# PRE-MITIGATION ASSESSMENT TEAM REPORT

# Mississippi Tornado Outbreak, April 23rd-24th

*Damage and Safe Room Performance Observations, Recommendations, and Conclusions*

FEMA

*July 2010*

**FOR PUBLIC RELEASE**

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**Cover Photo: Proprietary Safe Room affected by the April 23rd Mississippi Tornado. Safe Room installed by Life Saver Storm Shelters**

**FOR PUBLIC RELEASE**

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# Section 1: Introduction, Goals, and Objectives

In response to the April 23rd–April 24th, 2010 tornado outbreak in Mississippi, the Federal Emergency Management Agency (FEMA) deployed a Pre-Mitigation Assessment Team (PMAT) to survey the general structural damage and the performance of the residential and community safe rooms located along the path of the Tallulah-Yazoo City-Durant tornado. Tornado classification, building damage, building performance, and safe room information was collected through investigative site visits and surveys by the PMAT. These investigations allowed the Team to capture important observations, lessons learned, and recommendations regarding the performance of:

- FEMA-funded residential safe rooms impacted by tornadic winds and debris that had been constructed in accordance with FEMA 320, *Taking Shelter From the Storm: Building a Safe Room Inside Your House, Third Edition (2008)*
- FEMA-funded community safe rooms impacted by tornadic winds and debris that had been constructed in accordance with FEMA 361, *Design and Construction Guidance for Community Safe Rooms, First Edition (2000)* or *Second Edition (2008)*
- Community safe room operations plans

## 1.1 Mississippi Safe Room Programs

Since 2001, the Mississippi Emergency Management Agency (MEMA) has provided funding assistance for the design and construction of approximately 6,700 safe rooms statewide; including residential, small community, and large community safe rooms. Funding was provided through FEMA's Hazard Mitigation Grant Program (HMGP) and MEMA's *A Safe Place to Go* grant program. The first safe rooms in the State were funded under Presidential Declaration 1251 (DR-1251) and more may be funded under DR-1906 for the April 2010 tornado outbreak. In 2006–2008, under DR-1604, MEMA provided funding assistance for 4,497 safe rooms. Most of these safe rooms were residential safe rooms and small community safe rooms. Within the counties affected by the April 24th, 2010 Tallulah-Yazoo City-Durant tornado, 32 safe rooms in Yazoo County, 4 in Holmes County, 31 in Choctaw County, and 42 in Oktibbeha County were previously constructed under DR-1604 funds.

## 1.2 National Weather Service Event Summary

Starting on the afternoon of Friday April 23rd and lasting through the late evening of Saturday April 24th, 2010, the Arkansas, Louisiana, and Mississippi region experienced severe weather from a powerful storm system. Scattered severe thunderstorms, large hail storms, high winds, and multiple tornado touchdowns were reported during this time.[1]

While several storms on Friday and Saturday caused localized damage throughout the region, the most devastating storm from this event was a supercell that developed in the late morning hours over northern Louisiana and tracked northeast through central Mississippi.[2] The first report of damage from the April 23rd, 2010 storm was around 11 AM near Tallulah, LA. As this supercell tracked northeast into Mississippi, it spawned seven confirmed tornados that caused significant damage in the Eagle Lake area of Warren County, Valley Park in Issaquena County, Satartia and

[1] http://www.srh.noaa.gov/jan/?n=2010_04_23_24_tor_outbreak_reports_summary
[2] http://www.srh.noaa.gov/jan/?n=2010_04_24_main_tor_madison_parish_oktibbeha

Yazoo City in Yazoo County, Ebenezer and Durant in Holmes County, north of Kosciusko near Hesterville in Attala County, French Camp and Chester in Choctaw County, north of Starkville in Oktibbeha County, and east of West Point in Clay County.[3] Figure 1 shows the general path and damage swath of seven tornados in Mississippi from the April 23rd–24th, 2010 outbreak.

