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There are too many situations and incidents that can come to pass in everyday life, that when time is taken to learn and skills obtained, can mean the difference between life and death. Sept. 11, 2001 proved to the world that no matter how safe a person thinks they may be, death and injury can come from the most UN-LIKELY place, at any time. The documents presented in this series of digitized works, can help the average person with the knowledge within, to know how to save those persons closest to them in REAL disaster. Help spread this idea of sharing SURVIVAL INFORMATION.

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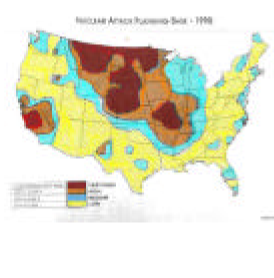
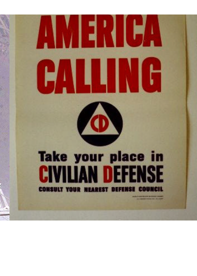
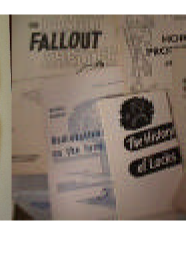
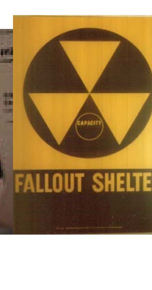









2 Protection Objectives

As noted in Chapter 1, FEMA has developed standard designs for in-home tornado shelters (or "safe rooms") designed to protect the occupants of a single home during severe wind events. The May 1999 BPAT investigation of the tornadoes in Oklahoma and Kansas made it clear that a severe wind event can cause a large loss of life or a large number of injuries in high-occupancy buildings (e.g., school buildings, hospitals and other critical care facilities, nursing homes, day-care centers, and commercial buildings) and in residential neighborhoods where people do not have access to either in-residence or community shelters. This manual provides design professionals with guidance they need to design community shelters for protection from high-wind events.

The design and planning necessary for extremely high-capacity shelters that may be required for use in large, public use venues such as stadiums or amphitheaters are beyond the scope of this design manual. An owner or operator of such a venue may be guided by concepts presented in this manual, but detailed guidance concerning extremely high-capacity shelters is not provided. The design of such shelters requires attention to issues such as egress and life safety for a number of people that is orders of magnitude greater than that proposed for a shelter designed in accordance with the guidance provided in this manual.

This manual provides guidance regarding issues such as designing and constructing a shelter as a "stand-alone" building; constructing a shelter in a new building; adding a shelter to an existing building; identifying additional wall and roof sections capable of withstanding impacts from windborne debris (missiles); and reconciling prototypical plans with the model building, fire, and life safety codes, as well as emergency operations plans.

NOTE

In May 1999, FEMA provided general criteria for all tornado shelters in the *National Performance Criteria for Tornado Shelters* (NPC). For community shelters, the specific guidance in this manual replaces the general guidance in the May 1999 edition of the NPC. The July 2000 edition of the NPC (available on the World Wide Web at www.fema.gov) now applies only to shelters with fewer than 12 occupants.

WARNING

A shelter designed according to the guidance presented in this manual provides near-absolute protection from death and injury. The shelter, however, may be damaged during a design event. (A design event is determined through the selection of the appropriate design wind speed from the map in Figure 2-2.)

2.1 Occupant Safety

This manual presents guidance for the design of engineered shelters that will protect large numbers of people during a high-wind event. Shelters designed by a professional according to the design and performance criteria outlined in this manual (including a design wind speed) are intended to minimize the probability of death and injury during a high-wind event by providing their occupants with near-absolute protection.

2.1.1 Occupant Risk Levels and Life Safety

The risk of death or injury from tornadoes or hurricanes is not evenly distributed throughout the United States. This manual will guide the reader through the process of identifying the risk of severe winds in a particular location and mitigating that risk. The intent of this manual is not to mandate the construction of shelters for high-wind events, but rather to provide design guidance for persons who wish to design and build such shelters. Levels of risk, and tools for determining the levels of risk, are presented in this chapter.

2.1.2 Design Limitations

The intent of this manual is not to override or replace current codes and standards, but rather to provide important guidance where none has been available. No known building, fire, or life safety code or engineering standard has previously attempted to provide detailed information, guidance, and recommendations concerning the design of tornado or other high-wind shelters intended to provide near-absolute protection. Therefore, the information provided in this manual is the best available at the time this this manual was published. This information will support the design of a shelter that provides near-absolute protection from a specified design wind speed that has been determined to define the wind threat for a given geographic area. Designing and constructing a shelter according to the criteria in this manual does not mean that the shelter will be capable of withstanding every possible high-wind event. The design professional who ultimately designs a shelter should state the shelter design parameters on the project documents.

Examples of actual shelters that have been designed to the criteria presented in this manual are presented in Appendixes C and D.

2.2 Risk Assessment Concepts

The decision to design and construct a shelter can be based on a single factor or on a collection of factors. Single factors are often related to the potential for loss of life or injury (e.g., a hospital that cannot move patients housed in an intensive care unit decides to build a shelter, or shelters, within the hospital; a school decides not to chance fate and constructs a shelter). A collection of factors to be considered in the risk assessment process could include the type of hazard event, probability of event occurrence, severity of the event, probable single and aggregate annual event deaths, shelter costs, and results of computer models that evaluate the **benefits and costs** of the shelter project.

