Final Report

Lucedale, MS Shelter Engineering Evaluation

HMTAP HSFEHQ-06-D-0162, Task Order 7

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FEMA

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1.1 PURPOSE

The purpose of this engineering evaluation is to determine whether the mainly unused building, located at 52 Virginia Street, Lucedale, MS, can effectively be rehabilitated to meet the Federal Emergency Management Agency (FEMA) community hurricane shelter policy requirements and the design criteria for community shelters set forth in FEMA Publication 361, *Design and Construction Guidance for Community Shelters* (2000). The facility is currently being used to house multiple non-profit organizations, such as Habitat for Humanity, the Red Cross, the Salvation Army, and the George County Disaster Recovery Center. Space is also leased to private enterprises; at the time of the evaluation, a marble-cutting company was utilizing a portion of the basement.

The site and building evaluation was conducted on July 25, 2007. The engineering team from URS Corporation included Bill Coulbourne, P.E., and Omar Kapur, EIT. The team was met at the building by Harold Moore, Director of the Disaster Recovery Center, and accompanied on a tour of the building by Dan Bass, Department of Homeland Security (DHS); Joe Anderson, DHS; George O'Conor, Mississippi Emergency Management Agency (MEMA); Fred Griffin, MEMA; and Melanie Dukes, MEMA. In addition, background information about the building and plans to remodel the interior were provided by a local architect, Dennis Cowart, and a local contractor, Larry Scott.

1.2 SITE DESCRIPTION

Lucedale is located approximately 40 miles north of Pascagoula, MS, in George County, MS. Site coordinates are 30° 55' 25" N and 88° 35' 5" W. It is also located approximately 35 miles Northwest of Mobile, AL, and is easily accessible via major roadways from other towns along the Gulf Coast. Lucedale appears to be in an ideal inland location for a community shelter capable of housing residents seeking shelter from high-wind and flood events. Access to the facility is provided by Highway 63, which is the primary thoroughfare in Lucedale (Main Street). In the event of a hurricane making landfall from the Gulf of Mexico, evacuees from Pascagoula, Biloxi, and other towns could travel from the coast on Highway 63 North, a four-lane divided highway, which eventually becomes a smaller two-lane road. Figure 1 shows the location of Lucedale relative to other cities along the Gulf Coast.

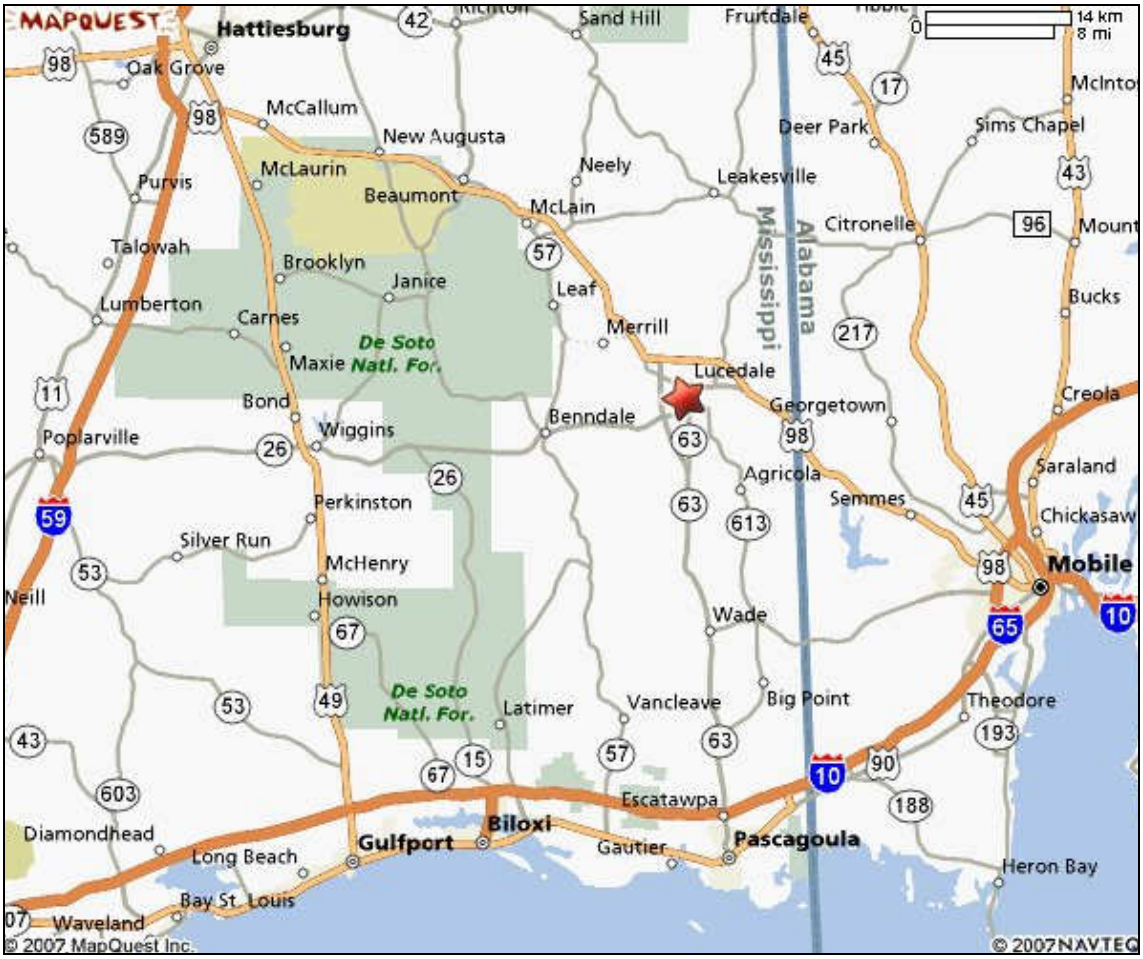

Figure 1: Map showing the Lucedale, MS, location

The facility is located on a 5-acre site with medium to large trees near the east side. The grading of the site is sloped down from the west toward the east of the lot. The main parking lot is located on the south side of the building (estimated capacity is 325 spaces, see Figure 2). Smaller parking lots are located on the east and north sides of the building. An access road runs along the entire circumference of the building, providing variable stand-off distance from large trees that exist around the perimeter of the site. The stand-off distance appeared to be sufficient to eliminate the threat of a tree landing on the building as a result of falling over. There are overhead power lines that are located around the exterior of the building on the west and south walls. Figure 3 shows the proximity of these power lines to the building.

Figure 2: Southside parking lot

Figure 3: West side of building showing power lines

2.1 TORNADOES/HURRICANES/HIGH WINDS

The site is located in a design wind speed area of approximately 125 mph[1] as shown on the current basic wind speed map from the American Society of Civil Engineers (ASCE) Standard 7-05, *Minimum Design Loads for Buildings and Other Structures*. This site has not been directly affected by a hurricane or large tornado. There was anecdotal evidence that some tornadoes were spawned from Hurricane Katrina in August 2005 near this location, but no damage was done to the building from these small, intense storms. The National Climactic Data Center shows some history of tornadoes in George County over the past 30 years, and has recorded some incidents of recent hurricanes and thunderstorms with high winds causing property damages to residential areas surrounding Lucedale. However, information on the effects of these storms is sparse, and no wind speeds have been recorded; the majority of the effects from recent hurricanes were not well documented in this area.

The shelter design wind speed at this site is 200 mph as shown on the wind speed map from FEMA 361. Figure 4 is the map from FEMA 361, and the Lucedale area is shown with a star. The hazard maps shown in FEMA 361 indicate that the Lucedale area is subject to both tornado and hurricane hazards and these storms, at the intensity anticipated, have the potential to generate significant windborne debris. FEMA 361 addresses this issue by stating that for near-absolute protection to be provided by a shelter in this area, the vertical surfaces of the facility must be capable of resisting debris impact from a 15-pound, 2x4 wood board traveling horizontally at 100 mph.

Recent work on a shelter standard that should be released by the International Code Council (ICC) in early 2008 addresses both the tornado and hurricane hazards in this area. For tornado shelter protection, the ICC standard (ICC-500) will require the same design wind speed and debris impact resistance as specified above, with a few minor differences. For hurricane shelter protection, the ICC-500 will require a shelter design wind speed of approximately 180 mph, and also require resistance to a horizontal missile traveling at 0.4 times the shelter design wind speed of 200 mph, and 0.1 times the wind speed for a vertical missile (80 and 20 mph, respectively).

