American Lifelines Alliance

A public-private partnership to reduce risk to utility and transportation systems from natural hazards and manmade threats

DRAFT

Guideline for Assessing the Performance of Oil and Natural Gas Pipeline Systems in Natural Hazard and Human Threat Events

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FEMA

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Although many of the procedures presented here have been validated through experience and practice, this is the first time a pragmatic approach has been developed to assess *system performance.* The *Guideline and Commentary for Assessing the Performance of Oil and Natural Gas Pipeline Systems* was developed by a team of experts in engineering and risk analysis, led by ImageCat, Inc. of Long Beach, California. A group of practicing engineers, academics, and industry personnel reviewed drafts of the document to provide industry input and an American Lifelines Alliance (ALA) oversight committee monitored the guideline development to ensure compliance with ALA project goals.

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1.0 Introduction

Oil and natural gas pipeline systems provide energy for transportation, generate electric power, and produce necessary goods and services, including home heating—all critical functions to maintaining a high quality of life in a modern society. The monetary losses and social disturbance attributable to a shutdown of oil and natural gas pipelines can be substantial, especially if extended service disruptions lead to an interruption of the fuel supply for electric power generation or industrial and manufacturing processes. The financial and social effects from the interruption in oil and natural gas delivery, be it from natural or human causes, can extend to customers hundreds of miles away. In addition to service and financial considerations, damage to crude oil or liquid products pipelines can endanger watersheds and groundwater supply, and the rupture of volatile hydrocarbon and natural gas pipelines can lead to explosions and fire.

Gas utilities and pipeline operating companies are familiar with preparing for and responding to natural hazard events such as landslides, erosion of stream crossings, unintentional damage from excavation activities, and intentional human acts such as vandalism. Widespread damage and service disruption caused by relatively rare or extreme events like a severe earthquake, flooding of historic proportions, or a concerted terrorist attack, however, can overwhelm the available emergency response capacity of a gas utility or pipeline operating company. While utilities that have experienced such infrequent severe events have generally taken effective steps to be adequately prepared for the future, many others have only partially prepared, and still others are not aware of their full exposure or vulnerability to these threats.

The methodology for dealing with the effects of natural hazards is well established. Very little information, however, is available to help gas utilities and pipeline operating companies plan for natural hazards and human threats. In particular, there is a general lack of consensus-based procedural guidance on how to apply the available methodology to the assessment of the vulnerability of oil and natural pipeline systems to natural hazards and human threats.

For the past several years, the American Lifelines Alliance (ALA), with support and funding from the Federal Emergency Management Agency (FEMA), has undertaken efforts to establish a methodology for assessing lifeline performance and identifying actions to reduce the risk to natural hazards and human threats. These efforts include the development and dissemination of materials to help gas utilities and pipeline operating companies understand these risks and develop a plan of action to mitigate unacceptable risks. This guideline is part of a larger arsenal of tools and methodologies that are being disseminated to gas utilities and pipeline operating companies by ALA.

1.1 Purpose of Guideline

The purpose of this guideline and the accompanying commentary is to define a multilevel process by which to evaluate the vulnerability and performance of oil and natural gas pipeline systems to natural hazards and human threats. The natural hazards addressed by this guideline include earthquakes, floods (riverine and coastal), windstorms (extreme winds, hurricane, and tornado), icing, and ground displacements (landslides, frost heave, and settlement). The human threats addressed include biological, chemical, radiological, blast, and cyber attacks.

This guideline outlines a screening process to identify significant natural hazards or human threats and any condition that may represent significant vulnerability. It also delineates procedures to establish the scope of an assessment that meets the objectives of specific performance inquiries while accommodating cost and schedule constraints. When combined with the commentary, this guideline provides ample information to define the specific steps that should be part of an assessment, the types of methods available to perform these analyses, the relative level of effort required to address a specific inquiry, and the types of expertise needed to implement the assessment. Although this guideline does not provide detailed descriptions of analytical procedures and concepts, references are cited for various technical topics. Interdependency issues that may identify other risks for gas utilities and pipeline operating companies, especially dependency conditions on other lifelines, are largely beyond the common state-of-practice and are not included in this guideline. The commentary includes an annotated bibliography of key references that form the basis of many of the methods used or cited in this guideline and a glossary of terms and definitions.

1.2 Intended Users

This guideline is written for gas utility and pipeline operating company personnel in management, operations, engineering, maintenance, public information, risk management, and data processing. Regulatory officials, government agencies, industry groups, professional organizations, research organizations, academia, and consulting engineers seeking a general understanding of the performance assessment process may also find the guideline useful.

The application of the assessment process requires various levels of expertise and specialization depending on the topic area and the level of assessment required for implementation. For relatively straightforward, lower level approaches, many organizations will be able to conduct the assessment with their own engineering and operations personnel. Special cases, particularly those related to infrequent hazards or risks, however, may require the participation of outside technical specialists. Examples of such cases might include special security problems dealing with human threats, assessing vulnerabilities to critical facilities from unexpected hazards (e.g., newly discovered earthquake faults), or attempting to balance efforts for multiple hazards under a systemwide risk reduction plan.

1.3 Organization of Guideline

This guideline is organized into the following major sections:

- An overview that describes the role of the inquiry leading to a need for a performance assessment, the major elements of an assessment process, the different phases of an assessment, and the concept of the levels of analysis (**Section 2**);
- Procedures that help to define the scope of an assessment (**Section 3**);
- Details on the screening phase of the assessment (**Section 4**);
- Details on performing a Level 1, Level 2, or Level 3 analysis for all parts of the assessment (**Section 5**);

- Examples that illustrate the application of the methodology described in the prior sections (**Section 6**);
- References (**Section 7**);
- National hazard maps for earthquake, landslide, hurricane wind and tornado, tornado only, and riverine and coastal flooding (**Section 8**); and
- A commentary that provides background information and resources to facilitate the use of this guideline (**Commentary**).

1.4 Using Guideline

This guideline and commentary contain a considerable amount of information that can be used to scope out a performance assessment. Some users may choose to concentrate on the "big picture" by focusing on the overall process and how the various steps fit together. Others, particularly those with more specialized technical backgrounds, may be more interested in the details of the process. One approach to implementing an assessment would be to form a team of internal experts to adapt the assessment process to a specific system or facility. Collectively, this team should have specific knowledge about 1) the operations of the system, 2) past history of hazard incidents or events, and 3) system design.

1.5 Limitations and Qualifications

This guideline is not a design manual, standard, or code. Although effort has been taken to define the methodology and to develop example applications, this guideline has not undergone the rigorous process of consensus validation and revision or widespread pilot testing in the industry. The content does, nevertheless, represent the current standard of practice in assessing the performance of oil and natural gas pipeline systems in natural hazards and human threat events. The procedures presented herein are considered appropriate for implementation, but are subject to revision when improved methods become available, particularly for the assessment of human threats.

As with most guidelines, a compromise between state-of-the-practice procedures (which can be expansive) and methods that can be applied with limited resources was necessary. Because the goal of this guideline is to reach as wide a range of users as possible, a multilevel approach has been developed. This approach includes procedures ranging from simple ones that can be applied in a few days to more comprehensive ones that require weeks to months to complete. This guideline is structured so that both small and large utilities and pipeline companies can carry out assessments that are appropriate to the inquiries they receive.

This guideline does not address interdependency issues that may involve other risks for the utility, especially dependency conditions on other lifelines.

Finally, this guideline should be viewed as a "living" document. As new data, information, and methods become available, the procedures in this document should be reviewed and modified to reflect current thinking on acceptable approaches for hazard, vulnerability, and system performance assessments. In this regard, the commentary, which contains a listing of applicable methods of analysis, becomes a key component of this guideline and should also be updated as new material becomes available.

While the materials in the Commentary were developed with U.S. natural gas utilities and pipeline operating companies in mind, the general approach in this guideline, especially the method of analysis, is applicable worldwide.

2.0 Overview of Assessment Process

This section introduces a systematic process for assessing the performance of oil and natural gas pipeline systems subjected to natural hazards or human threat events. The components of this process have been implemented, tested and validated by numerous utility and operating companies throughout the United States. This guideline captures the essence of these studies and formalizes the process by presenting procedures that can be adapted to utilities of various sizes throughout the country. This process is part of identifying and implementing the actions needed to adequately ensure the integrity of the system when subjected to natural hazards or human threat events. This section provides an overview of the mitigation process and where this guideline fits into that process.

2.1 Preparing for Natural Hazards and Human Threat Events

The impact of natural hazards on oil and natural gas pipeline systems is well chronicled, primarily because of the damage to lifelines in the 1971 San Fernando, California, earthquake and the attention given to the seismic design of the Trans-Alaska Pipeline in the 1970s. To mitigate unplanned service disruptions and to guard against threats to public safety and potential damage to the environment, leading gas utilities and pipeline operating companies have adopted a wide range of strategies to improve the resistance of critical facilities to these events and enable rapid service restoration if disruption occurs.

The need to assess the performance of a utility system is usually initiated by an inquiry—i.e., a question or request for information, which can be generated either internally or externally. To be responsive, the scope of the assessment must fully recognize the nature of the inquiry because the inquiry is the very essence of why an assessment is needed. The level of detail required in the assessment can also vary significantly depending on the source of the inquiry.

Figure 2-1 outlines a process for decision making that will assure acceptable system performance. The flowchart is not unique to a particular utility or pipeline operating company. Instead, it simply summarizes well-tested assessment procedures currently in practice. It begins by identifying the inquiry, or the basic reason for performing the assessment. The inquiry determines the part of the system that is being considered (e.g., a single subsystem or the whole system) and explicitly or implicitly identifies the assessment metric and performance target (see Table 2-1). For example, a gas distribution system in a large urban area might be required to maintain certain pressure minimums outside the immediate area of earthquake damage to prevent service disruption to the entire distribution network.

As illustrated in Table 2-1, there are a variety of ways in which system performance can be measured. These metrics, which are usually dictated by the inquiry triggering the need for an assessment, are discussed in Section 2.2.

Identifying hazards, assessing vulnerability, and assessing system performance are critical in the overall performance assessment process. These steps represent the essence of this guideline. They identify significant hazards, assess the vulnerability of the system's components to those hazards, and assess performance of the system while the system is in a damaged state. The remaining steps in Figure 2-1 are decision-making steps that compare the results of the system performance assessment to the performance target. The scope of the inquiry and the results of the performance assessment will determine whether the performance is deemed acceptable or the system is changed to meet the performance goal. Changes may include system-response or component-response modifications or adjustments to the performance goal.

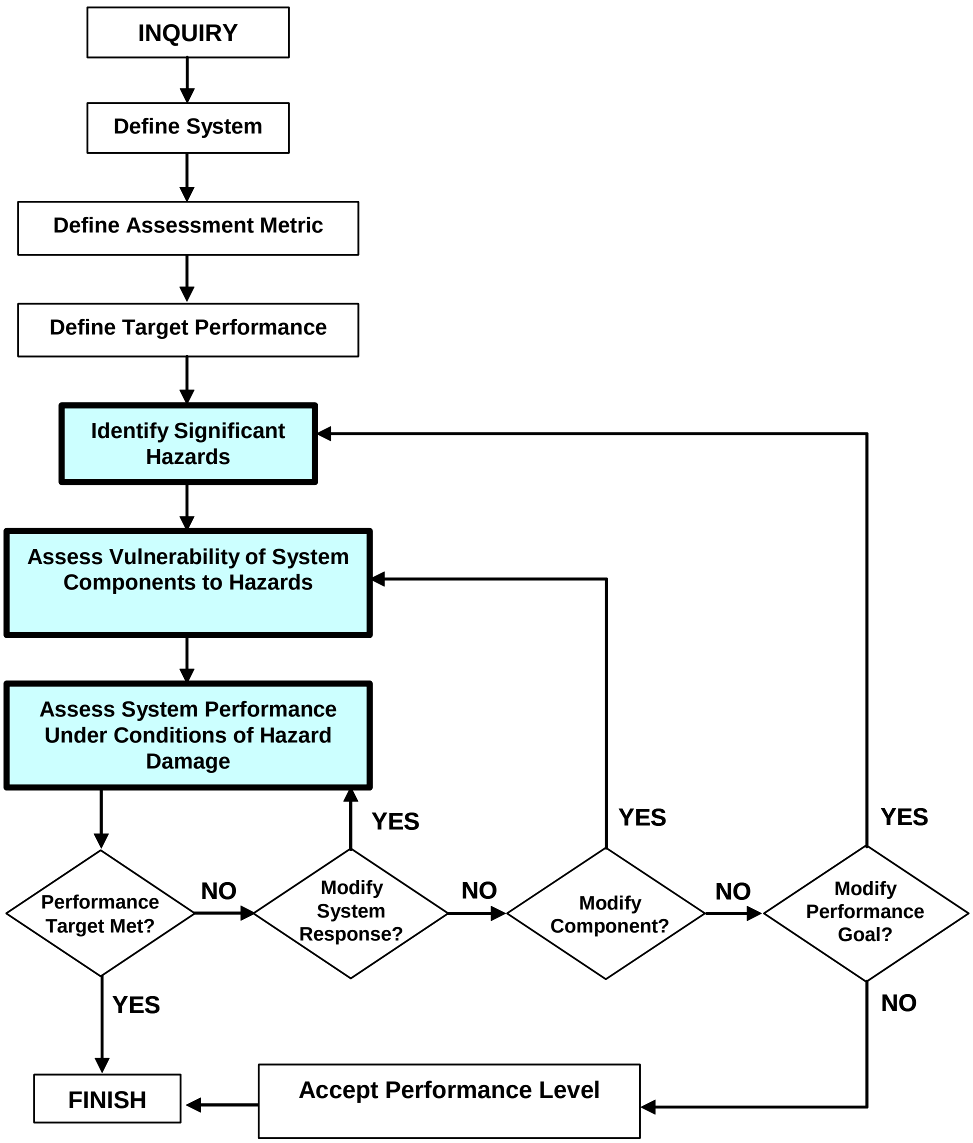

Figure 2-1. Decision-making Process for Ensuring System Performance Goals Are Met

The primary focus of this guideline is on the three shaded boxes. The other boxes define important decision-making steps that only the user can address. For example, deciding what part of the system to analyze or determining what the appropriate performance target should be are clearly decisions that must be addressed by the user. Section 2.2 provides general guidance that will help the user begin to frame the analysis.

Although mitigation measures are a part of the decision-making process and key in assuring that performance targets are met, they are not considered in this guideline. The user is encouraged to consult current literature (e.g., ASCE Monograph Series, see http://www.pubs.asce.org) on mitigation planning for lifeline systems.

2.2 System Performance Measures

Gas utility and pipeline system performance during extreme events is typically judged according to a set of desired outcomes or performance targets. Although performance targets may vary somewhat depending on the system or the nature of the hazard, the most important are:

- Protect public and employee safety,
- Maintain system reliability,
- Prevent monetary loss, and
- Prevent environmental damage.