CROSS-REFERENCE

A **benefit/cost** (B/C) analysis model for tornado and hurricane shelters is discussed in Section 2.2.7 and is provided on the CD-ROM inlcuded in Appendix A.

A risk assessment should be performed prior to the design and construction of the shelter. The flowchart in Figure 2-1 will help. The major steps of the risk assessment process—determining the nature, severity, and magnitude of the expected wind event, assessing the potential for death and injury, conducting a site assessment, identifying other influencing factors, and determining shelter costs and benefits—are discussed in Sections 2.2.1 through 2.2.7.

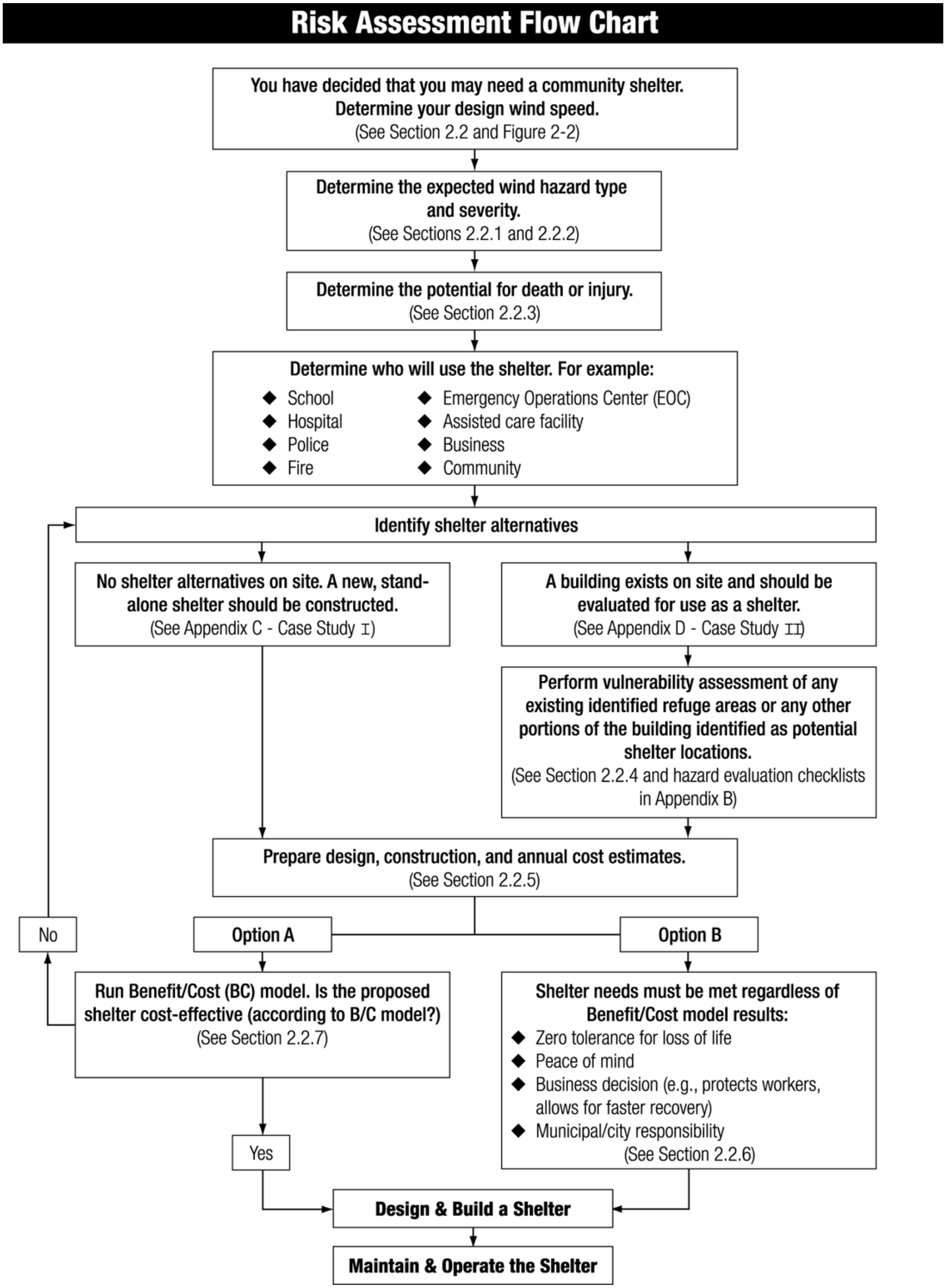


Figure 2-1 Risk assessment flowchart.

2.2.1 Design Wind Speed Map for Risk Assessment and Shelter Design

A map of extreme wind speeds was produced for FEMA 320, *Taking Shelter from the Storm; Building a Safe Room Inside Your House*. This design manual uses a revised version of that map, updated and adjusted to reflect the most recent data. The map (Figure 2-2) illustrates the design wind speeds for different geographic regions of the country. The engineer or architect should select the design wind speed for the proposed shelter according to the shelter's geographic location. For example, the design wind speed for a shelter being designed in Wichita, Kansas, is 250 mph, but the design wind speed for a shelter being designed in Rocky Mount, North Carolina, is 200 mph. Designs based on these wind speeds offer similar levels of protection for their respective locations.