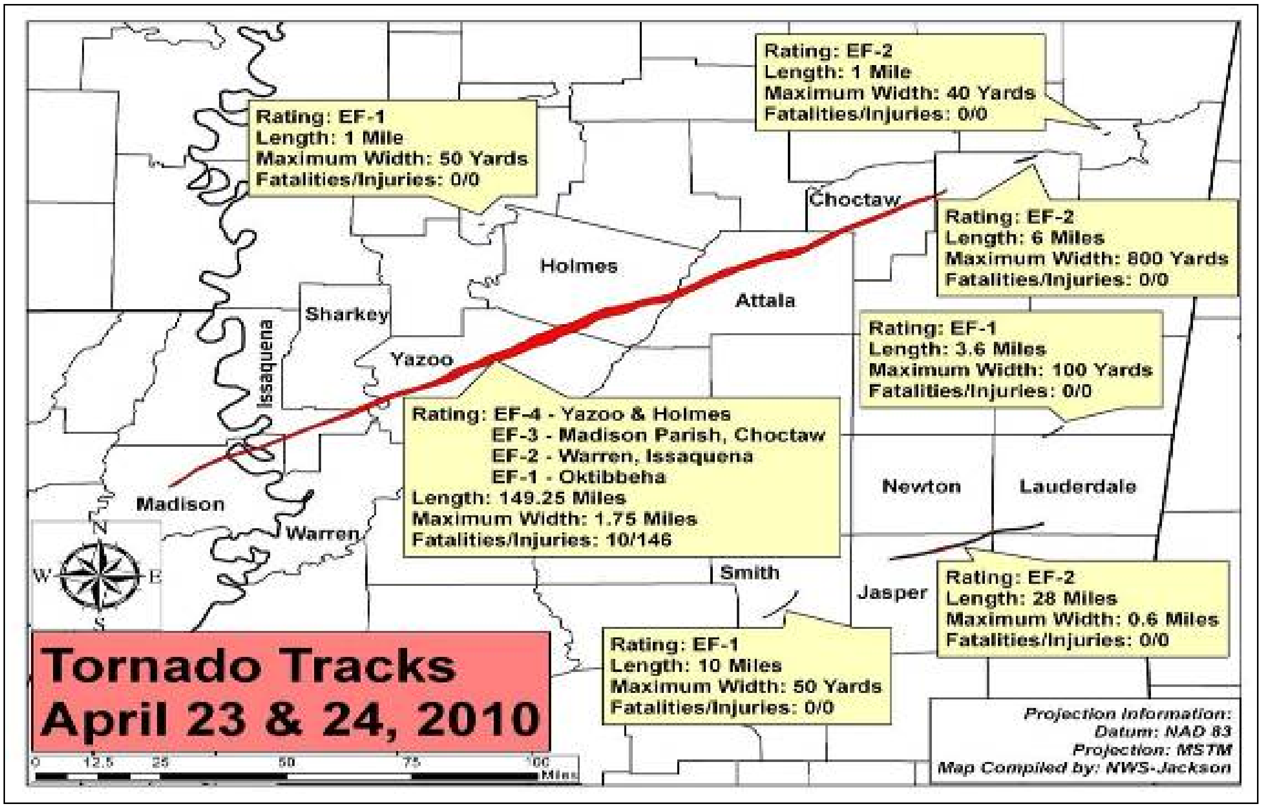


**Figure 1: National Weather Service Map of Tornado Path and Damage Swath[4,5]**

The primary tornado and track that was investigated by the PMAT was rated on the Enhanced Fujita (EF) Scale as an EF-4 by the National Weather Service (NWS); estimated maximum wind speeds of 170 miles per hour were provided by the NWS. This tornado had an approximate start location of 5 miles west of Tallulah, LA (32.408N, 91.283W). As the storm tracked northeast through Mississippi, its damage path length was documented as 149 miles with a maximum width of 1.75 miles. After a long and destructive path, the tornado rapidly weakened and dissipated after moving into Oktibbeha County with an end point approximately 5.5 miles north of Sturgis near West Point in Clay County, MS (33.430N, 89.054W).[6]

