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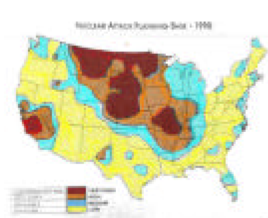
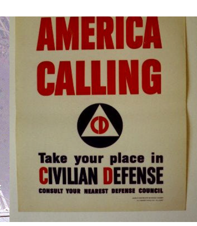
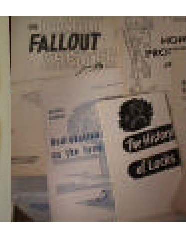






4 Shelter Types, Location, and Siting Concepts

A community shelter either will be used solely as a shelter or will have multiple purposes, uses, or occupancies. This chapter discusses community shelter design concepts that relate to the type of shelter being designed and where it may be located. This chapter also discusses how shelter use (either single or multiple) may affect the type of shelter selected and the location of that shelter on a particular site.

4.1 Shelter Types

This manual provides design guidance on two types of shelters:

- stand-alone shelters: shelters that are separate buildings
- internal shelters: shelter areas that are within or part of a larger building, but that have been designed to be structurally independent.

This is not meant to imply that these are the only two types of shelters that should be considered. Other shelter options, such as groups of smaller, often proprietary shelter systems, may be appropriate for residential communities, hospitals, schools, or at places of business. It is not possible to provide guidance concerning all sheltering options for all shelter locations. The guidance provided in this manual for stand-alone and internal shelters, including the design criteria, may be applied to other shelter options. If other shelter systems and types of shelters are designed to meet the criteria in this manual, they should be capable of providing near-absolute protection as well.

The guidance provided in this manual is for the design and construction of **new** shelters, not for the addition of shelters to existing buildings (i.e., retrofitting). Because of the variety of structural types and the number of different configurations of existing buildings, only a limited amount of guidance is provided on modifying existing buildings to create a shelter where none existed previously. However, a design professional engaged in a shelter retrofitting project should be able to use the guidance in this manual to determine the risk at the site and calculate the loads acting on the building. In addition, the checklists in Appendix B and information presented in the case studies in Appendixes C and D may be helpful in a shelter retrofitting project.

NOTE

This manual provides guidance for the design and construction of new shelters. The design professional performing retrofit work on existing buildings should apply the new design guidance presented in this manual to the retrofit design.

4.1.1 Stand-Alone Shelters

The results of the risk and site assessments discussed in Chapter 2 may show that the best solution to providing protection for large numbers of people is to build a new, separate (i.e., stand-alone) building specifically designed and constructed to serve as a tornado or hurricane shelter.

Potential advantages of a stand-alone shelter include the following:

- The shelter may be sited away from potential debris hazards.
- The shelter will be structurally separate from any building and therefore not vulnerable to being weakened if part of an adjacent structure collapses.
- The shelter does not need to be integrated into an existing building design.

Case Study I (see Appendix C) shows the calculated wind loads for a shelter in Zone III (200 mph) and how the design requirements were met for a stand-alone shelter. This shelter was designed to serve communities in North Carolina that housed families displaced by flooding caused by Hurricane Floyd.

CROSS-REFERENCE

Tornado Refuge Evaluation Checklists are discussed in Chapter 2 and presented in Appendix B. A risk assessment plan that uses these checklists can help determine which type of shelter is best suited to a given site.

4.1.2 Internal Shelters

The results of the risk and site assessments presented in Chapter 2 may show that a specifically designed and constructed shelter area within or connected to a building is a more attractive alternative than a stand-alone shelter, especially when the shelter is to be used by the occupants of the building. This section concentrates on design considerations that are important for internal shelters.

Potential advantages of an internal shelter include the following:

- A shelter that is partially shielded by the surrounding building may not experience the full force of the tornado or hurricane wind. (Note, however, that any protection provided by the surrounding building should not be considered in the shelter design.)
- A shelter designed to be within a new building may be located in an area of the building that the building occupants can reach quickly, easily, and without having to go outside.
- Incorporating the shelter into a planned renovation or building project may reduce the shelter cost.

Case Study II (see Appendix D) shows the calculated wind loads for a shelter in Zone IV (250 mph) and how the design requirements were met for a shelter connected to an existing building. This shelter was designed for a school in Wichita, Kansas, and replaced a portion of the school building that was damaged by the tornadoes of May 3, 1999.