The current editions of the 2006 International Building Code (IBC) and ASCE 7-05 also require that openings of buildings and facilities be designed to resist debris impact from windborne debris when the basic design wind speed is 120 mph or higher. The large missile that must be resisted is a 9-pound 2x4 wood board traveling at either 34 or 55 mph (depending upon facility use).

[1] Unless otherwise noted, all wind speeds provided in this evaluation are presented as 3-second gust wind speeds for Exposure C at 33 feet (10 meters).

2.2 FLOODING

The facility is located at an inland location that is not susceptible to storm surge. The facility is in a Flood Zone X (unshaded). Location of a site within this flood zone implies that the site itself is elevated above the 0.2 percent chance of exceedance (500-year) flood elevation and is not located within a Special Flood Hazard Area (SFHA). This data was confirmed on Flood Insurance Rate Map (FIRM) Index 280056C, dated April 15, 1986 (see Figure 5). Building staff indicated that there is no history of flooding, however site drainage issues exist. There is evidence of local ponding around the building, and the west side loading dock was identified as having collected water in the past and was flooded at the time of this evaluation.

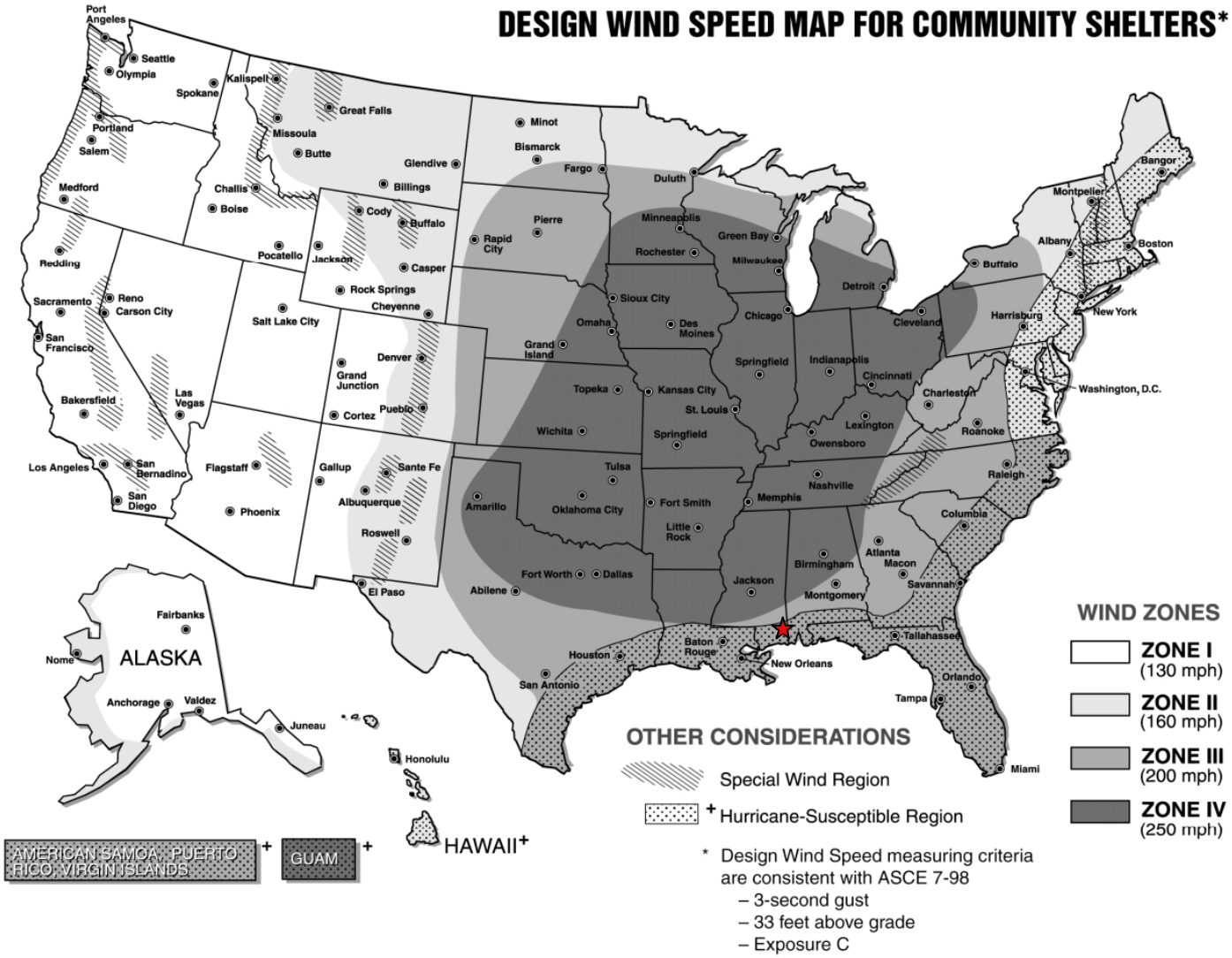

Figure 4: FEMA 361 Design Wind Speed Map. The red star on the map indicates the approximate position of Lucedale.

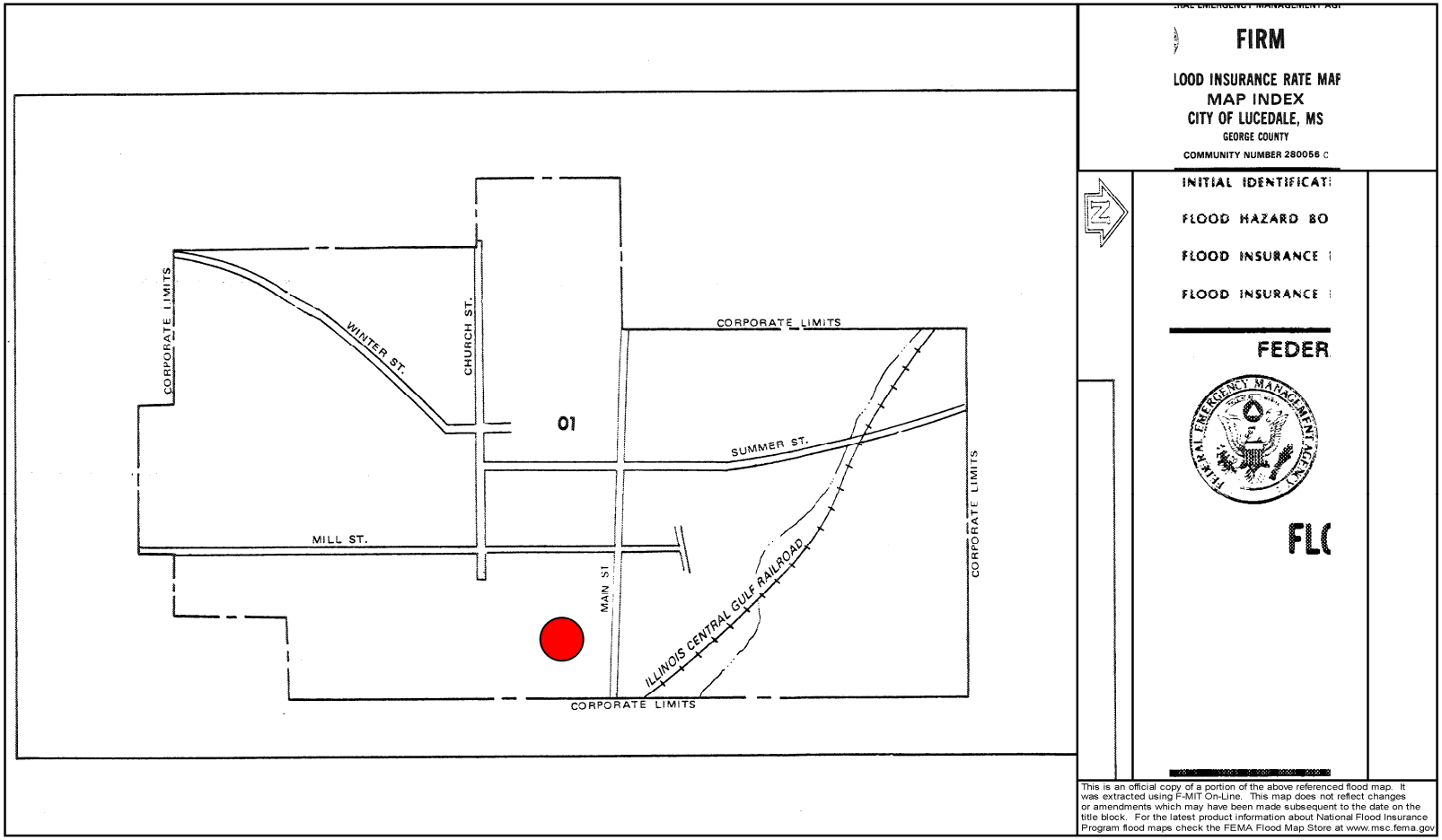

Figure 5: FIRM Index of area surrounding the city of Lucedale, MS. The red circle shows the building location.