Several different metrics can be used to quantify system performance relative to desired outcomes as illustrated in Table 2-1. Linking performance metrics to desired outcomes is important because it generally influences the methods of measurement chosen for quantification. Some performance metrics might require specialized methods, while others may simply make use of field information or expert opinion.

The entries in the columns of Table 2-1 relate the direct measures of system performance to desired outcomes. For example, “Casualties” and “Lost Product” are shown as the performance metrics for the desired outcome of “Protect public and utility personnel safety.” In other words, to protect the safety of the public and utility employees, casualties and loss of product must be avoided. There are also indirect consequences of an unfavorable outcome that are not indicated in Table 2-1. These indirect consequences can be significant, perhaps even greater than direct consequences. For example, the financial burden on the gas utility or pipeline operating company to satisfy liability claims or to provide for environmental clean up in the event of a hazardous materials spill would qualify as an indirect consequence and could be costly.

A system performance analysis should consider those principal components of a gas utility or pipeline system that are important in achieving various desired outcomes (see Table 2-2). Most major components should be included in a performance assessment directed at safety, system reliability, and prevention of monetary loss. Assessments directed at preventing environmental damage should focus mainly on components and systems related to the containment of liquid hydrocarbons, system control (shutdown and isolation) and emergency response (maintenance and support, equipment, and inventory of repair parts).

Table 2-1. Metrics to Measure System Performance Associated with Desired Outcomes

Desired Outcomes (Performance Targets)	**System Performance Metrics**					
	Capital Losses ($)	Revenue Losses ($)	Service Disruption (% service population)	Downtime (hours)	Casualties (deaths, injuries)	Lost Product
Protect public and utility personnel safety					X	X
Maintain system reliability			X	X		
Prevent monetary loss	X	X	X	X		X
Prevent environmental damage						X

Table 2-2. Key Components and Facilities Common to Gas Utility or Pipeline Systems

• Transmission Pipelines
• Pump Stations
• Compressor Stations
• Processing Facilities
• Storage Tanks
• Control Systems
• Maintenance and Operations Buildings and Equipment
• Pressure Regulating/Metering Stations
• Distribution Pipelines
• Service Lines or Connections (natural gas)

2.3 Two-Phase Approach

This guideline employs a two-phase assessment approach, which has numerous advantages:

- Systems or components that are clearly not at risk may be screened out early.
- Results from the initial phase may be used to prioritize and allocate appropriate resources for subsequent, more detailed assessments.
- Sequential performance of a screening (Phase 1) and more detailed analyses (Phase 2) offer an important means of gauging results to identify possible errors or faulty assumptions.
- The data or information needed for a more detailed assessment often are developed or uncovered in a preliminary phase.
- A phased approach usually allows the user to gauge the scope and cost of extensive projects relative to the anticipated consequences of hazard or threat events.

In summary, the two-phase approach provides for 1) a qualitative evaluation to determine whether the system is at significant risk and, if necessary, 2) a more comprehensive analysis to quantify system performance. Figure 2-2 illustrates the basic interrelationship between the two phases.

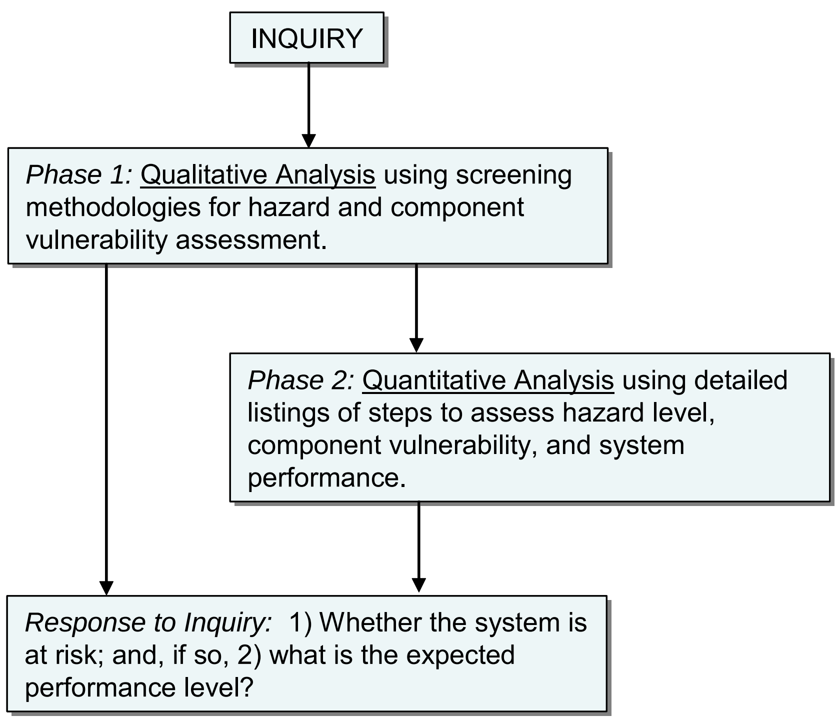

Figure 2-2. Two-Phase Approach to Performance Assessment

It is possible to arrive at a final assessment of performance after performing a Phase 1 evaluation. This can happen under a number of different scenarios. For example, the integrity of a transmission pipeline system may come into question because a published report states that pipelines are at risk from earthquakes. A Phase 1 assessment, however, could determine that the likelihood of a moderate to large earthquake is extremely small for the region and, thus, the risk of damage is low. If this low level of earthquake risk is less than the acceptable risk from other operational hazards that might result in similar damage consequences, then further evaluation of earthquake risk (Phase 2 analysis) would be of little practical value and management may decide to take no further action.

Similarly, the assessment of a small gas utility serving a small population through resale of natural gas would not be very meaningful unless the supply of gas could be assured through a similar hazard event. In other words, there is no need to assure distribution system reliability to a degree in excess of gas supply reliability. These boundary constraints would typically be examined in a Phase 1 assessment.

A strict interpretation of the Figure 2-2 flowchart shows that a Phase 1 assessment must always precede a Phase 2 evaluation. While one could skip directly to Phase 2, it is generally not advisable, because, as mentioned previously, the results of a Phase 1 assessment can provide baseline information for planning and executing subsequent Phase 2 evaluations. Details of the screening process are presented in Section 4.

2.4 Three Levels of Analysis for Phase 2

This guideline is built on the premise that the assessment process should be undertaken as a progressive, multilevel sequence of tasks, relatively simple at the lowest level and increasing in detail with each higher level. Tasks performed at lower analysis levels become part of the next higher level. Data and information collected in each lower-level task are used, as applicable, at higher levels. In practice, organizations of all sizes and types use some form of this progressive, multilevel analysis process.

The multilevel analysis concept applies to all parts of the performance assessment (see Section 5): hazard assessment, component vulnerability assessment, and system performance. Therefore, the three levels of analysis are defined here in generic terms.

- *Level 1* is designed to provide a preliminary estimate of hazard, vulnerability or system performance. This analysis can usually be completed within a matter of days[1] and, in most cases, can be completed by operations and engineering staff. The results are considered uncertain by a factor of 2 to 3 or more and may be used to scope out the extent of the problem in order to decide whether more detailed studies are needed. If the results from this level of analysis do not satisfy the inquiry, then a higher level of analysis should be used (Level 2).

- *Level 2* is characterized as a more quantitative analysis, which often depends on historical or statistical information to quantify hazard, vulnerability, and system performance, and

[1] Labor requirements are measured by the time required for one person working full time to complete the study. More details on this assignment are provided in Section 5.4.

involves collecting data from the field. Level 2 is typically completed within a matter of weeks rather than months or year and can be performed by operations and engineering staff with assistance as needed from external technical specialists. The accuracy of the results is better than approximate, often providing quantitative results within a factor of 2 or 3. If further detail or precision is required, then a Level 3 analysis is recommended.

- *Level 3* represents the highest level of analysis. It is quantitative with results accurate to the state-of-the-practice[2]. This level is characterized by more accurate and more complete data, the use of more advanced methods (e.g., proprietary software), and will generally require the participation of external technical specialists. Level 3 analyses often require extensive fieldwork, laboratory tests, and generally take months or even years to complete.

In general, employing three levels of analysis promotes the most efficient use of resources. By planning more broadly from the beginning (Level 1) and then ramping up to more detailed evaluations as needed (Levels 2 and 3), the use of a gas utility or a pipeline operating company's resources can be more effectively prioritized and optimized. Another advantage of using a multilevel analysis approach is that it extends the applicability of this guideline to the broadest possible range of gas utilities and pipeline operating companies and the performance-related inquiries they face by avoiding the "one size fits all" approach.

2.5 Methods of Analysis

In practice, the analysis methods can vary depending on the types of data available, regional characteristics or practices, resources available (time, staff, and budget), background and experience of the analysts, the nature of the estimate, and the accuracy required.

Although there may be a myriad of acceptable analytical approaches, this guideline emphasizes those believed to be the most practical for application by gas utilities and pipeline operating companies. Specific techniques, procedures, and practices have been identified for use in estimating such parameters as earthquake ground motions, hurricane wind speeds, equipment fragility, and, more broadly, system performance. The use of some of these methods requires specialized background and training. The intent is to provide the user with a broad view of available methods with respect to the overall assessment process without being exhaustive or excluding new or developing techniques.

The Commentary to this guideline contains a series of tables that list currently accepted methods for analyzing hazard, component vulnerability, and system performance. Included in the tables are brief summaries of advantages and disadvantages, statements of applicability, and available resource documents.

[2] This term is used to reflect the best accuracy possible given current, accepted technologies and analysis capabilities.

3.0 Defining the Scope of the Performance Assessment

This section introduces the concept of an inquiry (i.e., a question or request for information) and how it plays an important role in defining the scope of a performance assessment. The level of detail required to answer the inquiry will vary depending on a number of factors, including whether it is externally or internally generated. While each gas utility and pipeline system has its own unique features, there are certain common elements among such systems that can serve as a baseline for defining the tasks required to assess system performance.

3.1 A Roadmap for Performance Assessments

Before responding to a particular inquiry, it is useful to view the entire assessment process. The flowchart in Figure 3-1 provides a roadmap that lays out the major phases of the assessment, key decision points for expanding the assessment to a more detailed level, and consideration of cost and schedule constraints.

The assessment process begins with an inquiry. As noted previously, inquiries are requested by either an internal source (e.g., gas utility or pipeline operating company requesting a briefing on the assets at risk from a particular hazard) or an external inquiry (e.g., a regulatory body requesting actions be taken to assure the reliability of service to customers in the event of a major natural disaster or human threat event). In some instances, an actual event or incident may prompt an assessment from internal and external sources simultaneously. For example, an earthquake that caused damage to some part of a system not previously known to be vulnerable might prompt internal and external inquires to determine if the damage was associated with an isolated incident or an indication of a wider problem.

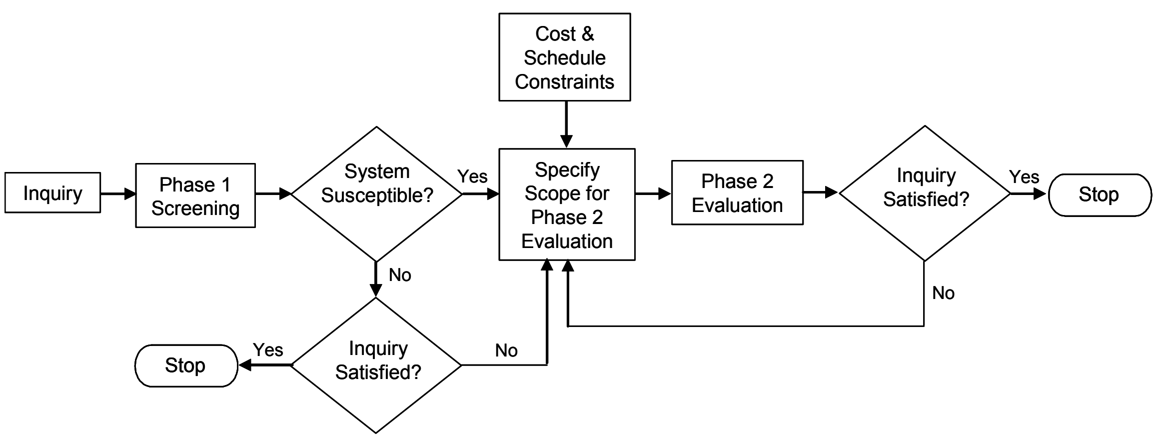

Figure 3-1. Basic Roadmap for System Performance Assessment

The second step in the flowchart calls for a Phase 1 screening evaluation (see Section 4.0). The evaluation consists of two stages: the determination of whether or not a potential significant hazard exists and, if so, whether existing facilities are susceptible to damage or failure from that hazard. If no significant hazard or risk of damage from the hazard exists, then the analysis process can be terminated. For example, some areas of the U.S. are not subject to damaging earthquakes, and as such, pipelines in those areas are not at significant risk of damage from earthquake-induced ground failure. Similarly, Gulf of Mexico coastal areas are subject to hurricane force winds, but buried pipelines essentially have no risk from damaging wind.

If the inquiry is not satisfied by a Phase 1 evaluation or the system is determined to be susceptible to damage or loss of function for the hazard under evaluation, a Phase 2 evaluation becomes necessary. The scope for the Phase 2 evaluation should contain an appropriate level of detail and take into account cost and schedule constraints. (See Sections 5.1 and 5.2 for guidance on determining the appropriate level of analysis.)

Once the analysis level has been determined, a step-by-step list of the needed tasks should be compiled (see Section 5.3). The task list is similar to a scope of work in a Request for Proposal. The scope of work may be performed within the normal activity of a utility operations or engineering department or may be more involved and require the participation of additional technical specialists with extensive background and experience.

The process in Figure 3-1 is sequential. In practice, however, the process may be cyclic, requiring several iterations to determine the appropriate level of analysis. The process, whether sequential or cyclic, basically remains the same:

- Screen the hazard severity and assess the generic vulnerability of the system to that hazard to determine the need for a more detailed evaluation;
- Ensure that adequate resources and expertise are available to perform the evaluation; and
- Determine the appropriate level of analysis based on the inquiry and available resources and schedule.

3.2 Selecting Components for Analysis

The components to be included in the analysis depend in large part on the inquiry and the performance target being investigated. For example, in the case of a customer approaching a gas utility about the reliability of the system to deliver natural gas to its facility following a major earthquake, the gas utility must decide which components should be assessed. Reliability in this scenario is measured by service disruption and downtime (Table 2-1). The gas utility uses Table 2-2 to identify critical components and finds that all components listed in the table except service lines or connections should be considered.

3.3 Inquiries

Because inquiries can come from a variety of sources inside or outside gas utilities and pipeline operating companies, the effort to develop a response can range from a matter of a few hours to a significant commitment of resources. It is impossible to come up with a list of inquiries for every conceivable situation. The following list of inquiries is representative (see Table 5-3 in Section 5.2 for a more extensive list).

