AmericanLifelinesAlliance

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 Electric Power Systems in Natural Hazard and Human Threat Events

April 30, 2004

FEMA

National Institute of BUILDING SCIENCES

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This report was written under contract to the American Lifelines Alliance, a public-private partnership between the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences (NIBS).

Acknowledgments

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. To accomplish this, it was necessary to enlist the participation of a broad group of experts in engineering and risk analysis. In addition, to ensure a rigorous review process, two sets of review committees were employed in this study: an Advisory Committee that provided industry review, and an Oversight Committee formed by the American Lifelines Alliance to ensure compliance with the goals of that organization.

This Guideline was developed by a team of consultants led by ImageCat, Inc. of Long Beach, California. A team representing practicing engineers, academics and industry personnel reviewed this report. The following individuals contributed to this Guideline:

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Table of Contents

List of Tables

List of Figures

1.0 Introduction

Electric power systems provide essential service to all facets of society. Energy for production of goods and services, lighting and heating for homes and businesses, power for communication and data processing services - these are all critical functions that sustain modern society. Natural hazards and human threats have the potential to damage and disrupt these systems with a broad range of consequences that could limit both the utility's and community's ability to recover from the disaster. For example, a recent study on the effects of a large New Madrid earthquake suggests that direct and indirect economic losses due to power disruption could reach as high as $5 billion (MCEER, 1998). At the time of that study, very little empirical evidence was available to suggest that such a loss was even possible. However, in August 2003, a major power outage occurred over a large portion of the Northeast. This event affected eight states and approximately 50 million people, and resulted in an estimated $5 billion of business interruption losses. Significant natural hazards and human threat events have the potential for causing similar devastating consequences.

Electric power utilities are familiar with preparing for and responding to natural hazard events such as strong windstorms and seasonal floods, and intentional human acts such as vandalism. However, relatively rare and extreme events like a severe earthquake, historically unique flood, or a concerted terrorist attack can overwhelm ordinary utility experience and preparation, and could result in widespread damage and service disruption. While those utilities who have experienced such severe events have generally taken steps to adequately prepare for future disasters, many others have only partially prepared, and still others are not aware of their full exposure or vulnerability to these threats.

This Guideline is intended to provide clear, concise, and national-scale guidance to electric power utilities on assessing the performance of these systems to natural hazards and human threats. It specifies procedures to follow and information to consider in performing standardized assessments. With the results of such assessments, utility owners can effectively establish and carry out risk management programs that address well-defined needs and vulnerabilities, and ultimately help them achieve appropriate levels of performance in future events.

This Guideline is an important initiative of the American Lifelines Alliance (ALA), a public-private partnership among the Department of Homeland Security / Federal Emergency Management Agency (DHS/FEMA), the National Institute of Building Sciences (NIBS), utility companies, and consultants. ALA's goal is to systematically reduce the risk to our nation's utilities and transportation systems from natural hazards and human threat events. This Guideline and the other products and activities supported by ALA and its partners in the private and public sector are based on best industry practice and are intended to become part of the consensus-based guidance to be used throughout the nation.

1.1 Purpose of this Guideline

The purpose of this Guideline and the accompanying Commentary is to provide a multilevel process by which the performance of electric power systems in natural hazards and human threat events can be assessed. This Guideline addresses the following natural hazards: earthquakes, floods (riverine and coastal), windstorms (extreme winds, hurricane and tornado), icing, and ground displacements (landslides, frost heave, and settlement). Human threats addressed by this Guideline include biological, chemical, radiological, blast, and cyber attacks. The Guideline does not cover the natural hazards of wildfire and lightning.

This Guideline establishes a two-phase assessment process that is sufficiently comprehensive to apply to electric power systems of all sizes. The Guideline delineates procedures to establish the scope of an assessment that meets the objectives of specific performance inquiries, while accommodating cost and schedule constraints. The Guideline and Commentary provide ample information to define the specific steps that should be a part of the 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 for implementation. Although this Guideline does not provide detailed descriptions of analytical procedures and concepts, references are cited for the various technical topics, and 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

The primary audience for this Guideline is electric power utility personnel in management, operations, engineering, maintenance, public information, risk management, and data processing. This Guideline may also serve as a resource for regulatory officials, government agencies, industry groups, professional organizations, research organizations, academia, and consulting engineers.

The application of the assessment process described in this Guideline requires various levels of expertise and specialization depending on the topic 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. However, special cases, particularly those related to infrequent risks, may require the participation of outside technical specialists. Some examples might be 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 utility-wide risk reduction plan.

1.3 Organization of this Guideline

This Guideline is organized into eight major sections beginning with Section 2, and is accompanied by a Commentary:

- An overview that describes the role of the inquiry that establishes the need for a performance assessment, the major elements of the assessment process, the different phases of an assessment, and the concept of level of analysis (**Section 2**);
- Procedures that help to define the appropriate scope of an assessment (**Section 3**);
- Details on the Phase 1 or screening phase of the assessment (**Section 4**);

- Details on performing a Level 1, Level 2, or Level 3 analysis for Phase 2 of the assessment (**Section 5**);

- Examples that help illustrate the application of the methodology described in the prior sections (**Section 6**);

- References for this Guideline (**Section 7**);

- National hazard maps for earthquake, landslide, hurricane wind and tornado, tornado only, and riverine and coastal flooding hazards (**Section 8**); and

- A commentary that provides background information and resources to facilitate the use of the Guideline (**Commentary**).

1.4 Use of this Guideline

This Guideline and Commentary contain a considerable amount of information that can be used to establish the appropriate scope of 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. Other users, particularly those with more specialized technical backgrounds, may be more interested in the details of the process. A typical approach to implementation 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 should not be considered 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. Nevertheless, the content of this Guideline represents the current standard-of-practice in assessing the performance of electric power systems in natural hazards and human threat events. The procedures in this Guideline are considered appropriate for implementation, but are subject to revision when improved methods become available, particularly for the assessment of human threats.

Because the goal of this Guideline was to reach the broadest audience possible, a multilevel approach was developed. This approach includes procedures that range 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 can carry out assessments that are appropriate to the inquiries they receive.

The Guideline does not address interdependency issues that may identify other risks for the utility, especially dependency conditions on other lifelines.

Finally, this Guideline should be viewed as a "living" document. That is, 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 also should be updated as this new information becomes available.

2.0 Overview of Assessment Process

This section introduces a systematic process for assessing the performance of electric power systems subjected to natural hazards or human threat events. The components of this process have been implemented, tested, and validated by numerous utility companies and agencies throughout the United States. This Guideline captures the essence of these previous 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 need for a performance assessment is usually initiated by an inquiry, i.e., a question or request for information, which could be generated either internally or externally to the utility organization. To be responsive, the scope of the assessment must be developed with full recognition of the nature of the inquiry, since it is the very essence of why an assessment is needed. The level of detail required in the assessment could vary significantly depending whether the inquiry is from an external or internal source. For example, a safety-related inquiry from a regulatory agency would likely require a more detailed assessment than a general inquiry pertaining to system reliability from an individual customer.

A decision-making process to assure acceptable system performance is illustrated by the flowchart in Figure 2-1. The flowchart is not unique to any particular utility organization; instead, it simply summarizes well-tested assessment and decision-making procedures currently in practice. It begins by identifying the inquiry - the basic reason for performing the assessment. The inquiry establishes 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, an electric power distribution system might have as a performance target the reestablishment of service to critical facilities (e.g., hospitals) within a certain period of time after a large earthquake or hurricane. As suggested 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 the next section.

The next three steps are highlighted in Figure 2-1 and are critical in the overall performance assessment process. These steps represent the essence of this Guideline and cover the following tasks: the identification of significant hazards; the assessment of vulnerability of system components to those hazards; and the assessment of system performance while 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. Depending on the scope of the inquiry and the results of the performance assessment, either the performance is deemed acceptable or the system is changed in some way to meet the performance goal. Changes may take the form of system response or component response modifications (e. g., replacing vulnerable components or adding redundancy to vulnerable portions of the system), or of adjustments to the performance goal.

As stated above, the primary focus of this Guideline is on the steps in the three shaded boxes. The other boxes define important initial 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. General guidance is provided in Section 2.2 that will help the user begin to frame these elements of the analysis.

A part of the decision-making process that is not considered in this Guideline is the evaluation of mitigation alternatives associated with the diamonds in the lower part of Figure 2-1. Although key in assuring that performance targets are met, mitigation measures are not currently a part of 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.