The evaluation of this facility's suitability as a community shelter was conducted in accordance with FEMA 361. This document provides guidance for shelters to be built to near-absolute protection for the occupants, and requires that all relevant design and operational qualities of the shelter be considered.

Appendix B in FEMA 361 provides evaluation checklists for documenting the hazard and building information needed to demonstrate a potential shelter is capable of providing life-safety (near-absolute protection) from high-wind events. A copy of the completed checklists for this building is attached (see Appendix A) for the purpose of illustrating FEMA 361 methodology.

In addition to documenting site and building information on the checklists, the shelter evaluation method includes:

1. Calculating the design wind pressures for the various building components (roof, walls, windows, doors, etc.) using the shelter design wind speed (see Appendix B).
2. Analyzing the existing structure to determine likely performance of the existing building at those shelter design wind speed pressures.
3. Identifying mitigation that will provide one means of resisting the shelter design wind pressures.
4. Documenting the existing operational performance infrastructure, such as shelter populations (occupancy) for tornado or hurricane shelters at this building, the number of available bathrooms, access to the shelter during a high wind event, existence of an emergency generator, ability to handle special needs shelter occupants, responsibility for opening, cleaning and closing the shelter, etc.
5. Identifying the possible occupancy.

The entire facility has approximately 90,000 gross square feet of space, including a partial basement; the entire space is a series of interconnected buildings with a basement under a portion of the building (see floor plan, Figure 6). The building age appears to be primarily 1950s–1960s vintage, while the rear (east) end of the building appears to have been built in the 1970s.

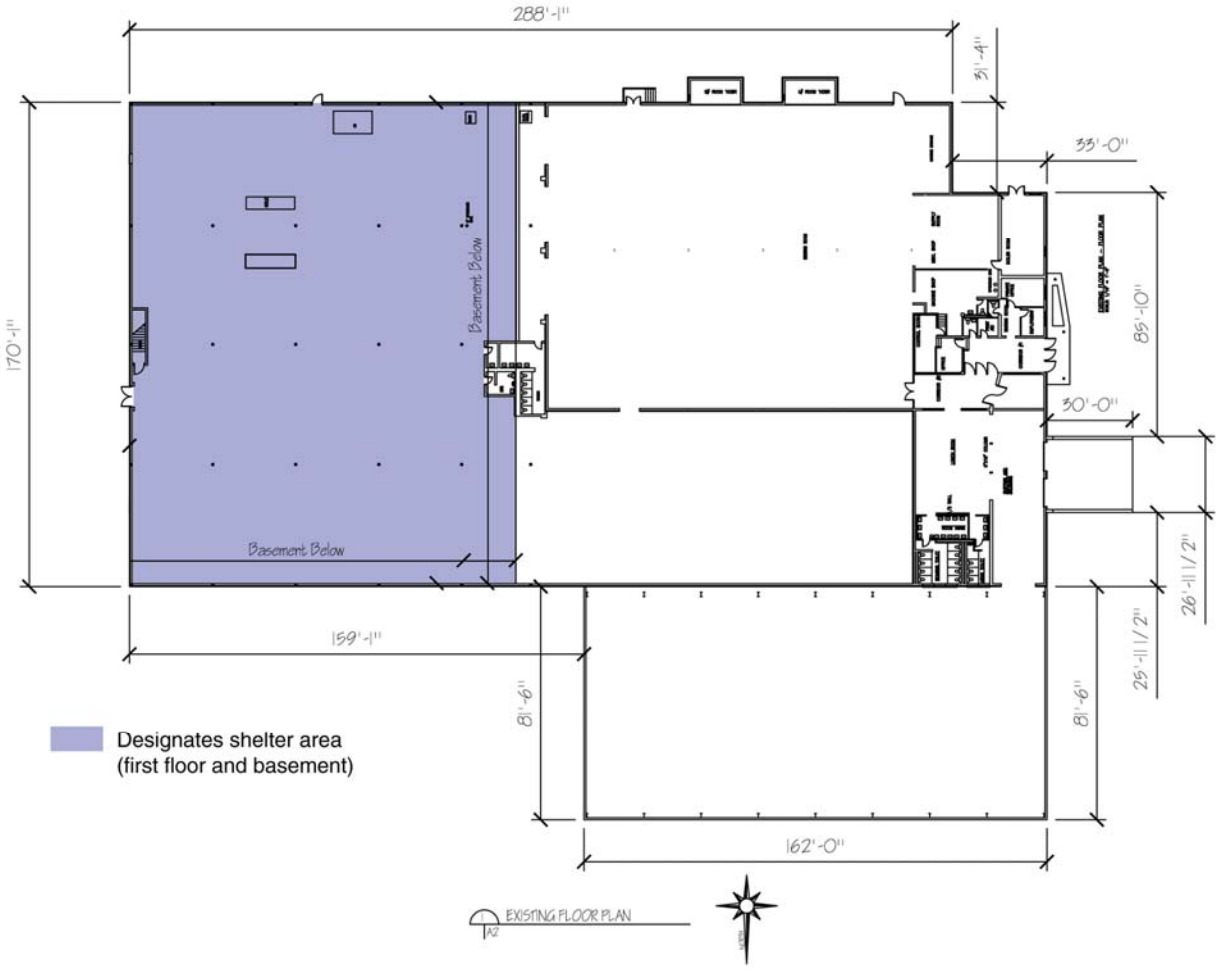

Figure 6: Existing floor plan showing proposed shelter areas.

The front section of the facility (1950s vintage) is one story high (approximately 12 feet) and accounts for approximately 3,500 square feet of the facility space. The primary structural system for this portion of the building is a structural steel, braced frame with masonry infill walls. The steel frame consists of vertical columns spaced 25 feet on center, founded on reinforced concrete footings and connected at ground level with a concrete slab; in this portion of the facility there is no basement. The infill walls appear to be 8-inch unreinforced concrete masonry units (CMU). The roof structure is small girder trusses supporting open web bar joists beneath a tectum roof deck.

On the north side of the facility, a 13,000-square foot pre-engineered metal building (PEMB) addition was added in the 1970s (see Figure 7). This addition was constructed immediately adjacent to the main portion of the facility, and is connected by an 8-foot by 8-foot wood sliding door. The bays of this steel-framed building are spaced approximately 17 feet on center, and roof

purlins connecting the bays are spaced approximately 5 feet on center (see Figure 8 for interior). The building has the typical metal-panel exterior wall and roof system associated with PEMBs; these panels were observed to be in fair condition at the time of the evaluation.

Figure 7: Metal building section of facility

Figure 8: Steel-framed building adjacent to main building

The northwest portion of the main building is approximately 2,000 square feet in area and is separated from the front office area by a CMU partition and a wooden door. The primary structural system for this portion of the building is a structural steel, braced frame with masonry

infill walls, similar to the front office section of the building. The roof framing consists of small girder trusses supporting open web bar joists with a tectum roof deck, again similar to the front office area. This area contains restrooms and a loading dock, with rolling doors that are not completely functional. This area is connected to a 7,500-square foot area (60 feet by 125 feet) that has two common walls with other facility space and an exterior wall that is 12-inch CMU. The primary structural system for this 7,500-square foot area is unreinforced CMU load-bearing walls that support a roof system that consists of 48–inch-wide, twin-tee precast concrete beams as shown in Figure 9. There is no continuous load path connection between the precast tees and the walls.

Figure 9: Double precast concrete roof tees. Also note the water stains on the masonry walls, more evidence of drainage problems with the facility.

The eastern-most room in the facility has 23,000 square feet on the first floor level (see Figure 10). The primary structural system is a reinforced concrete frame with 12-foot-high, unreinforced 8-inch thick CMU exterior infill walls. There are CMU pilasters spaced 12.5 feet on center. The roof system consists of single-tee precast concrete beams approximately 18-inches deep and spaced 4 feet on center. Interior concrete columns are spaced 25 feet on center in the east-west direction, and 45 feet on center in the north-south direction. The precast concrete tees span 45 feet in the north-south direction. The floor slab is 6-inch thick concrete. The columns extend into the basement level and are founded on concrete footings.

Figure 10: Proposed first floor shelter area

The east room of the facility also contains a hole in the concrete floor that is approximately 5 feet by 20 feet. This hole opens up directly into the basement area. There is also a 6.5 feet by 7 feet double door which leads to an exterior staircase to ground level, and an interior staircase leading directly to the basement. The partition between this room and the steel framed space immediately west consists of T-shaped CMU columns spaced 20 feet apart.

