and cost–benefit studies, when warranted.

**The committee also recommends that the risk assessment include a quantitative fate and effect consequence analysis to yield an understanding of the damage to natural resources and socioeconomic**

**impacts associated with different hazards, sizes of spills, and accident locations.** The committee believes that a preliminary consequence analysis should be conducted in Phase A and a more detailed analysis, including biological impacts, in Phase B.

### *Organization of the Risk Assessment Study*

An effective study organization is vital to the success of a risk assessment. The committee reviewed various risk assessment approaches and techniques, including those employed in recent marine risk assessments that are relevant to the problem at hand. This experience points to the importance of certain elements: the problem should be clearly defined, and a contractor should be provided with the specific scope of the study and explicit goals; a peer review group should be given responsibility for reviewing and commenting on the study methodology and the handling of uncertainties; and a stakeholder group should be included in framing the issues, identifying local expert knowledge, suggesting risk reduction measures, and reviewing final results.

**The committee recommends that the risk assessment be organized and managed by a team consisting of USCG, its designated fund management organization (the National Fish and Wildlife Foundation), and the State of Alaska.** The Management Team should provide oversight of the contractor(s) conducting the risk assessment.

**The committee recommends that the Management Team appoint a Risk Assessment Advisory Panel with a facilitator and members consisting of experts and key parties with an interest in furthering the goals of the risk assessment.** Recognizing the importance of stakeholder involvement to the success of the risk assessment, the committee suggests that the Advisory Panel represent all major Aleutian Islands stakeholders, who would provide relevant local knowledge and expertise to the contractors. The panel should review and comment on the framing of the study and its conduct at key stages and help identify and provide input on the risk reduction measures to be evaluated.

**The committee also recommends that the Management Team appoint a Risk Assessment Peer Review Panel with a facilitator and members consisting of experts in the techniques and methodologies of risk assessment to ensure that the study will be conducted**

**with sufficient attention to completeness, accuracy, rigor, and transparency.**

Finally, the committee's charge was to develop the framework for a risk assessment. The committee believes that ongoing risk management is a critical part of the risk assessment process. Thus, the framework proposed in this report is structured to ensure effective implementation of the most cost-effective risk reduction measures by establishing Phase B as a detailed risk management project.

### *Interim Actions to Enhance the Assessment*

During its review of existing data, the definition of the problem, and the current state of safety in the system, the committee identified interim actions that would help ensure a successful risk assessment. The committee is aware of the urgency of taking actions to improve the safety of shipping operations in the Aleutian Islands, and early actions that would provide additional data to build a solid risk assessment foundation should also be considered.

**The committee recommends that USCG take appropriate action to expand the AIS tracking network along the Aleutian chain and covering the southern North Pacific Great Circle Route.** The process for taking this action is already in place, and USCG has the authority to proceed as funding is made available. It would be valuable to implement these systems and to make available the data they yield as soon as possible so the complete traffic system can be described and analyzed with confidence as part of the risk assessment. Collection of additional AIS data should not delay this risk assessment. If it is not possible to install additional receivers and collect sufficient data to contribute to the study, the augmentation of the AIS system should be given careful consideration when the Phase A study results become available. When LRIT data become available, USCG should take steps to utilize these data to further improve vessel tracking in and around the Aleutian chain.

Having an adequate rescue tug capability in the region has been identified in the past as a risk reduction option with obvious benefits for responding to large commercial vessels in distress. This capability has been established in other locations where the potential for maritime accidents exists, and local stakeholders in the Aleutians have advocated this solution for many years. While the committee has not evaluated the costs and benefits of this option, it has concluded that such an evaluation could not begin without more information about costs and possible financing mechanisms. Therefore, **should the Phase A assessment conclude that rescue tugs have potential risk reduction benefits, the committee recommends that USCG and the State of Alaska be ready and available to investigate funding levels, sources, and mechanisms for an Aleutian Rescue Tug, with the expectation that the Risk Assessment Management Team and Advisory Panel might request this information for early consideration within the risk assessment process.**

**The committee further recommends that USCG be ready and available to investigate the possible structure and costs of a Vessel Traffic Information System within and near Unimak Pass and Dutch Harbor, with the expectation that the Risk Assessment Management Team and Advisory Panel might request the information thus generated early in the risk assessment process.** This action would facilitate the risk assessment and provide needed data for cost–benefit analyses of selected options.

**Subject to the findings of the Phase A Preliminary Risk Assessment, the committee also recommends early consideration of options for tracking and monitoring vessel traffic in certain congested areas, as well as for employing some common traffic management schemes that have shown merit in similar locations worldwide.** Implementing voluntary vessel traffic systems, establishing traffic lanes, and identifying particularly sensitive sea areas or areas to be avoided are among the measures that USCG could pursue without new authority. Some of these measures might require IMO consideration, while others might be adopted unilaterally.

## CONDUCT OF THE RISK ASSESSMENT STUDY

Building on the recommendations presented above, the committee has outlined the process and specific steps it believes should be followed to conduct a successful risk assessment for shipping operations in the Aleutian Islands.

### *Problem Definition, Scope, and Budget*

The primary goal of the risk assessment is to determine whether risk reduction measures are necessary and then to recommend the

**TABLE S-1 Hazardous Substances**

| Type | Marpol Annex or Other Code | Name | Example |
|---|---|---|---|
| Oil | Annex I | Oil cargo | Crude oil, asphalt-blending stocks, fuel oil no. 4, fuel oil no. 5, fuel oil no. 6, diesel oil |
| | Annex I | Biofuels and base petroleum fuels | |
| | Annex I | Bunkers | Diesel oil, lube oil, heavy fuel oil |
| Chemicals | Annex II and IBC Code (Chapters 17 and 18) | Noxious liquids in bulk and noxious liquid substances | Vegetable oils, oil-like substances |
| | Annex II and IBC Code | Biofuels | Biodiesel, fatty acid methyl esters, B100 and ethanol, ethyl alcohol E100 |
| Other hazardous substances | Annex III | Dangerous goods in package form and invasive species | Microorganisms, rats |

Note: IBC = international bulk container.

implementation of effective and efficient risk reduction measures. To achieve this goal within available resources, the study must focus on the specific problem at hand—risks related to accidental spills from vessels operating in the study region. To provide the needed focus, the committee has defined the types of hazardous substances, types of accidents, geographic region, and time frame to be considered for the study. Table S-1 identifies the hazardous substances that need to be addressed, while Figure S-1 illustrates the study region, which includes the entire Aleutian Island chain and encompasses the region traversed by commercial vessels on the North Pacific Great Circle Route.