4.2 Single-Use and Multi-Use Shelters

A stand-alone or internal shelter may serve as a shelter only, or it may have multiple uses—for example, a multi-use shelter at a school could also function as a classroom, lunchroom, or laboratory; a multi-use shelter intended to serve a manufactured housing community or single-family-home subdivision could also function as a community center. The decision to design and construct a single-use or a multi-use shelter will likely be made by the prospective client or the owner of the shelter. To help the designer respond to non-engineering and non-architectural needs of shelter owners, this section discusses how shelter use may affect the type of shelter selected.

4.2.1 Single-Use Shelters

Single-use shelters are, as the name implies, used only in the event of a natural hazard event. One advantage of single-use shelters is a potentially simplified design that may be readily accepted by a local building official or fire marshal. Single-use shelters typically have simplified electrical and mechanical systems because they are not required to provide normal daily accommodations for people. Single-use shelters are always ready for occupants and will not be cluttered with furnishings and storage items, which is a concern with multi-use shelters. Simplified, single-use shelters may have a lower total cost of construction than multi-use shelters. Examples of single-use shelters were observed during the BPAT investigation of the May 3, 1999, tornadoes, primarily in residential communities (FEMA 1999a). Small, single-use shelters were used in residential areas with a shelter-to-house ratio of 1:1 or ratios of up to 1:4. One example of a large, single-use community shelter was observed in a manufactured housing park in Wichita, Kansas.

The cost of building a single-use shelter is much higher than the additional cost of including shelter protection in a multi-use room. Existing maintenance plans will usually consider multi-use rooms, but single-use shelters can be expected to require an additional annual maintenance cost.

4.2.2 Multi-Use Shelters

The ability to use a shelter for more than one purpose often makes a multi-use stand-alone or internal shelter appealing to a shelter owner or operator. Multi-use shelters also allow immediate return on investment for owners/operators; the shelter space is used for daily business when the shelter is not being used during a tornado or hurricane. Hospitals, assisted living facilities, and special needs centers would benefit from multi-use internal shelters, such as hardened intensive care units or surgical suites. Internal multi-use shelters in these types of facilities allow optimization of space while providing near-absolute protection with easy access for non-ambulatory persons. In new buildings being designed and constructed, recent FEMA-sponsored projects have indicated that the construction cost of hardening a small area or room in a building is 10–25 percent higher than the construction cost for a non-hardened version of the same area or room.

BPAT investigations of the May 3, 1999, tornadoes, as well as investigations conducted after numerous hurricanes in the 1990s, found many examples of multi-use areas designed and retrofitted for use as shelters, such as the following:

- in school buildings – cafeterias, classrooms, hallways, music rooms, and laboratories
- in public and private buildings – cafeterias/lunchrooms, hallways, and bathrooms (see Figure 4-1)
- in hospitals – lunchrooms, hallways, and surgical suites