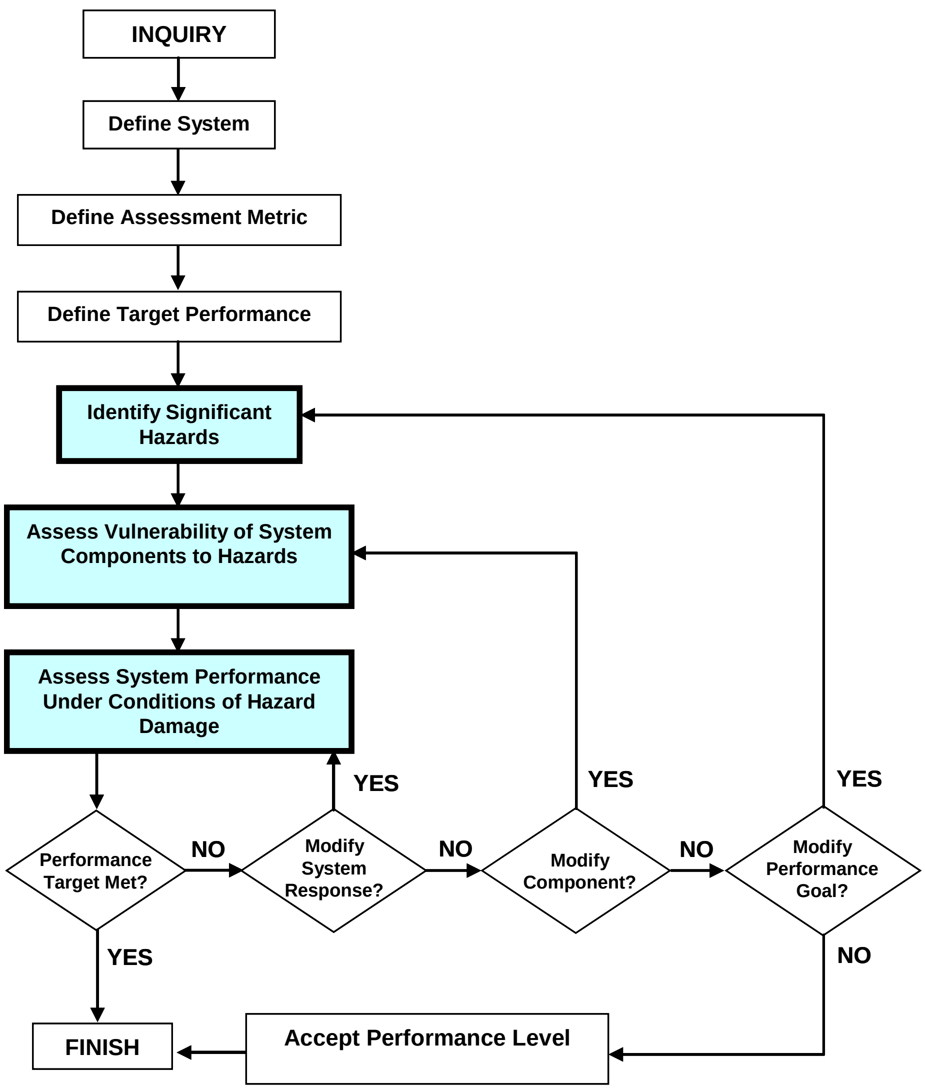

Figure 2-1. Decision Process for Ensuring that System Performance Goals are Met

2.2 System Performance Measures

Electric power system performance during natural hazards or human threat 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 utility personnel 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. The linkage of performance metrics to desired outcomes is important because it generally influences the choice of methods for quantification. Some performance metrics might require specialized methods, while others simply may 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. To illustrate, "Casualties" and "Hazardous Materials Spillage" are shown as the performance metrics for the desired outcome of "Protect public and employee safety". In other words, to protect the safety of the public and employees, casualties and hazardous material spillage must be avoided. There are also indirect consequences of an unfavorable outcome, which are not indicated in the entries in Table 2-1. For example, an indirect consequence of casualties or hazardous materials spillage would be the financial burden placed on the electric power utility to compensate victims or their families or to provide for environmental cleanup. Hence, it should be recognized that certain indirect consequences may be significant, perhaps even greater than direct consequences.

Table 2-2 maps the desired outcomes versus the principal components of an electric power system that should be included in a systems analysis. 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 hazardous materials, system control (shutdown and isolation) and emergency response (maintenance and equipment).

Table 2-1. Metrics to Measure System Performance

Desired Outcomes (Performance Targets)	**System Performance Metrics**					
	Capital Losses ($)	Revenue Losses ($)	Service Disruption (% service population)	Downtime (hours)	Casualties (deaths, injuries)	Hazardous Materials Spillage
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. Matrix Relating Damage Consequence to Component or System Vulnerability

Desired Outcomes (Performance Targets)	***Consider in Systems Analysis?***								
	Low Voltage control, protection and communication systems, e.g., SCADA	Transmission Substations	Transmission Lines	Transmission and Communication Towers and Distribution Poles	Distribution Substations	Distribution Lines	Distribution Service Transformers	General Office, Maintenance Buildings, Operations Buildings and their Equipment	Computer Equipment for Operations and Business Functions
Protect public and utility personnel safety	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maintain system reliability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prevent monetary loss	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prevent environmental damage	Yes	Yes	-	-	Yes	-	Yes	Yes	-

2.3 Two-Phase Approach

This Guideline employs a two-phase assessment approach, screening (Phase 1) and analysis (Phase 2), as diagrammed in Figure 2-2. The advantages of a two-phase approach are:

- It permits systems or components that are clearly not at risk to be screened out early;
- The results of the initial phase can be used to prioritize and allocate appropriate resources for subsequent, more detailed assessments;
- Sequential performance of screening and more detailed analyses offers an important means of gauging results to identify possible errors or faulty assumptions;
- The data and information needed for a more detailed analysis often are developed or uncovered in the screening phase; and
- A phased approach usually allows the user to efficiently gauge the scope and cost of extensive projects relative to the anticipated consequences of hazard or threat events.

In summary, the two-phase approach used in this Guideline 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.

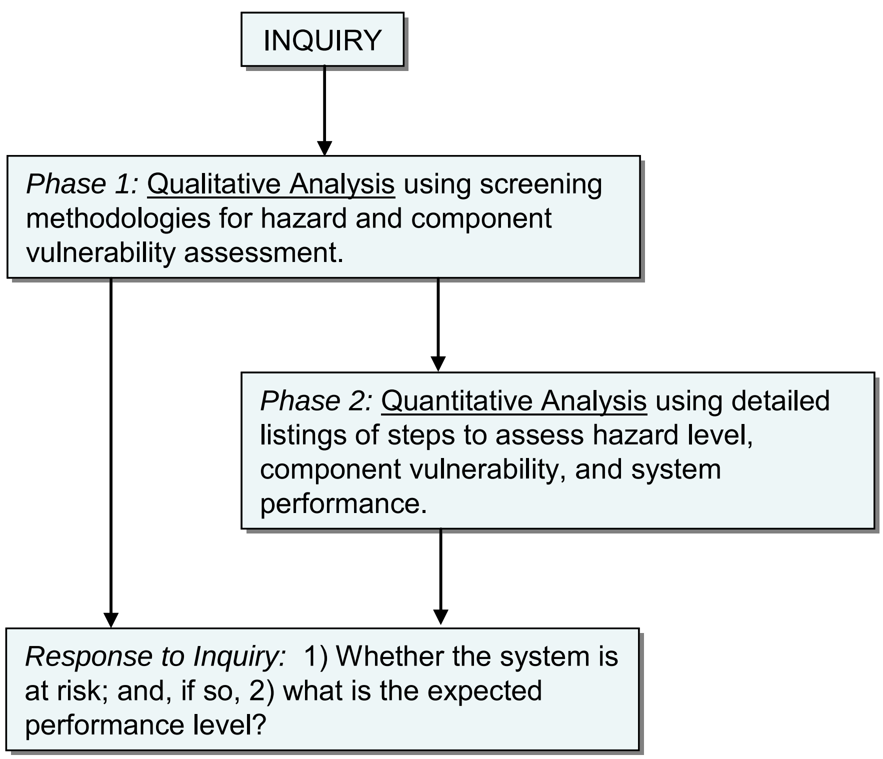

Figure 2-2. Two-Phase Approach Used in this Guideline

The flowchart in Figure 2-2 indicates that it is possible to arrive at a final assessment of performance after performing only a Phase 1 evaluation. This could happen under a number of different scenarios. For example, the integrity of a power system may have come into question because of a published report that states that substations are at risk from earthquakes, but under a Phase 1 evaluation, it is determined that the likelihood of a moderate to large earthquake is extremely small for the region, and thus the risk of damage is low. If, in simple terms, 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 (in a Phase 2 analysis) would be of little practical value.

A strict interpretation of the Figure 2-2 flowchart shows that Phase 1 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 Phase 1 can provide baseline information for planning and executing subsequent Phase 2 evaluations. The details of the screening process will be presented later in Section 4.

2.4 Three Levels of Analysis for Phase 2

This Guideline has been built on the premise that, following the screening in Phase 1, the analysis process of Phase 2 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 would become a part of the next higher level. Data and information collected in each lower level task would be used as applicable at higher levels. In practice, organizations of all sizes and types use some form of this progressive, multilevel analysis process.

Three levels of analysis have been established for this Guideline as set forth below. The multilevel analysis concept applies to all parts of the performance assessment (see Section 5): hazard, component vulnerability, and system performance. Therefore, the definitions provided below are presented 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 or 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 meet the objectives of the inquiry, then a higher level of analysis should be used (Level 2).

- Level 2 is characterized as a more quantitative analysis, often depending on historical or statistical information to quantify hazard, vulnerability, and system performance, and involving collection of data from the field. This level is typically completed within a matter of weeks rather than months or years, and could be performed by operations and engineering staff, with possible assistance from technical specialists. The accuracy of the

[1] Labor requirements are measured by a "full-time employee" unit, i.e., the time required for one person working full-time to complete the study. More details on this assignment are provided in Section 5.4.

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

In general, the use of three levels of analysis promotes the most efficient use of resources. By planning more broadly from the beginning and then ramping up to more detailed evaluations, the use of a utility's resources can be more effectively prioritized and/or optimized. Another advantage of using a multilevel analysis approach is that it extends the applicability of the Guideline to the broadest possible range of power utility companies by avoiding the type of detailed approach that could be implemented only by large organizations, which would be counter to the purpose of this Guideline.

2.5 Methods of Analysis

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

Although there may be a myriad of acceptable analytical approaches, this Guideline emphasizes methods believed to be the most practical for application by power utility companies. Specific techniques, procedures, and practices are identified in this Guideline for use in estimating such parameters as earthquake ground motions, hurricane wind speeds, equipment fragility, and, in a broad sense, system performance. The use of some of these methods requires specialized background and training. The intent is to provide the reader with a broad view of available methods with respect to the overall assessment process without being exhaustive or excluding new techniques as they develop.