Internal Inquiries

- Upper management requesting information on general financial exposure
- Addressing risk management or insurance issues
- Defining the scope of capital improvement programs
- Evaluating performance goals (reliability)
- Assessing post-hazard service to emergency facilities (e.g., hospitals)
- Preparing exercises and training for event response
- Conducting an internal investigation following a disaster that causes unexpected damage or impacts

Outside Inquiries

- Inquiry by a regulatory body (system exposure)
- Inquiry by a regulatory body (hazard concern)
- Inquiry by a regulatory body (consequence concern)
- Inquiry by a regulatory body (operating concern)
- Inquiry by a regulatory body (integrity concern)
- Customer questions about the reliability of service
- Investor concerns, primarily for private gas utilities
- Changes in law or operating requirements (depends on the change)
- Inquiries by the press or the public
- Interaction with professional organizations
- In response to a bond-rating process
- External investigation following a disaster that causes unexpected damage or impacts.

As discussed in Section 5.2, the nature and type of inquiry will influence, to a large degree, the recommended level of analysis. Although there are no specific rules that define the levels of analysis for specific inquiries, experience suggests that there are practical levels of analysis for certain general conditions and situations.

3.4 Key Elements of Performance Assessments

The major elements of a performance assessment are Hazard (H), Vulnerability (V), and System Performance (S).

- *Hazard* includes natural hazards and human threats, such as:

  – Earthquakes
  – Flooding
  – Windstorms, including hurricanes and tornados
  – Icing
  – Ground displacements, including landslides, frost heave, and settlement
  – Biological threats
  – Chemical threats

– Radiological threats
– Blast
– Cyber attacks
– Physical attacks, including armed assault and sabotage

- *Vulnerability* includes the potential for physical damage and loss of life with respect to:

  – Physical facilities
  – Functional systems
  – Environment
  – Administrative/financial activities
  – Human safety

- *System Performance* includes the consequences resulting from system damage or disruption as measured by:

  – Capital and revenue losses
  – Service disruption and downtime
  – Casualties
  – Hazardous materials release and environmental damage

Each of the three elements must be subjected to a series of analyses, the results of which are linked together to form a consistent methodology to estimate system performance. There are three levels of analysis that can be performed. A Level 1 analysis represents the simplest and least time-consuming level of effort; a Level 2 analysis is more quantitative and of moderate scope; and a Level 3 analysis is an extensive effort that will likely require significant resources and time to complete.

A performance assessment involves the selection of an appropriate level of analysis within each of the three elements. In aggregate, they constitute an appropriate approach for responding to an inquiry. For example, the recommended approach for an inquiry may all for a simplified hazard analysis (Hazard analysis–Level 1), a moderately detailed analysis of component fragility (Vulnerability analysis–Level 2), and a simplified (qualitative) systems analysis (System Performance analysis–Level 1). The primary emphasis in this example is on component performance with a secondary concern on how this performance will affect the overall operation of the system. In this guideline, the above analysis is simply denoted as an H1-V2-S1 analysis.

By using three levels of analysis, the performance assessment can be tailored to the content of the inquiry (the level of detail required to appropriately characterize the hazard, vulnerability, and system performance) and to the source of the inquiry (the appropriate level of detail needed for the regulatory agency, government, investment entities, insurers, customers, the public, or the management of the gas utility or pipeline operating company). In other words, different types of inquiries lead to different levels of assessment depending on their source, the context in which the inquiry is being made, and the underlying considerations for hazard, vulnerability, and system performance.

4.0 Phase 1–Screening for Significant Hazards and Susceptibility to Damage or Disruption

The purpose of a Phase 1 evaluation (introduced in Section 3.1) is to screen out a component or system evaluation if any of the following conditions are met:

- There are no significant hazards affecting the component or system, or
- The component or the system as a whole is not susceptible to damage or failure if subjected to the hazard(s) under consideration.

A system may be subjected to some hazard types, but not necessarily to all hazard types. Similarly, a system may be susceptible to damage or failure from some hazards, but not necessarily from all hazards.

The potential for extreme human threats has been treated as ever-present since the terrorist attacks of September 11, 2001. Consequently, Phase 1 screening should not rule out human threats on the basis of not being present or not capable of causing damage. Quite simply, there are no simple screening tools that will effectively identify or eliminate the presence of these threats. Therefore, for the assessment of human threat events, Phase 1 screening could be bypassed in favor of proceeding directly to Phase 2.

4.1 Natural Hazard Screening Tools

Natural hazards are identified as “local” or “regional” hazards. Local hazards are ones that can be characterized only by conducting fieldwork or by using microzonation maps (when available). This guideline defines local hazards as riverine flooding, landslides, surface fault rupture, liquefaction, and settlement. Regional hazards, which can be depicted on small-scale maps, such as on a national or state map, include earthquake ground shaking, severe winds (including extreme winds, hurricane, and tornado), coastal flooding, and icing. Hence, the distinction between local and regional hazards is important because of the relative spatial accuracy of the information portrayed for each.

This guideline uses national maps to characterize Phase 1 hazard levels for earthquake, landslide, severe wind (hurricane and tornado), and riverine and coastal flooding. For local hazards (e.g., flooding, landslides), the information on these maps is approximate and quite conservative in the sense that the presence of local hazards within a jurisdiction causes the entire jurisdiction to be classified according to the severity of the local hazard itself. A county, for example, could be classified as high risk for landslides because a relatively small portion of the county land area is situated on unstable slopes. Or, it could be considered hazardous for flooding with only a small area within an active floodplain. Therefore, it should be recognized that local hazards have a site-specific aspect that must be taken into account. The presence of local hazards anywhere within a designated county serves, for the purposes of a Phase 1 screening, as the basis for classifying the county at a medium or high hazard level. Considering the qualitative and approximate nature of Phase 1 screening, this does not cause an undue hindrance.

Table 4-1 summarizes the criteria used to establish low, medium, and high hazard levels for earthquake, landslide, wind, tornado, icing, flooding, and human threats. The values in Table 4-1 are considered to represent reasonable separation points or boundaries. Additional discussion of the range boundaries is provided in Section 3 of the commentary.

Table 4-1 Criteria Used in Establishing Relative Hazard Levels

Hazard Level	Earthquake	Landslide	Wind	Tornado	Icing[3]	Flooding	Human Threats[4]
Low	Peak Ground Acceleration (PGA) < 0.15 g	Low incidence	Not high or medium	< 5 tornadoes per 10,000 sq. mi.	≤ 0.25 in.	Q3 data not available for the county	Green (Low)
Medium	0.15 g ≤ PGA ≤ 0.5 g	Moderate Incidence or moderate susceptibility/ low incidence	Windspeed > 90 mph, but < 120 mph	5 to 25 tornadoes per 10,000 sq. mi.	Greater than 0.25 in. and less than 1.0 in.	Q3 data available for the county	Blue (Guarded) to Yellow (Elevated)
High	PGA > 0.5 g	High incidence or high susceptibility/ moderate incidence or high susceptibility/ low incidence	Windspeed ≥ 120 mph, or Gulf / Atlantic county whose basic wind-speed is 110 mph or greater, or Hawaii	> 25 tornadoes per 10,000 sq. mi.	≥ 1.0 in.	Q3 data available for the county	Orange (High) to Red (Severe)

Notes:

1. In establishing the earthquake hazard, the Guideline uses earthquake hazard maps depicting ground motions with a probability of exceedance equal to two percent in 50 years.
2. In establishing the icing hazard, the Guideline uses ASCE 7-05, Minimum Design Loads for Buildings and Other Structures. These maps represent 50-year mean recurrence interval uniform ice thicknesses due to freezing rain.
3. The digital Q3 Flood Data published by FEMA are designed to provide guidance and a general proximity of the location of Special Flood Hazard Areas. The digital Q3 Flood Data cannot be used to determine absolute delineation of flood risk boundaries, but instead should be seen as portraying zones of uncertainty and possible risks associated with flood inundation.

Hazard level maps for earthquake, landslide, severe wind (hurricane and tornado), tornado only, and riverine and coastal flooding are contained in Section 8. Each map is derived from a federal or state database. The information contained in each map is also available digitally, which makes the use of these maps very compatible with a "look-up" procedure. A comprehensive tabular listing of hazard levels by county (with exception of icing and human threats) is provided in the Commentary.

The most significant hazards in Table 4-1 for gas utilities and pipeline operating companies are earthquake, including various types of earthquake-induced ground failure; landslides; flooding (with respect to the threat of scour in river and stream bottoms due to increased flow); and human threats, such as terrorist attacks. Wind, tornado, and icing have relatively minor effects on

[3] In establishing the icing hazard, this guideline uses ASCE 7-02 (ASCE 2003), Minimum Design Loads for Buildings and Other Structures, Maps (Figures 10-2a, 10-2b, 10-3, and 10-4). These maps represent 50-year mean recurrence interval uniform ice thicknesses due to freezing rain.
[4] Levels based on Threats and Protection Advisory System used by the Department of Homeland Security (http://www.dhs.gov).

gas utilities and pipeline systems. Insignificant hazards will typically be eliminated from consideration in the Phase 1 screening.

Information on other time-dependent, weather-related natural hazards, such as wildfire and flooding, can be obtained through federal websites that have seasonal or more frequent updates (e.g., http://drought.unl.edu/dm, USGS/NWS flood advisories, etc.).

The time-dependent nature of human threat levels has been considered in developing the separation points for human threats in Table 4-1. The hazard level criteria in particular are based on the Threats and Protection Advisory System used by the Department of Homeland Security (http://www.dhs.gov). The high hazard level is based on the Orange (High) and Red (Severe) threat alerts and the existence of specific, credible information about a human threat against critical infrastructure and key industries. The medium hazard level is based on the Blue (Guarded) and Yellow (Elevated) threat alert levels and nonspecific, general information about the potential for a human-caused disruption of service. The threat alert levels have not fallen below Yellow (Elevated) or gone above Orange (High), which seems appropriate for the performance evaluations that have been conducted on gas utilities and pipeline operating companies with respect to human threat events since the alerts were established. The low hazard level is based on the Green (Low) threat alert level and the existence of no known threats to the oil and natural gas industry other than normal activities, which are generally tracked through reporting systems established by State Public Utilities Commissions and the Department of Transportation (Office of Pipeline Safety). The selection of low screening levels is consistent with common types of performance evaluations that were performed prior to September 11, 2001.

When using national hazard maps with this guideline, the user should bear in mind several cautions:

1) The "county level" for data mapping is used because it represents a reasonable and convenient geographic unit to map data (hazards) on a national level. The county level works better in states with smaller counties, which generally means areas east of the Rocky Mountains. The limitations of using small-scale maps to portray local hazards must be fully recognized, as discussed earlier in this section.

2) When using maps for characterization of hazards at the national or local level, the choices of separation points for low, medium, and high hazards must be established consistent with the underlying basis for the selected map. For example, the use of the earthquake hazard maps produced by the U.S. Geological Survey for the United States and its territories are associated with 2, 5, and 10 percent probabilities of exceedance of the mapped ground-motion values in 50 years. Naturally, the ground-motion value on these maps increases with the decreasing probability of exceedance. Current building codes, such as the 2003 International Building Code (ICC 2003) or NFPA (2003), use ground-motion criteria based on a 2 percent probability of exceedance in 50 years. Gas utilities and pipeline operating companies, however, might elect to base Phase 1 screening and the determination of analysis levels on different probabilities of exceedance. The methodology provided in this guideline should accommodate the various types of maps with their associated probabilities of exceedance, but due consideration should be given

to the choice of appropriate criteria separation points for low, medium, and high hazard levels.

3) ASCE-7 identifies special wind zones that require site-specific input from local building jurisdictions (local maps typically delineating special wind hazard areas). Such areas do not exist unless the wind hazard is significant; therefore, the existence of “special” wind zones is probably sufficient evidence to indicate a need for a Phase 2 evaluation.

4) Some caution should be exercised in the interpretation of flood hazard levels from the map provided in this guideline (Figure 8-5). The low-level separation point for the flooding hazard in Table 4-1 is keyed to the existence of Q3 maps (FEMA 1996, 2003). If a Q3 map is not available, then the hazard is assumed to be generally low. However, if a “local” flood hazard is known to exist for the area of consideration despite the absence of a Q3 map, then the assessment should be upgraded to a Phase 2 evaluation.

4.2 Component Susceptibility Screening

The second stage of the Phase 1 screening process addresses component vulnerability. Table 4-2 provides, based on the judgment of experienced practitioners, qualitative information on the vulnerability of key oil and natural gas pipeline system components. The table is intended to serve as a general guide for typical components and non-critical components. Special circumstances may exist that would cause a particular component, facility, or system to be more or less vulnerable than indicated in Table 4-2. In the case of components or systems that are critical to overall system operations, it may be prudent to skip this screening step and proceed directly to a Phase 2 assessment.

The entries in Table 4-2 identify the general degrees to which oil and natural gas pipeline system components are potentially vulnerable to the hazards and threats described in the Guideline. The entries are either in the form of an unqualified “H,” “M,” or “L” (high, moderate, or low) or may include the consideration of conditions or situations under which a particular component may be vulnerable. Usually these distinctions refer to whether or not a component is located above or below the ground. In general, belowground components tend to be vulnerable to permanent ground movement hazards (surface fault rupture, liquefaction, landslide, frost heave, and settlement). Aboveground components will be more affected by earthquake ground shaking, flooding, wind, icing, and other collateral hazards (blast, fire, dam inundation, collapses of nearby structures, and some human threats). The absence of an entry in a particular cell indicates that the corresponding component is not expected to be susceptible to damage or disruption regardless of hazard level. The entries in Table 4-2 assume that the component is of recent vintage (i.e., post-1945). If the component being evaluated is older than this, it may be more susceptible to damage. In these cases, the original design may not have accounted for some of these hazard types. In such situations, a Phase 2 evaluation is appropriate.

The user will also have to select the vulnerability level for an analysis that includes multiple components or facilities. In such cases, the Guideline recommends that all selected components (see Section 3.2) be evaluated, and that the highest level of vulnerability of the group be used to define the level of analysis.

4.3 Transition to Phase 2 Assessment

Even though the results from Phase 1 suggest otherwise, there may be several reasons to proceed to a Phase 2 assessment.

Some of these reasons include:

- A quantitative response to an inquiry is deemed necessary,
- A known localized hazard exists that is not identified by national level hazard maps,
- The hazard under assessment is a human threat,
- There are known incidents or failures that suggest a higher level of vulnerability than is implied by Table 4-2,
- The component under assessment is extremely critical to system operations, or
- Maintaining service is vital to national security.

As a general rule, if eliminating any subsequent studies (based on the results of the Phase 1 evaluation) appears questionable, the user should proceed to Phase 2. At a minimum, this would indicate the need for a Level 1 analysis, but not necessarily a higher level unless other significant factors come into consideration.