MEMA inventoried damaged structures from the entire storm event. A total of 414 residential and manufactured homes were either destroyed or sustained major structural damage and 798 residential and manufactured homes were affected by tornadic winds and debris. The severe weather event resulted in 10 documented deaths and 94 documented injuries to the residents of

[3] http://www.srh.noaa.gov/jan/?n=2010_04_24_main_tor_madison_parish_oktibbeha
[4] http://www.srh.noaa.gov/jan/?n=2010_04_23_24_tor_outbreak_reports_summary
[5] See Appendix A for a larger version of this map.
[6] http://www.srh.noaa.gov/jan/?n=2010_04_23_24_tor_outbreak_reports_summary

Mississippi. Table 1 shows the breakdown of damage to commercial and residential structures in further detail.

**Table 1: Breakdown of Damage to Structures**

| Structure/Damage | Destroyed | Major | Minor | Total |
|---|---|---|---|---|
| Residential Homes | 159 | 95 | 302 | 556 |
| Manufactured Homes | 103 | 57 | 82 | 242 |
| Business | 18 | 6 | 9 | 33 |
| Agriculture | 3 | 3 | 12 | 18 |
| **Total:** | **283** | **161** | **405** | **849** |

*Damage data taken from internal MEMA document dated 5/11/2010

## 1.3 The PMAT

The PMAT consisted of six members: a hazard mitigation specialist from MEMA, a hazard mitigation architect from FEMA Region IV, two contractor engineers from FEMA Headquarters, and a subject matter expert engineering professor and a graduate student from Texas Tech University. The PMAT spent May 3-4, 2010 in the field, investigating damaged structures and residential and commercial safe rooms along the path of the large, EF-4 Tallulah-Yazoo City-Durant tornado that traversed Yazoo, Holmes, Choctaw, and Oktibbeha Counties.

The mission of the PMAT was to locate safe rooms in and along the path of damage and to characterize the general damage in the vicinity of the safe rooms and evaluate the condition and performance of the safe rooms. The locations of the safe rooms were obtained from the FEMA and MEMA grant program databases, and with guidance from local agencies.

## 1.4 Locations Observed

The PMAT visited safe rooms located within 1 to 3 miles of the large, EF-4 tornado path based on past grant award recipient lists. On the first day, May 3rd, the PMAT visited four residential safe rooms in Yazoo County, three in Yazoo City, and one in Benton. The Team also visited one community safe room in Ebenezer, Holmes County, and one community and one residential safe room in Durant, Holmes County. On the second day, May 4th, the PMAT visited one residential safe room in Weir, Choctaw County, and three residential safe rooms in Starkville, Oktibbeha County. Figure 2 shows the safe room locations that were observed in relationship to the damage path of the tornado.