NOTE

The wind speeds associated with the Saffir-Simpson Hurricane Scale are recorded as 1-minute sustained winds. Figure 2-2 presents the design wind speeds as 3-second gusts. Therefore, 154-mph winds in a high-end Category 4 Hurricane on the Saffir-Simpson Hurricane Scale are equivalent to 194-mph winds recorded as 3-second gusts. More information on wind speed conversions is provided in Chapter 10.

Shelters are designed for winds that occur in tornadoes, hurricanes, or thunderstorms. Along the Gulf of Mexico and Atlantic coasts and in the Caribbean and Pacific Islands, hurricane winds control the design (typhoons control the design for the Pacific Islands); in the interior of the United States and Alaska, either tornadoes or thunderstorms are likely to control shelter design.

This change of guidance from FEMA's *National Performance Criteria for Tornado Shelters* is a more refined approach to the design of larger shelters and considers the probability of high winds occurring. The design professional can use the wind speeds shown on the map to design a shelter that provides near-absolute protection for a specific geographic area within the United States. Designing a shelter to protect against the maximum wind speeds possible during the rarest of extreme events is impractical; in addition, such wind speeds are often a matter of debate within the scientific and engineering communities. A design wind speed of 250 mph is considered to be a reasonable maximum design speed for the entire country. Note, however, that Zones I, II, and III have a reduced potential for high-wind events and thus have design wind speeds of 130 mph, 160 mph, and 200 mph, respectively. (Wind speeds stated are 3-second gust, Exposure C, and correspond to an elevation of 33 feet above grade—consistent with ASCE 7-98.)

NOTE

ASCE 7-98 is the national engineering standard for load determination promulgated by the American Society of Civil Engineers (ASCE) and is incorporated by reference into the International Building Code (IBC) and International Residential Code (IRC). The design parameters defined in this manual are for use with the design methodology in ASCE 7-98 except where noted.

Wind speed measurements higher than the design wind speeds are frequently reported immediately after an extreme-wind event that are not borne out by careful evaluation. Highly contested wind speed measurements that are outliers in the statistical wind speed data for the United States are not practical design parameters for community shelters. The wind speed measurement devices used and their ability to function properly during a severe event are often questioned. Questions arise about whether the devices were calibrated properly, whether they were rated for the wind speed being measured, and whether they functioned properly (e.g., was the device a hot-wire anemometer that became wet and gave a false reading?). In addition, the wind