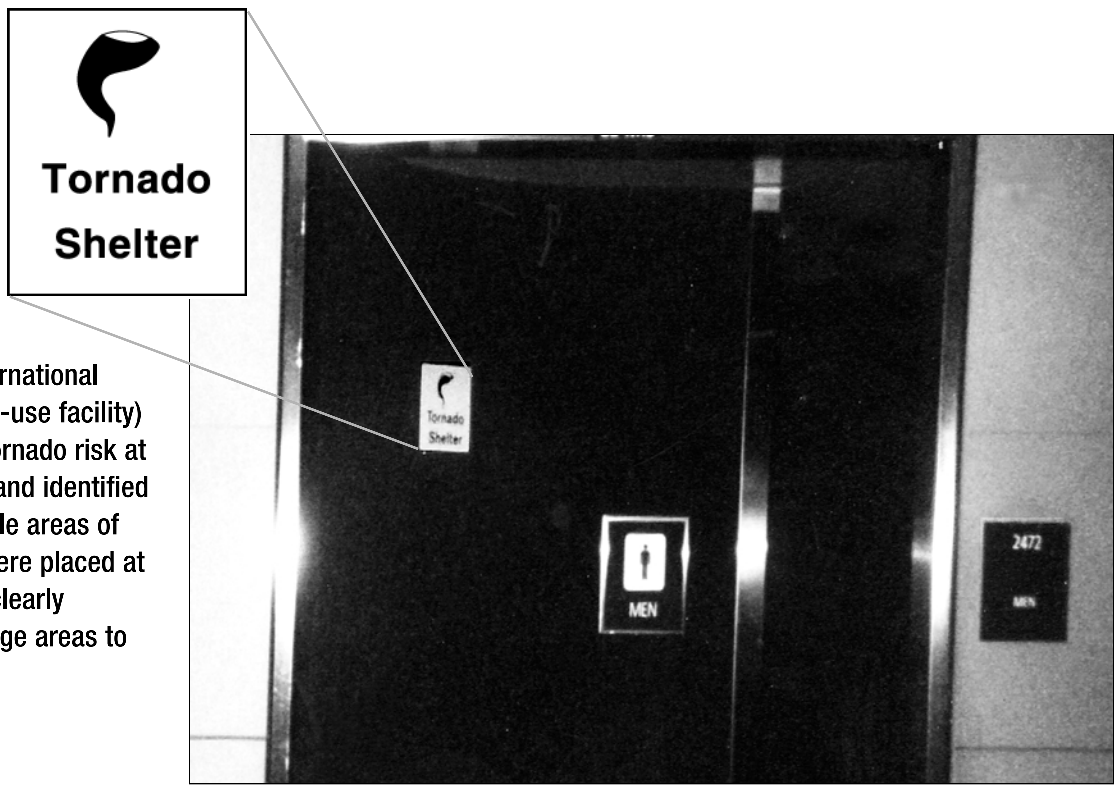


Figure 4-1
The Denver International Airport (a public-use facility) evaluated the tornado risk at the airport site and identified the best available areas of refuge. Signs were placed at these areas to clearly identify the refuge areas to the public.

4.3 Modifying and Retrofitting Existing Space

If a tornado or hurricane shelter is designed and constructed to the criteria presented in this manual, the shelter will provide its occupants with near-absolute protection during a high-wind event.

4.3.1 General Retrofitting Issues

Although retrofitting existing buildings to include a shelter can be expensive and disruptive to users of the space being retrofitted, it may be the only option available. When retrofitting existing space within a building is considered, corridors are often designated as the safest areas because of their short roof spans and the obstruction-free area they provide. Recent shelter evaluation projects have indicated that, although hallways may provide the best refuge in an existing building, retrofitting hallways to provide a near-absolute level of protection may be extremely difficult. Hallways usually have a large number of doors that will need to be upgraded or replaced before near-absolute protection can be achieved based on the criteria outlined in Chapters 5 and 6. Designers should be aware that an area of a building currently used for refuge may not necessarily be the best candidate for retrofitting when the goal is to provide near-absolute protection.

CROSS-REFERENCE

The checklists in Appendix B may be used to identify refuge areas as candidates for retrofit projects.

Examples of interior spaces within buildings where people can take refuge from tornadoes and hurricanes were listed in Section 4.2.2; additional examples include, interior offices, workrooms, and lounges. Guidelines for choosing the best available space are provided in Chapter 2. The design modifications that might be required should follow the recommendations of this manual for new construction (see Appendixes E and F for examples of wall sections, doors, and door hardware that are capable of withstanding the impact of the 100-mph, 15-lb design missile).

Upgrades to improve levels of protection (until a shelter can be designed and constructed) may include the following retrofits:

- replacing existing doors (and door hardware) with metal door systems described in Chapters 5 and 6
- adding metal door systems to replace glazing that is vulnerable to failure from wind pressures or missile impacts
- adding metal door systems to sections of rooms, hallways, and other spaces, and creating protected refuge areas
- removing all glazing, or retrofitting or replacing glazing with either impact-resistant glazing systems or wall sections that meet impact criteria defined in Chapter 6
- adding alcoves to protect existing doors from the direct impact of windborne debris, as described in Chapter 6

NOTE

An existing area that has been retrofitted to serve as a shelter is unlikely to provide the same level of protection as a shelter designed according to the guidance presented in this manual. Also, the additional cost of providing shelter in a new, multi-purpose room is less than the cost of retrofitting an existing space. However, limited space at the proposed shelter site or other constraints may make retrofitting a practical alternative in some situations.