Because the system and the problem are so complex, the committee recommends that the study be conducted in phases—beginning with qualitative and semiquantitative analyses and assessments, followed by selected detailed quantitative assessments of significant risks and most promising risk reduction measures. The prioritization of potential risk reduction measures should be an ongoing, iterative process throughout all of these efforts, reflecting analysis results as they become available, changing circumstances, and emerging technologies and opportunities.

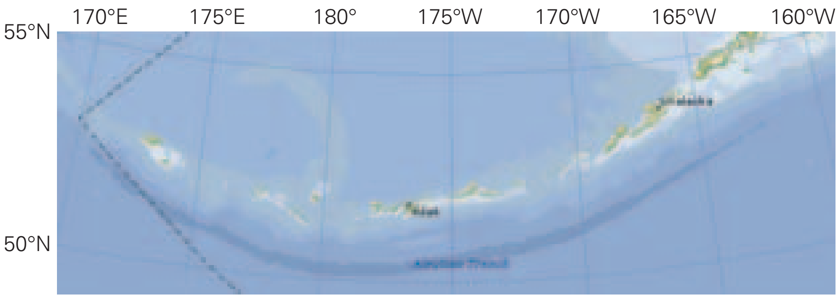



**FIGURE S-1 Complete Aleutian chain.**

The Advisory Panel should be structured to build trust, clarify the values and goals for the assessment, provide local knowledge, and identify needed organizational learning and policy changes. It should also help establish tolerance parameters for risk and, together with the Management Team, perform an initial prioritization of risk reduction measures. The committee has concluded that, regardless of how rigorous it may be, an analytical approach to risk assessment alone is insufficient for decision making. The needs and values of stakeholders play a key role and must be considered in the decision-making process.

The basic steps and time line for the risk assessment are shown in Figures S-2 and S-3. The figures show the relationships among the four groups involved in management, oversight, and conduct of the risk assessment and the primary responsibilities of each. The committee believes that approximately 2 years will be required for the full assessment. The process is structured so that a qualitative prioritization of risk reduction measures will be available after the first year, which may allow for earlier implementation of those measures that stand out as particularly effective.

In accordance with the court settlement resulting from a commercial vessel accident and large oil spill in 2004, $3 million has been set aside for the overall risk assessment and projects identified by the assessment. The committee is confident that the available funds are more than sufficient to cover the costs of a credible comprehensive risk assessment; however, the Management Team must control the scope of the effort to ensure that the work is done in a timely fashion and that early efforts are not devoted to detailed analyses that will not influence the final decisions.