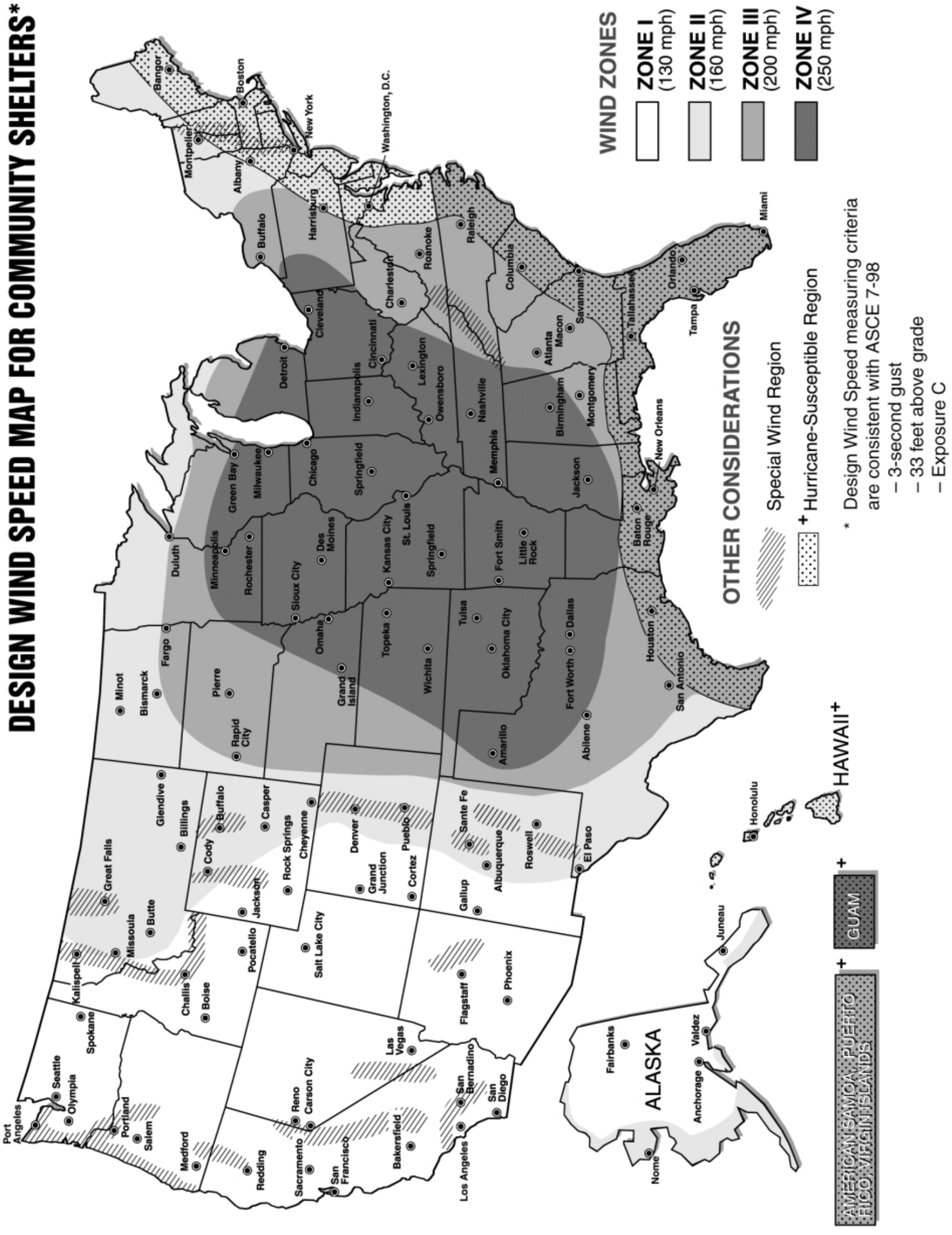


Figure 2-2 Design wind speeds for community shelters.

NOTE

It is important to note that FEMA does not intend to revise FEMA 320 to provide designs for in-home shelters that resist wind speeds of less than 250 mph. The 250-mph criterion has resulted in a series of designs that provide a consistent level of protection. In small, in-residence shelters, the wall and roof sections required to resist missile impacts can easily be designed to resist pressures from wind speeds of 250 mph. Any savings that would result from constructing to resist a lower wind speed are insignificant for these small shelters. However, for the longer-span wall and roof sections required for community shelters, wind pressure, rather than missile impact, becomes a much more significant factor in design.

measurement may have been taken high above the ground surface (e.g., measurements taken with Doppler radar that do not reflect wind speeds at the ground surface), or they may have been taken with instruments known to have deficiencies in the severe environments in which the instruments were used.

An example of a recently contested wind speed was the 318-mph wind speed reported by a mobile Doppler-on-Wheels Radar during the May 3, 1999, tornado outbreak. The details of this recorded wind speed do not specify at what elevation between 0 and 200 meters (660 feet) above the ground the speed was measured; therefore, this speed is not considered a reasonable design parameter. What was measured by the Doppler-on-Wheels Radar and exactly at what elevation could not be specified to the satisfaction of many in the engineering and scientific communities. Further, additional effort has been spent validating reported high wind speeds that are currently being contested by the engineering and scientific communities. Resolution of this debate is left to other engineering and scientific teams. The design wind speeds recommended in this manual reflect the judgment of the Project Team of credible wind speeds as estimated by the observed damage to buildings during extreme-wind events.

The development of the wind speed map in Figure 2-2, which considers both tornadoes and hurricanes, is based on historical data. Since 1995, an average of more than 1,200 tornadoes has been reported nationwide each year. Tornadoes are short-lived, are on average less than 500 feet wide, and traverse less than 2,000 feet. Some large tornadoes have been known to cause damage paths that are 3/4 mile wide and traverse many miles; however, tornadoes such as these occur only a few times each year. The land area directly impacted by all tornadoes in a year is relatively small. At present, it is not possible to directly measure wind speeds in a tornado because of its short life. Thus, the data available for tornadoes, intensity, and area of damage are relatively sparse and require special consideration in the probability assessment of wind speeds.

CROSS-REFERENCE

A discussion of the design wind speeds for tornadoes and hurricanes is presented in Chapter 10.

For hurricane wind speeds along the Gulf of Mexico and Atlantic coasts, ASCE 7-98 uses the Monte Carlo numerical simulation procedure to establish design wind speeds. The numerical simulation procedure provides reasonable wind speeds for an annual probability of exceedance of 0.02 (50-year mean recurrence interval [MRI]). For wind speeds with an extremely low probability of occurrence, the current numerical procedure gives unusual answers (e.g., wind speed estimates in Maine are higher than those in Florida). Because the available technology is not precise for low-probability wind speeds, the determination of design wind speeds for hurricanes must be based on the available data and subjective judgment.

Tornadic and hurricane design wind speeds for shelter design are unified to one averaging time of 3 seconds. The resulting 3-second gust speeds are consistent with the reference wind speeds used in ASCE 7-98. Consequently, they can be used in conjunction with ASCE 7-98 to determine wind loads as discussed in Chapter 5.

The wind speeds shown in Figure 2-2 are valid for most regions of the country; however, the Special Wind Regions (e.g., mountainous terrain, river gorges, ocean promontories) shown on the map are susceptible to local effects that may cause substantially higher wind speeds. Mountainous areas often experience localized winds of considerable magnitude. For instance, mountain-induced windstorms in the lee of the Colorado Front Range have been documented at speeds approaching 120 mph. In Boulder, Colorado, straight-line winds in excess of 60 mph are observed about once a year. The frequency and maximum intensity of such high-wind events at higher elevations within Special Wind Regions are likely to be more frequent and even stronger. When the desired shelter location is within one of these regions, or there is reason to believe that the wind speeds on the map do not reflect the local wind climate, the design professional should seek expert advice from a wind engineer or meteorologist.