The basement of the facility under the east end of the building is approximately 23,000 square feet (135 feet by 170 feet). Located at the basement floor level are three loading dock doors that are 8.5 feet by 8 feet (see Figure 11). The first floor is supported by 15-inch square columns spaced 25 feet on center in the east-west direction and 25 feet on center in the north-south direction. There are 4-foot-square windows with louvers spaced 25 feet on center around the basement's exterior walls. The ceiling of the basement (which is the first floor) consists of precast concrete single-tee panels, 18 inches deep and approximately 40 inches wide.

Figure 11: Roll-down loading doors located in basement

The exterior of the entire building is brick facade. The front of the building on Virginia Avenue faces west, as shown in Figure 3. The roof is flat and is built up tar and gravel on top of the tectum roof deck. There are gutters and downspouts around the building to handle rain water runoff from the roof.

There is very little glazing anywhere except the west (front) side. The percentage of glazing is estimated to be less than 1 percent. All of the brick exterior walls have backup 8-inch unreinforced CMU.

There is an emergency generator on site, but the identification plate was painted over and the size could not be determined. This generator was housed in a small metal building adjacent to the south wall. It was not apparent that the generator had been exercised recently.

Observations

1. There are severe settlement cracks in both the southeast and northeast corners of the building. See Figures 12 and 13. The crack in the northwest corner is approximately ¼-inch wide. These cracks indicate settlement of the foundation in these two corners, apparently from poor drainage at these locations. Downspouts drain water from the roof to the ground and contribute to drainage problems by depositing water adjacent to both building corners.

Figure 12: Northwest building corner showing settlement crack

Figure 13: Southeast building corner showing settlement crack

2. There is water ponding in the loading dock area at the front (west side) of the facility as shown in Figure 14. This ponding is most likely due to a clogged drain in the below-grade loading dock area. During the evaluation visit, the loading dock area was being pumped out, and water was flowing around the building and running past the settled northeast foundation corner.

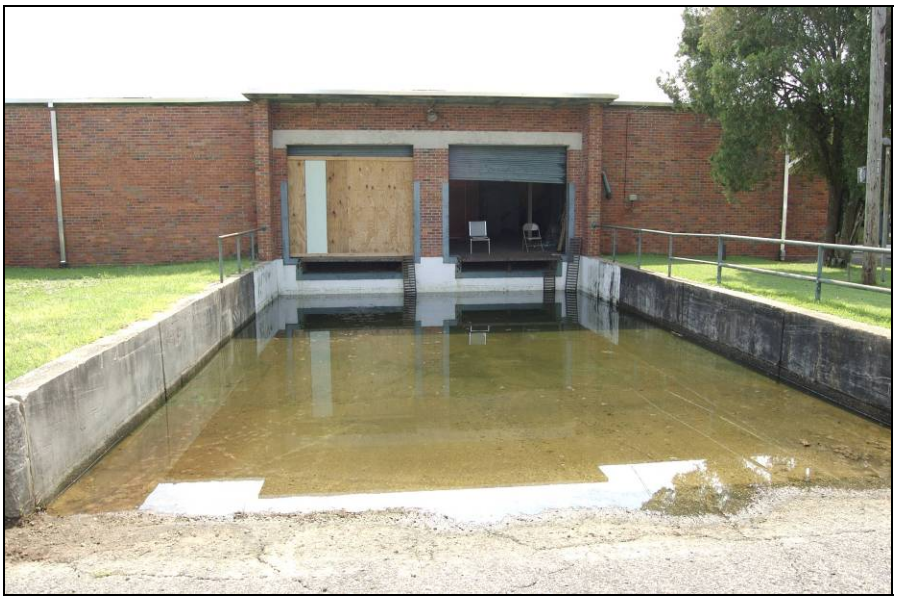

Figure 14: Water ponding at loading dock doors on west side

3. There is little glazing on the exterior walls of the building on either the first floor or basement levels. This small percentage of glazing improves the ability of the exterior walls to resist damage or penetration by windborne missiles because the remainder of the exterior walls are constructed of brick masonry.
4. There are several areas on the exterior that require mortar repair and tuck pointing, however none of these areas will compromise the ability of the building to function as a shelter.
5. There are three roll up doors on the east side basement level. These doors are not rated for high wind resistance (wind pressures) or for debris impact resistance. The area directly behind these doors is an area of the building that has been identified as one of the areas that could be retrofitted for shelter use. To use this area as a shelter, the doors would need to be upgraded or protected to resist wind pressures and windborne debris. These doors are shown in Figure 15.

Figure 15: East side of building showing roll-up doors

6. Existing roof flashings are poorly attached to the exterior wall surfaces, making them highly susceptible to failure during a high-wind event. If the flashings fail, they may result in a peel back or failure of the entire roof covering on that portion of the facility. Figure 16 shows the loose edge flashing.

Figure 16: Edge of concrete roof tees showing through masonry and loose edge flashing

7. The roof decks in many of the proposed shelter areas consist of a light-weight tectum roof deck system. These deck systems have a poor history of performance in high-wind events and should be removed and replaced.

8. The eastern most portion of the facility (identified on the floor plan as the preferred shelter location), including the basement areas below, is clear of obstructions and consists of a reinforced concrete frame. The roof support system of single concrete tees is also very strong in resisting gravity loads. The roof deck of the upper level is tectum and should be replaced with a concrete deck on top of the precast concrete tees. The connections between the concrete roof tees and the concrete beams appear to provide a continuous load path. This 23,000 square feet of space (46,000 square feet on two floors) does appear to best satisfy the requirements of a FEMA 361 compliant shelter, after mitigation described in the next section.
9. The exterior walls around the eastern-most portion of the facility appear to be 8-inch unreinforced masonry infill walls between the concrete columns. One of the FEMA 361 design criteria is that the height and length to thickness ratios should not exceed 13. The length to thickness ratio and the height to thickness ratio are 12 feet/8 inches or (12x12)/8 = 18. The walls will have to be reinforced in order to reduce the ratios of height and length to thickness, allowing them to perform adequately.
10. The 8-inch-thick unreinforced masonry walls of the eastern portion of the facility will not stop a missile traveling 100 mph, according to missile impact tests conducted by Texas Tech University. The CMU infill walls will have to be reinforced in order to provide adequate missile protection.
11. The hole in the floor of the eastern-most portion of the facility should be permanently covered with new concrete in order to provide increased floor area and to prevent any falling debris from the first floor from going into the basement.
12. Louvers located in the basement walls are not rated for debris impact resistance and open to an area recommended for shelter use (with retrofit). These louvers will need to be replaced or protected to prevent windborne debris from penetrating into the proposed shelter areas.
13. There is interior damage at columns at both the southeast and northeast corners that is reflective of the exterior damage at these corners. There are some cracks in the concrete beams on the east and west walls that indicate outward movement of the east wall caused by settlement at the corners. Figure 17 illustrates this crack in the beam.

Figure 17: Separation in concrete beam indicating east wall movement

Building Areas Not Recommended for Shelter Retrofit:

1. The 13,000-square foot PEMB addition to the facility should not be used as a shelter. The work required to meet the FEMA 361 criteria for sheltering of occupants would be extensive, with no guarantees of adequate protection when completed. Concerns in upgrading this area are focused on proving adequate load path continuity and envelope protection.
2. The 1950s-era front portion of the facility (constructed of a structural steel frame with masonry infill walls) should also not be used as a shelter. While the steel framing looks to be in good condition, the analysis of the riveted trusses and connections would be very extensive, with no guarantees that all checks had been sufficiently done to provide near-absolute protection.
3. The double precast roof tee section located south of the PEMB should not be used as a shelter. The concrete tees span approximately 52 feet and are not secured onto either of the supporting CMU walls to transfer any loads; the connections are only bearing, “gravity” connections. The ends of the tees are visible through the masonry wall, confirming that there is no structure above the tees that would help keep the tees in place during a severe wind event. Figure 16 shows the ends of the concrete tees at the edge of the masonry wall.

Implementing all of the mitigation activities recommended should result in this facility meeting the FEMA 361 shelter criteria. Only a portion of this facility is being recommended for these mitigation activities, thus only the portion of the facility where the mitigation occurs will qualify as a shelter.