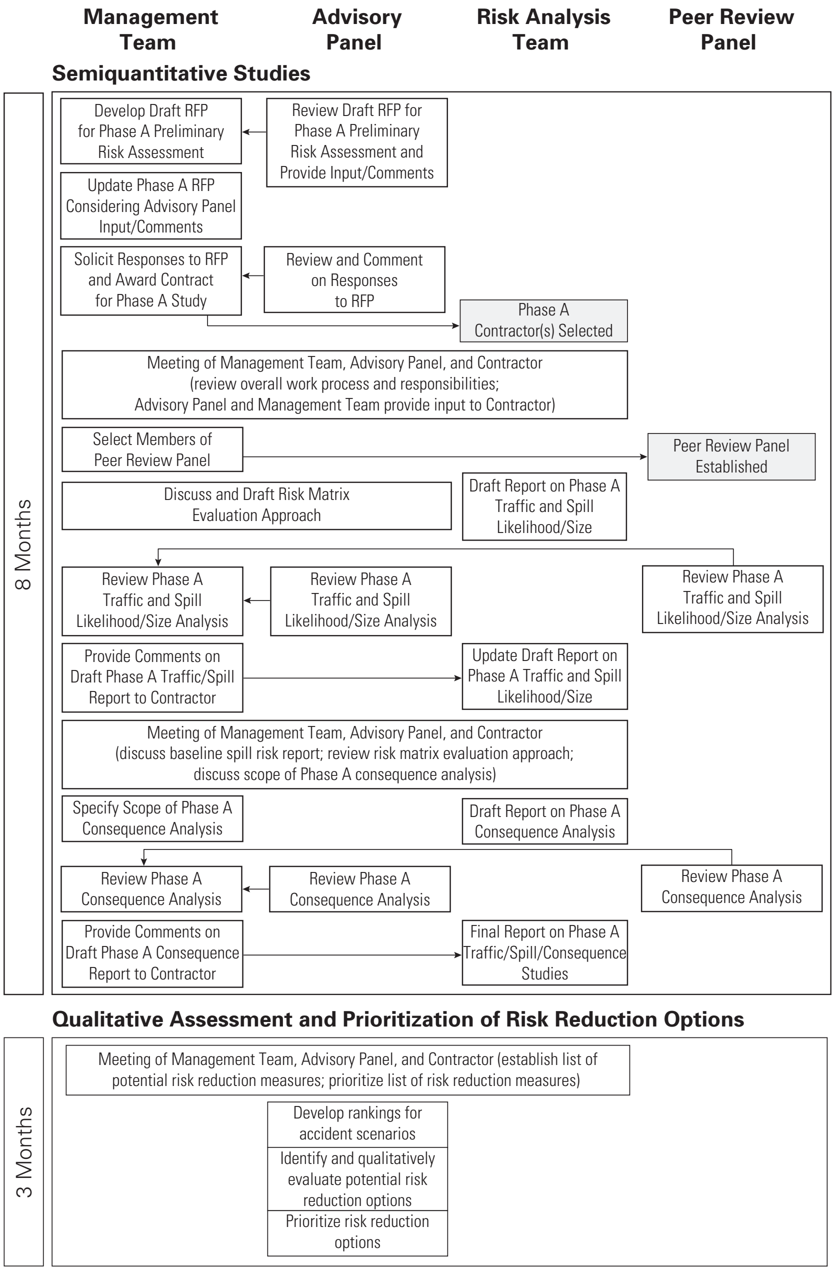



**FIGURE S-2 Phase A Preliminary Risk Assessment. (RFP = request for proposals.)**

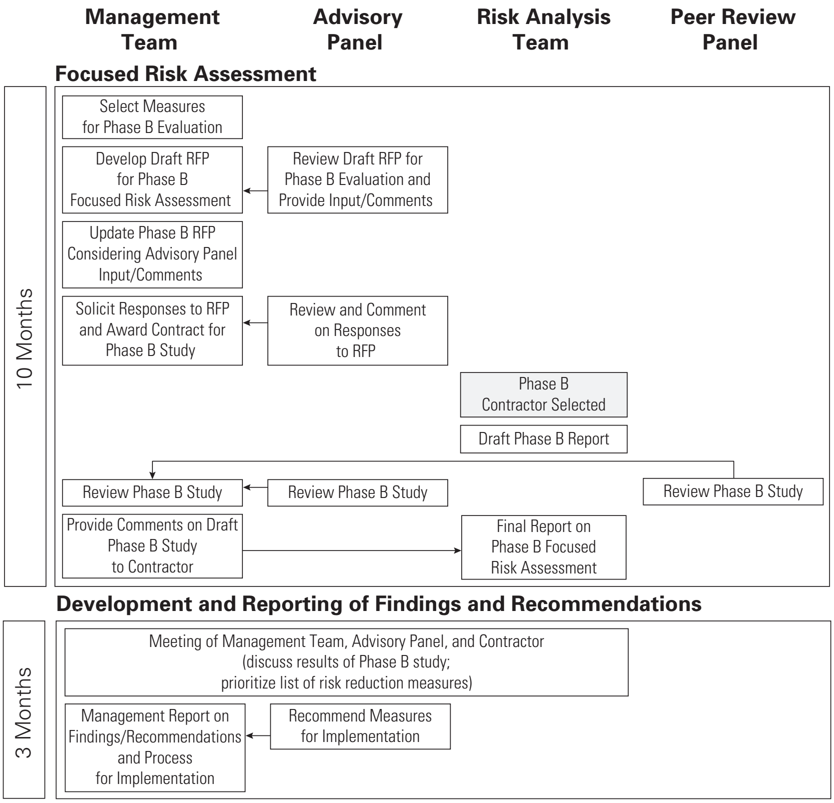



**FIGURE S-3 Phase B Focused Risk Assessment.**

The Phase A characterization of risk is needed for the initial qualitative assessment of risk reduction measures and should serve as a baseline for the focused quantitative risk reduction investigations. Care must be taken to avoid spending too much of the budget on the Phase A effort; the committee believes that this effort can be completed for about 25 percent of the overall budget. In the Phase B analysis, there may be a natural tendency to assess more options in greater detail than resources allow, so the scope and schedule should be defined and adhered to as closely as practicable. If additional studies are deemed desirable, they should be considered after the study has been completed as part of the ongoing effort of risk management.

### *Technical Approach*

The committee's proposed technical approach for conducting the risk assessment begins with the Phase A Preliminary Risk Assessment. The semiquantitative portions of the Phase A analysis (i.e., traffic characterization and projections and spill estimates) should rely on historical data supplemented by results of prior risk studies and expert opinion. This analysis should help identify geographic locations and spill scenarios for a limited number of focused environmental impact investigations. The Phase A study should identify the highest risks in terms of the types of spills and vessels involved, the types of accidents and their likely causes and scenarios, and the spill sizes and likely locations, and it should provide some sense of the environmental impacts. The intent is to provide sufficient information with which to prioritize risk reduction measures on a qualitative basis.

The committee recommends the following specific steps to accomplish the semiquantitative portions of Phase A:

- *Traffic study:* Characterize the existing fleet and traffic and the quantities of hazardous cargoes moved. Project growth in trade, changes in vessels, and impacts of expected regulatory changes. Project the fleet makeup over a 25-year study period.
- *Spill baseline study:* Develop an oil spill baseline over the study period on the basis of projected movements of oil and hazardous materials and estimated spill rates and frequencies. The projection should provide an understanding of the most important hazards and serve as a baseline for later assessment of benefits.
- *Identification of high-risk accidents:* Identify the hazardous substances, representative spill sizes, and locations of spills associated with the highest-risk accidents.
- *Phase A consequence analysis:* For representative high-risk accidents, perform a high-level spill trajectory and fate analysis to gain an understanding of the relative impacts of spill size, type, and location.
- *Accident scenario and causality study:* Determine representative accident scenarios to develop probabilities for their principal causes and associated consequences.

The Phase A Preliminary Risk Assessment should end with a qualitative assessment of risk reduction options that should lead to the identification of certain measures that merit immediate implementation, some that are unjustifiable, and others that warrant more detailed analysis.. The Advisory Panel and Management Team should populate risk matrices, compile lists of potential risk reduction measures, qualitatively assess the benefits and costs of each measure, and prioritize the measures. The Risk Analysis Team should be available during these deliberations to provide background information and insight into the Phase A investigations. Figure S-4 illustrates a risk matrix that the committee recommends using as a structured process for reaching conclusions and establishing priorities for risk reduction measures.