Table 4-2. Degree of Component Vulnerability to Damage or Disruption from Natural Hazards and Human Threats

Hazards	Degree of Vulnerability									
	Transmission Pipelines	Pump Stations	Compressor Stations	Processing Facilities	Storage Tanks	Control Systems	Maintenance and Operations Buildings and Equipment	Pressure Regulating/Metering Stations	Distribution Pipelines	Service Lines or Connections
Natural Hazards										
Earthquake Shaking	L	M	M	M	H	M	H	L	L	M
Earthquake Permanent Ground Deformations (fault rupture, liquefaction, landslide and settlement)	H	–	–	–	L	–	–	L	H (Buried)	M
Ground Movements (landslide, frost heave, settlement)	H	–	–	–	L	–	–	L	H (Buried)	M
Flooding (riverine, storm surge, tsunami and seiche)	L	H	H	H	M	H	H	H	L	M
Wind (hurricane, tornado)	L (Aerial)	–	–	–	–	L	L	–	–	–
Icing	L	–	–	–	–	–	–	–	L	–
Collateral Hazard: Blast or Fire	M	H	H	H	H	M	L	L	L	M
Collateral Hazard: Dam Inundation	L	H	H	H	M	H	H	H	L	M
Collateral Hazard: Nearby Collapse	–	L	L	L	–	L	L	L	M	L
Human Threats										
Physical Attack (biological, chemical, radiological and blast)	M	M	M	M	–	M	M	–	M	–
Cyber Attack	–	L	L	L	–	H	L	–	L	–

Note Degrees of vulnerability: H=High, M=Moderate, and L=Low. When a component or system is located within a building, the vulnerability of both the building and component should be considered. For example, where there is a potential for building collapse or mandatory evacuation, the equipment housed within is at risk. The entries in Table 4-2 assume that the component is of recent vintage, i.e., post 1945.

5.0 Phase 2–Recommended Steps in Performing Level 1 through Level 3 Analyses

For those components and systems found to be at risk in the Phase 1 screening, a Phase 2 analysis is recommended. This section introduces scoring criteria used to initiate a Phase 2 evaluation. Selection of a Level 1, Level 2, or Level 3 analysis for Phase 2 depends on factors such as the scope of the inquiry, hazard level, vulnerability level, nature of consequence, and system redundancy level.

Conducting a Phase 2 analysis generally results in some quantitative outcome, which is valuable because the performance can be assessed relative to specific metrics and compared to measurable performance targets. For this reason, Phase 2 analyses are particularly useful in hazard reduction programs where the benefits and costs of mitigation can be compared directly.

Determining the appropriate level for the performance analysis is integral to Phase 2. To facilitate this decision, a set of scoring criteria is employed to determine an appropriate level of analysis based on hazard, vulnerability, and system information. This section also provides guidance on how to modify these determinations using information from the inquiry itself. A long list of inquiries serves as examples for these modifications.

The detailed tables at the end of the section identify specific tasks that should be considered under each level of analysis. Examples of the recommended types of analysis can also be found in the commentary.

5.1 Initial Selection of Analysis Level Based on Systematic Scoring Criteria

Individuals with requisite experience in risk assessment can often intuitively select the appropriate analysis levels for the hazard, vulnerability, and system performance. As an alternative to such experience and intuition, a systematic scoring procedure for determining a baseline level of analysis has been developed specifically for this guideline. The resulting baseline from scoring can be adjusted upward or downward for particular analysis elements depending on the type of inquiry, budget and schedule constraints, and consideration of specific performance measures. Examples of hazard, vulnerability, and system performance analysis levels for specific inquiries are discussed in Section 5.2.

The scoring system provides a systematic and objective process for determining an overall or baseline level of analysis for performance assessments. It is assumed that a Phase 1 screening has been completed (see Section 4) and that analyses associated with no hazard or no vulnerability have been eliminated from consideration. The scoring system accounts for

- Severity of the hazard,
- Vulnerability of the system or component,
- Damage consequences, including life safety, financial loss, disruption of service, and environmental and other impacts,
- Degree of redundancy inherent in the system being assessed (i.e., highly redundant, redundant, or non-redundant), and

- Size of the system.

The first step in the scoring process is to compute an overall level index for the performance assessment. It is defined as the product of individual severity indices for Hazard, Vulnerability and Consequence of Damage. The index is compared to defined ranges that suggest the overall analysis level, either Level 1, Level 2, or Level 3. This evaluation must be conducted on a hazard-by-hazard basis (i.e., there is no attempt at integrating the results from different hazards).

The level index (I_L) is defined as the product of the individual severity indices

$$I_L = H \times V \times \max (C_{LS}, C_{FL}, C_{SD}, C_{EI}) \quad (5\text{-}1)$$

where,

H = Hazard score (Low = 1, Medium = 2, High = 3 as defined in Table 4-1)

V = Vulnerability score (Low = 1, Moderate = 2, High = 3 as defined in Table 4-2)

C_{LS} = Life safety consequence score, varies from 1 to 6 as defined in Table 5-1

C_{FL} = Financial loss consequence score, varies from 0.5 to 6 as defined in Table 5-1

C_{SD} = Service disruption consequence score, varies from 0.5 to 6 as defined in Table 5-1

C_{EI} = Environmental impact consequence score, varies from 1 to 6 as defined in Table 5-1

In Table 5-1, adjustment factors are used to modify the individual consequence scores to account for special conditions that could result in an increase or decrease in consequential effects due to the failure of a system component (e.g., a pipeline). The adjustment factors allow the flexibility of weighting certain performance conditions according to the relative threat to life safety, redundancy in source or service options, and special environmental consequences. Respectively, these adjustment factors are R_{LS}, R_S, and R_{EI}.

- Life safety adjustment factor (R_{LS}) is used in the determination of the life safety score (C_{LS}). R_{LS} has a value of either 1 or 2. Ordinarily, it should be calculated as 1 for gas utility or pipeline systems operating under normal circumstances. If the system is transporting an unusually hazardous gas or liquid product in areas where the safety of the public could be seriously threatened by a release, R_{LS} should be calculated as 2.

- System-type modifier or redundancy factor (R_S) is used to determine the financial loss consequence score (C_{FL}) and the service disruption consequence score (C_{SD}). The use of the system-type modifier accounts for the mitigation of consequences through the presence of system redundancy; that is, the effect of redundancy is to reduce the system performance consequences of damage due to a hazard event. The system-type modifier should typically be set to 1 unless circumstances exist to warrant adjusting the financial loss or service disruption factors. For example, a gas utility may rate the system-type modifier as 2 (non-redundant) because it has no alternative means of providing natural gas service to a critical customer, while the customer may rate the redundancy factor as 0.5 because of the presence of a back-up energy source on site. Thus, the service disruption factor (C_{SD}) could vary depending on the nature of the inquiry and who is performing the assessment. Similar considerations for the nature of the inquiry arise when applying the system modifier to the financial loss factor *(C_{FL})*. For example, the financial loss associated with the repair of damage may not be as significant to a gas utility compared to an industrial customer or local community with no alternate energy source.

- Environmental adjustment factor *(R_{EI})* is used in the determination of the life safety score *(C_{EI})*. R_{EI} has a value of either 1 or 2. It should be calculated as 1 for all gas systems and most liquids pipeline systems. R_{EI} should, however, be calculated as 2 for liquids pipelines in particularly fragile environmental areas or areas with high potential for watershed or groundwater contamination.

Table 5-1. System Performance Consequence Scoring

Consequence	Severity of Consequence		
	Low	Moderate	High
Life Safety, C_{LS}	Minimal impact on life safety; no significant impact to gas utility or pipeline operating company personnel or the public in the immediate area of the facility. $C_{LS} = R_{LS}$	Damage or disruption may result in some injuries to gas utility or pipeline operating company personnel or the public in the immediate area of the facility. $C_{LS} = 2\ R_{LS}$	Damage or disruption will result in a significant impact on the life-safety to gas utility or pipeline operating company personnel or the public in the immediate area of the facility. $C_{LS} = 3\ R_{LS}$
Financial Loss, C_{FL}	Little or no impact on the financial resources of the gas utility or pipeline operating company. $C_{FL} = R_S$	Damage or disruption can result in major financial losses; losses, however, will have little or no impact on the financial integrity of the gas utility or pipeline operating company. $C_{FL} = 2\ R_S$	Damage or disruption will have a significant impact on the financial integrity of the gas utility or pipeline operating company or a customer. $C_{FL} = 3\ R_S$
Service Disruption, C_{SD}	Little or no impact on service population. $C_{SD} = R_S$	Disruption of service will impact a small portion of the service population (less than 10%) for less than a day and does not affect a critical customer. $C_{SD} = 2\ R_S$	Disruption of service will either 1) impact a sizable portion of the service population (greater than 10%), 2) potentially affect service populations in excess of 100,000, 3) cause widespread outages for more than a day, or 4) affect the operation of a critical facility. $C_{SD} = 3\ R_S$
Environmental Impact, C_{EI}	Little or no impact on environment. $C_{EI} = R_{EI}$	Failure or disruption can result in limited environmental damage. $C_{EI} = 2\ R_{EI}$	Failure or disruption can result in major environmental damage (i.e., it will take months to years to remediate). $C_{EI} = 3\ R_{EI}$

Note: The factors R_{LS}, R_S, and R_{EI} are adjustment factors that are used to modify the individual consequence scores in Table 5-1. R_{LS} is a life safety adjustment factor, which should be taken as 1 for gas utility or pipeline systems operating under ordinary circumstances or 2 for systems transporting an unusually hazardous gas or liquids in areas with significant population density. R_S is a system-type modifier that accounts for system redundancy: 0.5 for highly redundant (i.e., the failure of component does not degrade system performance), 1 for redundant (i.e., the failure of component degrades system performance), and 2 for non-redundant (the function served by that component cannot be alternatively served). R_{EI} is an environmental adjustment factor that should be taken as 1 for all gas systems and most liquids pipeline systems. R_{EI} should be taken as 2 for liquids pipelines in particularly fragile environmental areas or areas with high potential for watershed or groundwater contamination.

The second and final step of the scoring process is to compare the level index (I_L) to a set of preset range cutoffs that define a recommended baseline level for the performance assessment. Based on all possible permutations of input parameters, the level index may range in value from 0.5 to 54. The baseline level for the performance assessment is determined by the following range:

Table 5-2. Selection of Appropriate Levels of Analysis

Level Index, I_L	Baseline Level for Performance Assessment
$I_L \leq 6$	No Assessment
$7 \leq I_L < 17$	Level 1
$17 \leq I_L < 35$	Level 2
$I_L \geq 35$	Level 3

As mentioned earlier, the baseline level represents a starting point for establishing the level of analysis. Analysis levels might require upward or downward adjustment depending upon the type and source of the inquiry (see Section 5.2).

5.2 Factoring the Source and Content of the Inquiry into the Levels of Analysis

The scoring system described in the previous section indicates the recommended levels of evaluation based on hazard information, component vulnerabilities, system redundancies, and the consequences of system failure or disruption. In actual practice, the source of the inquiry and the content of the inquiry may limit or expand the levels of evaluation required. Table 5-3 contains numerous sample inquiries and the levels of evaluation that may result when one considers the source (who is asking the question) and content of the inquiry (what is being asked). These sample inquiries are developed to assist in adapting the generic assignments of evaluation level (as described in Section 5.1) to specific conditions or situations that may be prompted by a particular inquiry or inquiry source. The assessment levels associated with the sample inquiries may also be used directly to obtain a preliminary estimate of the likely scope of the assessment. In this table, H, V, and S are defined in terms of the levels of effort (see Section 2.4) required to perform a hazards, vulnerability, or systems evaluation, respectively.

There are three types of cases in Table 5-3 in which the overall scoring system may be modified by considering the source and content of the inquiry. The first type only requires a general response to an issue that may otherwise merit a high level of effort. The general response does not end all inquiry; instead, it satisfies the party making the inquiry with respect to the level of detail required for this response. The second type occurs when the source requires a higher level of analysis than would otherwise be deemed necessary by the scoring system. In this case, the scoring system can serve as one basis for maintaining that a lower level of analysis may be desirable, if only in the initial stages of the evaluation. The third type occurs when some of the component evaluations (for hazards, vulnerabilities, or systems) are either below or above the overall level of analysis recommended by the scoring system. In these cases, more detailed or less detailed analyses are suggested in order to more adequately address the essence of the inquiry.

Table 5-3. Sample Inquiries and Suggested Levels of Analysis for Hazards (H), Vulnerability (V), and System (S) Evaluations

Sample Inquiry Content	Source of Inquiry	Level of Analysis			Key Considerations
		H	*V*	*S*	
1. Inquiry by a regulatory body on general system exposure	External	1	1	1	Source and content may limit levels required.
2. Customer request on reliability of service	External	1	1	1	Source may limit levels required.
3. General inquiry by the press or public	External	1	1	1	Source may limit levels required.
4. Interaction with professional associations	External	1	1	1	Source may limit levels required.
5. Inquiry by a regulatory body on location of a landslide hazard relative to a facility	External	2	1	1	Content may limit levels required.
6. Inquiry by a regulatory body on consequence of a local hazard on a facility	External	1	2	1	Scoring system may imply a Level 1 or Level 2 overall evaluation; source and content require more than a Level 1 effort.
7. Inquiry by a regulatory body on consequence of a local hazard on a critical facility	External	2	2	2	Consistent with scoring a Level 3 overall effort, except that systems issues are assumed.
8. Inquiry by a regulatory body on detailed evaluation of hazards relative to a cluster of facilities	External	3	1	1	Source and content imply levels of analysis suggested.
9. Inquiry by a regulatory body on detailed evaluation of a hazard relative to a facility	External	3	2	1	Source and content imply levels of analysis suggested.
10. Regulatory body wanting more detailed information on criticality and hazard design parameters	External	2	1	2	Source and content imply levels of analysis suggested.

Continued

11. New regulation to require a given performance level for specific hazards	External	3	3	3	Source and content imply levels of analysis suggested.
12. Regulatory body requesting detailed evaluation of potential service losses given specific localized hazards (e.g., landslides)	External	2	1	3	Source and content imply levels of analysis suggested; levels of analysis for systems evaluation may be less than "3" due to systems evaluation capabilities already present.
13. Regulatory body requesting detailed evaluation of potential single-contingency service losses with respect to specific critical facilities	External	3	3	3	Consistent with likely overall score; levels of analysis for systems evaluation may be less than "3" due to systems evaluation capabilities already present.
14. Regulatory body requesting detailed evaluation of potential service losses given detailed evaluation of localized hazards	External	3	1	3	Consistent with likely overall score.
15. Inquiry to know general information on criticality and detailed information on hazards used in new design	Internal/ External	3	1	2	May be consistent with overall score—content implies limited analysis on component vulnerability evaluations.
16. Regulatory body wanting a detailed evaluation of unexpected high system losses	Event/ External	3	3	2	Likely to be consistent with overall score.
17. Upper management wanting to know general financial exposure	Internal	1	2	1	Content implies that the focus is on expected repair and replacement cost forecasts.
18. Addressing risk management or insurance issues	Internal	1	2	1	Content implies a major focus on repair and replacement cost forecasts.
19. Investor concerns	Internal	2	2	2	Source implies significant but not highest level of analysis.
20. Upper management wanting to know general exposure	Internal	2	2	2	Source implies significant but not highest level of analysis.
21. Upper management request to identify the most critical facilities relative to mapped localized hazards (e.g., landslides)	Internal	1	1	3	Content implies that only systems evaluations are needed at a higher level.