Where mitigation projects are being implemented to meet the FEMA 361 criteria, several factors must be achieved. In summary, these factors or criteria are:

1. There must be a continuous load path to resist wind loads. A continuous load path must be present to insure the performance of the shelter in a high-wind event. If the load path of the existing building cannot be confirmed from the roof of the building to the foundation, then additional retrofitting projects to ensure stronger connections between the building components will be required.
2. All walls, roof sections, windows, doors, and openings (i.e., louvered vents, etc.) must be retrofitted to provide protection for occupants. The level of protection requires resistance to penetration from the current standard shelter missile, which is a 15-pound 2x4 wood member traveling 100-mph horizontally and 67 mph vertically. The impact resistance for doors and windows can be improved by replacing them with tested and certified products, while the impact resistance of walls is a variable of the type of construction and reinforcement, and may require reconstruction of these elements.
3. The human factors criteria in FEMA 361 gives guidance on proper ventilation, distance and accessibility of the shelter to desired occupants, special needs requirements in shelters, lighting, occupancy duration, emergency provisions, and emergency power. It also discusses square footage and occupancy requirements stated in number of square feet (area) per person, depending on shelter use (tornado, hurricane, etc.). The recommended floor space (area) per person used in this evaluation is thus taken from FEMA 361.

Only the eastern most portion of the building (shown on the floor plan as the recommended shelter area) is being recommended as a shelter space. There is a total of approximately 46,000 square feet of space that could be retrofitted to meet the FEMA 361 shelter criteria. For a hurricane shelter, assuming a density of 10 square feet per person (FEMA criteria), the available square footage could provide shelter for a maximum of 4,600 people. This assumes no loss of space because of fixtures, attached partitions, egress walkways, etc. Because of fixed objects such as restrooms and the need for egress, the shelter maximum occupancy in the proposed space will be reduced.

All of the following mitigation activities must be completed to meet the FEMA 361 shelter requirements:

1. Fill in the 5-foot by 20-foot hole in the floor with a new 6-inch thick reinforced concrete slab, tied into the existing concrete floor with #5 reinforcing steel.
2. Replace 23,000 square feet of existing tectum roof deck with a metal roof deck and a lightweight concrete roof surface tied into the existing concrete precast tees. Cover the concrete with a single ply roof membrane fully adhered to the surface for a weather-resistant finish. Do not install aggregate ballast on the roof surface. Insure that the roof slopes to the north and south walls, and to the gutters and downspouts in these areas. The weight of this concrete deck should be analyzed to make certain that the extra weight does not exceed the dead load capacity for the single precast concrete tee system.

3. Close up openings inside the facility that connect the shelter area to the other space with 6-inch thick, fully reinforced and grouted CMU walls. These walls must be tied into the slab at the west edge of the basement area, and into the roof system at the west edge of the first floor shelter area.
4. Install a missile-resistant baffle wall inside the basement area, parallel to the east wall at the loading dock doors. This wall is to be 6 inches thick, fully reinforced, and grouted and tied into the floor slab and the roof system above. This will mitigate the debris hazard and not require replacement of the overhead doors (allowing for loading and unloading operations); however, removal of the large overhead outdoor canopy would be required as it would be highly susceptible to damage during a high-wind event (see Figure 15).
5. Provide missile protection on the inside of both the first floor and basement walls (those that are exposed to the outside) by installing a grid (cage) of #4 rebar at 12 inches on center in both directions, tied to the existing concrete floors, concrete beams, and concrete columns. Install 6-inch-thick gunite or shotcrete (5,000 psi concrete) over the #4 rebar cage and trowel to the desired finish.
6. Install missile protection over the louvers in the basement area that can be closed from the inside of the shelter area.
7. Install bathrooms to allow one toilet per 50 occupants (or 92 toilets for an occupancy of 4,600 people) and one hand washing station per 100 occupants (or 46 sinks for an occupancy of 4,600 people). These requirements come from the ICC Shelter Standard, since the FEMA criteria on this issue lacks detail.
8. The minimum ventilation requirement is 12 square inches of area per occupant, or 55,200 square inches (383 square feet) of natural vent area. Mechanical ventilation may be provided in lieu of the natural ventilation in accordance with the IBC, but any such mechanical system must be supported by the backup emergency generator; and both the generator and the components of the mechanical system must be able to resist wind forces associated with the shelter design wind speed and the windborne debris impact criteria of FEMA 361.

The following other mitigation activities should be considered to ensure successful operation and use of the shelter:

- Access roads to the shelter that will not be blocked with downed trees or power lines
- The power lines at or on the building should be buried, so downed power lines are not a safety concern at the building
- Parking space for the likely vehicle count
- Location of restrooms and hand washing stations for the shelter population
- Emergency generator and fuel storage for the generator with a capacity for at least 48 hours
- Signage for the shelter so it is clear where people are supposed to congregate

Appendix A

FEMA 361 Site Assessment Checklist

General Building Information

CONTACT INFORMATION

Site Name: George County Disaster Recovery Center

Street Address: 52 Virginia St.

City, State, Zip: Lucedale, MS 39452

Contact Person : Harold Moore

Contact Phone #: (601) 766-0730

Total population: Lucedale: 2,948; George County: 20,800; Shelter area: ~5-15

Typical hours the building is occupied: _____

Is the building locked at any time? _____

BUILDING DATA

Size/Square Footage: ~90,000 sq. ft. Number of Stories: 1 - 2

Describe the building configuration: Inter-connected buildings of various types of construction

General description of surrounding area: Slight slope, medium to large surrounding trees

Are there any portable/temporary units: No How many: _____

Describe the condition of the building (are there cracks in the walls, signs of deterioration, rusting, peeling paint, or other repair needs):

Cracks observed from both exterior and interior in east corners, ponding in loading dock, some louvers and doors need to be replaced

What are the power or fuel sources for the following utilities (natural gas, oil, electric, LP, etc.)? _____

☐ Heating: _____ ☐ Cooling: _____ ☐ Cooking: _____

Is there a refuge area or shelter already identified within the building? No

Was this shelter designed for high winds? (indicate the design professional and all relevant design parameters, specifically design wind speed): No, not designed as a shelter.

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

SELECTING THE REFUGE AREA

What are all the potential areas in the building that provide adequate space for the entire population during a high-wind event?
(For Tornado Use, Required Square Footage [RSF] = Total Population x 5 square feet)
(For Hurricane Use, RSF = Total Polulation x 10 square feet)

East and South portions of main facility and basement.
1st floor: 23,000 SF; Basement: 23,000 SF

Which areas should be eliminated because of excessive glazing (greater than 6% windows) and/or long unsupported wall and roof spans (greater than 40 feet)?

A portion of main building (adjacent to upper loading area) has ~60' span. Areas under consideration do not have much glazing.

Which areas should be eliminated because of potential damage from nearby heavy collapsed structures (e.g., concrete towers, telephone poles, chimneys)?

None, although there are poles and power lines and large trees surrounding the building.

Of remaining candidates, how accessible is the refuge area to all building occupants, including the disabled?

Upper floor is accessible, basement is not.

If refuge area is cluttered, can materials be easily moved to create additional usable space?

Areas are extremely cluttered. Major renovations required.

How much usable space exists? Is USF≥RSF [USF = ASF x 0.85]? ~46,000 ASF
Required Squared Footage = RSF Available Square Footage = ASF Usable Square Footage = USF
[Note: when bathrooms are used, USF = ASF x 0.50]

USF = (46,000)*0.85 = 39,000

No required amount.

On basis of information above, choose best refuge areas (interior spaces provide best protection). Explain choice and rank them from most desirable to least desirable.

Basement and east room (upper) are most desirable because of their construction.