CROSS-REFERENCE

Tables that show conversions from fastest 1/4-mile speeds and 1-minute sustained speeds to 3-second gust speeds are presented in Chapter 10.

2.2.2 Tornado and Hurricane Histories

A map that shows F3, F4, and F5 tornado occurrence in the United States, based on historical data, is presented in Figure 2-3. The history of tornado occurrence in a given area, alone or with the other factors mentioned in this section on risk assessment, is also an important factor in the decision-making process of whether or not to construct a community shelter for protection against high-wind events. BPAT investigations conducted after the May 3, 1999, tornadoes indicated that buildings can be retrofitted to resist the effects of smaller tornadoes (F0–F2). However, to resist the forces of larger tornadoes and provide near-absolute protection from all tornadoes, engineered shelters are needed.

As noted in Section 2.2.1, the map in Figure 2-2 shows the design wind speeds for the country based on combined tornado and hurricane threats. Figure 2-3 presents the recorded statistical history of tornado occurrence for strong and violent tornadoes (F3, F4, and F5) for one-degree squares (approximately 3,700 square miles) over a 48-year period. It is because of the threat of these strong and violent tornadoes that the design wind speed map shows wind zones with wind speeds up to 250 mph throughout the center of the country. Similar statistics exist for smaller, F1 and F2 tornadoes and for hurricane landfalls from 1900 to 1999. This statistical data group was used to define Zones I–III in Figure 2-2.

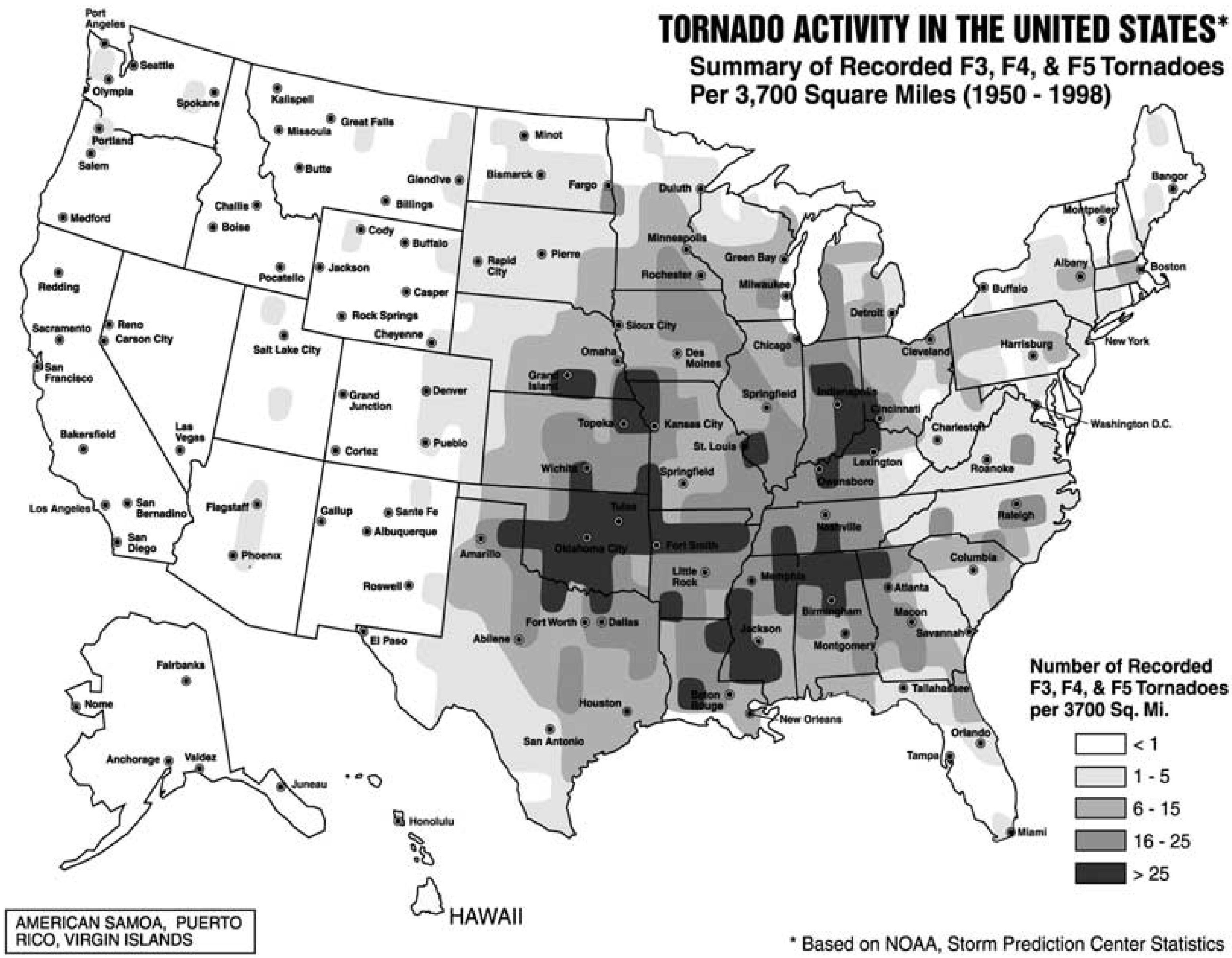


Figure 2-3 Tornado occurrence in the United States based on historical data.