Continued

22. Follow-up request to characterize in greater detail the vulnerabilities of critical facilities	Internal	1	2	3	Content implies increased component evaluation level.
23. Follow-up request to analyze in detail the vulnerabilities implied by 23	Internal	1	3	3	Content implies significant component evaluation level.
24. Determining post-hazard service to critical facilities served (e.g., hospitals)	Internal	2	2	3	Level of analysis likely to be consistent with overall scoring.
25. Upper management wanting a thorough natural hazards management system emphasizing detailed evaluations of hazards	Internal	3	2	3	Source and content set levels of analysis.
26. Upper management wanting a natural hazards risk management system that allays all concerns about due diligence	Internal	3	3	3	Source and content set levels of analysis.
27. Inquiry by the Board of Directors for the gas utility or pipeline operating company on a specific hazard concern	Internal	1	1	1	Source limits desired levels of analysis.
28. Disaster that causes slightly unexpected damage	Event/ Incident	1	1	1	Content dictates levels of analysis.
29. Inquiry on specific hazards leading to unexpected damage having significant system impacts	Event	3	2	2	Likely to be consistent with overall scoring.

5.3 Recommended Tasks in Performing Level 1 through Level 3 Analyses

Sections 5.1 and 5.2 provide general guidance for determining the level of analysis appropriate for each element of the performance assessment (hazard, component vulnerability, and system performance). The next step in the assessment process identifies the specific tasks required to perform a Level 1 (simplified), Level 2 (intermediate), or Level 3 (detailed) analysis.

Tables 5-4 through 5-9 summarize the recommended tasks for performing analyses for Levels 1 through 3. Tables 5-4 through 5-6 address natural hazards, and Tables 5-7 through 5-9 address human threats. Each set of tables contains a table for quantifying the hazard (Tables 5-4 and 5-7), a table for assessing component vulnerability (Tables 5-5 and 5-8), and a table for examining system performance (Tables 5-6 and 5-9). Specific tasks are identified in each row of the tables and the diamonds indicate inclusion of the task in one or more levels of analysis. Consistent with the terminology introduced previously, the letters refer to a specific element of the assessment (H refers to hazard; V, vulnerability; and S, system performance) and the number after the letter indicates the level of analysis (e.g., H1 refers to Hazard Level 1).

Tasks at each lower level are typically repeated at higher levels. This is intentional because the details of each subsequent analysis level build on the information and data collected in lower levels. The absence of a diamond in a lower level means that the associated analysis task can only be conducted at a higher level.

The tasks that are reflected in each of the tables are key to defining the precise scope of the assessment. As previously noted, they may be equated to the tasks delineated in a Request for Proposal (RFP). Furthermore, the type of inquiry that initiated the planning of the performance assessment serves to define the overall objective of the assessment. The guidance provided in Section 5.4 should assist the user in developing a rough estimate of the cost and time required to complete the assessment. In total, the information contained in Tables 5-4 through 5-9 and the discussion in the previous sections should be sufficient for developing a scope of work for a Phase 2 assessment.

Background discussion of methods for conducting individual tasks in Tables 5-4 through 5-9 is included for reference in the commentary.

5.4 Factoring in Cost and Schedule

Cost and schedule considerations also affect the selection of analysis levels for a Phase 2 performance assessment. It is important to develop realistic estimates for the level of effort and resources, including technical expertise, required for an assessment. Table 5-10 provides estimates of the range of effort generally required for the different elements of a performance assessment (hazard, vulnerability, and system performance). The level of effort is measured in terms of the number of days, weeks, or months required by the equivalent of an appropriately qualified full-time employee to perform a specific scope of work. For purposes of establishing a baseline, this guideline assumes that the system under investigation is a large gas utility or pipeline system with many sites and components. Smaller systems, with fewer sites and components, or investigations of isolated parts of the system would require resources that are more modest.

The estimated levels of effort in Table 5-10 are intended to serve as general ranges only. The level of effort required to complete these assessments may vary considerably according to the background and experience of the personnel or specialists assigned to the work tasks. Similarly, the completion schedule can vary according to the total resources that can be devoted to the effort.

As shown in Table 5-3 and discussed in Section 5.2, various combinations of hazard (H), vulnerability (V), and system performance (S) assessments are possible. The accuracy and completeness of a Phase 2 performance assessment can vary according to the selection of the individual levels of analysis (i.e., the selected levels of H, V, and S). Generally, the accuracy and completeness of the analysis improve by increasing the resources and time devoted.

5.5 Dealing with Multiple Hazards

Most gas utilities and pipeline systems are exposed to a variety of natural hazards and human threats. This is due in large part to the extended nature of these systems, both geographically and operationally. Therefore, a comprehensive analysis of risks and vulnerabilities will likely involve more than one hazard.

The ideal assessment process is one that integrates the results of multiple hazard studies so that the overall risk to the system is minimized. To do so, however, would require that risks and/or consequences be evaluated based on all contributing hazards with each hazard being evaluated using the same framework (usually probabilistic). Unfortunately, this type of integration, while meaningful, is beyond the current state-of-practice and is not addressed by this guideline.

Given the tools provided in this guideline, it is possible to develop a relative ranking of hazard studies and results for the most significant hazards. For example, the scoring system presented in Section 5.1 can be used to determine an overall score for each hazard considered. These overall scores can then be used to rank the different hazards eventually leading to a possible prioritization of studies based on relative risk. This type of process (relative ranking) is quite common in the evaluation of multiple risks. It allows an owner to decide how best to reduce significant risks while maintaining a simple and relatively tractable evaluation framework.

Table 5-4. Hazard Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Natural Hazards

Hazard/Task	Notes	H1	H2	H3
1.1 Earthquake Hazard – Surface Fault Rupture				
1.1.1 Review active fault hazard mapping for area, if available		◆	◆	◆
1.1.2 Review topographic maps		◆	◆	◆
1.1.3 Review stereo aerial photographs, if available	1		◆	◆
1.1.4 Perform field reconnaissance (by qualified geologist)	1		◆	◆
1.1.5 Characterize active faults through fault trenching	1			◆
1.1.6 Estimate fault displacements using empirical methods	2		◆	◆
1.1.7 Determine fault displacements and their likelihood through fault trenching, sampling, age dating and analysis	2			◆
1.2 Earthquake Hazard – Liquefaction				
1.2.1 Review literature on regional seismicity	3	◆	◆	◆
1.2.2 Perform systemwide probabilistic seismic hazard assessment (PSHA)	2, 4		◆	◆
1.2.3 Review topographic maps		◆	◆	◆
1.2.4 Review surface geology maps		◆	◆	◆
1.2.5 Review available geotechnical data		◆	◆	◆
1.2.6 Conduct minimal soil borings, standard and/or cone penetration tests (SPTs and CPTS)			◆	
1.2.7 Conduct extensive soil borings, standard and/or cone penetration tests (SPTs and CPTS)				◆
1.2.8 Perform field reconnaissance (by qualified geotechnical engineers)			◆	◆
1.2.9 Identify potentially liquefiable soil deposits by judgment		◆	◆	◆
1.2.10 Identify potentially liquefiable soil deposits by engineering analysis of soils data	2		◆	◆
1.2.11 Estimate lateral spread displacements using empirical methods	2		◆	◆
1.2.12 Estimate liquefaction potential using liquefaction susceptibility maps	2		◆	◆
1.2.13 Perform detailed analysis using analytical tools such as FLAC (Fast Lagrangian Analysis of Continua). Estimate likelihood of liquefaction and extent of lateral spread displacements	2			◆
1.3 Earthquake Hazard – Strong Ground Shaking				
1.3.1 Review literature on regional seismicity	3	◆	◆	◆
1.3.2 Review seismic hazard mapping for area, if available	4	◆	◆	◆
1.3.3 Review surface geology maps		◆	◆	◆
1.3.4 Develop ground motion amplification factors			◆	◆
1.3.5 Estimate ground motion levels using judgment and existing maps	2	◆	◆	◆
1.3.6 Estimate ground motion levels using empirical methods	2		◆	◆
1.3.7 Estimate ground motion levels using analytical methods or tools	2			◆
1.3.8 Perform systemwide PSHA	2, 4			◆

Table 5-4. Hazard Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Natural Hazards

Hazard/Task	Notes	H1	H2	H3
1.4 Earthquake Hazard – Landslide				
1.4.1 Review surface geology maps		◆	◆	◆
1.4.2 Review topographic maps		◆	◆	◆
1.4.3 Review stereo aerial photographs, if available			◆	◆
1.4.4 Review rainfall maps for area		◆	◆	◆
1.4.5 Perform field reconnaissance (by qualified geologists)			◆	◆
1.4.6 Review available ground shaking hazard maps for region	2, 4	◆	◆	◆
1.4.7 Evaluate landslide potential using expert judgment		◆	◆	◆
1.4.8 Evaluate landslide potential using slope stability maps			◆	◆
1.4.9 Evaluate landslide potential using statistical or empirical analysis	2		◆	◆
1.4.10 Evaluate landslide potential using analytical methods	2			◆
1.5 Earthquake Hazard –Tsunami				
1.5.1 Locate facilities within 10 miles of major water bodies		◆	◆	◆
1.5.2 Review topographic maps of coastal areas		◆	◆	◆
1.5.3 Review bathymetric maps of near-shore areas			◆	◆
1.5.4 Estimate potential tsunami flooding using expert judgment	2	◆	◆	◆
1.5.5 Estimate potential tsunami flooding using judgment and evaluation of potential tsunami sources	2		◆	◆
1.5.6 Perform site-specific inundation analysis	2			◆
2.1 Ground Deformation Hazard – Landslide (Non-earthquake related)				
2.1.1 Review surface geology maps		◆	◆	◆
2.1.2 Review topographic maps		◆	◆	◆
2.1.3 Review stereo aerial photographs, if available			◆	◆
2.1.4 Review rainfall maps for area		◆	◆	◆
2.1.5 Perform field reconnaissance (by qualified geologists)			◆	◆
2.1.6 Evaluate landslide potential using expert judgment	2	◆	◆	◆
2.1.7 Evaluate landslide potential using statistical or empirical analysis	2		◆	◆
2.1.8 Evaluate landslide potential using analytical methods	2			◆
2.2 Ground Deformation Hazard – Settlement				
2.2.1 Review surface geology maps		◆	◆	◆
2.2.2 Review topographic maps		◆	◆	◆
2.2.3 Review groundwater maps and available geotechnical reports		◆	◆	◆
2.2.4 Perform field reconnaissance (by qualified professionals)			◆	◆
2.2.5 Evaluate settlement potential using expert judgment	2	◆	◆	◆
2.2.6 Evaluate settlement potential using empirical methods	2		◆	◆

Table 5-4. Hazard Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Natural Hazards

Hazard/Task		Notes	H1	H2	H3
2.2.7	Evaluate settlement potential using advanced analytical methods	2			◆
2.2.8	Determine potential for manmade-induced settlement (e.g., groundwater withdrawal)		◆	◆	◆
2.3 Ground Deformation Hazard – Frost Heave					
2.3.1	Review surface geology maps		◆	◆	◆
2.3.2	Perform field reconnaissance (by qualified geotechnical engineers)			◆	◆
2.3.3	Review existing soil borings, test pits, and ditch logs, as available		◆	◆	◆
2.3.4	Conduct limited soil borings			◆	◆
2.3.5	Conduct extensive soil borings				◆
2.3.6	Evaluate frost-heave potential using expert judgment	2	◆	◆	◆
2.3.7	Evaluate frost-heave potential using empirical methods	2		◆	◆
2.3.8	Evaluate frost-heave potential using advanced analytical methods	2			◆
3 Wind Hazard					
3.1	Review national wind maps (ASCE 7-02)		◆	◆	◆
3.2	Review literature on local wind history		◆	◆	◆
3.3	Identify local conditions that may increase wind hazard	5		◆	◆
3.4	Gather historical storm (hurricane) patterns	6		◆	◆
3.5	Identify potential windstorms using expert judgment		◆	◆	◆
3.6	Conduct field evaluations			◆	◆
3.7	Estimate potential wind hazards using expert judgment		◆	◆	◆
3.8	Perform systemwide probabilistic wind hazard assessment (PWHA)	2			◆
4 Icing Hazard					
4.1	Review national icing hazard map (ASCE 7-02)		◆	◆	◆
4.2	Review literature on local icing history		◆	◆	◆
4.3	Identify local conditions that may increase icing hazard			◆	◆
4.4	Estimate potential icing hazards using expert judgment		◆	◆	◆
4.5	Perform systemwide probabilistic icing hazard assessment				◆
5 Flooding Hazard					
5.1	Review Q3 digital flood maps and national Flood Insurance Rate Maps	7	◆	◆	◆
5.3	Gather local flood data from local/regional jurisdiction	8	◆	◆	◆
5.4	Overlay flood maps onto system maps			◆	◆
5.5	Collect topographic, stream, rainfall data			◆	◆
5.6	Identify potential flooding hazard from local dams or floodways		◆	◆	◆
5.7	Evaluate flooding potential using expert judgment		◆	◆	◆
5.8	Perform analytical flood hazard analysis (HEC RAS, HAZUS-MH)	2		◆	◆

Notes

1 – Generally applies to western U.S. faults because they tend to be expressed by geologic features near the surface.
2 – See Commentary for list of peer-reviewed methods.
3 – There are numerous sources of information on regional seismicity, including a USGS open-file report (USGS 1997) and the USGS website (www.usgs.gov).
4 – Probabilistic seismic hazard maps have been prepared for many areas of the U.S. A good source of publicly available maps for the entire U.S. is the USGS website (http://eqhazmaps.usgs.gov).
5 – Some of these factors are terrain, location of nearby urban developments, etc.
6 – Some of this information is contained on the NOAA website (www.noaa.gov).
7 – Flood hazard maps are available on the FEMA website (www.fema.gov/fhm).
8 – Most local jurisdictions have detailed flood maps for their respective areas.