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

WIND HAZARD CHECKLIST

Address the following evaluation statements, giving the most appropriate answer for each question. After selecting the appropriate answer, take the score for that answer (# in the parentheses) and enter it into the score block for that question. Evaluation judgment is subject to limitations of visual examination. Questions have been grouped into sections based on structural issues, cladding and glazing, envelope protection, and non-structural issues. These questions apply only to the refuge area. **After all questions have been appropriately scored, sum the score column and determine the final wind hazard score for the refuge area.**

QUESTION	SCORE
STRUCTURAL ISSUES	
Refuge Area Size Length: 135' Width: 170' Height: ~12-13 Stories: 2	NO SCORE
Usable square footage for this area: ~39,000	NO SCORE
When was building constructed? Check box below. ☐ 1995 or newer (0) ☐ 1994 - 1988 (2) ☐ 1987 - 1980 (4) ☒ 1979 - 1970 (6) ☒ 1969 - 1951 (8) ☐ Pre - 1950 (10) **Date on plans:** No date given; seems primarily 1950s-60s w/ some additions in 70s	8
The building was designed according to the following building code: ☐ Uniform Building Code, Year: ☐ International Residential Code: Year: ☐ Standard Building Code, Year: ☐ International Building Code, Year: ☐ National Building Code, Year: ☒ Other Code: Unk.	NO SCORE
What is the structural construction material of the refuge area? ☐ Concrete (10) ☐ Pre-Cast Concrete (10) ☐ RM (10) ☐ Engineered/Heavy Steel Frame (12) ☐ PRM (15) ☒ URM (20) ☐ Wood or Metal Studs (20) ☐ Light Steel Building/Pre-engineered (20) ☐ Unknown (20)	20

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

What building plans are available for the inspection? ☐ As-built Plans (including full architectural and structural plans (0) ☐ Design/Construction Plans (including full architectural and structural plans) (2) ☐ Structural Plans only (3) ☐ Architectural Plans only (5) ☐ Partial set of plans (8) ☒ No plans are available (12)	12
Vertical and Lateral Load Resisting Systems (select the system that applies) ☐ Moment Resisting Frame (identify infill wall below) (0) ☐ Concrete Beams/Columns ☒ Precast Concrete Beams/Columns ☐ Steel Beams/Columns ☐ Wood Beams/Columns ☐ Steel Bar Joist and Concrete or Masonry Columns ☐ Infill Wall of Moment Resisting Frame (identify infill/shear wall below) ☐ Concrete Shear Wall (0) ☐ RM Shear Wall (0) ☐ PRM Shear Wall (2) ☒ URM Shear Wall (5) (Reinforcement unknown) ☐ Plywood Shear Wall (5) ☐ Other: _____ (5)	5
☒ Braced Frame (or cannot confirm moment frame) (0) ☐ Concrete Beams/Columns ☒ Precast Concrete Beams/~~Columns~~ ☐ Steel Beams/Columns (heavy) ☐ Wood Beams/Columns ☐ Steel Beams/Columns (light) ☐ Steel Bar Joist and Concrete or RM Columns ☐ Shear Wall of Braced Frame; bracing or support is provided by: ☐ Concrete Shear Wall (0) ☐ RM Shear Wall (0) ☐ PRM Shear Wall (2) ☐ URM Shear Wall (5) ☐ Plywood Shear Wall (5) ☐ Other: _____ (5) ☐ Load Bearing Wall System ☐ Concrete Walls (0) ☐ RM Walls (0) ☐ PRM Walls (4) ☐ URM Walls (6) ☐ Framed Walls (wood or metal stud) (6) ☐ Other: _____ (6)	
Elevated Floor or Roof Deck Systems (check all that apply) ☒ Concrete Beams & Slab ☐ Concrete Flat Slab ☐ Precast Concrete Deck ☐ Steel Deck with Concrete ☐ Steel Deck with Insulation Only ☐ Diagonal Sheathing ☐ Plywood Sheathing ☐ Wood Joists/Beams ☐ Wood Trusses ☐ Wood Plank ☐ Concrete Plank ☐ Concrete Waffle Slab ☐ Open Web Steel Joist ☐ Steel Beam	**NO SCORE**

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

Do the connections in the structural systems provide a continuous load path for all loads (gravity, uplift, lateral)? ☐ Yes (0) ☐ No (10) unknown If YES, identify the following connections: Actual connectors of the roof structure and the spacing unknown Actual connectors between the roof and wall and the spacing unknown	10

Connection Details for Refuge Area (check at least one item in each column)

	Roof to Roof Structure	Roof Structure to Wall Structure	Within Wall	Walls to Foundation
Reinforcing Steel	☐ (0)	☐ (0)	☐ (0)	☐ (0)
Welded (not tack)	☐ (0)	☐ (0)	☐ (0)	☐ (0)
Bolted	☐ (0)	☐ (0)	☐ (0)	☐ (0)
Metal Clips/Fasteners	☐ (1)	☐ (1)	☐ (1)	☐ (1)
Metal Hangers	☐ (1)	☐ (1)	☐ (1)	☐ (1)
Self Tapping Screws	☐ (1)	☐ (1)	☐ (1)	☐ (1)
Wire Fastener	☐ (2)	☐ (2)	☐ (2)	☐ (2)
Nailed	☐ (4)	☐ (4)	☐ (2)	☐ (4)
Other:_____ (possible tack weld)	☐ (5)	☐ (5)	☐ (5)	☐ (5)
Gravity Connection	☐ (6)	☐ (6)	☐ (6)	☐ (6)
Unknown	☒ (6)	☒ (6)	☒ (6)	☒ (6)

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If walls are masonry units, are they grouted? Which cells are grouted (every cell, every 4th cell, etc.?

Walls do not appear to have grout or steel reinforcement.

NO SCORE

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

For all unreinforced masonry walls, both load-bearing and non-load-bearing-fill in the blanks and answer the following two questions. Maximum height: ~12-13' Longest span: 45' Thickness: 8" - 12"	**NO SCORE**
Is the maximum wall height/wall thickness (h/t) ratios for **unreinforced masonry walls (URM)** in excess of those noted in AFM 32-1095, page G-63 (see chart below.) [x] Yes (5) [ ] No (0) [ ] Not applicable (0)	5
Is the maximum wall length/wall thickness (l/t) ratios for **unreinforced masonry walls (URM)** in excess of those noted in AFM 32-1095, page G-63 (see chart below). (Measure longest span between column or pilaster supports or from end wall to wall opening.) [x] Yes (5) [ ] No (0) [ ] Not applicable (0)	5

NOTE: Additional guidance concerning the design and construction of masonry walls is provided in *Design of Conrete Masonry Warehouse Walls*, TEK 37, published by the National Concrete Masonry Association.

Allowable Value of Height-to-Thickness Ratio of URM Walls in High Wind Regions

Wall Types	Maximum l/t or h/t	
	Solid or Solid Grouted	All Other
Bearing Walls		
Walls of one-story buildings	16	13
First-story wall of multi-story building	18	15
Walls in top story of multi-story building	13	9
All other walls	16	13
Nonbearing Walls (Exterior and interior[1])	15	13
Cantilever Walls	3	2
Parapets	2	1 1/2

[1] Interior wall ratio should be the same as the exterior wall ratio due to the risk of internal pressure through breached openings.
Chart from Air Force Manual (AFM) 32-1095: Structural Evaluation of Existing Buildings for Seismic and Wind Loads, page G-63.

What are the debris hazards (choose all that apply): [ ] Large light towers (such as for an athletic field) and/or antennas within 300 ft of structure? (2) [ ] Portable classroom/trailers, small light frame buildings, HVAC units within 300 ft of the structure? (4) [x] Unanchored fuel tanks within 300 ft of structure? (5) Various utilities surrounding building	5
Is the refuge area located such that occupants must go outdoors to get to it? [x] No (0) [ ] Yes (2)	0

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

If the refuge area is a section of a building, are the wall systems separated from the remainder of the building structure with expansion joints? ☐ Yes (0) ☐ No (3) Unk.	3
Does the refuge area have its own roof system (i.e., the roof does not extend over other sections of the building outside the refuge area or is separated by joints)? ☐ Yes (0) ☐ No (5) Unk.	5
Is the height of the refuge area roof less than 30 feet above ground level? ☒ Yes (0) =30' ☐ No (2)	0
Is there a roof span in the refuge area longer than 40 feet from support to support? ☒ Yes (10) ☐ No (0)	10
Is the pitch of the roof less than 30^0 or less than 6/12 pitch? ☒ Yes (4) ☐ No (0)	4
Are there any parapet walls taller than 3 feet (as compared to the adjacent roof level)? If yes, check any of the following that apply. ☐ Structurally attached to the refuge area (2) ☐ Adjacent egress routes (if parapet walls collapse, may block egress routes to the refuge area) (2)	
Does a roof overhang exist that is more than 2 feet wide? ☐ Yes (2) ☒ No (0)	0
STRUCTURAL ISSUES SUBTOTAL =	116

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

CLADDING AND GLAZING ISSUES	
What is the percentage of windows and doors on the outer perimeter of the refuge area? ☐ no windows/protected doors (0) ☐ no windows/unprotected doors (1) ☒ 0% - 1% (1) ☐ 2% (2) ☐ 3% - 4% (4) ☐ 5% - 6%(6) ☐ 7% or more (10)	1
Are doors to the refuge area secured at top and bottom with connections to resist suction effects that may pull the doors open (3-point latches)? ☐ Yes (0) ☒ No (10)	10
Are there skylights or overhead atrium glass or plastic? ☐ Yes (5) ☒ No (0)	
What is the roof covering on the refuge area? **NOTE: If more than one material type is used on the roof, choose the one with the highest penalty.** ☐ Storm-resistant shingles (0) (greater than 100 mph rating) ☐ Built-up roof, with stone ballast (2) ☐ No roof covering (0) ☒ Single-ply membrane with ballast (2) ☐ Traditional metal roofing (1) ☐ Wood shingles and shakes (2) ☐ Built-up roof, without ballast (1) ☐ Clay tile (2) ☐ Single-ply membrane without ballast (1) ☐ Material other than those listed above (2) ☐ Asphalt/metal shingles (1)	2
CLADDING AND GLAZING ISSUES SUBTOTAL =	13