The commentary to this Guideline contains a series of tables that list currently accepted methods for analysis of hazard, component vulnerability, and system performance. Included in the tables are brief summaries of advantages and disadvantages ("pros" and "cons"), 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 describes the process used to define the scope of a performance assessment. While each utility system has its own unique features, there are certain elements that are generally common among such systems. These commonalities serve as a baseline for defining the tasks required to assess system performance.

As noted in Section 2.1, the performance assessment process begins with an inquiry, i.e., a question or request for information. 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. This section expands the concept of an inquiry and how it plays an important role in defining the scope of an investigation.

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" for system performance assessment. The roadmap 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 process in Figure 3-1 begins with the inquiry. As mentioned previously, the source of the inquiry could be either internal or external. An internal inquiry might originate from the utility's management requesting a briefing on the assets at risk from a particular hazard. An example of an external inquiry could be a regulatory body asking about actions being taken to ensure the reliability of service to customers in the event of a major natural or human threat event. In other cases, an actual event or incident might prompt an assessment. For instance, the occurrence of an earthquake causing damage to some part of a system that was not previously known to be vulnerable might prompt internal or external inquiries to determine if the damage was associated with an isolated incident or an indication of a wider problem.

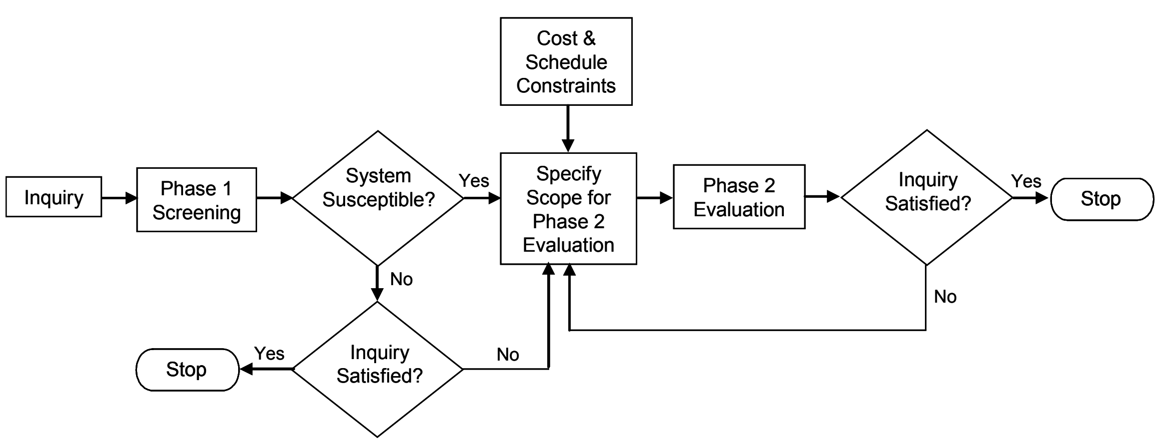

Figure 3-1. Basic Roadmap for System Performance Assessment

The second step in the flowchart (Figure 3-1) calls for a Phase 1 screening evaluation (see Section 4.0). This evaluation consists of two stages. The first stage calls for the determination of whether or not a potential significant hazard exists, and if so, a second stage would call for the determination of whether existing facilities are susceptible to damage or failure from that hazard. If the result of the screening indicates no significant hazard or no significant risk of damage from the hazard, then there is no need for subsequent analysis, and the process can be terminated with a completed response to the inquiry. For example, not all areas of the U.S. are subjected to damaging earthquakes, and as such, power systems in those areas are not at significant risk of damage from earthquake shaking. If the inquiry is not satisfied as a result of Phase 1 results, then the user is prompted to begin a Phase 2 assessment.

If the system is determined to be susceptible to damage or loss of function for the hazard under evaluation, it then becomes necessary to proceed to a Phase 2 evaluation. The scope for the Phase 2 evaluation should contain an appropriate level of detail and should take into account cost and schedule constraints. General guidance on determining the appropriate level of analysis is provided in Sections 5.1 and 5.2.

After determination of the appropriate level of detail, it is necessary to develop a step-by-step list of the tasks that should be performed. This part of the process is described in Section 5.3. This listing of tasks is similar to a scope of work in a Request for Proposal (RFP). The scope of work could range from relatively straightforward tasks that could be performed within the normal activity of an operations or engineering department, or tasks requiring the participation of 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 detail. The basic process, however, remains the same, that is, 1) screen the hazard severity and assess the generic vulnerability of the system to that hazard to determine the need for a more detailed evaluation; 2) ensure that adequate resources and expertise are available to perform the evaluation; and 3) determine the appropriate level of detail based on the inquiry and available resources and schedule.

3.2 Selection of Components for Study

The selection of which components to include in the analysis will depend in large part on the inquiry and the performance target being investigated. For example, a utility may have been approached by a key customer regarding the reliability of the system to provide power to that facility in a major earthquake. In this case, reliability is measured by service disruption (outage areas) and downtime (Table 2-1). In order to respond to this inquiry, the utility must decide what components should be considered in this assessment. The utility uses Table 2-2 to identify critical components; the utility finds that all the components listed in the table should be considered.

3.3 Inquiries

Inquiries can come from a variety of sources inside or outside the utility, and the effort to develop a response could range from a matter of a few hours to a significant commitment of resources. Although it is not possible to come up with a list of inquiries for every conceivable situation, a representative list is provided below. A more extensive list is presented later in Table 5-3 in Section 5.2.

Internal Inquiries:

- Upper management requesting information on general financial exposure.
- Addressing risk management or insurance issues.
- Defining the scope of capital improvement programs.
- Evaluating utility performance goals (reliability).
- Assessing post-hazard service to emergency facilities (e.g., hospitals).
- Preparing exercises and training for event response.
- Internal investigation following 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).
- A customer question on the reliability of service.
- Investor concerns, primarily for private 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 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 both natural hazards and human threats:

  - 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

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

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

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

  - 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. Recalling the discussion in Section 2.4, there are three levels of analysis that can be performed: a Level 1 analysis, representing the simplest and least time-consuming level of effort; a Level 2 analysis, which is more quantitative and of moderate scope; and a Level 3 analysis, which is an extensive effort requiring significant resources and time to complete.

A performance assessment involves the selection of an appropriate level of analysis within each of the three elements discussed above. In aggregate, they constitute an appropriate approach for responding to an inquiry. For example, a recommended approach might involve: Hazard analysis – Level 1; Vulnerability analysis – Level 2; and System Performance analysis – Level 1. For notational purposes, this would be denoted as an H1-V2-S1 analysis. The meaning of this sequence is as follows: a simplified hazard analysis; a moderately detailed analysis of component fragility; and a simplified (qualitative) systems analysis. 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.

The use of three levels of analysis permits the performance assessment to be tailored to the content of the inquiry (using 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 utility management). In other words, different types of inquiries will lead to different levels of assessment depending on their source, the context in which the inquiry is being made, and underlying considerations for hazard, vulnerability and system performance.

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

The concept of Phase 1 hazard and vulnerability screening was introduced in Section 3.1. The purpose of a Phase 1 evaluation 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 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 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 would effectively identify or eliminate the presence of these threats. Therefore, for the assessment of human threat events, Phase 1 screening should be bypassed in favor of proceeding directly to Phase 2.

4.1 Natural Hazard Screening Tools

Before introducing the basic tools for a natural hazard screening evaluation, it is important to distinguish between "local" and "regional" hazards. Local hazards are ones that can be characterized only by doing fieldwork or by using microzonation maps (when available). For this Guideline, local hazards include riverine flooding, landslides, surface fault rupture, liquefaction, and settlement. Regional hazards can be portrayed effectively on small-scale maps, such as on a national or statewide level. Hazards that fall under this category 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.

In this Guideline, national maps are used to characterize hazard levels for earthquake, landslide, severe wind (hurricane and tornado), and riverine and coastal flooding. For those hazards that are considered 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 (county) causes the entire jurisdiction to be classified according to severity of the local hazard itself. For example, a county could be classified as high risk for landslides due to a relatively small portion of the county land area being situated on unstable slopes. Similarly, a county 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. For Phase 1 screening, the presence of local hazards anywhere within a designated county will serve as the basis for classification at a medium or high hazard level. Considering the approximate nature of Phase 1 screening, this does not cause an undue hindrance.

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

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.	No Q3 data are available for the county	ES-ISAC – 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	ES-ISAC – 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 windspeed is 110 mph or greater, or Hawaii	> 25 tornadoes per 10,000 sq. mi.	≥ 1.0 in.	Q3 data available for the county	ES-ISAC – Orange (High) to Red (Severe)

Note: 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 of this Guideline. 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 electric power systems are earthquake, including various types of earthquake-induced ground failure; severe wind (hurricane, tornadoes); icing; and human threats such as sabotage. The other hazards listed in Table 4-1, landslide and flooding, can also cause damage to power system components, but to a lesser degree. Insignificant hazards will typically be eliminated from consideration in the Phase 1 screening as

[3] In establishing the icing hazard, the Guideline uses ASCE 7-02, 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 Electric Sector – Information Sharing and Analysis Center (ES-ISAC at http://www.esisac.com/) for physical or cyber threat levels. References: NERC (2002a); NERC (2002b).

described below, assuming that they were conspicuous enough to have become the subject of an inquiry.

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. In particular, the hazard level criteria are based on ES-ISAC Orange (High) and Red (Severe) threat alert levels. With these separation points, the high hazard level is based on the existence of specific, credible information about a human threat against the electric power industry. The medium hazard level is based on Blue (Guarded) and Yellow (Elevated) threat alert levels. This selection is based on nonspecific, general information about the potential for a human-caused disruption of service. Since the ES-ISAC threat alert levels were developed after the September 11, 2001, terrorist attacks, the threat alert levels have not fallen below Yellow (Elevated) or above Orange (High), which seems appropriate for the evaluations of the performance of electric power systems that have been conducted with respect to human threat events since that time. The low hazard level is based on the ES-ISAC Green (Low) threat alert level. This level is based on the existence of no known threats to the electric power industry other than normal human threats such as vandalism, which are generally tracked through reporting systems established by State Public Utilities Commissions.