Table 5-5. Component Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Natural Hazards

Component/Task	Notes	V1	V2	V3
1 Assess Pipeline Vulnerability to Ground Movement Hazards				
1.1 Assess crossings of potential ground movement hazards entirely by engineering judgment for various levels of permanent ground deformation.		◆	◆	◆
1.2 Detailed pipeline analysis for a limited number of representative cases according to pipe diameter, wall thickness, direction of movement relative to pipeline, etc.			◆	◆
1.3 Detailed pipeline analysis for site-specific cases			◆	◆
1.4 Determine pipeline strain criteria based on knowledge of current condition of pipe and welds and review of technical literature on pipe performance	1	◆	◆	◆
1.5 Determine pipeline strain criteria using pipe shell FEA models.	1		◆	◆
1.6 Determine pipeline analysis acceptance criteria using laboratory test programs coupled with pipe shell finite element analysis	1			◆
2 Fragility Assessment of Critical Buildings				
2.1 Gather information by interviewing company operations managers and building maintenance personnel		◆	◆	◆
2.2 Identify critical functions within buildings and the damage that would impair or impede these functions		◆	◆	◆
2.3 Perform general site survey(s) to assess local conditions and to collect information on the general vulnerability of buildings, their contents, and any nearby equipment and their supports	2		◆	◆
2.4 Perform general site survey(s) to assess collateral hazards from off-site sources and nearby structures and equipment	3		◆	◆
2.5 Assess performance of building and support equipment using judgment (estimates or informed estimates) and/or experience (statistical) data from past events or using empirical damage models with minimal field data collection	4	◆	◆	◆
2.6 Review architectural and structural drawings, design calculations, foundation investigation reports, and past structural assessment reports to assess building capacity			◆	◆
2.7 Perform independent structural calculations to assess building capacity	4		◆	◆
2.8 Develop computer-based structural analysis model(s) to assess building response	4			◆
3 Assess Storage Tanks				
3.1 Assess tank structural integrity by engineering judgment		◆	◆	◆
3.2 Assess tank structural integrity using API 650 Standard or equivalent tank design methodology			◆	◆
3.3 Assess effects of tank overtopping by sloshing			◆	◆
3.4 Assess effects of tank sloshing on floating roofs (internal or external)			◆	◆

Notes

1 – Pipeline strain criteria should be established with a margin of safety commensurate with the consequences of failure.
2 – There are several manuals that identify key steps in conducting a site survey. See Commentary for references. Users should, however, consider whether equipment items are restrained and, if so, how they are restrained.
3 – Key items to note are steep slopes, the locations of large tanks or reservoirs, possible chemical spill sources, and large towers or trees (especially on slopes near ingress and/or egress routes).
4 – See Commentary for examples.

Table 5-6. System Performance Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Natural Hazards

Task	Notes	S1	S2	S3
1 System Performance Assessment				
1.1 Review system maps		◆	◆	◆
1.2 Review system performance in past natural hazards/events		◆	◆	◆
1.3 Develop system model of critical operations			◆	◆
1.4 Overlay system model onto map of different hazards (GIS function)	1		◆	◆
1.5 Estimate system performance using expert judgment	2	◆	◆	◆
1.6 Perform systems analysis for limited scenarios (minimum 3)			◆	◆
1.7 Perform systems analysis for full probabilistic analysis	3			◆

Notes

1 – Most utilities are moving towards some type of geographic information system (GIS) to map key system data and information.
2 – One way of examining performance is to create a set of scenarios that can be reviewed by key operations personnel.
3 – See Commentary for examples.

Table 5-7. Hazard Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Human Threats

Hazard/Task	Notes	H1	H2	H3
1.1 Hazard Assessment – Biological, Chemical, Radiological and Blast				
1.1.1 Collect historic data on incidents and near misses		◆	◆	◆
1.1.2 Collect historic data on other companies and industrial systems – statistical approach	1	◆	◆	◆
1.1.3 Review one-call activity reports			◆	◆
1.1.4 Review third-party activity and incident history reports			◆	◆
1.1.5 Review federal and state homeland security agency data	2	◆	◆	◆
1.1.6 Consult with internal experts – expert opinion and estimate	3	◆	◆	◆
1.1.7 Consult with local law enforcement agencies – expert opinion			◆	◆
1.1.8 Consult with other gas utilities or pipeline operating companies				◆
1.1.9 Create threat scenarios that can be reviewed with operations personnel	4			◆
1.2 Hazard Assessment – Cyber				
1.2.1 Collect historic data on other companies and industrial systems	1	◆	◆	◆
1.2.2 Review federal and state homeland security agency data		◆	◆	◆
1.2.3 Consult with internal experts	3	◆	◆	◆
1.2.4 Consult with other gas utilities or pipeline operating companies				◆
1.2.5 Consult with information technology companies dealing with cyber security				◆

Notes

1 – Many of these reports can be obtained from the Federal Energy Regulatory Commission (FERC) or the Department of Homeland Security.
2 – Some agencies that might provide useful data include: Department of Homeland Security – Critical Infrastructure Protection Initiative; Federal Emergency Management Agency; Center for Strategic and International Studies; American Society for Industrial Security, and Rand Corporation.
3 – These would include Director of Security, Chief Information Officer, etc.
4 – This may require the help of experts who deal specifically with these kinds of threats.

Table 5-8. Component Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Human Threats

Task	Notes	V1	V2	V3
1 Data Collection				
1.1 Collect system operations and maintenance data		◆	◆	◆
1.2 Collect design, material, and construction records for critical systems		◆	◆	◆
1.3 Collect information on emergency response plans		◆	◆	◆
1.4 Collect data on right-of-ways and nearby urban development		◆	◆	◆
1.5 Collect data on company staffing levels, schedules, and emergency response capabilities		◆	◆	◆
2 Exposure Assessment				
2.1 Assess local conditions surrounding key systems (e.g., system or facility visibility, location of system relative to businesses and/or public systems, and local terrain conditions)			◆	◆
2.2 Review hard and soft target security procedures in place		◆	◆	◆
2.3 Review internal and external security coordination			◆	◆
2.4 Review public safety consequences communication procedures				◆
2.5 Review firefighting capabilities at systems, including training and equipment			◆	◆
2.6 Review federal, state, and local emergency service capabilities and locations		◆	◆	◆
2.7 Review system operating characteristics (e.g., manned/unmanned status, frequency of visual inspections, operator training, and equipment failure reports)			◆	◆
2.8 Review control room procedures and field coordination			◆	◆
2.9 Review backup plans for communication and power failures			◆	◆
3 Vulnerability Assessment				
3.1 Identify possible motivations for threat (e.g., political, social, religious, ideological, economic, or revenge/retribution)		◆	◆	◆
3.2 Review internal procedures with outside federal, state, and local security agencies – estimate			◆	◆
3.2 Use expert judgment (internal and/or external) to assess system vulnerabilities – expert opinion		◆	◆	◆
3.3 Use commercial or government software to assess system vulnerabilities – simulation and penetration tests	1			◆

Notes

1 – See the Commentary for examples.

Table 5-9. System Performance Evaluation Matrix for Oil and Natural Gas Pipeline Systems – Human Threats

Task	Notes	S1	S2	S3
1 System Performance Assessment				
1.1 Contact federal, state, and local agencies, industrial organizations and insurance firms regarding system assessments		◆	◆	◆
1.2 Evaluate the effectiveness of security assessment methods and their mitigative risk control activities			◆	◆
1.3 Evaluate the effectiveness of current management systems and processes in support of security integrity decisions			◆	◆
1.4 Use expert judgment (internal and outside) to estimate expected system performance		◆	◆	◆
1.5 Perform simulation studies on selected subsystems			◆	◆
1.6 Conduct penetration tests at critical facilities such as operations control centers (i.e., red and white cells – field and table top exercises)	1			◆

Notes

1 – In this type of analysis, a white cell communicates information during a simulation between the gas utility or pipeline operating company and the red cell component of the exercise; a red cell performs the reconnaissance and scenario development and exploits particular incidents during an exercise.

Table 5-10. Range of Effort Needed to Perform Different Assessments at Different Levels

				VULNERABILITY ASSESSMENT		
				V1	V2	V3
SYSTEM ASSESSMENT LEVEL	S1	HAZARD ASSESSMENT	H1			
			H2			
			H3			
	S2	HAZARD ASSESSMENT	H1			
			H2			
			H3			
	S3	HAZARD ASSESSMENT	H1			
			H2			
			H3			

Level of effort – 1 to 15 days of a full-time employee equivalent

Level of effort – 3 to 10 weeks of a full-time employee equivalent

Level of effort – 3 to 9 months of a full-time employee equivalent

6.0 Examples

The following hypothetical examples illustrate how to use of this Guideline. These examples are based primarily on external inquiries. They neither apply to an actual oil or natural gas system nor represent an actual inquiry. Moreover, these examples are not intended to be representative of any requirements, legislation, or standards that exist at this time.

Example 1: Inquiry by a Regulatory Body – Exposure of a Liquid Products Pipeline to Landslide Hazard

Inquiry: Because the loss of vegetative cover during an unusually severe summer season of wildfires in San Bernardino County, California, was widespread, the county is anticipating severe landslides during the winter rains. The county emergency management agency asks an engineering manager for a pipeline company to report on the vulnerability of a liquid products pipeline to landslide hazards. The schedule for completing the assessment is limited to no more than six weeks.

Assessment: The pipeline company will base its response on 1) the location of its pipeline relative to the burn areas, 2) the steepness of slopes, 3) slope drainage features that might exacerbate the potential for landsliding, and 4) the vulnerability of the pipeline to ground displacement.

Step 1: *Determine general hazard exposure (Phase 1 assessment).* The hazard level for landslides in San Bernardino County, California, is designated "High" (see Figure 8-2).

Step 2: *Determine general vulnerability to damage or disruption (Phase 1).* The vulnerability matrix in Table 4-2 indicates that transmission pipelines have a High vulnerability to permanent ground deformations such as landslides. Because both the hazard and vulnerability level are high, the user is prompted to proceed to a Phase 2 assessment.

Step 3: *Determine the hazard rating and score.* The landslide hazard for San Bernardino County is High (see Figure 4-2 and Appendix A of the Commentary). The hazard score per Section 5.1 for a High rating is 3.

Step 4: *Determine the vulnerability rating and score.* Table 4-2 indicates buried pipelines have a High vulnerability to landslides. The vulnerability score per Section 5.1 for a High rating is 3.

Step 5: *Determine the consequence rating and score.* Using Table 5-1, the adjustment factors for life safety (R_{LS}) and environmental impact (R_{EI}) are taken as 1 because the pipeline does not transport an unusually hazardous product and the environment is not considered fragile. The system-type modifier (R_S) is taken as 2 because the liquid products line is a non-redundant transmission line. From Table 5-1, the consequence of failure of liquid products pipeline can be characterized as:

- Life safety, low, $C_{LS} = R_{LS} = 1$

- Financial loss, low, $C_{FL} = R_S = 2$
- Service disruption, low, $C_{SD} = R_S = 2$
- Environmental impact, moderate, $C_{EI} = 2$ $R_{EI} = 2$

The maximum consequence rating for use in Equation 5-1 is 2.

Step 6: *Determine the overall rating.* Using Equation 5-1 with the hazard, vulnerability, and consequence scores from Steps 3 through 5, the level index is computed to be:

$$I_L = H \times V \times \max(C_{LS}, C_{FL}, C_{SD}, C_{EI}) = 3 \times 3 \times 2 = 18$$

For a level index (I_L) of 18, Table 5-2 recommends a baseline Level 2 for performance assessment, which means an H2-V2-S2 analysis. The V2 vulnerability analysis, however, must be reduced to V1 (as described in Step 8) because there is insufficient time to complete the work. Furthermore, the S2 system assessment can be reduced to S1 because the inquiry is limited to the pipeline only and has little effect on the system as a whole. Hence, the analysis level becomes H2-V1-S1.

Step 7: *Perform Level 2 Hazard (H2) Analysis.* Referring to Table 5-4, an H2 analysis consists of tasks 1.4.1 through 1.4.9 of Table 5-4 (review of topographic maps, aerial photographs, and rainfall maps; field reconnaissance; ground shaking hazard; and evaluation of landslide potential using slope stability maps and statistical/empirical analysis).

Step 8: *Perform Level 1 Vulnerability (V1) Analysis.* The results of scoring in Step 5 indicate a Level 2 vulnerability analysis. Examination of the task list for Level 2 in Table 5-5, however, calls for fairly detailed and extensive finite element analysis to evaluate pipeline response and to determine applicable strain criteria. The six-week schedule is inadequate for this level of effort, so it is necessary to drop the vulnerability analysis to Level 1. A Level 1 vulnerability analysis consists only of task 1.1 and task 1.4, respectively, to assess ground movement hazards entirely by engineering judgment and to determine applicable pipeline strain criteria based on current condition of the pipe and welds and review of technical literature on pipe performance.

Step 9: *Perform Level 1 Systems (S1) Analysis.* For a Level 1 systems analysis, Table 5-6 recommends tasks 1.1, 1.2, and 1.5, which include a review of system maps to determine pipeline segments at risk, a review of system performance in past (similar) events, and an estimate of system performance in potential landslide areas using expert judgment.

Results: If the risk of pipeline failure and associated consequences as determined by the performance assessment are judged unacceptable, further assessment using higher levels in one or more of the analysis elements may be necessary. A more quantitative and reliable result would be expected for higher analysis levels.

Example 2: Inquiry by a Regulatory Body – Definition of a Local Hazard on a Crude Oil Storage Tanks

Inquiry: Eighteen large crude oil storage tanks are housed in a Pacific Northwest crude oil terminal facility located approximately two miles from a newly discovered subsurface thrust fault. Owing to its location at a port, the Environmental Protection Agency is concerned about the possibility of environmental damage to the surrounding coastal area and asks the crude oil facility to report on the vulnerability of the storage tanks to the thrust fault.

Assessment: The terminal facility will base its response on 1) the location of the terminal in proximity to the fault, 2) the design of the tanks for seismic loading, 3) the current condition of the tanks, 4) fluid levels for usual operating scenarios, and 5) secondary containment.

Step 1: *Determine exposure of region to seismic hazards (Phase 1).* According to Figure 8-1, the seismic hazard for this area is considered "High."

Step 2: *Determine general vulnerability to damage or disruption (Phase 1).* The vulnerability matrix in Table 4-2 indicates the oil storage tanks have a High vulnerability to ground shaking. Because both the hazard and vulnerability levels are high, the user is prompted to proceed to a Phase 2 assessment.

Step 3: *Determine the hazard rating and score.* The seismic hazard of the Pacific Northwest is High (see Figure 8-1). In addition, there is a newly discovered seismic source, which the seismic hazard map of Figure 8-1 simply confirms. The hazard score per Section 5.1 for a High rating is 3.

Step 4: *Determine the vulnerability rating and score.* Table 4-2 indicates the vulnerability of a crude oil storage tank to earthquake shaking is High. The vulnerability score per Section 5.1 for a High rating is 3.