Hurricane histories from 1900 to 1999 were also studied and considered in the preparation of the design wind speed map. These statistics indicate that 79 Category 3, 4, and 5 hurricanes struck the southeast and gulf coast states during that period. These statistics also contributed to the wind zones on Figure 2-2.

The probability data for tornado and hurricane strikes for the United States have been considered in the preparation of the design wind speed map, but are not presented graphically in this manual. However, tornado and hurricane occurrences and their associated probabilities have been included within the benefit/cost model that is discussed in Section 2.2.7 and provided on CD-ROM in Appendix A.

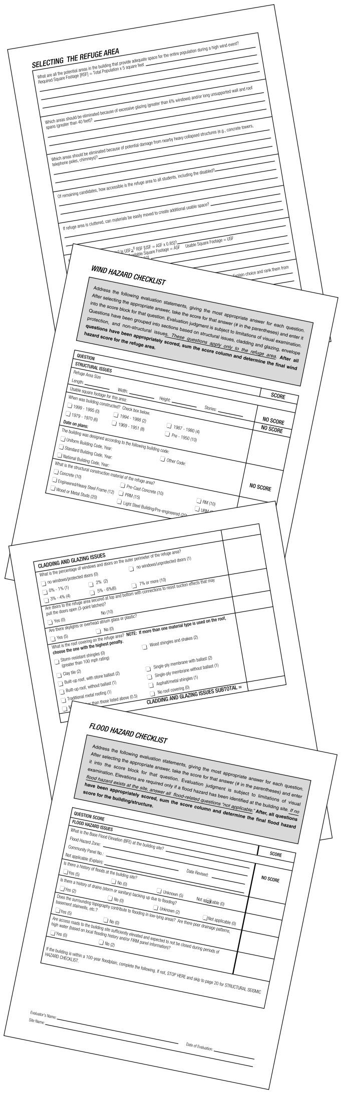
2.2.3 Single and Annual Event Deaths

The owner or user of a potential shelter may decide that, regardless of the probability of a high-wind event occurring at the building site, a certain number of deaths associated with a single event may constitute a reason to construct a shelter. Annualized data on event deaths over specified times may also be a significant factor in the decision to construct or not construct a shelter at a given site.

A convenient source of such data is the World Wide Web. For this project, a significant amount of data was gathered from the Southeast Regional Climate Center (SERCC) and its three-tiered national climate services support program. The partners in this program include the National Climatic Data Center (NCDC at www.ncdc.noaa.gov), the six Regional Climate Centers (RCCs), and the individual and collective State Climate Offices. Private sites also contain significant information regarding deaths, injuries, and costs associated with all types of natural hazard events. The benefit/cost software provided in Appendix A and described in Section 2.2.7 can be used to estimate deaths or injuries both with and without a specially engineered shelter.

2.2.4 Evaluating Existing Areas To Be Used as a Shelter

In inspecting areas of existing buildings that are used as shelter areas, FEMA has found that owners may overlook the safest area of a building. In addition, the safety of a hallway or other shelter area may be overestimated. Evaluating shelter areas in an existing building helps the owner (1) determine whether the safest part of the building is being used as a shelter, (2) identify possible ways to make existing areas safer, and (3) decide whether to design and build a shelter according to the guidance in this manual. A preliminary evaluation may be performed by a design professional or by a potential shelter owner, property owner, emergency manager, building maintenance person, or other interested party provided he or she has a basic knowledge of building sciences and can read and understand building design plans and specifications.



CROSS-REFERENCE

Guidance concerning the siting of shelters is presented in Chapter 4 of this manual.

The wind hazard evaluation checklists in Appendix B will help the user assess a building's susceptibility to damage from high-wind events such as tornadoes and severe hurricanes. Although the threat of damage from high-wind events is the predominant focus of the evaluation, additional threats may exist from flood and seismic events; therefore, flood and seismic hazard evaluations should be performed in conjunction with the wind hazard evaluation to assess the multi-hazard threat at the site. Checklists for flood and seismic hazard evaluations are also provided in Appendix B; however, they are designed to support only a generalized evaluation (the wind hazard section of the checklists includes detailed screening processes for the building structure).

The wind, flood, and seismic hazard evaluation checklists in Appendix B may be used for the preliminary assessment. Prior to the design and construction of a shelter, a design professional should perform a more thorough assessment in order to confirm or, as necessary, modify the findings of a preliminary assessment. The checklists in Appendix B can provide a starting point for this more thorough assessment.

An entire building or a section of a building may be designated a potential shelter area. If an existing building is selected for use as a community shelter, the hazard evaluation checklists will help the user identify potential shelter areas within the building and evaluate their vulnerability to natural hazards. The checklist evaluation process will guide the user through the selection of the best shelter areas within the building and focus the evaluation on the critical sections of the building. For example, an evaluator who inspects a portion of a building being considered for use as a shelter should determine whether that portion is structurally independent of the rest of the building, is easily accessible, and contains the required square footage.