In the Phase B Focused Risk Assessment, the assessment approaches and techniques should be applied in more detailed, quantitative analyses to determine whether particular measures are justified and to understand their secondary effects. A variety of techniques, such as numerical simulations, as well as expert elicitation, should be used to quantify the likelihood and consequences of an accident with and without a risk reduction measure in place. Uncertainty and sensitivity analyses should help bound the confidence level of the characterization of risks and benefits. Such quantitative assessments should also supply data needed for cost–benefit analyses.

The Phase B risk analysis should follow the basic steps of Phase A. The specific modeling and analysis methods may differ because the analysis needs to be more focused, with sufficient detail, precision, and data quality to allow more robust decisions on the selection, design, and implementation of cost-effective risk control measures. As noted, to the extent possible, Phase B should be a quantitative assessment. Other characteristics of the Phase B risk analysis should include the use of hybrid modeling methods for risk scenarios; more detailed causal modeling; consideration of human factors and adoption of human-error analysis techniques; evaluation of rare, high-consequence events; advanced modeling; formal use of expert opinion; and rigorous uncertainty and sensitivity analyses.

The final step in the committee's proposed approach is decision making and implementation of risk reduction measures. Implementation of risk reduction measures will involve many challenges, including establishing sources for funding and reaching agreement with the various agencies and stakeholders that will influence the failure or success of a measure. Risk management is not a one-time solution; it requires continuous monitoring and reassessment. Thus, the committee stresses the need for a mechanism to ensure that the risk management plan remains a living document.

| **Frequency of Occurrence/ Likelihood** | **Severity of Incident (or Consequences)** | | | | |
|---|---|---|---|---|---|
| | Incidental (1) | Minor (2) | Serious (3) | Major (4) | Catastrophic (5) |
| Frequent (5) | | | | **High** | **Risk** |
| Occasional (4) | | | | | |
| Seldom (3) | | | | | |
| Remote (2) | **Low** | **Risk** | | | |
| Unlikely (1) | | | | | |

**FIGURE S-4 Proposed risk matrix.**

### *Implementation of Risk Reduction Measures*

The development of risk reduction measures for implementation will require consideration of who the decision makers are and what capacities they have to effect recommended changes. For example, USCG rulemaking depends on consideration of benefits relative to costs. The State of Alaska and local municipalities also have specific decision-making roles. Securing federal funds will involve other U.S. government branches, and IMO will have a role if changes to international regulations are desired. Successful implementation of certain initiatives may require the collaboration of various government decision makers, the support of stakeholders, and a relatively longer time.

### *Need for Transparency*

If the objectives of the risk assessment study are to be met, its final report should be fully transparent, describing the study process and all relevant assumptions:

- Hazards and risks should be clearly identified. For risk reduction measures that merit detailed analysis, benefits and costs should be clearly defined.
- All sources of data should be documented and assumptions explained. Models and methodologies should be explained in suf-

ficient detail to allow a third party to understand the assessment's basic assumptions and limitations.

- Judgments applied during the assessment should be explicitly stated. The process for elicitation and analysis of expert opinion should be explained.
- Uncertainty and associated sensitivity analyses should be clearly documented and explained. Results should be presented in a way that does not create a false sense of precision.
- The analyses should be of sufficient depth to address the needs and expectations of those with expertise in risk assessment while being understandable to the layperson.

## CONCLUSION

Despite the complexity of the system and the open-ended nature of the problem, the committee is confident that a rigorous and comprehensive risk assessment of shipping in the Aleutian Islands can be conducted within the available resources and that needed safety improvements can be justified in the process. The committee also understands that, while certain historical and time-series data are limited, they can be enhanced and supplemented by relevant worldwide data and local expertise and judgment. This report presents a framework for conducting such a risk assessment, explaining the underlying principles and offering guidelines for applying both qualitative and quantitative techniques where appropriate. Finally, throughout this report, the committee emphasizes principles that are key to ensuring a successful outcome. These include keeping the work focused on a clear definition of boundaries and scope, designing the assessment process to incorporate continuous involvement of local stakeholders, and applying a phased approach to set priorities for early action and allocate resources efficiently.

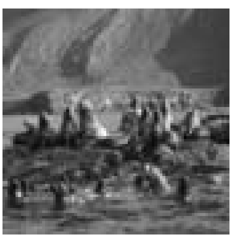
SPECIAL REPORT 293

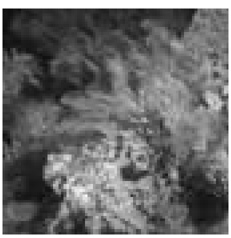
# Risk of Vessel Accidents and Spills in the Aleutian Islands

## DESIGNING A COMPREHENSIVE RISK ASSESSMENT

**Committee on the Risk of Vessel Accidents and Spills in the Aleutian Islands: A Study to Design a Comprehensive Assessment**

TRANSPORTATION RESEARCH BOARD
*OF THE NATIONAL ACADEMIES*





TRANSPORTATION RESEARCH BOARD
Washington, D.C.
2008
www.TRB.org

**Transportation Research Board Special Report 293**

Subscriber Categories
IV operations and safety
IX marine transportation

Transportation Research Board publications are available by ordering individual publications directly from the TRB Business Office, through the Internet at www.TRB.org or national-academies.org/trb, or by annual subscription through organizational or individual affiliation with TRB. Affiliates and library subscribers are eligible for substantial discounts. For further information, contact the Transportation Research Board Business Office, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-3213; fax 202-334-2519; or e-mail TRBsales@nas.edu).



NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This report was sponsored by the State of Alaska and the U.S. Coast Guard.