The use of national hazard maps with this Guideline is subject to a number of cautions as described below:

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 in 50 years. Naturally, the ground motions values on these maps increase with decreasing probability of exceedance. Current building codes, e.g., the 2003 International Building Code (ICC, 2002) or NFPA (2003), use ground motion criteria based on a 2 percent probability of exceedance in 50 years. However, power companies 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 (typically local maps 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). Specifically, 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 qualitative information on the vulnerability of key electric power system components based on the judgment of experienced practitioners. This table is intended to serve as a general guide for typical components and non-critical components. There may be special circumstances 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. For example, if the consequence of failure from that component is high (e.g., impact a sizable portion of the service population, or impact service to major customers), then a Phase 2 assessment is recommended.

The entries in Table 4-2 identify the components and systems that are potentially vulnerable to the hazards and threats described in this Guideline. The entries are either in the form of an unqualified "H", "M", or "L" (high, moderate or low) or a qualified answer stating the 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); while aboveground components will be affected more by earthquake ground shaking, flooding, wind, icing, and other collateral hazards (fire, dam inundation, nearby collapses of other structures, and some human threats such as blast). 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 what hazard level is expected. The entries in Table 4-2 assume that the facilities are of recent vintage, i.e., post-1945. If the facility 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 areas. In such situations, a Phase 2 evaluation is appropriate.

The user will also have to make a choice on what vulnerability level to select for an analysis that includes multiple components or facilities. In these cases, the Guideline recommends that all components that should be a part of an assessment (see Section 3.2 for a discussion of component selection) be evaluated and the highest level of vulnerability for the group be used to define the level of analysis.

4.3 Transition to Phase 2 Evaluation

There may be several reasons to proceed to a Phase 2 evaluation even though the results from Phase 1 suggest otherwise.

Some of these reasons are:

- 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 elimination of any subsequent studies (based on the results of the Phase 1 evaluation) appears questionable, it is recommended that the user proceed to Phase 2. The most adverse result from this decision is that a Level 1 analysis is performed.

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

Hazards	Degree of Vulnerability								
	Low Voltage control, protection and communication systems, e.g., SCADA	Transmission Substations	Transmission Lines	Transmission and Communication Towers and Distribution Poles	Distribution Substations	Distribution Lines	Distribution Service Transformers	General Office, Maintenance Buildings, Operations Buildings and their Equipment	Computer Equipment for Operations and Business Functions
Natural Hazards:									
Earthquake Shaking	M	H	-	-	M	M	M	M	M
Earthquake Permanent Ground Deformations (Fault Rupture, Liquefaction, Landslide and Settlement)	-	M	H	H	M	H	M	H	-
Ground Movements (Landslide, Frost Heave, Settlement)	-	M	H	H	M	H	M	H	-
Flooding (Riverine, Storm Surge, Tsunami and Seiche)	H	H	M	H	H	H	H	H	L
Wind (Extreme Wind, Hurricane, Tornado)	M	M	H	H	M	H	H	M	-
Icing	-	L	H	L	L	H	L	-	-
Collateral Hazard: Blast or Fire	H	H	M	H	H	M	H	H	H
Collateral Hazard: Dam Inundation	H	H	H	H	H	H	H	H	H
Collateral Hazard: Nearby Collapse	M	M	M	H	M	H	H	M	H
Human Threats:									
Physical Attack (Biological, Chemical, Radiological and Blast)	H	H	M	M	H	M	M	H	H
Cyber Attack	L	-	-	-	-	-	-	L	H

Notes: H- High, M – Moderate, 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.

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 to be used to initiate a Phase 2 evaluation. Depending on factors such as hazard level, vulnerability level, type of consequence, system redundancy level, or type of inquiry, a user is prompted to perform a Level 1, Level 2 or Level 3 analysis.

In general, performing a Phase 2 analysis will result in some quantitative result. The value in having a quantitative result is that performance can be assessed relative to measurable targets or metrics. For this reason, Phase 2 analyses are particularly useful in hazard reduction programs where the benefits of mitigation can be directly compared to the cost of that mitigation.

A key step in the Phase 2 process is determining the appropriate level of detail for the performance analysis. To facilitate this decision, a set of scoring criteria are introduced that allow the user to determine an appropriate level of analysis based on hazard, vulnerability and system information. In addition, this section provides guidance to the user on how to modify these determinations using information from the inquiry itself. A long list of inquiries serves as examples for these modifications.

Finally, this section ends with detailed tables that identify specific tasks that should be considered under each level of analysis. Examples of the types of analysis that are recommended can also be found in the Commentary to this Guideline.

5.1 Initial Selection of Analysis Level Based on Systematic Scoring Criteria

The selection of appropriate analysis levels for the hazard, vulnerability, and system performance can often be made on an intuitive basis by individuals with requisite experience in risk assessment. As an alternative to such experience and intuition, a systematic scoring procedure for determining a baseline level of analysis has been developed specifically for use in this Guideline. The resulting baseline level of analysis from scoring can be adjusted upward or downward for particular analysis elements depending on type of inquiry, budget and schedule constraints, and consideration of specific performance measures. Examples of H-V-S 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 cases associated with no hazard or no vulnerability have been eliminated from consideration. The scoring system accounts for the following attributes:

- Severity of the hazard;
- Vulnerability of the system or component;
- Failure 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 level, i.e., there is no attempt at integrating the results from different hazards.

The level index I_L is defined as the product of H, V and the maximum of C_{LS}, C_{FL}, C_{SD}, and C_{EI}.

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

where,

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

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

C_{LS} = Life safety consequence score, varies from 1 to 3 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 3 as defined in Table 5-1

In Table 5-1, a "System Type" modifier or redundancy factor, R_C, is used in the determination of the financial loss consequence score, C_{FL}, and the service disruption consequence score, C_{SD}, but not in the determination of the consequence scores for life safety and environmental impact. The use of the system type modifier accounts for the mitigation of consequences through the presence of system redundancy, i.e., the effect of redundancy is to reduce the consequences of damage due to a hazard event.

The system modifier allows the flexibility of "weighting" certain performance conditions differently depending on whether actual alternative sources of service are available. For example, an electric power utility may rate the system type modifier, R_C, as 2 (non-redundant) because they have no alternative means of providing service to a critical customer, whereas, that customer may rate the redundancy factor as 0.5 because on-site back-up generators exist. Depending on the source and type of inquiry and who is performing the assessment, the service disruption factor (C_{SD}) could vary. Similar considerations for the type and source 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 utility compared to an industrial customer or local community with no feasible means of providing sufficient alternative power. It is expected that the system modifier will typically be set to 1 unless circumstances exist to warrant adjusting the financial loss or service disruption factors.

Table 5-1. Consequence Scoring

Consequence	Severity of Consequence		
	Low	Moderate	High
Life Safety, C_{LS}	Minimal impact on life safety; no significant impact to personnel or the general public in the immediate area of the facility. $C_{LS} = 1$	Damage or disruption may result in significant injury to personnel or the general public in the immediate area of the facility. $C_{LS} = 2$	Damage or disruption will result in significant impact to utility personnel, the general public in the immediate area of the facility. $C_{LS} = 3$
Financial Loss, C_{FL}	Little or no impact on the financial resources of the utility. $C_{FL} = R_C$	Damage or disruption can result in major financial losses; losses, however, will have little or no impact on the financial integrity of the utility. $C_{FL} = 2\ R_C$	Damage or disruption will have a significant impact on the financial integrity of the utility or one or more major customers. $C_{FL} = 3\ R_C$
Service Disruption, C_{SD}	Little or no impact on service population. $C_{SD} = R_C$	Disruption of service will impact a small portion of the service population (less than 10%) and is less than a day; and does not affect a critical customer. $C_{SD} = 2\ R_C$	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. $C_{SD} = 3\ R_C$
Environmental Impact, C_{EI}	Little or no impact on environment. $C_{EI} = 1$	Failure or disruption can result in limited (or isolated) environmental damage. $C_{EI} = 2$	Failure or disruption can result in major environmental damage, i.e., it will take months to years to remediate. $C_{EI} = 3$

Notes: R_C is a "System Type" modifier: 0.5 for highly redundant (e.g., failure of component does not degrade system performance); 1 for redundant (e.g., failure of component degrades system performance) and; 2 for non-redundant (the function served by that component cannot be alternatively served). The scoring system does not involve precise estimates. The assignment of decimal values in place of Low = 1, Moderate = 2, and High = 3 is not intended and is strongly discouraged.

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 cutoffs:

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 or source of inquiry (see Section 5.2).

5.2 Factoring in Source and Content of Inquiry into 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 a large number of 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, S are defined in terms of 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 is when only a general response to an issue is required that may otherwise suggest 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 effort 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 effort 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 effort recommended by the scoring system. In these cases, more detailed or less detailed analyses are suggested in order to more adequately evaluate the essence of the inquiry.

Table 5-3. Sample Inquiries and Suggested Levels of Analysis

Sample Inquiry	Source of Inquiry	Level of Analysis			Key Considerations
		H	*V*	*S*	
1. Inquiry by a regulatory body (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 (location of a landslide hazard relative to a facility).	External	2	1	1	Content may limit levels required.
6. Inquiry by a regulatory body (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 (consequence of a local hazard on a critical facility).	External	2	2	2	Consistent with scoring a Level 3 overall effort - save that systems issues are assumed.
8. Inquiry by a regulatory body (detailed evaluation of hazards relative to a cluster of facilities).	External	3	1	1	Source and content imply levels of effort suggested.
9. Inquiry by a regulatory body (detailed evaluation of a hazard relative to a facility).	External	3	2	1	Source and content imply levels of effort suggested.
10. Inquiry by a regulatory body (detailed evaluation of a hazard relative to an extremely critical facility).	External	3	3	1	Likely to be consistent with scoring system—save that systems issues are assumed.
11. Regulatory body wanting more detailed information on criticality and hazard design parameters.	External	2	1	2	Source and content imply levels of effort suggested.
12. New regulation to require a given performance level for specific hazards.	External	3	3	3	Source and content imply levels of effort suggested.