The checklists consist of questions pertaining to structural and non-structural characteristics of the area being considered. The questions are designed to identify structural and non-structural vulnerabilities to wind hazards based on typical failure mechanisms. Structural or non-structural deficiencies may be remedied with retrofit designs; however, depending on the type and degree of deficiency, the evaluation may indicate that the existing structure is unsuitable for use as a shelter area. The checklists are not a substitute for a detailed engineering analysis, but they can assist the decision-makers involved with hazard mitigation and emergency management determine whether a building or section of a building has the potential to serve as a shelter.

The checklists are also used to comparatively rank multiple facilities within a given geographic region that are considered potential shelter sites. A scoring system is included to enable the user to compare performance characteristics at various potential shelter sites and to highlight vulnerabilities. For each question on the checklist, deficiencies and vulnerabilities are assessed penalty points. Therefore, a high score reflects higher hazard vulnerability and a low score reflects lower hazard vulnerability, but only relative to the other buildings considered in the scoring system. There is a minimum possible score for the checklists, but this minimum score will vary, depending on the design wind speed selected from Figure 2-2. Therefore, although a low score is desired, there is no "passing score" or "minimum acceptable score for protection." Again, these checklists help a user determine which area of a building is likely to perform best during a high-wind event and which areas require engineering and retrofit design if they are to provide protection from a tornado, a hurricane, or both.

CROSS-REFERENCE

An additional discussion of probability of high-wind events is presented in Chapter 10.

Electronic versions of the blank checklists and summary score sheet in Appendix B are included on the CD-ROM in Appendix A. Therefore, the user may print additional copies as necessary.

2.2.5 Shelter Costs

Costs for the design, construction, and maintenance of community shelters will vary by location and construction type. As part of the risk assessment plan, budgetary cost estimates (estimates that will be ± 20 percent accurate) should be prepared by the design professional for each proposed shelter alternative.

The most cost-effective means of constructing a shelter at a site is to incorporate the shelter into a new building being planned for construction. The cost to design and construct **hardened** shelter areas within new buildings is much lower than in retrofit situations, in which existing buildings or portions of existing buildings are hardened. For example, in recent FEMA-funded mitigation projects in many midwestern and southeastern states, construction costs for retrofit shelters have been approximately 10–15 percent higher than construction costs for shelters in new buildings. It is important to remember, however, that this increase in cost applies only to a small area of the building (i.e., the area being hardened and not the entire building).

DEFINITION

The term **hardening** refers to the process of modifying the design and construction of a building or part of a building so that it can resist wind pressures and missile impacts during a high-wind event and serve as a shelter. If the hardening is designed by an engineer or architect to meet the criteria in this manual, the hardened area is capable of providing near-absolute protection from the design wind speed (and associated windborne missiles) selected from the map in Figure 2-2.

2.2.6 Other Factors for Constructing a Tornado or Hurricane Shelter

A number of factors can influence the decision-making process. The potential for death or injury discussed in Section 2.2.3 may be a sufficient reason to build a shelter at a given building site. The benefit/cost ratio of constructing a shelter discussed in Section 2.2.7 may be a contributing factor or a requirement of the shelter design process, depending upon the funding source. However, additional factors may be involved in the decision-making process:

- Do the residents feel safe without a shelter?
- Does a business want to provide the protection for its workers?
- Does a shelter allow for faster business recovery after a high-wind event?

- Is the building in question a government-owned building that is required to have a shelter?
- Do zoning ordinances require it?
- Are there insurance benefits?

2.2.7 Benefit/Cost Model

Benefit/cost (B/C) analysis requires knowledge of the probability of occurrence for events of varying magnitude. Appendix A includes a CD-ROM that contains the B/C model software and a user's guide. For tornadoes, the model uses probabilities calculated from data retrieved from the NOAA Storm Prediction Center's Historical Tornado Data Archive. This database contains records of tornado occurrence for all counties in the United States. For hurricanes, the design wind speeds from ASCE 7-98 are used to predict hurricane winds for different probabilities of occurrence for each county. Therefore, the computation of probabilities is geographically based and requires information applicable to specific sites. The purpose of the software is to facilitate the computation of B/C ratios for shelter construction by providing a user-friendly tool for processing the required data.

The model inputs are as follows:

- location, including target county
- project descriptive information (e.g., address, disaster number, project number, project description)
- model run identification
- entire building dimensions
- shelter area
- shelter construction type
- shelter tornado occupancy by hour
- shelter hurricane occupancy by day
- mitigation construction costs
- mitigation maintenance costs
- mitigation useful life and discount rate
- injury and mortality damage functions for each construction type for various wind speeds
- mitigation effectiveness against injury and mortality for various wind speeds
- geographic region around target county for tornado statistics

The model predicts project benefits by determining the monetary savings realized from the proposed mitigation design in terms of the value of avoided deaths of, and injuries to, shelter occupants. The project costs are determined from the cost of construction and maintenance of the proposed mitigation design. To calculate the benefits and costs, the model requires information about the mitigation project being considered and the hazards posed by tornado and hurricane winds. The model has an internal database of tornado hazard data for all counties.