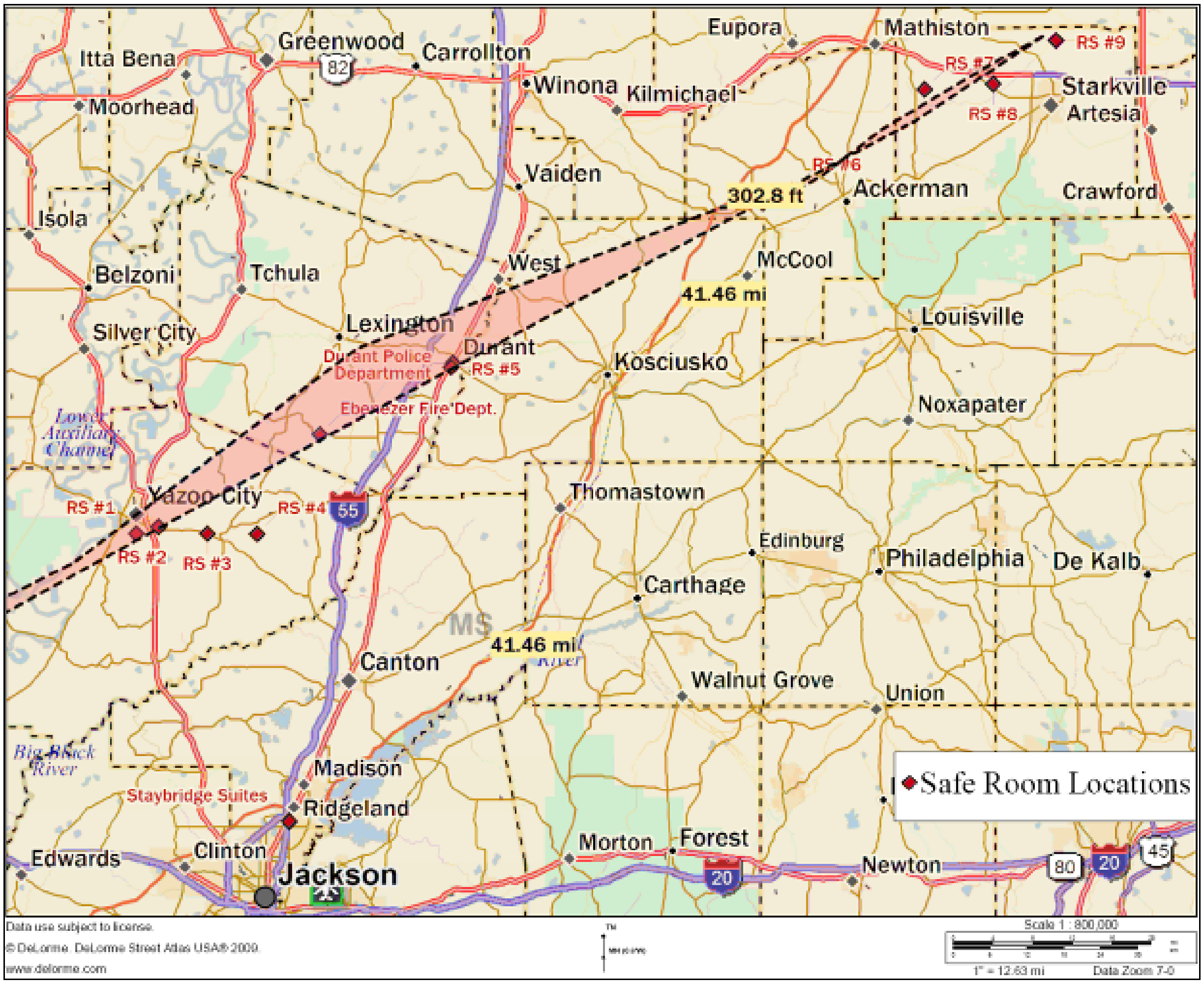


Figure 2: Safe Room Sites Observed by the PMAT[7]

## 1.5 Local Resources Utilized

In addition to the FEMA and MEMA databases, the PMAT utilized local resources to collect data from the field investigations. These resources included representatives of MEMA, local safe room installers, and local police and fire departments.

# Section 2: Damage Observations

Normally, storm intensity is determined by comparing satellite imagery and aerial photography with ground truthing. Tornado damage is typically classified using the EF Scale by field teams from the NWS. Once the tornado damage has been identified, the NWS teams further check the weather records of the day to verify and ultimately rank or classify the tornadoes themselves. The PMAT used the EF Scale in their investigation to characterize the general damage around the safe rooms and safe room communities.