Step 5: *Determine the consequence rating and score.* Using Table 5-1, the life safety factor (R_{LS}) is taken as 1 because the storage tanks contain crude oil, which is not "unusually hazardous" to the public. The system-type modifier (R_S) is taken as 0.5 because it is reasonable to assume that the tanks in a tank farm would be filled to different levels, such that some of the tanks would experience only minimal inertial loading, thereby lowering the propensity for damage. The environmental impact (R_{EI}) is taken as 2 due to the extreme concern for protecting the coastal environment. From Table 5-1, the consequence of failure of crude oil storage tanks can be characterized as:

- Life safety, low, $C_{LS} = R_{LS} = 1$
- Financial loss, moderate, $C_{FL} = 2\ R_S = 2 \times 0.5 = 2$
- Service disruption, low, $C_{SD} = 2\ R_S = 2 \times 0.5 = 2$
- Environmental impact, low (due to secondary containment), $C_{EI} = R_{EI} = 2$

The maximum consequence rating for use in Equation 5-1 is 2.

Step 6: *Determine the overall rating.* Using Equation 5-1 with the hazard, vulnerability, and consequence scores from Steps 3 through 5, the level index is computed to be:

$$I_L = H \times V \times \max(C_{LS}, C_{FL}, C_{SD}, C_{EI}) = 3 \times 3 \times 2 = 18$$

For a level index (I_L) of 18, Table 5-2 recommends a baseline Level 2 for performance assessment, which implies an H2-V2-S2 analysis.

Step 7: *Perform Level 2 Hazard (H2) Analysis.* Referring to Table 5-4, an H2 analysis for ground shaking effects consists of tasks 1.3.1 through 1.3.6 (review of regional seismicity, seismic hazard mapping, surface geology maps, and ground motion amplification followed by estimates of ground motion levels using judgment, existing maps, and empirical methods).

Step 8: *Perform Level 2 Vulnerability (V2) Analysis.* Per Table 5-5, a Level 2 vulnerability analysis for a storage tank consists of tasks 3.1 through 3.4 for the analysis of tank structural integrity, overtopping by sloshing, and sloshing damage to floating roofs.

Step 9: *Perform Level 2 System (S2) Analysis.* For a Level 2 system analysis, Table 5-6 recommends tasks 1.1 through 1.6. Considering the facility under examination is a tank farm, however, the systems tasks related to tanks involve tasks 1.5 and 1.6 to determine credible scenarios of tank volumes and thereby the likelihood of one or more tanks losing containment.

Results: If the risk of tank failures and associated consequences as determined by the performance assessment are judged unacceptable, further assessment using higher levels of analysis may be required.

Example 3: Inquiry by a Regulatory Body – Detailed Evaluation of a Hazard Relative to an Extremely Critical Facility

Inquiry: The Public Utilities Commission requests a natural gas utility to assess the risk of chemical/biological attack on its operations control center (OCC).

Assessment: The utility will base its response on its vulnerability to the identified threats and the actions currently being taken to reduce the potential for such an event to occur.

Step 1: *Determine the overall rating.* As stated in Section 4, because human threat events appear to be ever-present, the evaluation proceeds directly to a Phase 2 assessment.

Step 2: *Determine the hazard rating and score.* Because the current threat level is yellow or elevated, the hazard level is, according to Table 4-1, assigned a Medium index. The hazard score per Section 5.1 for a Medium rating is 2.

Step 3: *Determine the vulnerability rating and score.* Table 4-2 indicates the vulnerability of an operations control center to physical attack is High. The vulnerability score per Section 5.1 for a High rating is 3.

Step 4 *Determine the consequence rating and score.* Using Table 5-1, the life safety factor (R_{LS}) is taken as 1 because the loss of the OCC does not present a hazard to the public. The system-type modifier (R_S) is taken as 1.0 because an OCC will have at least rudimentary backup if its main center goes off line. The environmental impact (R_{EI}) is taken as 1 because the loss of the OCC does not present a hazard to the environment because of a fail-safe control systems design. From Table 5-1, the consequence of failure or loss of the OCC can be characterized as:

- Life safety, low, $C_{LS} = R_{LS} = 1$
- Financial loss, moderate, $C_{FL} = 2\ R_S = 2 \times 1.0 = 2$
- Service disruption, moderate, $C_{SD} = 2\ R_S = 2 \times 1.0 = 2$
- Environmental impact, low, $C_{EI} = R_{EI} = 1$

The maximum consequence rating for use in Equation 5-1 is 2.

Step 5 *Determine the overall rating.* Using Equation 5-1 with the hazard, vulnerability, and consequence scores from Steps 2 through 4, the level index is computed to be:

$$I_L = H \times V \times \max(C_{LS}, C_{FL}, C_{SD}, C_{EI}) = 2 \times 3 \times 2 = 12$$

For a level index (I_L) of 12, Table 5-2 recommends a Low baseline level for performance assessment, which implies an H1-V1-S1 analysis.

Step 6: *Perform Level 1 Hazard (H1) Analysis.* Referring to Table 5-4, a Level 1 analysis for physical attack consists of tasks 1.1.1, 1.1.2, 1.1.5, and 1.1.6 (collect data on past incidents and near misses; collect historic data on other companies and industrial systems; review federal and state homeland security agency data; and consult with internal experts).

Step 7: *Perform Level 1 Vulnerability (V1) Analysis.* Per Table 5-5, a Level 1 vulnerability analysis for physical attack consists of various steps under tasks 1 through 3 (data collection, exposure assessment, and vulnerability assessment).

Step 8: *Perform Level 1 System (S1) Analysis.* For a Level 1 system analysis, Table 5-6 recommends tasks 1.1 and 1.4 (contact federal, state, and local agencies and use expert judgment to estimate system performance).

Results: Depending on the outcome of the analysis, the utility will be able to demonstrate that 1) it has adequately assessed the likelihood of anticipated threats, 2) it has taken significant measures to prevent or mitigate the impacts of the event should the event occur, or 3) further study may be necessary in order to fully quantify the magnitude of the threat and it's impact on the performance of the system.

7.0 References

American Society of Civil Engineers (ASCE). 2002. *Minimum Design Loads for Buildings and Other Structures* (ASCE-7-02 Standard). Reston, Va.: American Society of Civil Engineers.

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8.0 Hazard Maps

Hazard maps for earthquake, landslide, hurricane wind and tornado, tornado only, and riverine and coastal flooding are presented on the following pages. With the exception of flooding, these maps contain designations for low, medium, and high hazard levels. For a definition of these levels, see Table 4-1. In addition, hazard designations may be obtained from Appendix A of the Commentary.

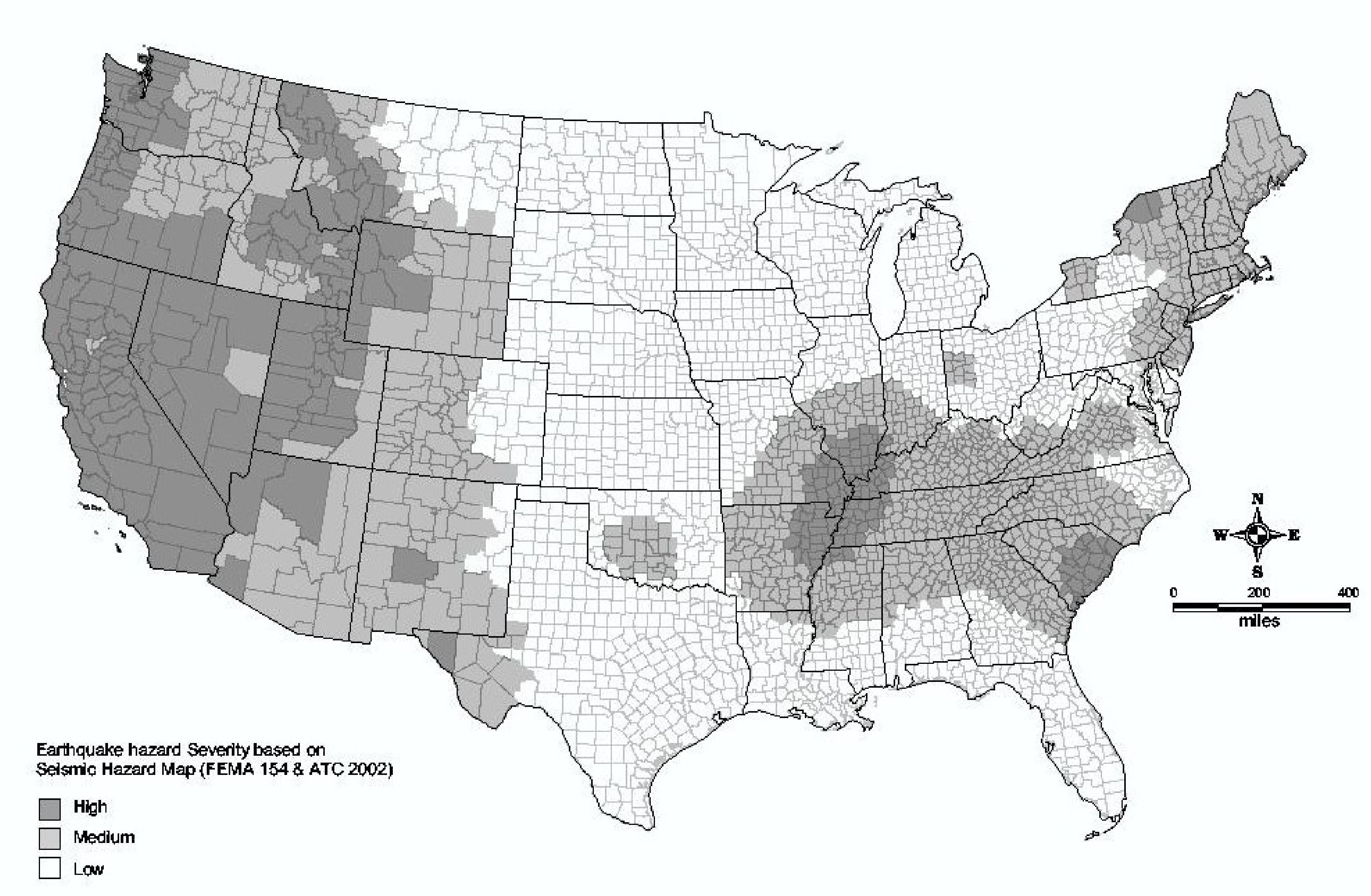

Figure 8-1. Hazard Level Map for Earthquake (Source: FEMA 2002)

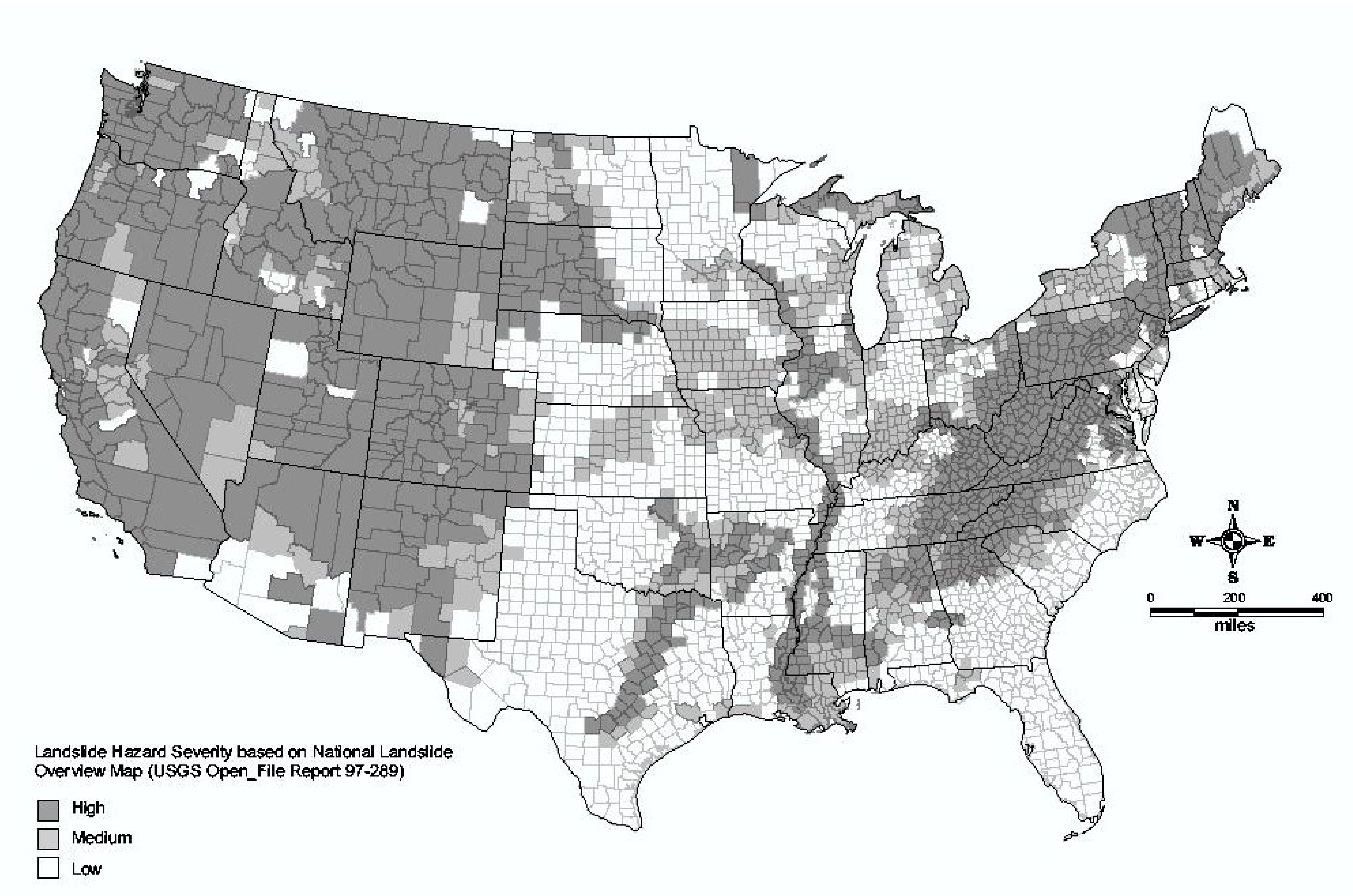

Figure 8-2. Hazard Level Map for Landslide (Source: USGS 1997a)