4.3.2 Specific Retrofitting Issues

An existing area that has been retrofitted to serve as a shelter is unlikely to provide the same level of protection as a shelter designed according to the guidance presented in this manual. BPAT investigations and FEMA-funded projects have indicated that when existing space is retrofitted for shelter use, issues have arisen that have challenged both designers and shelter operators. These issues arise when attempts are made to improve the level of protection in areas not designed originally for shelter or refuge use. When retrofit projects call for improving levels of protection through retrofitting doors, windows, and other openings to meet the missile impact requirements of Chapter 6, the designer should look carefully at the area being retrofitted. For example, protecting the openings of a refuge area that is structurally unable to withstand wind pressures and impact loads will not be a wise retrofit project.

Issues related to the retrofitting of existing refuge areas (e.g., hallways/corridors, bathrooms, workrooms, laboratory areas, kitchens, and mechanical rooms) that should be considered include the following:

- **The roof system.** Is the roof system over the proposed refuge area structurally independent of the remainder of the building? If not, is it capable of resisting the expected wind and debris loads? Are there openings in the roof system for mechanical equipment or lighting that cannot be protected during a high-wind event? It may not be reasonable to retrofit the rest of the proposed shelter area if the roof system is part of a building that was not designed for high wind load requirements.
- **The wall system.** Can the wall systems be accessed so that they can be retrofitted for resistance to wind pressure and missile impact? It may not be reasonable to retrofit a proposed shelter area to protect openings if the walls systems (loadbearing or non-loadbearing) cannot withstand wind pressures or cannot be retrofitted in a reasonable manner to withstand wind pressures and missile impacts.
- **Openings.** Windows and doors are extremely vulnerable to wind pressures and debris impact. Shutter systems may be used on hurricane shelters but should not be relied upon to provide protection for tornado shelters. There is often only minimal warning time before a tornado; therefore, a shelter design that relies on manually installed shutters is impractical. Automated shutter systems may be considered, but they would require a protected backup power system to ensure that the shutters are closed before an event. Doors should be constructed of impact-resistant materials (e.g., steel doors) and secured with six points of connection (typically three hinges and three latching mechanisms). Door frames should be constructed of at least 16-gauge metal and adequately secured to the walls to prevent the complete failure of the door/frame assemblies.

CROSS-REFERENCE

Design criteria for shelter systems are provided in Chapters 5 and 6. Examples of wall and door systems that have passed missile impact tests are presented in Appendixes E and F, respectively.

- **The contents of the refuge area.** What are the contents of the refuge area? For example, bathrooms have been used as refuge areas during tornadoes and hurricanes since they often have a minimal number of openings to protect. However, emergency managers may find it difficult to persuade people to sit on the floor of a bathroom when the sanitary condition of the floor cannot be guaranteed. Also, mechanical rooms that are noisy and may contain hot or dangerous machinery should be avoided as refuge areas when possible. The contents of a proposed shelter area (e.g., permanent tables, cabinets, sinks, large furniture) may occupy what was expected to be available space within the shelter, may make the shelter uncomfortable for its occupants, or may pose a hazard to the occupants. These types of shelter areas should be used only when a better option is not available.

4.4 Community Shelters for Neighborhoods

Community shelters intended to provide protection for the residents of neighborhoods require designers to focus on a number of issues in addition to structural design, including ownership, rules for admission, pets, parking, ensuring user access while preventing unauthorized use, and liability. FEMA post-disaster investigations have revealed issues that need to be addressed in the planning of such community shelters. Many of these issues are addressed in the sample **Shelter Operations Plans** in Chapter 9 and Appendix C for community shelters. The following are additional considerations:

CROSS-REFERENCE

Sample community **Shelter Operations Plans** are presented in Chapter 9 and the case study in Appendix C.

- **Access and Entry.** Confusion has occurred during past tornado events when residents evacuated their homes to go to a community shelter but could not get in. During the Midwest tornadoes of May 3, 1999, residents in a Wichita community went to their assigned shelter only to find it locked. Eventually, the shelter was opened prior to the event, but had there been less warning time for the residents, loss of life could have occurred. The Shelter Operations Plan should clearly state who is to open the shelter and should identify the backup personnel necessary to respond during every possible event.