Table 5-3. Sample Inquiries and Suggested Levels of Analysis

Sample Inquiry	Source of Inquiry	Level of Analysis			Key Considerations
		H	*V*	*S*	
13. 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 effort suggested; levels of effort for systems evaluation may be less than "3" owing to systems evaluation capabilities already present.
14. 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 effort for systems evaluation may be less than "3" owing to systems evaluation capabilities already present.
15. Regulatory body requesting detailed evaluation of potential service losses given detailed evaluation of localized hazards.	External	3	1	3	Consistent with likely overall score.
16. 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 effort on component vulnerability evaluations.
17. Regulatory body wanting a detailed evaluation of unexpected high system losses.	Event/ External	3	3	2	Likely to be consistent with overall score.
18. 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.
19. Addressing risk management or insurance issues.	Internal	1	2	1	Content implies a major focus on repair and replacement cost forecasts.
20. Investor concerns.	Internal	2	2	2	Source implies significant but not total effort.
21. Upper management wanting to know general exposure.	Internal	2	2	2	Source implies significant but not total effort.
22. 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.

Table 5-3. Sample Inquiries and Suggested Levels of Analysis

Sample Inquiry	Source of Inquiry	Level of Analysis			Key Considerations
		H	*V*	*S*	
23. Follow-up request to characterize in greater detail the vulnerabilities of critical facilities.	Internal	1	2	3	Content implies additional component evaluation effort.
24. Follow-up request to analyze in detail the vulnerabilities implied by 23.	Internal	1	3	3	Content implies significant component evaluation effort.
25. Determining post-hazard service to critical facilities served (e.g., hospitals).	Internal	2	2	3	Level of effort likely to be consistent with overall scoring.
26. Upper management wanting a thorough natural hazards management system emphasizing detailed evaluations of hazards.	Internal	3	2	3	Source and Content set levels of effort.
27. 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 effort.
28. Inquiry by the Utility's Board of Directors - Specific Hazard Concern.	Internal	1	1	1	Source limits desirable levels of effort.
29. Disaster that causes slightly unexpected damage.	Event/ Incident	1	1	1	Content dictates levels of effort.
30. Inquiry on specific hazards leading to unexpected damage having 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

General guidance was provided in Sections 5.1 and 5.2 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 is to identify the specific tasks required to perform a Level 1 (simplified), Level 2 (intermediate), or Level 3 (detailed) analysis.

The recommended tasks for performing analyses for Levels 1 through 3 are summarized in matrix form in Tables 5-4 through 5-9. 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 final table for examining system performance (Tables 5-6 and 5-9). Specific tasks are identified in each row of the tables followed by columns with "diamond" bullet entries to 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 (e.g., H refers to hazard; V indicates vulnerability; and S applies to system performance) and the number after the letter indicates the level of analysis. For example, H1 refers to Hazard Level 1.

Referring to Tables 5-4 through 5-9, it is observed that tasks at each lower level are typically repeated at higher levels. This is intentional, i.e., the details of each subsequent analysis level build on the information and data collected in lower levels. The absence of "diamond" entries in a lower level means there are no simpler ways of conducting that task of the analysis.

The tasks that are reflected in each of the tables are key in defining the precise scope of the assessment. In a sense, they may be equated to the tasks delineated by 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. Finally, the guidance provided in Section 5.4 helps to provide a rough indication 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 work scope for Phase 2.

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 affect the selection of analysis levels for Phase 2. It is important to develop realistic estimates of the level of effort and resources, including technical expertise, required for an adequate assessment. Table 5-10 provides estimates of the range of effort generally required for the different elements of a Phase 2 analysis (hazard, vulnerability, and system performance) introduced previously in this section. Level of effort (or time) is measured in terms of the number of days, weeks, or months required by a full-time employee equivalent (i.e., a suitably qualified person working full time) to perform a specific work scope. For purposes of establishing Table 5-10, the Guideline assumes that the system under investigation is a large utility with many sites and components. Smaller utilities, with fewer sites and components, or investigations of isolated parts of the system will require more modest resources.

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 analyses 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 previously in Section 5.2, various combinations of hazard (H), vulnerability (V) and system performance (S) analyses are possible. The accuracy and completeness of Phase 2 analyses 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 analyses improve by increasing the resources and time devoted.

5.5 Dealing with Multiple Hazards

Most electric power 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.

Ideally, one would prefer an assessment process 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 in this Guideline.

What is possible given the tools provided in this Guideline is a relative ranking of analyses for each hazard where several significant hazards and vulnerabilities are identified. 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 Phase 2 analyses 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 eliminate significant risks while maintaining a simple and relatively tractable evaluation framework.

Table 5-4. Hazard Evaluation Matrix for Electric Power 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 system-wide 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, SPTs, and/or CPTs			◆	
1.2.7 Conduct extensive soil borings, SPTs, and/or 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 system-wide PSHA	2,4			◆

Table 5-4. Hazard Evaluation Matrix for Electric Power 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 ground water 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 Electric Power 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 wind storms using expert judgment		◆	◆	◆
3.6	Conduct field evaluations			◆	◆
3.7	Estimate potential wind hazards using expert judgment		◆	◆	◆
3.8	Perform system-wide 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 system-wide 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 since these faults tend to be located near the surface.
2 – See commentary for list of peer reviewed methods.
3 – There are numerous sources of information on regional seismicity. Some of these can be viewed on the U.S. Geological Survey (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 will have detailed flood maps for their respective areas.

Table 5-5. Component Evaluation Matrix for Electric Power Systems - Natural Hazards

Component/Task	Notes	V1	V2	V3
1 Fragility Assessment of Electric Power System Equipment				
1.1 Gather information by interviewing utility design engineers, field engineers and operations managers. Obtain performance assessments (estimates, informed estimates) and any performance data (statistics) that they may be aware of.		◆	◆	◆
1.2 Gather information by performing site survey(s) to assess local conditions and information on the general vulnerability of components.	1		◆	◆
1.3 Gather information by performing site survey(s) to assess collateral hazards from off-site sources, and nearby structures and equipment.	2		◆	◆
1.4 Gather information by reviewing drawings and calculations for critical equipment items.			◆	◆
1.5 Gather information by performing site visits to verify installation details for critical equipment items.	3		◆	◆
1.6 Perform structural calculations to verify the adequacy of observed installation details for critical equipment items, or conformance to performance-based specifications.				◆
1.7 Assess equipment fragilities using estimates, informed estimates and experience data from past events (statistics) with minimal field data collection	4	◆	◆	◆
1.8 Assess equipment fragilities using representative field data from Tasks 1.2 through 1.5 and from more detailed data on shipping loads, equipment qualification and fragility testing.	5		◆	◆
1.9 Assess equipment fragility using actual field data (as described in Tasks 1.2 through 1.6) and the results of structural analysis of selected equipment.	4			◆
2 Fragility Assessment of Critical Buildings				
2.1 Gather information by interviewing utility operations managers and building maintenance personnel.		◆	◆	◆
2.2 Identify critical functions within buildings, and the damage state 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.	1		◆	◆
2.4 Perform general site survey(s) to assess collateral hazards from off-site sources, and nearby structures and equipment.	2		◆	◆

Table 5-5. Component Evaluation Matrix for Electric Power Systems - Natural Hazards

Component/Task	Notes	V1	V2	V3
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 assessments, with minimal field data collection.	4	◆	◆	◆
2.6 Review architectural and structural drawings, design calculations, foundation evaluation 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 to assess building response.	4			◆

Notes:

1 – There are several manuals that identify key steps in conducting a site survey. See commentary for references. User should note, however, that important considerations is whether equipment items are restrained and if so, how they are restrained.

2 – Key items to note are steep slopes; the locations of large tanks or reservoirs; possible chemical spill sources; large towers or trees (especially on slopes near ingress and/or egress routes).

3 – It is important to assess whether actual installations are per design, i.e., according to standard procedures.

4 – See commentary for examples.

5 – It is important to gather information and data from enough sites so that general installation practices can be assessed.

Table 5-6. System Performance Evaluation Matrix for Electric Power 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 Electric Power 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 & estimate	3	◆	◆	◆
1.1.7 Consult with local law enforcement agencies – expert opinion			◆	◆
1.1.8 Consult with other utility 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 utility companies security				◆
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 Electric Power 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 utility staffing levels, schedules, 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., man/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(s), 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 (e.g., Sandia, 2002) to assess system vulnerabilities – simulation & penetration tests	1			◆

Notes:

1 – See Commentary for examples.

Table 5-9. System Performance Evaluation Matrix for Electric Power 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 sub-systems			◆	◆
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 utility 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

				VULNERABILITY ASSESSMENT		
				V1	V2	V3
SYSTEM ASSESSMENT LEVEL	S1	HAZARD ASSESSMENT	H1	1 to 15 days	1 to 15 days	3 to 10 weeks
			H2	3 to 10 weeks	3 to 10 weeks	3 to 10 weeks
			H3	3 to 10 weeks	3 to 9 months	3 to 9 months
	S2	HAZARD ASSESSMENT	H1	3 to 10 weeks	3 to 10 weeks	3 to 10 weeks
			H2	3 to 10 weeks	3 to 10 weeks	3 to 10 weeks
			H3	3 to 9 months	3 to 9 months	3 to 9 months
	S3	HAZARD ASSESSMENT	H1	3 to 10 weeks	3 to 10 weeks	3 to 9 months
			H2	3 to 10 weeks	3 to 9 months	3 to 9 months
			H3	3 to 9 months	3 to 9 months	3 to 9 months

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

Three hypothetical examples are provided in this section to illustrate the use of this Guideline. These examples are primarily based on external inquiries. The examples are hypothetical; they neither apply to an actual power system nor do they represent an actual inquiry. Furthermore, 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 – General System Exposure of Distribution Lines to Wind Hazard

Inquiry: A local government Council in Harris County, Texas (which includes the City of Houston) queries whether it should pass an ordinance that requires tree-trimming and spacing of trees away from electric power distribution and transmission lines. If enacted, this ordinance would go beyond the powers of the electric power utility system, which does not have jurisdiction over such tree-trimming and spacing of trees. The council makes this query to the local electric power utility, which has about 40,000 customers. The goal of such an ordinance would be to reduce the number of outages during natural hazards such as severe storms.