Evaluator's Name: _____ Date of Evaluation: _____

Site Name:

ENVELOPE PROTECTION	
Is there roof mounted equipment (e.g., air handling units, fans, large satellite dishes, large equipment screens/shields) that may separate from the roof, leaving large holes or openings? ☐ Yes (5) ☐ No (0) Unk.	
☐ Are there buildings with roof gravel within 300 ft of the structure? (including building site itself) (2) ☐ Are there debris generating sources (e.g., lumber yards, nurseries, and junk yards) within 300 ft of the structure? (4) ☒ Is the refuge area vulnerable to trees, telephone poles, light poles, and other potential missiles? (4)	4
What is the material on the exterior walls of the refuge area (excluding window and door systems)? ☐ Concrete (0) ☐ RM (0) ☐ PRM (4) ☐ Brick & block composite wall with reinforcing steel @ 4'-0" O/C (6) ☒ 3-wythes of solid masonry brick (6) ☐ URM (8) ☐ Metal/vinyl siding (10) ☐ Metal panels (pre-engineered metal building) (10) ☐ Wood or metal studs with drywall (12) ☐ Combination (other than EIFS) (12) ☐ EIFS (on substrate other than reinforced concrete or RM) (15)	6
What is the material of the roof deck/elevated floor at the refuge area? ☐ Reinforced concrete at least 6 inches thick (0) ☐ Metal deck at least 14 gauge (0) ☐ Reinforced concrete at least 3 inches thick (2) ☐ Metal deck at least 20 gauge (4) ☐ Wood panels at least 1 inch thick (4) ☒ Cement fiber board/deck (tectum) (6) ☐ Metal deck 22 gauge or higher (8) ☐ Wood panels at least ½ inch thick (8) ☐ Other (10)	10

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

Will the structure adjacent to the refuge area or surrounding it pose a threat if subject to collapse (structural components become debris that creates impact loads on the refuge area)? Specify. [x] Yes (5) [ ] No (0) No significant partition protects refuge area.	5
Are there large, roll-down or garage type doors (metal, wood, plastic) on the exterior of the refuge area? [x] Yes (5) [ ] No (0)	5
In what wind zone region is the school located based on the Wind Zones Map provided in Figure 1? [ ] Zone I [130 mph] (4) [ ] Zone II [160 mph] (6) [x] Zone III [200 mph] (8) [ ] Zone IV [250 mph] (10)	8
ENVELOPE PROTECTION SUBTOTAL	88

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

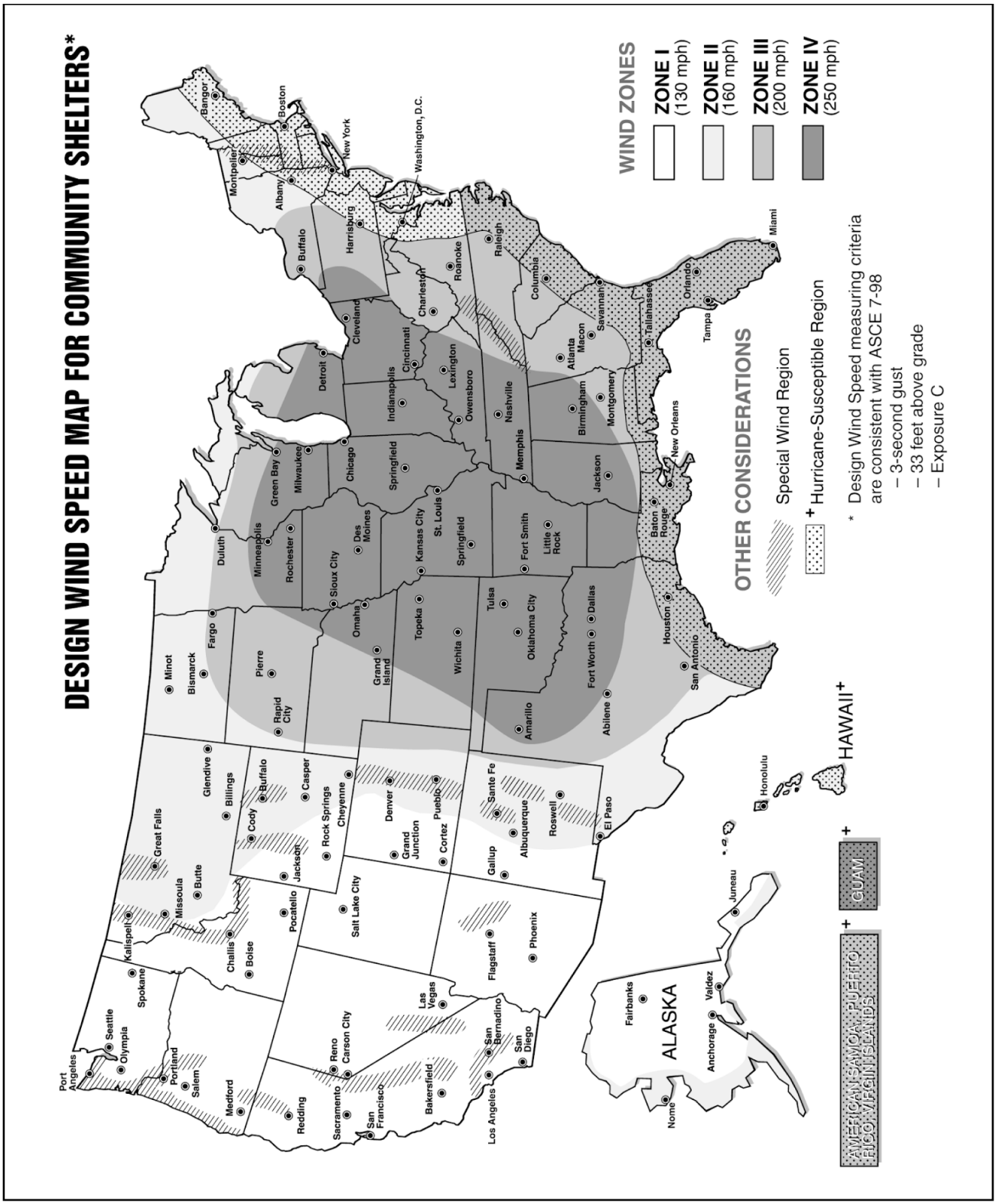

Figure 1: Design wind speed map for community shelters (Federal Emergency Management Agency). Additional information about wind zones is presented in Chapter 10 of *Design and Construction Guidance for Community Shelters*, FEMA 361.

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

NON-STRUCTURAL ISSUES	
Does a combustible gas line run through the refuge area? ☐ Yes (10) ☐ No (0) ☒ Unknown (10)	10
Is there a back-up power source/generator? ☐ Yes (0) ☒ No (8) very old; not tested If YES, what is the power source: ☐ Battery powered (0) ☐ Other power (indicate fuel type) (2) Is there an automatic transfer switch? ☐ Yes (0) ☐ No (2) What is the duration of lighting under the back-up power source? ☐ 0-2 hours (2) ☐ 3-6 hours (1) ☐ 7 or more hours (0)	8
If the back-up power supply is not within the refuge area, is it in a place where it will be protected during a high wind event (in an interior room, or below grade)? located outside in a work shed. ☐ Yes (0) ☒ No (5) ☐ Not Applicable (0)	5
Is there a back-up communication system (if yes, list type)? ☐ Yes (0) ☒ No (2)	2
Are bathrooms accessible within the refuge area? ☒ Yes (0) ☐ No (2)	0
Is the refuge area ADA accessible? ☐ Yes (0) ☒ No (2) (Upper floor is accessible; baseement is not.)	2
Is an operations plan in place for evacuation to a refuge area during a high-wind event? ☐ Yes (0) ☒ No (8) If YES, answer the following questions. Does the evacuation plan include practice drills? ☐ Yes (0) ☐ No (2) What type of warning signal is used to indicate a tornado drill?: Does it differ from a fire drill alarm? ☐ Yes (0) ☐ No (1) Can all occupants reach the candidate refuge area within 5 minutes? ☐ Yes (0) ☐ No (2) ☐ Unknown (2) List time: _____	8
NON-STRUCTURAL SUBTOTAL =	35
TOTAL WIND HAZARD SCORE =	202