*Cover design by Debra Naylor, Naylor Design, Inc.*
*Cover photographs by Kevin Bell, U.S. Fish and Wildlife Service (stellar sea lions); Peggy Michel (bald eagle); and National Oceanic and Atmospheric Administration Fisheries (coral).*

**Library of Congress Cataloging-in-Publication Data**

National Research Council (U.S.). Transportation Research Board. Committee on the Risk of Vessel Accidents and Spills in the Aleutian Islands: A Study to Design a Comprehensive Assessment.
Risk of vessel accidents and spills in the Aleutian Islands : designing a comprehensive risk assessment / Committee on the Risk of Vessel Accidents and Spills in the Aleutian Islands: A Study to Design a Comprehensive Assessment.
p. cm.—(Transportation Research Board special report ; 293)
Includes bibliographical references.
1. Oil spills—Risk assessment—Alaska—Aleutian Islands Region. 2. Oil spills—Risk assessment—Bering Sea. 3. Navigation—Alaska—Aleutian Islands Region. 4. Marine accidents—Risk assessment—Alaska—Aleutian Islands Region. 5. Marine accidents—Risk assessment—Bering Sea. I. Title.
TD427.P4C635 2008
363.738'22097984—dc22

2008033069

ISBN 978-0-309-11332-8

# THE NATIONAL ACADEMIES

*Advisers to the Nation on Science, Engineering, and Medicine*

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

**www.national-academies.org**

# Committee on the Risk of Vessel Accidents and Spills in the Aleutian Islands: A Study to Design a Comprehensive Assessment

**R. Keith Michel,** *Chair,* Herbert Engineering Corp., Alameda, California
**Dennis C. Bley,** Buttonwood Consulting, Inc., Oakton, Virginia
**Thomas M. Leschine,** University of Washington School of Marine Affairs, Seattle
**Henry S. Marcus,** Massachusetts Institute of Technology, Cambridge
**Denise McCafferty,** American Bureau of Shipping, Houston, Texas (through April 2008)
**Ali Mosleh,** University of Maryland, College Park
**Robert C. North,** North Star Maritime, Inc., Queenstown, Maryland
**Margaret Williams,** Bering Sea Ecoregion Program and Russia Projects, World Wildlife Fund, Anchorage, Alaska

*Transportation Research Board Staff*
**Beverly M. Huey,** Senior Program Officer
**Peter Johnson,** Senior Program Officer

# Preface

The Aleutian Islands are home to natural resources found nowhere else in the world, and the regional economy is dominated by commercial fishing. Protection of the region's natural resources is therefore a paramount public concern.

The Aleutian region is intersected by major commercial marine shipping routes—a large and growing international fleet of ships carrying various cargoes from the west coast of North America to Asia along the North Pacific Great Circle Route. With the exception of a few containerships that call on the port of Dutch Harbor, most of these commercial ships transit through or near the Aleutians and do not stop except for emergencies. Some accidents involving these ships have resulted in oil spills that have had serious environmental consequences. Indeed, history has shown that oil spill accidents in the Aleutians are not uncommon, in large part because of the frequent and sudden storms, high winds, and severe sea conditions to which the region is subject. Response to these events is often ineffective because of the severe weather and a lack of appropriate infrastructure.

A commercial vessel accident and large oil spill in 2004 focused public attention on the risks inherent in commercial shipping in the region. The court settlement resulting from this accident established funding for a comprehensive risk assessment and directed the U.S. Coast Guard to take actions necessary to conduct this assessment.

Risk assessment is a systematic approach used to evaluate the level of safety of a complex system and to identify appropriate safety improvements. It is an established engineering discipline and has been used in the maritime industry in the past with varying degrees of success. Both the State of Alaska and the U.S. Coast Guard have had experience with maritime risk assessments, and both understand the complexity of the problem at hand, as well as the need for a well-designed process that will ensure a successful outcome. Consequently, they asked the National Academies to examine the available data and develop a framework and the most appropriate and scientifically rigorous approach possible for the mandated comprehensive risk assessment, and to design the assessment with a logical sequence of building blocks so that it could be conducted in discrete steps.

To conduct this study, the Transportation Research Board (TRB) within the National Academies empaneled the Committee on the Risk of Vessel Accidents and Spills in the Aleutian Islands: A Study to Design a Comprehensive Assessment. The committee included individuals with expertise in risk assessment methods and practices; risk assessment data and analyses; risk analyses, with emphasis on evaluation and prevention of ship accidents; commercial shipping, with emphasis on North Pacific operations; navigation safety and voyage planning; U.S. Coast Guard missions and operations related to waterway management and accident response; environmental protection; and regulatory approaches to ship safety and accident prevention. (Biographical sketches of the committee members can be found at the end of the report.) This report presents the committee's analysis of the problem; reviews the available data; describes the structure and design of an appropriate risk assessment; and presents the committee's recommendations for organizing, managing, and conducting a comprehensive assessment of the risk of vessel accidents and spills in the Aleutian Islands.

The committee met three times. During a multiday meeting (October 29–November 2, 2007) in Alaska with a site visit to Dutch Harbor, the committee heard from stakeholders and reviewed available data pertinent to its charge. Stakeholders discussed specific hazards presented by Aleutian shipping operations and a range of possible mitigation measures they believed should be considered for implementation. At its second meeting, held January 7–8, 2008, the committee received presentations on the following topics:

- Related maritime risk assessments, including the following:
  - Methodologies and approaches in recent and ongoing assessments in the United States (Puget Sound and San Francisco)

  - Methodologies and approaches in recent assessments in Europe
  - Methodologies employed in limited-scope risk analyses
- Spill response and environmental impacts:
  - Vessel casualties and oil outflow modeling
  - Impacts from spills of persistent oils
- Commercial vessel operations and practices
- Spill risk from a shipowners Protection and Indemnity (P&I) Club perspective
- Available and accessible U.S. Coast Guard data

At its third meeting, held March 13–16, 2008, at the Beckman Center of the National Academies in Irvine, California, the committee reviewed draft sections of this report, finalized the report structure, discussed its conclusions and recommendations, and continued drafting the text. In addition to these full committee meetings, a subgroup of the committee met during the last week of March, and members of the committee held numerous conference calls.