The user selects a region of interest around a target county to provide a statistically significant sample with which to estimate tornado probabilities. The model also contains hurricane wind hazard data for each county, based on the design wind speeds in ASCE 7-98. The hurricane hazard is computed for the target county. With the probabilities known for tornado and hurricane wind hazards, the benefits are calculated from default damage avoidance information contained in the model. Figure 2-4 is a flowchart for the B/C model.

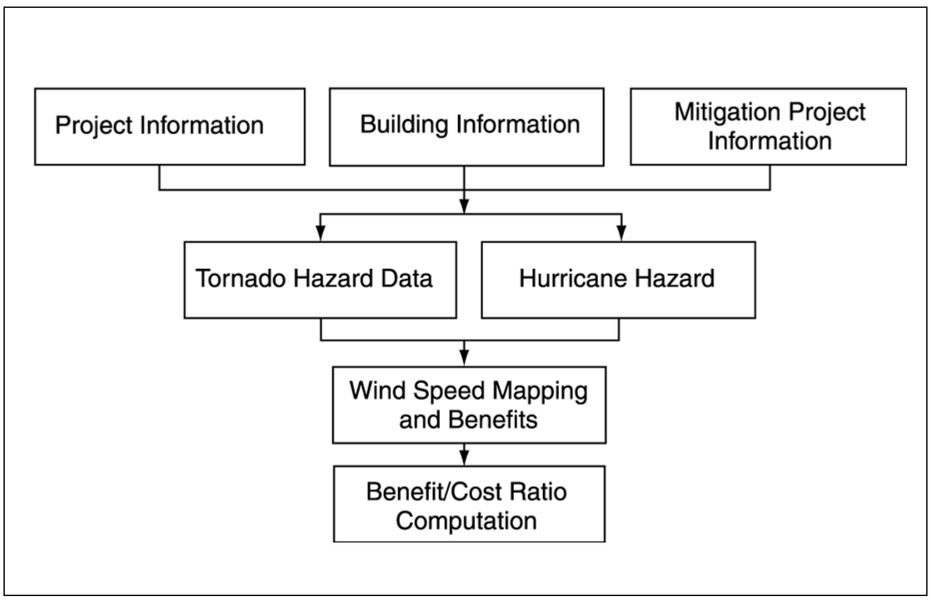


Figure 2-4
Flowchart for the benefit/cost model.

Details about B/C Model Components

Project Information – Requests data about the project: location, including target county, disaster number, run dates, and other basic information. Most of this information is for identification purposes.

Building Information – Requests dimensions, building type, and occupancy by time of the day for tornado hazards and average occupancy for hurricane hazards.

Mitigation Project Information – Requests description of the proposed mitigation project, construction and maintenance costs, useful life, and mitigation effectiveness against tornadoes and hurricanes. For tornadoes and hurricanes, the mitigation effectiveness is measured as the reduction in deaths and injuries for occupants.

Tornado Hazard Data – Requests the selection of a region around the target county. The tornado hazard data are the probabilities that describe the odds of the building being hit by a tornado at a particular time of the day. Because tornadoes are infrequent events in most locations, it is unlikely that there will be a sufficient number of tornadoes in a particular county to compute probabilities. Therefore, the sample region needs to be expanded to encompass surrounding counties. This region can be selected as a buffer with a selected radius around the target county or the entire state, or manually selected county by county. The model indicates when a sufficient number of counties have been selected. The tornado statistics for the target county and the counties of the sample region were obtained from the National Oceanic and Atmospheric Administration/National Weather Service.

Hurricane Hazard Data - Requires the selection of a target county. Based on ASCE 7-98, each county has a 50-year design wind speed and an adjustment equation for different recurrence intervals. This procedure provides the probability of exceedance for a wide range of wind speeds.

CROSS-REFERENCE

The **Fujita Tornado Scale** and the **Saffir-Simpson Hurricane Scale** are discussed in Chapter 3.

Benefit Computation Based on Wind Speeds – The model uses the tornado and hurricane hazard data to calculate benefits based on avoided deaths and injuries. Each building type provided in the model has an associated injury and mortality rate for specific wind speed ranges, which correspond to **Fujita** tornado damage classes and **Safford-Simpson Hurricane Scale** categories. The user can enter adjustments to these "pre-mitigation" and "post-mitigation" rates for injury and mortality based on the mitigation project design effectiveness. The model uses these pre- and post-mitigation damage rates in conjunction with the tornado and hurricane hazard data to calculate the project benefits.

CROSS-REFERENCE

Technical details of the B/C model are discussed in Appendix A.

B/C Ratio Computation – The model calculates benefits and a B/C ratio and prints reports. The model adds the benefits computed (for tornadoes and hurricanes) and discounts them to current value using the Federal discount rate and the useful life of the project. The capital cost of the project and any annual maintenance costs are also converted to current value.

The development of the model software relied on expert engineering and scientific judgement in a number of areas as described in Appendix A. The model looks at the loss of life and injuries associated with both tornadoes and hurricanes. The assumptions, logic, and methodology used to develop the model are presented along with the users' manual in Appendix A.