Assessment: The utility response to this inquiry is based on understanding the inherent risk associated with falling trees and the impact that these types of incidents have on the performance of transmission and distribution components, namely power lines. In order to respond to the local government Council, the utility must 1) determine the vulnerability of power lines to wind hazards, 2) assess the likelihood of significant wind hazards in the region, and 3) evaluate what the likely impacts will be in the region should power lines be damaged by falling trees.

Step 1: *Determine whether this region is susceptible to severe wind hazards (Phase 1 Assessment).* Since this service region is located along the Gulf Coast where hurricanes are a significant hazard, the designated hazard level (as determined from **Figure 8-3** and **Appendix A** in the **Commentary**) is determined to be "High."

Step 2: *Determine general vulnerability to damage or disruption (Phase 1).* The vulnerability matrix in **Table 4-2** indicates that distribution lines have a "High" vulnerability to severe winds. 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.* Based on the information above, it is determined that wind severity in the county is a "High." The hazard score per Section 5.1 for a "High" rating is 3.

Step 4: *Determine the vulnerability rating and score.* From **Table 4-2**, it is determined that the vulnerability of a distribution line to severe wind 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 "system type" modifier is taken as 1, because there is generally redundancy in the system at this level. From Table 5-1, the consequence of failure of distribution lines can be characterized as follows:

- Life safety, low, $C_{LS} = 1$
- Financial loss, low, $C_{FL} = R_C = 1$
- Service disruption, low, $C_{SD} = R_C = 1$
- Environmental impact, low, $C_{EI} = 1$

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

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:

$$I_L = H \times V \times \text{Max}(C_{LS}, C_{FL}, C_{SD}, C_{EI}) = 3 \times 3 \times 1 = 9$$

For a level index, I_L, of 9, Table 5-2 recommends a "Low" baseline level for Phase 2 analysis, which implies an H1-V1-S1 analysis.

Step 7: *Perform Level 1 Hazard (H1) Analysis.* Referring to **Table 5-4**, an H1 analysis consists of Tasks 3.1, 3.2, 3.5 and 3.7 (review national wind maps; review literature on local wind history; identify potential wind storms using expert judgment; and estimate potential wind hazards using expert judgment).

Step 8: *Perform Level 1 Vulnerability (V1) Analysis.* The results of scoring in Step 6 indicate a Level 1 vulnerability analysis. A Level 1 vulnerability analysis consists only of Tasks 1.1 and Task 1.7 in **Table 5-5**, that is, gathering information by interviewing utility design engineers, field engineers and operations managers, and assessing power line fragilities using estimates, informed estimates and experience data from past events, respectively.

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 distribution lines at risk, review of system performance in past (similar) events, and an estimate of system performance in severe winds using expert judgment.

If the risk of distribution line failure and associated consequences as determined by the performance assessment is 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.

Results: Depending on the outcome of the analysis, the utility will be able to demonstrate that the likelihood of power line damage from falling trees is minimal, or if the likelihood of damage is high, what corrective actions could be taken to mitigate future damage from this type of damage.

Example 2: Inquiry by a Public Official – Consequence of a Local Hazard at a High-Voltage Substation

Inquiry: A State official has reviewed electric power system maps and determined that a specific high-voltage substation appears to be critical to overall power system operations in the State. He queries the electric power utility on the consequences of failure of this substation should it be damaged by a newly discovered fault in southern California.

Assessment: The electric power utility will base its response on three factors: 1) the credibility of the analysis that identifies the presence of the new fault, 2) the present vulnerability of this high-voltage substation to earthquake hazards, and 3) the overall impacts on the system should this substation be damaged and/or disrupted.

Step 1: *Determine general vulnerability to damage or disruption (Phase 1 Assessment).* The vulnerability matrix in **Table 4-2** indicates that high-voltage substations have a "High" vulnerability to earthquake hazards. Since all of southern California is considered a "high" seismic hazard area, the user is prompted to proceed to a Phase 2 analysis.

Step 2: *Determine the hazard rating and score.* From Figure 8-1, the seismic hazard of southern California is determined to be "High". Furthermore, the inquiry itself indicates a newly discovered seismic source, and the seismic hazard map of Figure 8-1 simply confirms the seismic hazard. The hazard score per Section 5.1 for a "High" rating is 3.

Step 3: *Determine the vulnerability rating and score.* From **Table 4-2**, it is determined that the vulnerability of a transmission substation to earthquake shaking 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 "system type" modifier is taken as 1, because although this particular facility is one of several major facilities that service the southern California area, damage at this site could result in system-wide disruptions affecting a large portion of the state. From Table 5-1, the consequence of failure of a major transmission substation can be characterized as follows:

- Life safety, low, $C_{LS} = 1$
- Financial loss, moderate, $C_{FL} = 2 R_C = 2 \times 1.0 = 2$
- Service disruption, high, $C_{SD} = 3 R_C = 3 \times 1.0 = 3$
- Environmental impact, low, $C_{EI} = 1$

The maximum consequence rating for use in Equation 5-1 is 3.

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:

$$I_L = H \times V \times \text{Max}\,(C_{LS}, C_{FL}, C_{SD}, C_{EI}) = 3 \times 3 \times 3 = 27$$

For a level index, I_L, of 27, Table 5-2 recommends a "Moderate" baseline level for Phase 2 analysis, which implies an H2-V2-S2 analysis. However, because the inquiry must be answered in the next two weeks, the analysis levels are adjusted downward as follows, H1-V2-S1. The level of analysis for component vulnerability remains Level 2 because the focus of the inquiry is on the performance of a specific substation.

Step 6: *Perform Level 1 Hazard (H1) Analysis.* Referring to **Table 5-4**, an H1 analysis for ground shaking effects (i.e., no known ground failure conditions exist at the site) consists of Tasks 1.3.1 through 1.3.3, and Task 1.3.5 of Table 5-4 (review of regional seismicity, seismic hazard mapping, surface geology maps, and estimates of ground motion levels using judgment and existing maps).

Step 7: *Perform Level 2 Vulnerability (V2) Analysis.* Per **Table 5-5**, a Level 2 vulnerability analysis for electric power equipment consists of Tasks 1.1 through 1.5 (gather information from interviews, site surveys on local conditions and to assess possible collateral hazards; review drawings and calculations for key equipment at substation site) and Tasks 1.7 and 1.8 (assess equipment fragilities using expert judgment; and assess equipment fragilities using detailed data on shipping loads, equipment qualification and fragility testing).

Step 8: *Perform Level 1 System (S1) Analysis.* For a Level 1 systems analysis, **Table 5-6** recommends Tasks 1.1, 1.2 and 1.5 (review system maps, review system performance in past events, and evaluate system performance using expert judgment).

Results: Depending on the outcome, the utility will be able to 1) document that the information collected on the newly discovered fault is insufficient to warrant a more detailed analysis of the substation, 2) demonstrate that current design and construction measures are sufficient to resist damaging ground motions from the newly discovered fault, 3) indicate that more detailed information or analysis (e.g., Level 3) is required before responding to the inquiry, or 4) indicate what measures will be taken to mitigate damage from the new earthquake threat.

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

Inquiry: An electric power utility has been requested by the Public Utilities Commission to assess the risk of chemical/biological attack on its operations control center (OCC).

Assessment: The utility will base its response on how vulnerable it is to the identified threats, and what actions are currently being taken to reduce the potential for such an event to occur.

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

Step 2: *Determine the hazard rating and score.* From **Table 4-1**, knowing that the current threat level is yellow or elevated, the hazard level is 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.* From **Table 4-2**, it is determined that 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 "system type" modifier is taken as 1.0, because an OCC will have at least rudimentary backup if their main center goes off-line. From Table 5-1, the consequence of failure or loss of the OCC can be characterized as follows:

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

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:

$$I_L = H \text{ x } V \text{ x Max } (C_{LS}, C_{FL}, C_{SD}, C_{EI}) = 2 \text{ x } 3 \text{ x } 2 = 12$$

For a level index, I_L, of 12, Table 5-2 recommends a "Low" baseline level for Phase 2 analysis, which implies an S1-H1-V1 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 thoroughly assessed the likelihood of anticipated threats, 2) it has taken or will take significant measures to prevent or mitigate the impacts of the event should the event occur, or 3) further assessment is necessary to fully quantify the magnitude of the threat and its impact on the performance of the system.