## ACKNOWLEDGMENTS

The work of this committee was greatly facilitated by the thoughtful advice and background information provided by all of the presenters at its meetings, as well as other individuals with relevant technical expertise, stakeholder groups, and government and industry officials who were consulted during the study. The committee also gratefully acknowledges the contributions of time and information provided by the sponsor liaisons. The committee is especially indebted to liaisons Leslie Pearson, manager of the Prevention and Emergency Response Program in the Division of Spill Prevention and Response at the Alaska Department of Environmental Conservation; and CDR James Robertson of U.S. Coast Guard District 17 (Alaska region), who responded promptly and with a generous spirit to the committee's numerous requests for information.

In addition, the committee thanks the many industry, trade association, and state and local government representatives and other individuals who provided input for this study: Sam Albanese, National Oceanic and Atmospheric Administration (NOAA); Dave

Aplin, World Wildlife Fund; Capt. Dave Artz, Alaska Marine Pilots; Jim Ayers, Oceana; Bill Benning, Marine Exchange of Alaska; Poppy Benson, Alaska Maritime National Wildlife Refuge, Fish and Wildlife Service (FWS); Catherine Berg, FWS; Rich Berkowitz, Transportation Institute, Seattle; Vernon Byrd, Alaska Maritime National Wildlife Refuge, FWS; LCDR Xochitl Castañeda, U.S. Coast Guard, Washington, D.C.; Paul Cojeen, U.S. Coast Guard, Washington, D.C.; Bubba Cook, World Wildlife Fund; Capt. Mark DeVries, U.S. Coast Guard, Captain of the Port for Western Alaska; Dustin Dickerson, local fisherman, Dutch Harbor; Lt. Ben Duarte, U.S. Coast Guard Marine Safety Detachment, Dutch Harbor; Cheryl Eldemar, Oceana, Juneau; Diana Evans, North Pacific Fishery Management Council, NOAA; Gary Folley, Alaska Department of Environmental Conservation; Tim Fowler, DNV Energy, United Kingdom; Capt. Pete Garay, Alaska Marine Pilots; John Gardenier (retired), Pragmatica Corp.; Turkan Gardenier, Pragmatica Corp.; Capt. Tom Gemmell (U.S. Coast Guard, ret.), Marine Conservation Alliance; Martha Grabowski, Rensselaer Polytechnic Institute and LeMoyne College; Rodney Gregory, Business Transformation Agency, Reston; Scott Habberstad, Manager Regional Sales, Alaska, Alaska Airlines; Tim Hall, DNV Energy; Geoffrey Harben, Alaska Department of Environmental Conservation; Bruce Harland, Crowley Marine Services, Alaska; John R. (Jack) Harrold, George Washington University; Larry Hartig, Commissioner, Alaska Department of Environmental Conservation; Bob Heavilin, Alaska Chadux Corporation; Jon Heifetz, NOAA; Kris Holderied, NOAA Kasitsna Bay Laboratory; Amy Holman, NOAA Alaska Regional Collaboration Team; Chris Jones, Maritime Operations Project Manager, Prince William Sound Regional Citizens' Advisory Council; Ian Jones, Memorial University of Newfoundland; ADM Robert Kramek (U.S. Coast Guard, ret.), American Bureau of Shipping; Christopher Krenz, Oceana; Kathy Kuletz, Migratory Bird Management, FWS; Tom Lakosh, Parker & Associates, Anchorage; LCDR James Larson, U.S. Coast Guard Headquarters; John LeClair, Alaska Chadux Corporation; LCDR Vivianne Louie, U.S. Coast Guard, Washington, D.C.; Karl Lumbers, UK P&I Club, London; Dan Magone, Magone Marine Services, Inc.; Shirley Marquardt, Mayor, City of Unalaska; Molly McCammon, Alaska Ocean Observing System; Deborah French McCay, Applied Science Associates, Inc.; Jimmer MacDonald, Dutch Harbor local diver and commercial fisherman; Jason Merrick, Virginia Common-

wealth University; Colin Moore, Herbert Engineering Corporation; David Moore, Minerals Management Service, Department of the Interior (DOI); Doug Mutter, Office of Environmental Policy and Compliance, DOI, Anchorage; CDR Christopher Myskowski, U.S. Coast Guard; Capt. Ed Page (U.S. Coast Guard, ret.), Marine Exchange of Alaska; Leslie Pearson, Alaska Department of Environmental Conservation; Dimitri Philemonof, Aleutian Pribilof Islands Association; Todd Ripley, Maritime Administration; CDR James Robertson, U.S. Coast Guard, District 17; Carolyn Rosner, North Pacific Research Board, Alaska Ocean Observing System; Bob Schoephoester, Alaska Chadux Corporation; Carven Scott, NOAA; CDR Sandra Selman, District Legal Officer, U.S. Coast Guard; Whit Sheard, Pacific Environment; Capt. Julio Soares, American President Lines; Mike Sollosi, U.S. Coast Guard, Washington, D.C.; Rick Steiner, Shipping Safety Partnership; Barry Strauch, National Transportation Safety Board; Kent Sundseth, Alaska Maritime National Wildlife Refuge, FWS; Tyanc Thayer, U.S. Coast Guard, Washington, D.C.; Kirsi Tikka, American Bureau of Shipping; Jeremy Weiss, U.S. Coast Guard, Washington, D.C.; Carter Whalen, Alaska Marine Pilots; John Whitney, NOAA; and Bruce Wright, Aleutian Pribilof Islands Association.