Evaluator's Name: _____ Date of Evaluation: _____

Site Name:

FLOOD HAZARD CHECKLIST

Address the following evaluation statements, giving the most appropriate answer for each question. After selecting the appropriate answer, take the score for that answer (# in the parentheses) and enter it into the score block for that question. Evaluation judgment is subject to limitations of visual examination. Elevations are required only if a flood hazard has been identified at the building site. If no flood hazard exists at the site, answer all flood-related questions "not applicable." **After, all questions have been appropriately scored, sum the score column and determine the final flood hazard score for the building/structure.**

QUESTION SCORE	SCORE
FLOOD HAZARD ISSUES	
What is the Base Flood Elevation (BFE) at the building site?* NA What is the 500-year flood elevation at the building site?** NA Flood Hazard Zone: Zone X (unshaded) Community Panel No.: 280056C Date Revised: 4/15/1986 Not applicable (Explain):	**NO SCORE**
Is there a history of floods at the building site? ☐ Yes (5) ☒ No (0) ☐ Unknown (5) ☐ Not applicable (0)	0
Is there a history of drains (storm or sanitary) backing up due to flooding? ☐ Yes (2) ☒ No (0) ☐ Unknown (2) ☐ Not applicable (0)	0
Does the surrounding topography contribute to flooding in low-lying areas? Are there poor drainage patterns, basement stairwells, etc.? ☒ Yes (5) ☐ No (0) Water drains away from site, but evidence of damage is clear	5
Are access roads to the building site sufficiently elevated and expected to not be closed during periods of high water (based on local flooding history and/or FIRM panel information)? ☒ Yes (0) ☐ No (2)	0
Is the building within the 100-year floodplain and/or 500-year floodplain? ☐ Yes - 100-year and 500-year floodplains (10) ☐ Yes - 500-year floodplain only (5) ☒ No - Outside 500-year floodplain (0)	0
If the building is within a 500-year floodplain, complete the following. If not, STOP HERE and skip to page 20 for STRUCTURAL SEISMIC HAZARD CHECKLIST.	

* BFEs are shown on the Flood Insurance Rate Map (FIRM) for the community.
** 500-year flood elevations are not shown on the FIRM; they are provided in the Flood Insurance Study (FIS) report for the community.

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

STRUCTURAL ISSUES ***	
What is the building/structure type? ☐ Concrete (0) ☐ RM (2) ☐ Steel (2) ☐ PRM (5) ☐ URM (8) ☐ Wood (10) ☐ Unknown (10)	
What is the elevation of the lowest floor/level of the building? _____ Is this elevation: ☐ Above the 500-year flood elevation (0) ☐ Above the BFE, below the 500-year flood elevation (4) ☐ Below the BFE or unknown (8) ☐ Not applicable (0)	
What is the elevation of the second lowest floor of the building? _____ Is this elevation: ☐ Above the 500-year flood elevation (0) ☐ Above the BFE, below the 500-year flood elevation (5) ☐ Below the BFE or unknown (10) ☐ Not applicable (0)	
If the lowest floor is below the 500-year flood elevation, are there openings in the walls to allow water to pass through the wall, thus avoiding pressure buildup on foundation and first floor walls? ☐ Yes (0) ☐ No (5) ☐ Not applicable (0)	
Is the space below the 500-year flood elevation used for classroom or office space? (If this area is used for storage, access, and parking only, answer "No"). ☐ Yes (2) ☐ No (0) ☐ Not applicable (0)	
Is the building material below the 500-year flood elevation constructed of entirely flood-resistant material? ☐ Yes (0) ☐ No (2) ☐ Not applicable (0)	
FACILITY AND UTILITY ISSUES	
Are the heating, electrical, and other utilities located in a basement or on a slab area that is below the 500-year flood elevation? ☐ Yes (4) ☐ No (0) ☐ Not applicable (0)	
Is there a method of removing flood waters from the building (e.g., sump pump)? What is the size and capacity of the pump? ☐ Yes (0) ☐ No (4) ☐ Not applicable (0)	
TOTAL FLOOD HAZARD SCORE =	5

******** Ensure that all structure elevations that are compared to either Base Flood Elevations (BFEs) or 500-year flood elevations are referenced to the vertical datum stated on the FIRM panel. (Do not compare local benchmarks to MSL, NGVD 1929, etc.)

Evaluator's Name: _____ Date of Evaluation: _____

Site Name: _____

Appendix B

Design Wind Pressure Calculations

ASCE 7-05 Wind Load Analysis for Community Shelter in Lucedale, MS
Using Exposure C

General Data

$K_z = 0.85$ Velocity Pressure Exposure Coefficient
$I = 1.00$ Importance Factor
$V = 200$ Wind Speed (mph) from FEMA Wind Zone Map
$K_{zt} = 1$ Topographic Factor
$K_d = 0.85$ Wind Directionality Factor
$H = 30$ Maximum Building Height (ft)
$L = 321$ Building Length (ft)
B – 251 Building Width (ft)

Velocity Pressure

$q_z = (0.00256)(K_z)(K_{zt})(K_d)(V^2I)$ $q_z = 73.98$ psf
$q_h = q_z$
$q_h = 73.98$ psf

External Pressure Coefficients for Walls

L/B = 1.28
$C_{p1} = 0.8$ Windward Wall
$C_{p2a} = -0.44$ Leeward Wall
$C_{p3} = -0.7$ Side Wall

B/L = 0.78
$C_{p1} = 0.8$ Windward Wall
$C_{p2b} = -0.5$ Leeward Wall
$C_{p3} = -0.7$ Side Wall

Roof Pressure Coefficients

h/L = 0.093 (**Note**: Let $C_{p4} = C_{p4a} = C_{p4b}$ due to roof geometry)
$C_{p4a} = -0.9$ from 0-15 feet from windward edge
$C_{p4b} = -0.9$ from 15-30 feet from windward edge
$C_{p5} = -0.5$ from 30-60 feet from windward edge
$C_{p6} = -0.3$ more than 60 feet from windward edge

Gust Factor

G = 0.85

Internal Pressure Coefficients for Buildings

GC_{pipos} = 0.55 for partially enclosed buildings
GC_{pineg} = -0.55 for partially enclosed buildings

Design Wind Pressures

(for positive internal pressures)

$p_{wi} = (q_z)(G)(C_{p1} - q_h)(GC_{pipos})$	p_{wi} = 9.62 psf	Windward wall
$p_{lee2a} = (q_z)(G)(C_{p2a} - q_h)(GC_{pipos})$	p_{lee2a} = -68.36 psf	Leeward wall (parallel)
$p_{lee2b} = (q_z)(G)(C_{p2b} - q_h)(GC_{pipos})$	p_{lee2b} = -72.13 psf	Leeward wall (perpend.)
$p_{side} = (q_z)(G)(C_{p3} - q_h)(GC_{pipos})$	p_{side} = -84.71 psf	Side wall
$p_{roof1} = (q_z)(G)(C_{p4} - q_h)(GC_{pipos})$	p_{roof1} = -97.28 psf	Roof pressure (0-30 ft)
$p_{roof2} = (q_z)(G)(C_{p5} - q_h)(GC_{pipos})$	p_{roof2} = -72.13 psf	Roof pressure (30-60 ft)
$p_{roof3} = (q_z)(G)(C_{p6} - q_h)(GC_{pipos})$	p_{roof3} = -59.55 psf	Roof pressure (>60 ft)

(for negative internal pressures)

$p_{wi} = (q_z)(G)(C_{p1} - q_h)(GC_{pineg})$	p_{wi} = 91.00 psf	Windward wall
$p_{lee2a} = (q_z)(G)(C_{p2a} - q_h)(GC_{pineg})$	p_{lee2a} = 13.02 psf	Leeward wall (parallel)
$p_{lee2b} = (q_z)(G)(C_{p2b} - q_h)(GC_{pineg})$	p_{lee2b} = 9.25 psf	Leeward wall (perpend.)
$p_{side} = (q_z)(G)(C_{p3} - q_h)(GC_{pineg})$	p_{side} = -3.33 psf	Side wall
$p_{roof1} = (q_z)(G)(C_{p4} - q_h)(GC_{pineg})$	p_{roof1} = -15.91 psf	Roof pressure (0-30 ft)
$p_{roof2} = (q_z)(G)(C_{p5} - q_h)(GC_{pineg})$	p_{roof2} = 9.25 psf	Roof pressure (30-60 ft)
$p_{roof3} = (q_z)(G)(C_{p6} - q_h)(GC_{pineg})$	p_{roof3} = 21.82 psf	Roof pressure (>60 ft)