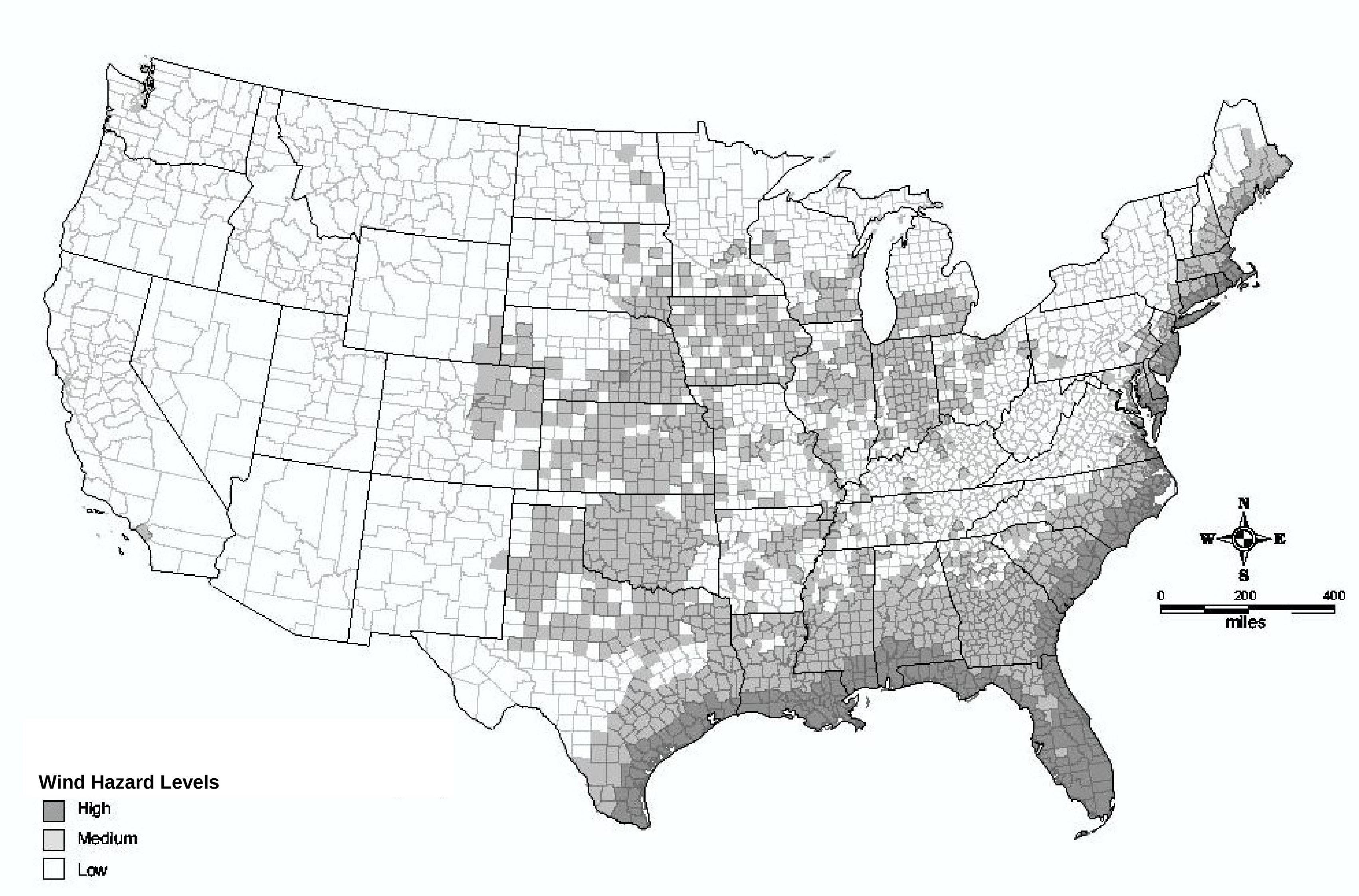

Figure 8-3. Hazard Level Map for Severe Wind, Hurricane Wind, and Tornado (Sources: ASCE 2002, ICC 2002, NOAA 1999)

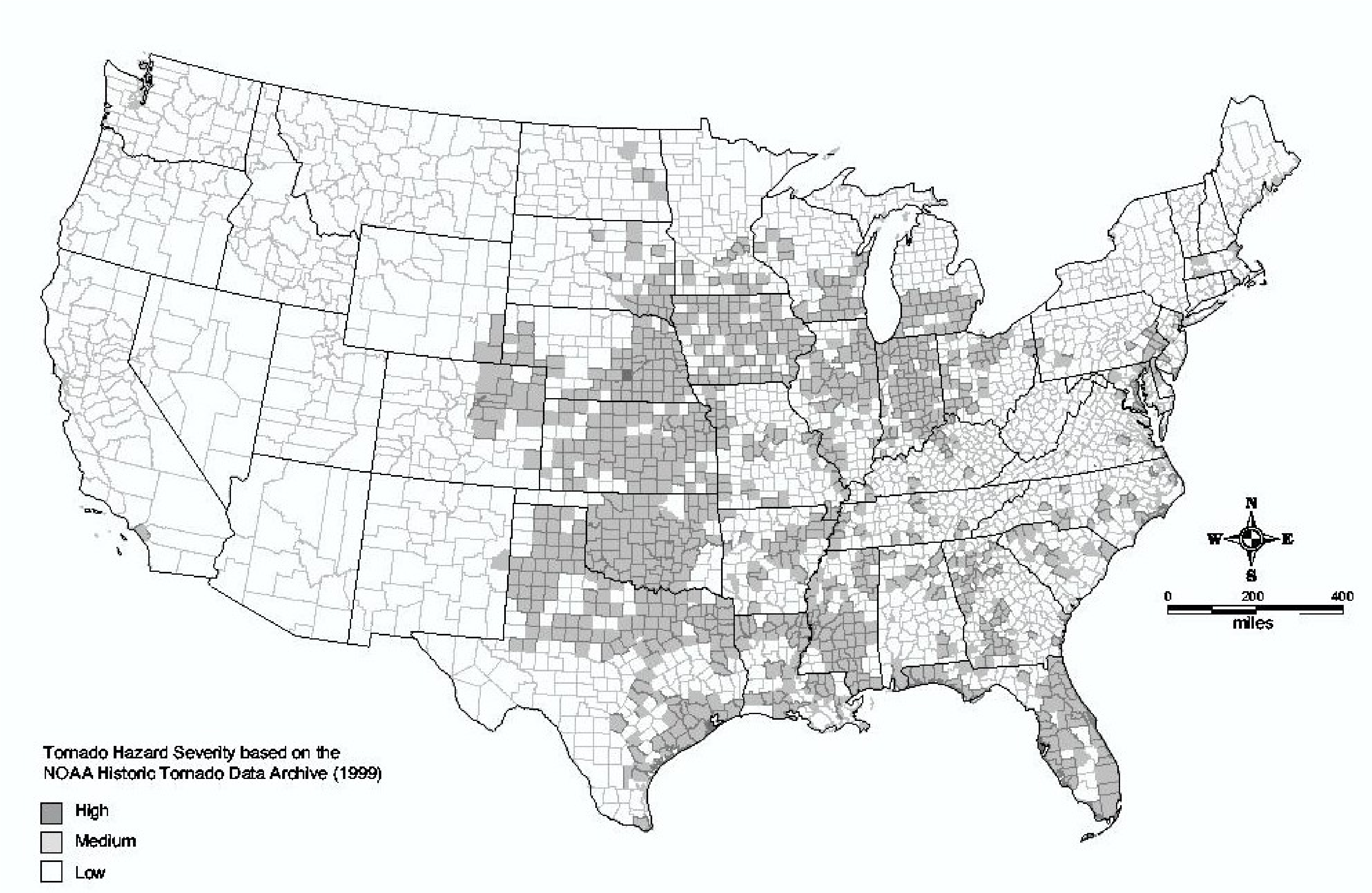

Figure 8-4. Hazard Level Map for Tornado Only (Source: NOAA 1999)

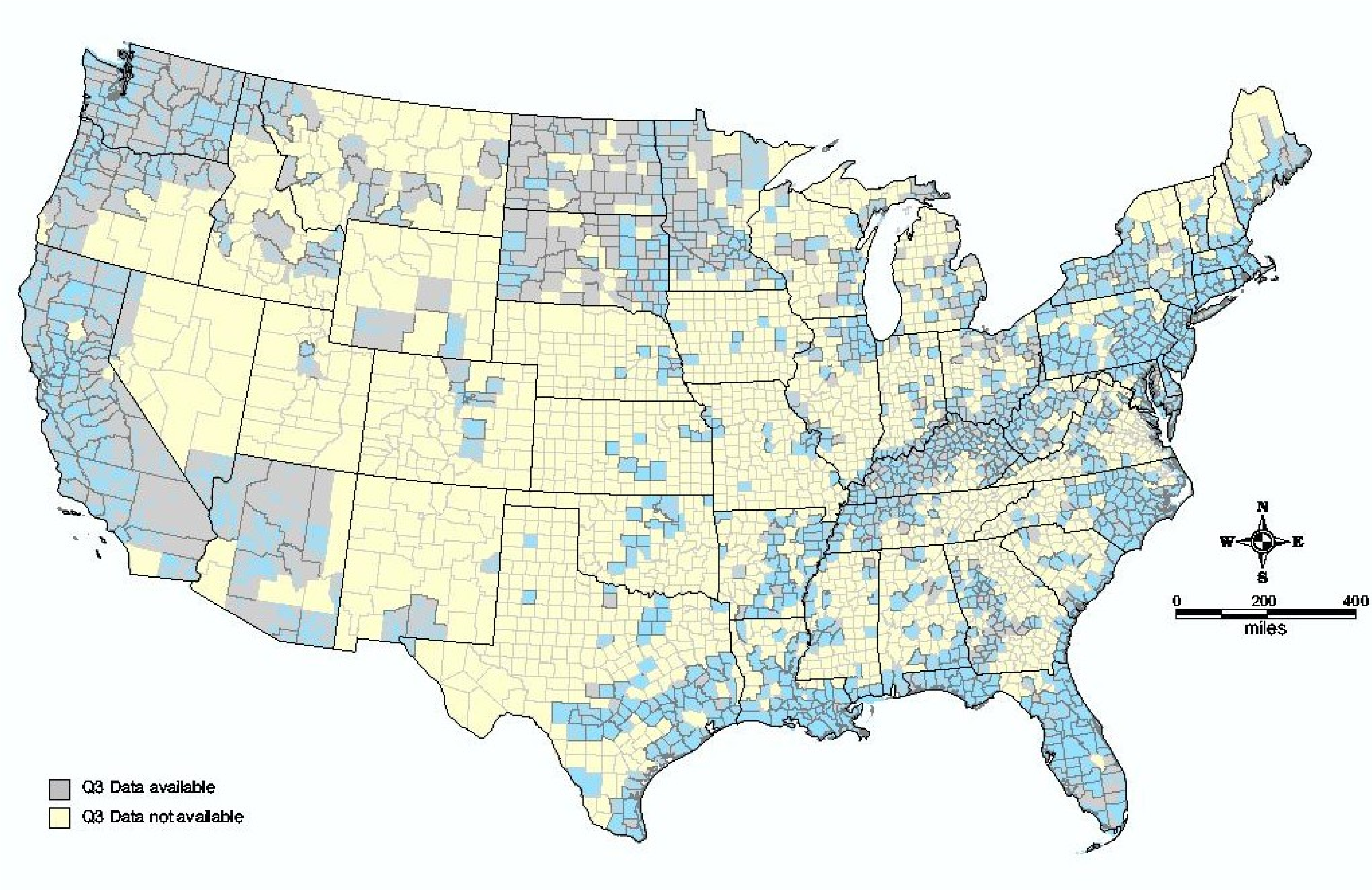

Figure 8-5. Hazard Level Map for Riverine and Coastal Flooding (Source: FEMA 2003)

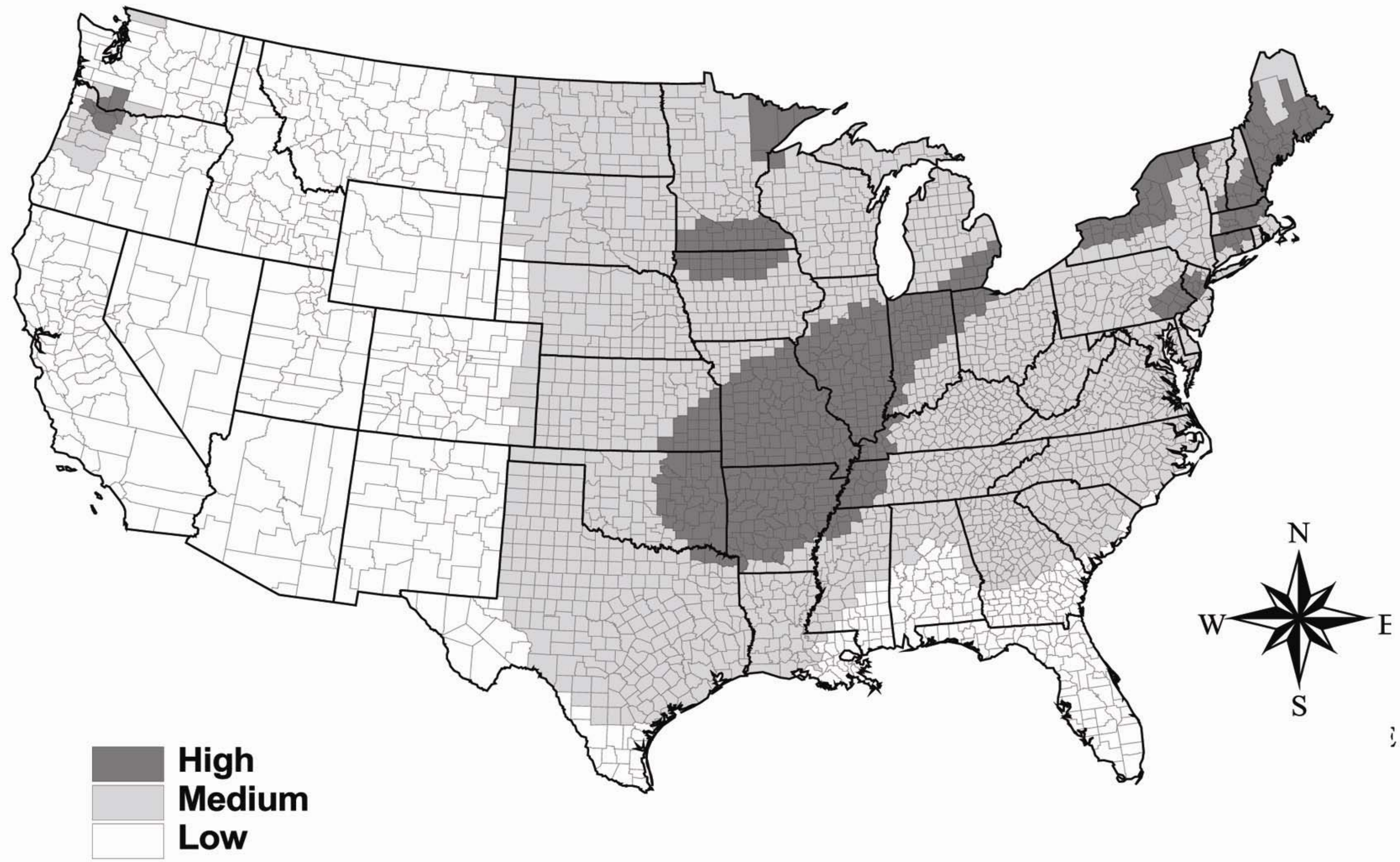

Figure 8-6. Hazard Level Map for Ice Load
(Source: ASCE Standard 7 – 2005, ALA Report on Extreme Ice Thicknesses from Freezing Rain 2004)