The committee also thanks the crews of the tug *Gyrfalcon* [one of the local rescue assets in Dutch Harbor that has responded to various emergencies in and around the harbor and whose crew has been trained with the Emergency Towing System (ETS)] and the tug *James Dunlop* (another local responder whose crew has been trained with the ETS and is on call around the clock for emergency response). Thanks are extended as well to employees of Magone Marine Services, a local company with more than 30 years of experience in diving, underwater demolition, and vessel recovery in the Aleutian Islands; employees of NC Machinery, diesel mechanics for fishing vessels, tugs, and ships with experience in safety maintenance, severe-weather shutdowns, and mechanical emergencies that arise at sea; and the members of the City Council of Unalaska, who took time from their busy schedules to share their knowledge and insights with the committee during its site visit to Dutch Harbor.

This study was performed under the overall supervision of Stephen R. Godwin, TRB's Director of Studies and Special Programs. The committee gratefully acknowledges the work and support of Beverly Huey, who served as project director, and Peter Johnson, under whose guidance this study was initiated, both of whom provided invaluable assistance to the committee during the information gathering, data analysis, report writing, and report review stages. The committee expresses its admiration and appreciation of Peter Johnson's continued commitment to the success of this effort, even after his retirement at the end of 2007. The committee also acknowledges the work and support of Suzanne Schneider, Associate Executive Director of TRB, who managed the review process; Rona Briere, who edited the report; Alisa Decatur, who prepared the manuscript; Jennifer J. Weeks, TRB Editorial Services Specialist, who formatted and prepared the prepublication files for website posting; Senior Editor Norman Solomon, who provided editorial guidance; Juanita Green, Production Manager, who coordinated the design, typesetting, and printing; and Javy Awan, Director of Publications, under whose supervision the report was prepared for publication.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee thanks the following individuals for their review of this report: Gregory Baecher, University of Maryland, College Park; Duane Boniface, ABS Consulting, Arlington, Virginia; Warner Chabot, Ocean Conservancy, San Francisco, California; John Lee, University of Iowa, Iowa City; Molly McCammon, Alaska Ocean Observing System, Anchorage; Jacqueline Michel, Research Planning, Inc., Columbia, South Carolina; Danny Reible, University of Texas at Austin; and Steve Scalzo, Marine Resources Group, Seattle, Washington. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the report's findings and conclusions, nor did they see the final draft before its release.

The review of this report was overseen by Marcia McNutt, Monterey Bay Aquarium Research Institute, Moss Landing, Cali-

fornia. Appointed by NRC, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

—R. Keith Michel, *Chair*
Committee on the Risk of Vessel Accidents
and Spills in the Aleutian Islands: A Study
to Design a Comprehensive Assessment

# Glossary

Following are the definitions of a number of terms used in this report.

**Accident.** An unintended event leading to loss of life, property, or damage to the environment. Examples of marine accidents include collisions, powered groundings, drift groundings, fire and explosion, and founderings (see the definitions below).

**Alaska Marine Highway (System).** A ferry service operated by the State of Alaska along the state's south-central coast, the eastern Aleutian Islands, and the Inside Passage of Alaska and British Columbia, Canada. The ferries (which can transport people, freight, and vehicles) also serve communities in southeastern Alaska that lack road access.

**Allision.** The impact of a vessel with a fixed object other than the bottom of the body of water (e.g., a bridge, pier, or offshore platform).

**Area to be avoided (ATBA).** An area with defined limits where either navigation is particularly hazardous or it is exceptionally important to avoid casualties. All ships or certain classes of ships may be instructed to avoid these areas.

**Automatic identification system (AIS).** A communications medium that automatically provides vessel position and other data to other vessels and shore stations and facilitates the communication of vessel traffic management and navigational safety data from designated shore stations to vessels.

**Beaufort scale.** A method for estimating wind strengths without the use of instruments, developed in 1805 by Sir Francis

Beaufort. It is still used for this purpose, as well as for combining various components of weather (wind strength, sea state, and observable effects) into a unified picture. Force 6 winds range from 22 to 27 knots on the scale, with sea heights of 9.5 to 13 feet. At Force 7, winds range from 28 to 33 knots, with sea heights of 13.5 to 19 feet. Force 8 winds are 34 to 40 knots, with seas from 18 to 25 feet high. In Force 9 conditions, winds range from 41 to 47 knots and sea heights from 23 to 32 feet. At Force 11, winds are 56 to 63 knots and seas from 37 to 52 feet high.

**Bunkers.** Fuel used for ship propulsion and power. Bunkers may be heavy residual fuel oils (referred to as HFO), or lighter refined oils, such as diesel oil (DO) and marine gas oil (MGO).

**Causality.** The precursor event to an incident. Examples include failure to take appropriate precautions, inattention, and component failure.

**Collision.** The impact of a vessel under way with another vessel under way.

**Consequence.** The outcome of an event or accident.

**Deadweight (DWT).** The difference between the displacement of a ship in water at a specific gravity of 1.025 at the assigned summer load waterline and the lightship weight, generally measured in metric tons. The lightship is the displacement of a ship without cargo, consumables (e.g., fuel, fresh water), ballast water, passengers, or crew.

**Diurnal tides.** One high tide and one low tide each tidal day.

**Drift grounding.** The impact of a vessel with the ground when the vessel loses its ability to navigate (e.g., through loss of propulsion, steering, or towline separation) and is blown aground before it can get under way or is taken under tow.

**Foundering.** Loss of a vessel from flooding, which may be due to insufficient stability or inadequate freeboard.

**Frequency.** The likelihood of an event or accident (number of events per unit time).

**Great circle route.** The shortest distance between two places on the earth's surface. The route follows a line described by the intersection of the surface with an imaginary plane passing through the earth's center.

**Gross ton (GT).** A unit of measurement calculated in accordance with international conventions and national requirements; a function of a vessel's space within the hull and of enclosed spaces above deck.