7.0 References

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8.0 Hazard Maps

This section of the guideline contains hazard maps for earthquake, landslide, hurricane wind and tornado, tornado only, and riverine and coastal flooding. With the exception of flooding, these maps contain designations for low, medium and high hazard levels. For a definition of these levels, the user is referred to Table 4-1. In addition, hazard designations may be obtained from Appendix A of the Commentary
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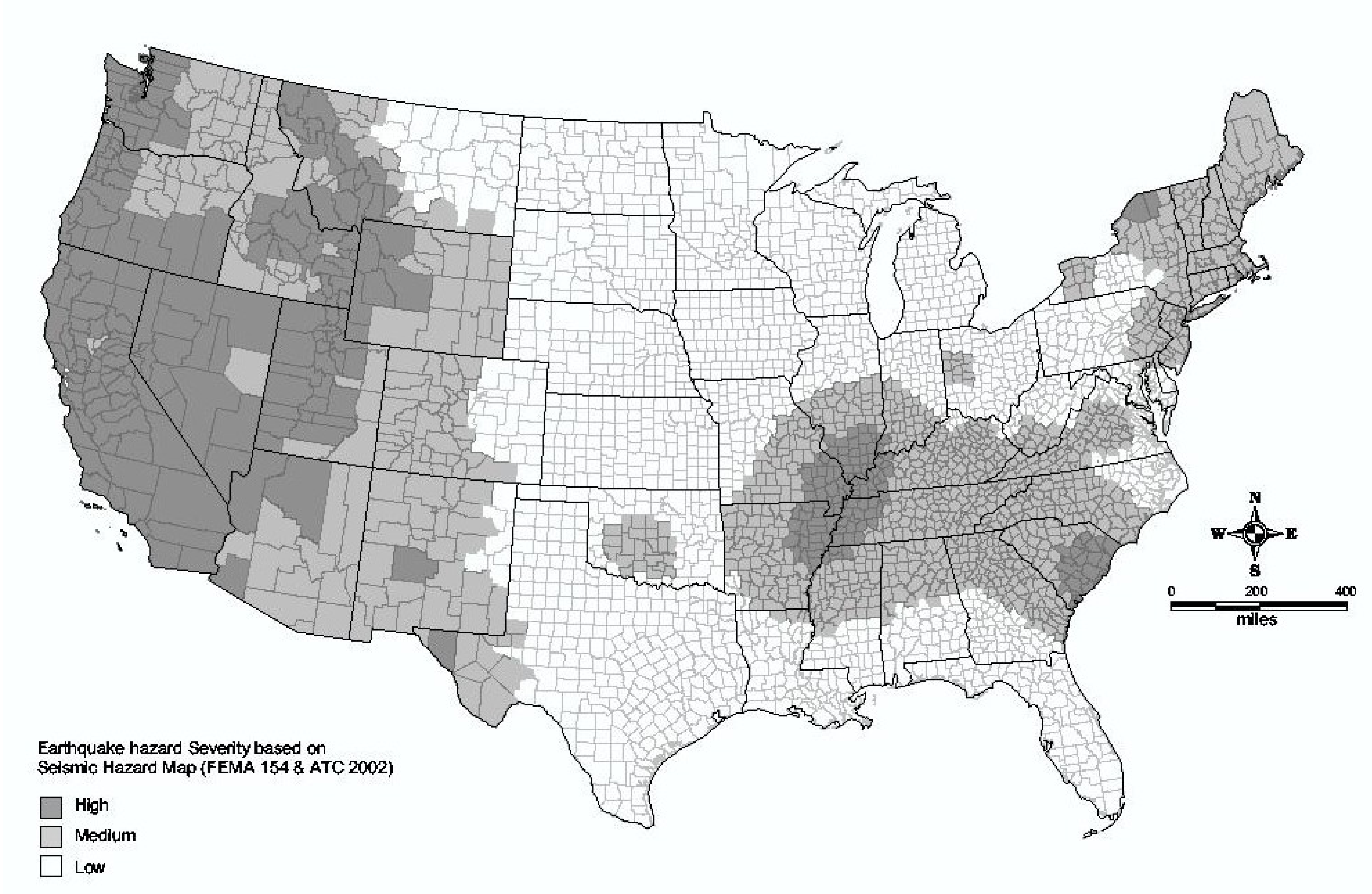

Figure 8-1. Hazard Level Map for Earthquake (Source: FEMA, 2002; ATC, 2002)

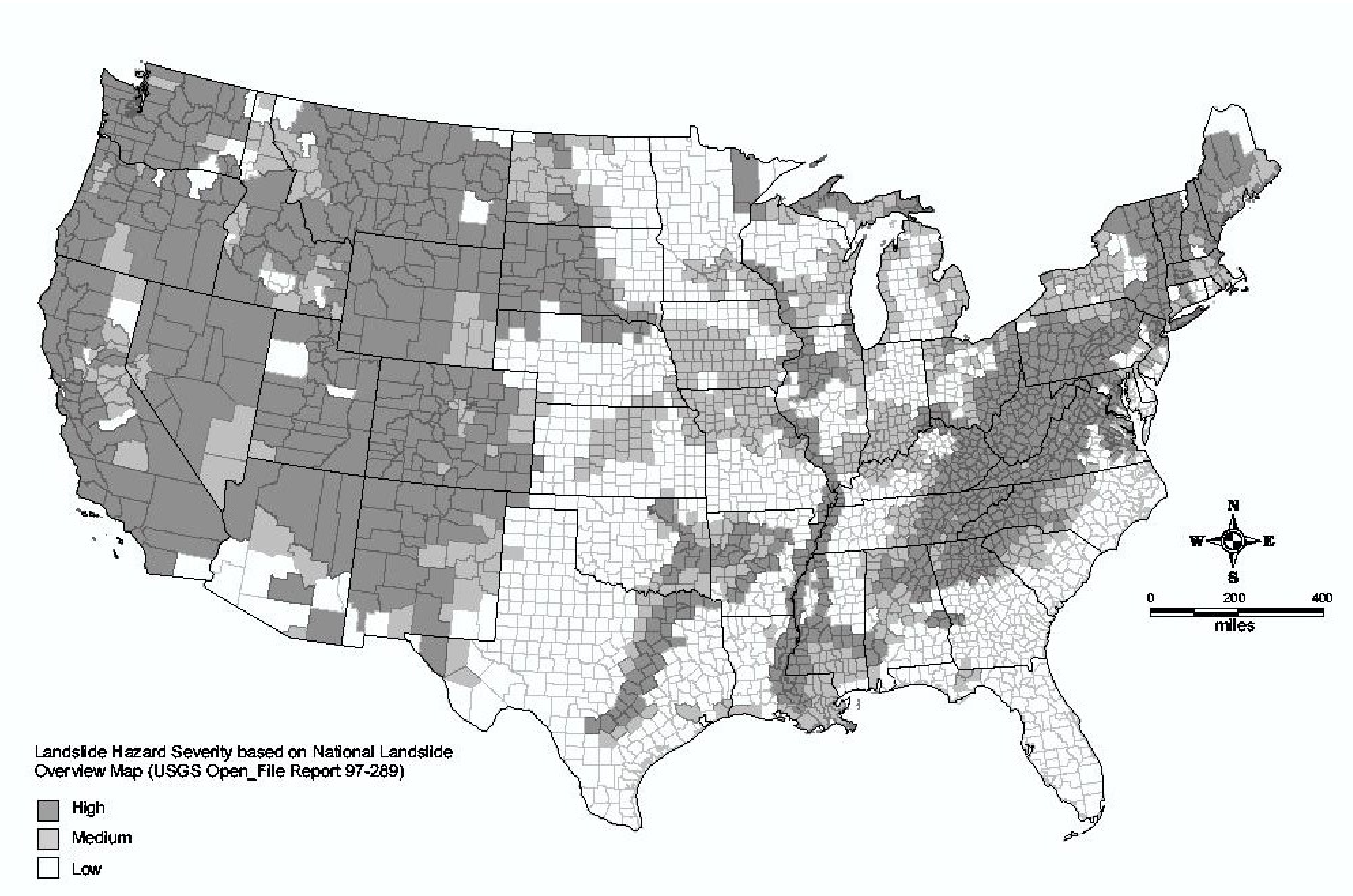

Figure 8-2. Hazard Level Map for Landslide (Source: USGS, 1997a)