- **Signage.** Signage is critical for users to be able to readily find and enter the shelter. In addition to directing users to the shelter, signs can also identify the area the shelter is intended to serve. Confusion about who may use the shelter could result in overcrowding in the shelter, or, worse, people being turned away from the shelter. Signs can also inform the residents of the neighborhood served by the shelter about the occupancy limitations during any given event. Examples of tornado shelter signage are presented in Chapter 9 and the North Carolina shelter case study in Appendix C.

- **Warning Signals.** It is extremely important that shelter users know the warning signal that means they should report to the shelter. The owners/operators of shelters should conduct public information efforts (e.g., mass mailings, meetings, flyer distribution) to ensure that the residents of the neighborhood served by the shelter know the meaning of any warning signals to be used.

- **Parking.** Parking at residential shelters can be a problem. Neighborhood residents, who are expected to walk, may instead drive to the shelter from their homes. Residents returning home from work may drive directly to the shelter. Parking problems can adversely affect access to the shelter, again preventing occupants from getting to the shelter before a tornado or hurricane strikes. The Shelter Operations Plan should clearly discuss parking limitations.
- **Pets.** Many people do not want to leave their pets during a disaster. However, tornado and hurricane shelters are typically not prepared to accommodate pets. The policy regarding pets in a community shelter should be clearly stated in the Shelter Operations Plan and posted to avoid misunderstandings and hostility when residents arrive at the shelter.
- **Maximum Recommended Occupancy.** In determining the maximum recommended number of people who will use the shelter, the design professional should assume that the shelter will be used at the time of day when the maximum number of residents are present. A community may also wish to consider increasing the maximum recommended occupancy to accommodate additional occupants such as visitors to the community who may be looking for shelter during a wind event. The maximum recommended occupancy should be posted within the shelter area.

4.5 Community Shelters at Public Facilities

Community shelters at public facilities also require designers to focus on issues other than structural design requirements for high winds. Some issues that have arisen from post-disaster investigation include:

- **Protecting Additional Areas.** If the shelter is at a special needs facility such as a nursing home or hospital, additional areas within the facility may need to be protected. These include medical and pharmaceutical supply storage areas and intensive/critical care areas with non-ambulatory patients. A shelter should address all the needs of its users.
- **Signage.** Signage is critical for users of public facilities to be able to readily find and enter the shelter. However, signage can be confusing. For example, tornado shelters in schools in the Midwest are often designed for use only by the school population, but aggressive signage on the outside of the school may cause surrounding residents to assume that they may use the shelter as well. This may cause overcrowding in the shelter, or, worse, people being turned away from the shelter. Similar problems may occur at hospitals, where the public may go seeking refuge from a tornado or hurricane. The owners/operators of shelters in public-use facilities such as these should inform all users of the facility about the occupancy limitations

of the shelter during any given event. Examples of tornado shelter signage may be found in Chapter 9 and the North Carolina shelter case study in Appendix C.

- **Warning Signals.** It is extremely important that shelter users know the warning signal that means they should report to the shelter. In schools, work places, and hospitals, storm refuge drills and fire drills should be practiced to ensure that all persons know when to seek refuge in the shelter and when to evacuate the building during a fire.
- **Pets.** Many people do not want to leave their pets during a disaster. This is the same problem as identified for the community shelters in neighborhoods. Hurricane and tornado shelters are typically not prepared to accommodate pets. The policy regarding pets in a neighborhood shelter should be clearly stated in the Shelter Operations Plan and posted to avoid misunderstandings and hostility when residents arrive at the shelter.
- **Off-hours Shelter Expectations.** It is important for shelter owners and operators to clearly indicate to the shelter users when the shelter will be open. For example, at a school, will the shelter be accessible after the regular school day? At places of business, will the shelter be accessible after normal work hours? At hospitals, can employees bring their families to the hospital shelter? These types of questions should be anticipated in the design and operation of a community shelter.

CROSS-REFERENCE

Additional human factors criteria are presented in Chapter 8. In addition, sample community Shelter Operations Plans are presented in Chapter 9 and Appendix C.