**Groundfish.** Any marine fish except halibut, smelt, herring, and salmon.

**Hazard.** An agent that can harm life, property, or the environment.

**Incident.** An event in which a vessel or its contents are put at risk. Examples are loss of propulsion, loss of steering, and navigational errors.

**Innocent passage.** The right of vessel passage through a state's territorial sea when not calling at a port in that state (up to 12 nautical miles from the baseline).

**International Maritime Organization (IMO).** The United Nations' specialized agency responsible for improving maritime safety and preventing pollution from ships.

**International strait.** A strait used for international navigation between one part of the high seas or an exclusive economic zone and another part of the high seas or exclusive economic zone.

**Invasive species.** With respect to a particular ecosystem, any species (including its seeds, eggs, spores, or other biological material capable of propagating that species) that is not native to that ecosystem and whose introduction does or is likely to cause harm to the economy, the environment, or human health.

**Long-range identification and tracking system (LRIT).** A maritime domain awareness initiative that will allow member states to receive position reports from vessels operating under their flag, vessels seeking entry to a port within their territory, or vessels operating in proximity to the state's coastline.

**Nonpersistent oil.** As used herein, No. 2 diesel oil and other light refined products, which tend to evaporate and disperse more readily than persistent oils (see below) when spilled.

**Oil.** As used herein, all petroleum oils, such as crude oils, fuel and residual oils, and waste oils.

**Particularly sensitive sea area (PSSA).** An area that needs special protection through action by the International Maritime Organization because of its significance for recognized ecological, socioeconomic, or scientific reasons and that may be vulnerable to damage by international maritime activities.

**Persistent oil.** Crude and residual oils, which tend to result in more widespread contamination when spilled and are more difficult to clean up than nonpersistent oils (see above).

**Powered grounding.** The impact of a vessel with the ground or shoreline while the vessel is under power.

**Risk.** The combination of the likelihood of an event and its consequences.

**Scenario.** A sequence of events leading to an accident.

**Semidiurnal tides.** Two high tides and two low tides of approximately equal height per tidal day.

**Spill event.** An accident resulting in oil or chemical outflow into the environment.

**Strait.** A natural, constricted channel of water that connects two larger bodies of water.

**Traffic separation scheme (TSS).** A vessel-routing scheme separating opposing streams of traffic by separation zones. Within international waters, TSSs are established by the International Maritime Organization.

**Transit passage.** The right of passage through an international strait that is used for international navigation between one part of the high seas or an exclusive economic zone and another part of the high seas or an exclusive economic zone.

**Vessel traffic system (VTS).** A vessel traffic management system whereby authorities monitor vessel movements within a waterway by radar surveillance and disseminate navigational information with regard to potential hazards.

# Contents

**Summary** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1

**1 Introduction** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **19**
Study Context . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .19
Current Risk Reduction Measures . . . . . . . . . . . . . . . . . . . . . .22
Study Objectives and Scope. . . . . . . . . . . . . . . . . . . . . . . . . .25
Structure of the Report . . . . . . . . . . . . . . . . . . . . . . . . . . . . .26

**2 Fundamentals of Risk Assessment** . . . . . . . . . . . . . . . . . . . **28**
Overview of Risk Assessment. . . . . . . . . . . . . . . . . . . . . . . . .29
Organization of Risk Assessment . . . . . . . . . . . . . . . . . . . . . .36
Risk Assessment Approach . . . . . . . . . . . . . . . . . . . . . . . . . .41
Risk Assessment of Aleutian Shipping Operations . . . . . . . .50

**3 The Aleutian Islands: Framing the Issues** . . . . . . . . . . . . . **57**
Local Assets and Their Vulnerability. . . . . . . . . . . . . . . . . . .59
Geology, Oceanography, and Climate. . . . . . . . . . . . . . . . . . .64
Supporting Maritime Infrastructure . . . . . . . . . . . . . . . . . . . .67

**4 Vessel Traffic, Accidents, and Spills in the Aleutians** . . . . **73**
Vessel Traffic . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .73
Movements of Oil, Chemicals, and Other
Hazardous Goods . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .77
Vessel Accidents. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .79
Spills of Oil and Other Hazardous Substances. . . . . . . . . . . .83
Regulatory Framework. . . . . . . . . . . . . . . . . . . . . . . . . . . . . .90

**5 Organization of the Aleutian Islands Risk Assessment . . . 96**
Problem Definition . . . . . 97
Assessment Organization and Management Structure . . . . 101

**6 Technical Approach to the Aleutian Islands Risk Assessment . . . . . 110**
Phase A Preliminary Risk Assessment: Semiquantitative Studies . . . . . 112
Phase A Preliminary Risk Assessment: Qualitative Assessment and Prioritization of Risk Reduction Options . . . . . 123
Phase B Focused Risk Assessment. . . . . 131
Development and Reporting of Recommendations for Decision Makers on Risk Reduction Measures to Be Implemented. . . . . 139

**7 Conclusions and Recommendations . . . . . 142**
Conclusions . . . . . 143
Recommendations . . . . . 146
Final Thoughts . . . . . 149

**Appendices**
A Potential Risk Reduction Options . . . . . 151
B *Selendang Ayu* Plea Agreement . . . . . 155
C Expert Judgment . . . . . 182
D Human Reliability Analysis . . . . . 189
E Uncertainty, Sensitivity, and Bayesian Methods . . . . . 194
F Event Sequence Diagram Method and Risk Scenario Development . . . . . 199
G Sample List of Salvage Incidents near Dutch Harbor . . . . . 203
H Summary Incident and Casualty Data from U.S. Coast Guard's Marine Safety Management System, 1991–2000, and Marine Information Safety and Law Enforcement System, January 2000–March 2003 . . . . . 205
I Resource Dependency and Community Vulnerability . . . . 216

**Study Committee Biographical Information. . . . . 221**