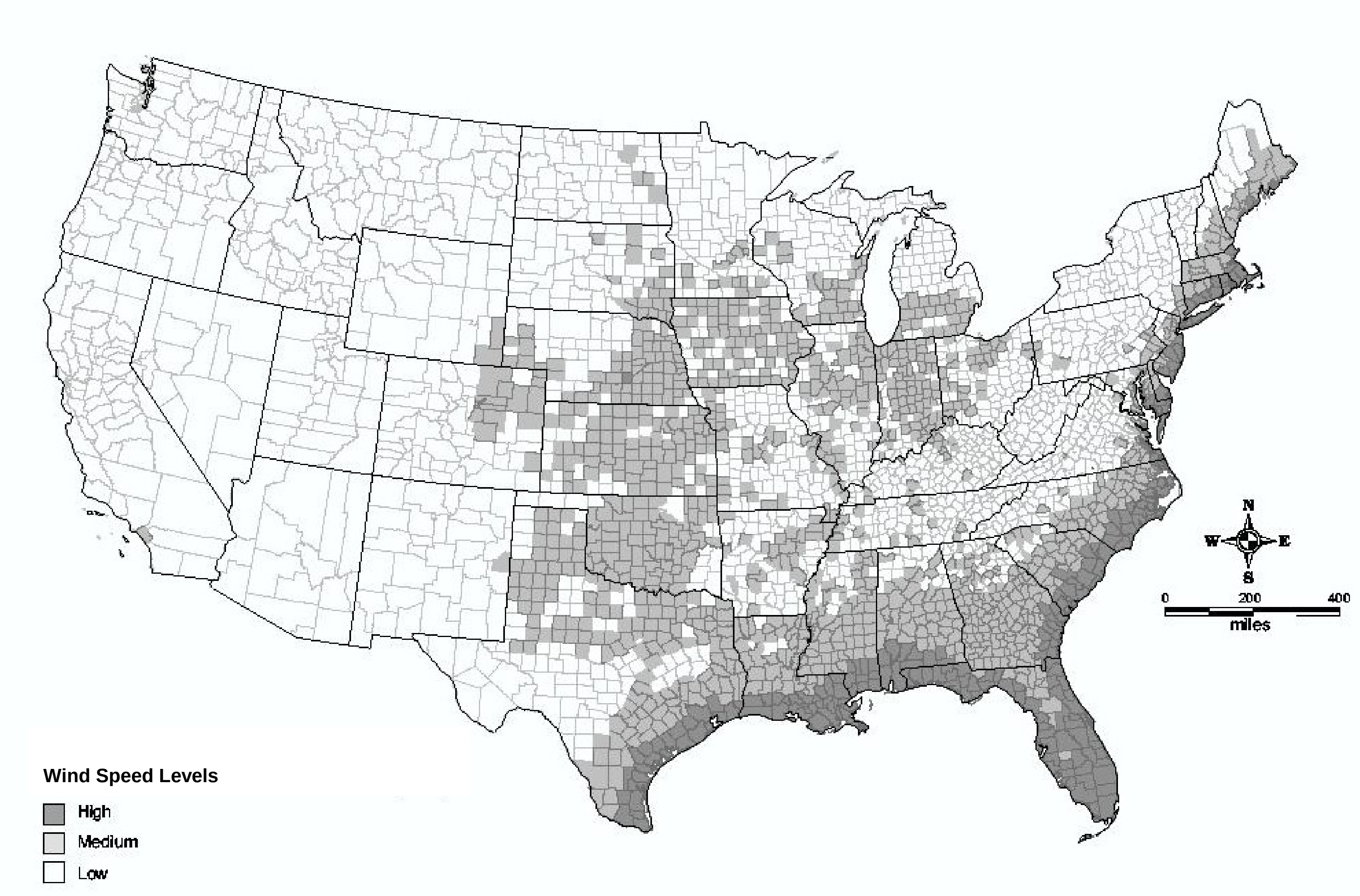

Figure 8-3. Hazard Level Map for Severe Wind, Hurricane Wind and Tornado (Sources: ASCE, 2002; ICC, 2002; NOAA, 1999)

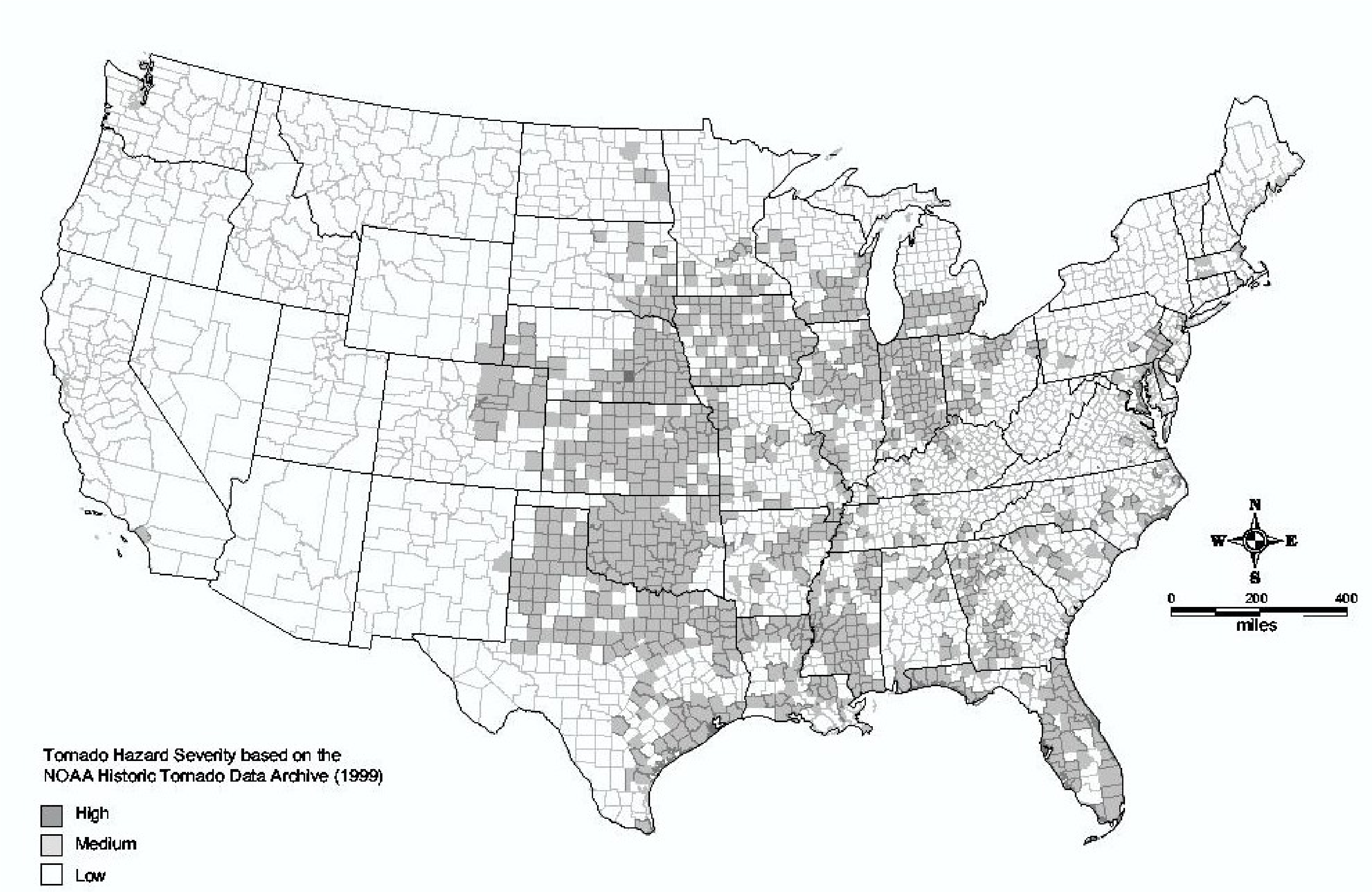

Figure 8-4. Hazard Level Map for Tornado Only (Source: NOAA, 1999)

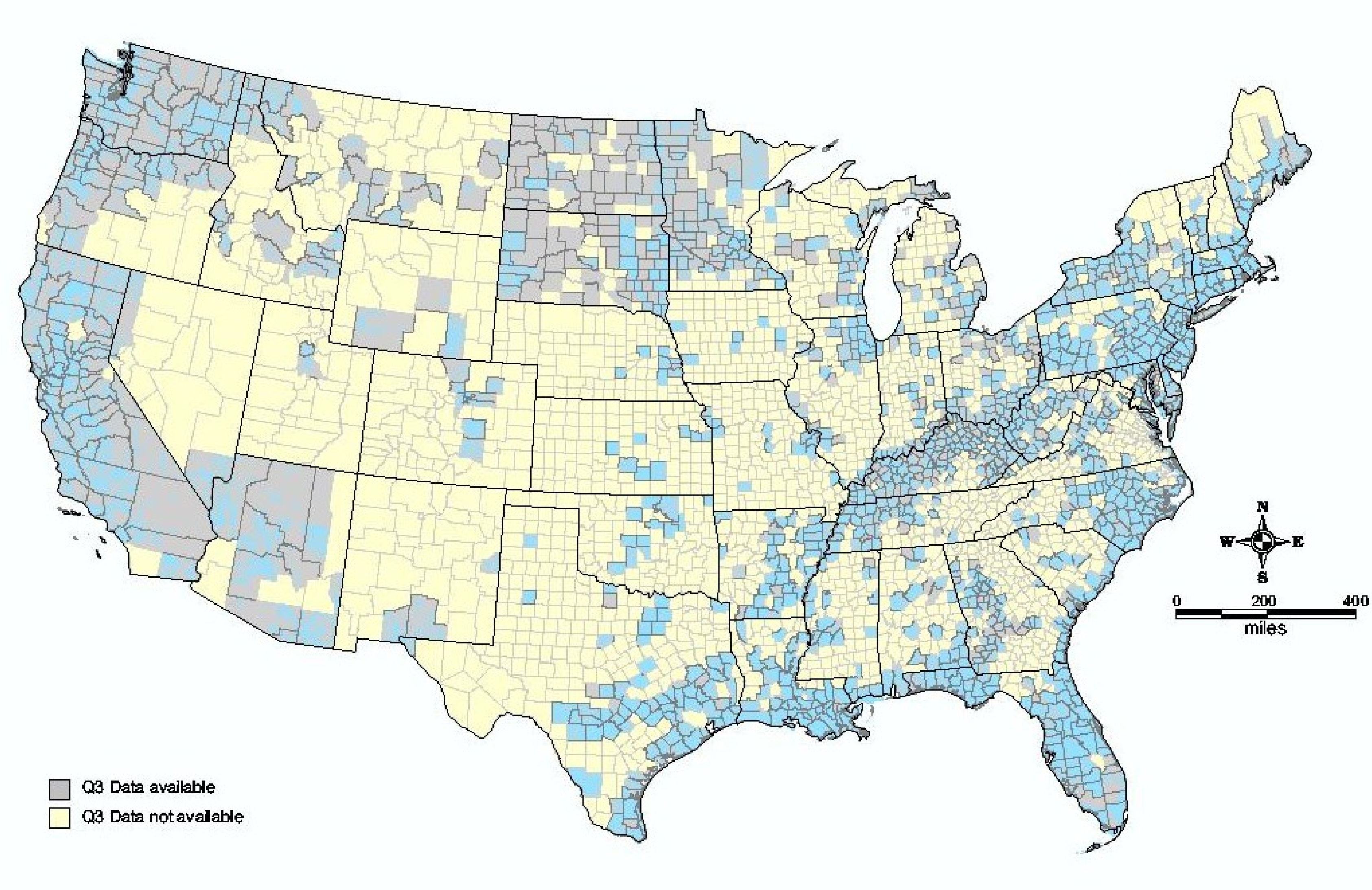

Figure 8-5. Hazard Level Map for Riverine and Coastal Flooding (Source: FEMA, 2003)