4.6 Locating Shelters on Building Sites

The location of a shelter on a building site is an important part of the design process for tornado shelters. The shelter should be located such that all persons designated to take refuge may reach the shelter with minimal travel time. Shelters located at one end of a building or one end of a community, office complex, or school may be difficult for some users at a site to reach in a timely fashion. Routes to the shelter should be easily accessible and well marked.

Shelters should be located outside areas known to be floodprone, including areas within the 500-year floodplain. Shelters in floodprone areas will be susceptible to damage from hydrostatic and hydrodynamic forces associated with rising flood waters. Damage may also be caused by debris floating in the water. Most importantly, flooding of occupied shelters may well result in injuries or deaths. Furthermore, shelters located in floodprone areas but properly elevated above the 500-year flood elevation and the elevations of any floods of record will become isolated if access routes are flooded. As a result, shelter occupants could be injured and no emergency services would be available.

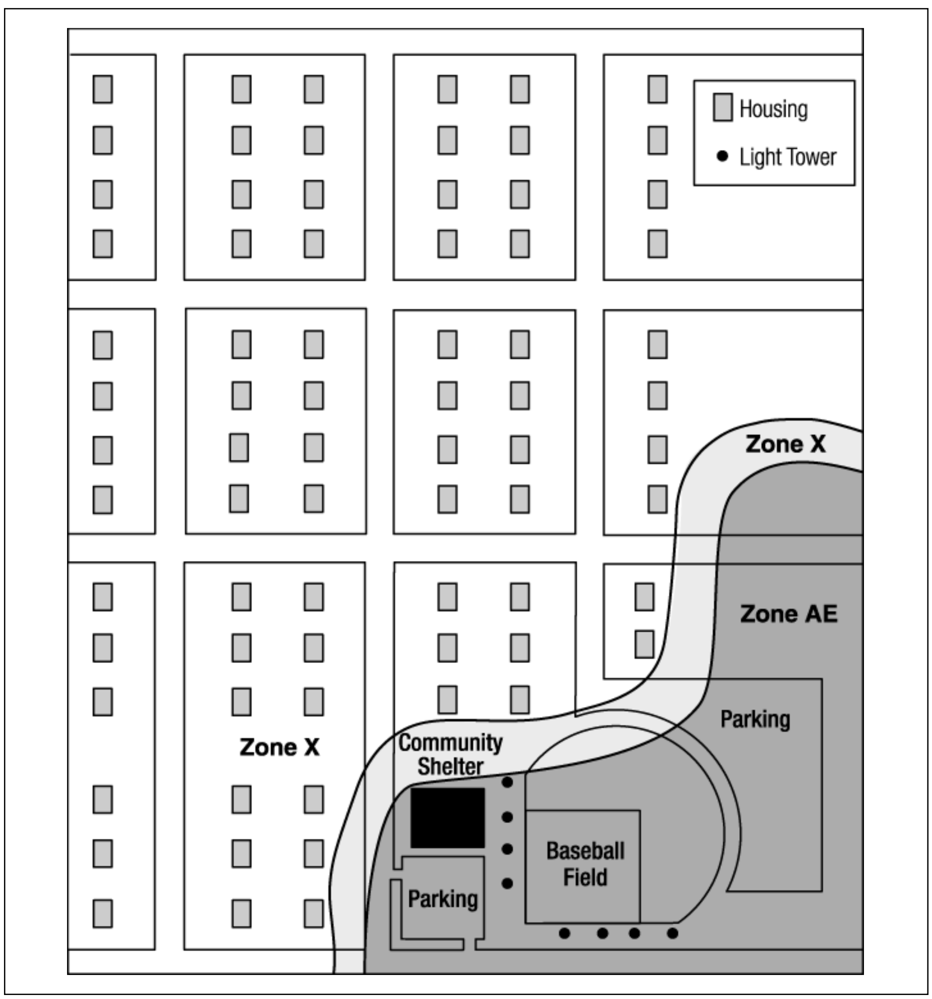
WARNING

Shelters should be located outside known floodprone areas, including the 500-year floodplain, and away from any potential large debris sources.

Where possible, the shelter should be located away from large objects and multi-story buildings. Light towers, antennas, satellite dishes, and roof-mounted mechanical equipment may be toppled or become airborne during tornadoes or hurricanes. Multi-story buildings adjacent to a shelter may be damaged or may fail structurally during tornadoes and hurricanes. When these types of objects or structures fail, they may damage the shelter by collapsing onto it or impacting it. The impact forces associated with these objects are well outside the design parameters of any building code. Some limited debris impact testing was performed in the preparation of this manual and is discussed in Chapter 6.

Examples of improper and proper locations of tornado or hurricane shelters on residential sites are presented in Figures 4-2 and 4-3. Figure 4-2 shows an improperly sited community shelter in a residential area. The shelter is within an SFHA, near large light towers that may fall on the shelter, and near an outside boundary of the community. Figure 4-3 shows a properly sited shelter that is outside the SFHA, away from the towers, and more centrally located within the community.

Figure 4-2
Improperly sited shelter – in an SFHA (Zone AE in this figure), adjacent to light towers that could become falling debris, at the periphery of the community.



NOTE

500-year floodplains are shown as either Zone B or shaded Zone X on FIRMs.

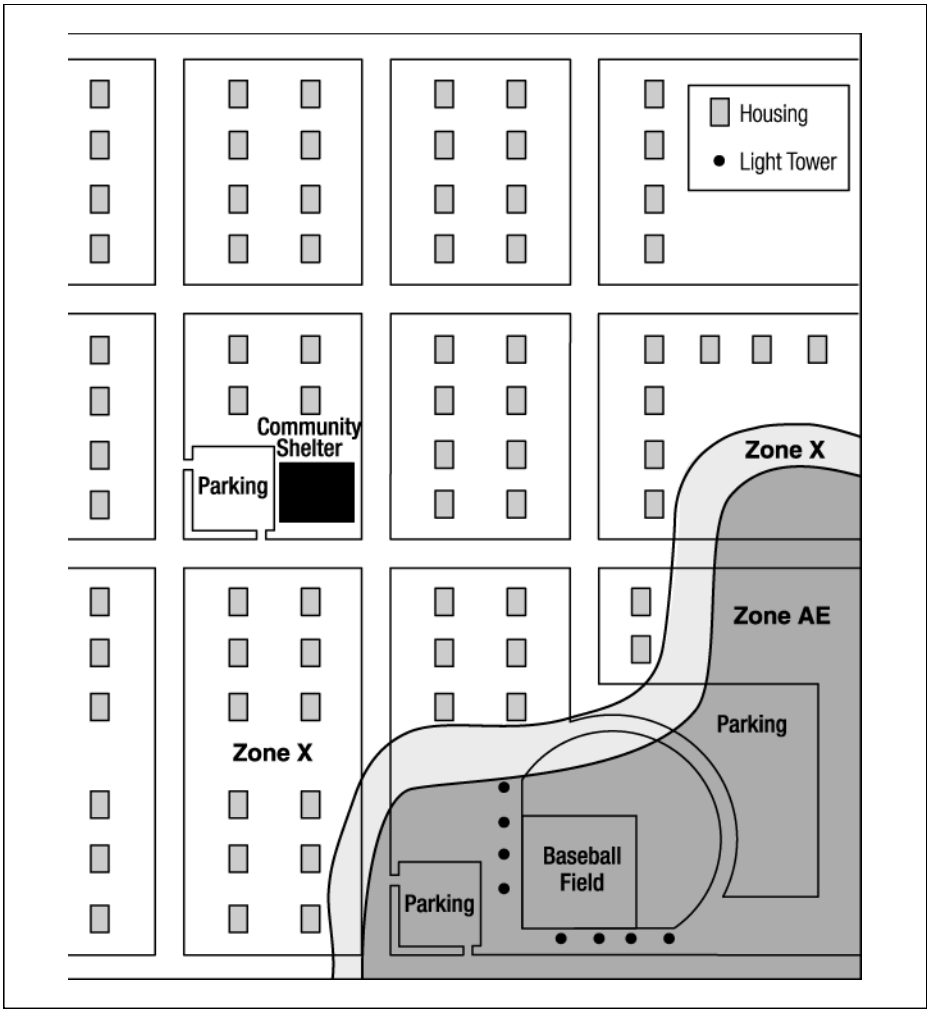


Figure 4-3
Properly sited shelter – outside the SFHA and 500-year floodplain, away from potential falling debris, and centrally located within the community.

NOTE

500-year floodplains are shown as either Zone B or shaded Zone X on FIRMs.