Observations were made of both general damage along the tornado path (Section 2.2) and specific damage to buildings. Additionally, a total of 11 residential and community safe rooms

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[7] See Appendix B for a larger version of this map.

were observed (see Sections 3.1 and 3.2). The general damage areas assessed were not sought out specifically but rather observed as the team came across sites with significant damage when traveling from one safe room to another (refer to appendix A for the path of the field teams).

## 2.1 Enhanced Fujita Scale

Unlike the original Fujita Scale that did not account for quality and construction type, the EF Scale utilizes 28 Damage Indicators (DIs) to indicate the building use and type of construction; each DI includes Degrees of Damage (DODs), damage descriptors associated with an expected estimated wind speed. The DOD includes a lower wind speed boundary and an upper wind speed boundary that could produce the observed damage. Photographs are included in the EF Scale support documents to assist the investigator/storm evaluator. Table 2 compares wind speeds used in the original derived Fujita Scale with the operational EF Scale. Table 3 provides the 28 DIs of the EF Scale. The red arrow shown in Table 3 indicates the general structure typed observed by the PMAT. An example of a DI for a single family residence and the associated DOD scale is shown in Table 4. The red arrow in Table 4 denotes the general degree of damage observed in many of the one- to two- family residences by the PMAT.

**Table 2: Fujita Scale Converted to EF Scale**

| Fujita Scale | Derived Scale: 3-Second Gust (mph) | Enhanced Fujita Scale | Operational Scale: 3-Second Gust (mph) |
|---|---|---|---|
| 0 | 45-78 | 0 | 65-85 |
| 1 | 79-117 | 1 | 86-110 |
| 2 | 118-161 | 2 | 111-135 |
| 3 | 162-209 | 3 | 136-165 |
| 4 | 210-261 | 4 | 166-200 |
| 5 | 262-317 | 5 | Over 200 |

**Table 3: 28 EF Scale Damage Indicators[8]**

| DI No. | Damage Indicator (DI) | *Use* |
|---|---|---|
| 1 | Small Barns or Farm Outbuildings (SBO) | *Residential* |
| 2 | One- to Two-Family Residences (FR12) | |
| 3 | Manufactured Home – Single Wide (MHSW) | |
| 4 | Manufactured Home – Double Wide (MHDW) | |
| 5 | Apartments, Condos, Townhouses [3 stories or less] (ACT) | |
| 6 | Motel (M) | *Commercial & Retail Structures* |
| 7 | Masonry Apartment or Motel Building (MAM) | |
| 8 | Small Retail Building [fast food restaurant] (SRB) | |
| 9 | Small Professional Building [doctor's office, branch bank] (SPB) | |
| 10 | Strip Mall (SM) | |
| 11 | Large Shopping Mall (LSM) | |
| 12 | Large, Isolated Retail Building [K-Mart, WalMart] (LIRB) | |
| 13 | Automobile Showroom (ASR) | |
| 14 | Automobile Service Building (ASB) | |

[8] NOAA, W.D.T.B. (2007) *Introducing the Enhanced Fujita Scale.*

| DI No. | Damage Indicator (DI) | *Use* |
|---|---|---|
| 15 | Elementary School [single story; interior or exterior hallways] (ES) | *Schools* |
| 16 | Junior or Senior High School (JHSH) | |
| 17 | Low-Rise building [1–4 Stories] (LRB) | *Professional Buildings* |
| 18 | Mid-Rise building [5–20 Stories] (MRB) | |
| 19 | High-Rise Building [more than 20 stories] (HRB) | |
| 20 | Institutional Building [hospital, government, or university] (IB) | |
| 21 | Metal Building Systems (MBS) | *Metal Buildings & Canopies* |
| 22 | Service Station Canopy (SSC) | |
| 23 | Warehouse Building [tilt-up walls or heavy timber const] (WHB) | |
| 24 | Transmission Line Towers (TLT) | *Towers/Poles* |
| 25 | Free-Standing Towers (FST) | |
| 26 | Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP) | |
| 27 | Trees: Hardwood (TH) | *Vegetation* |
| 28 | Trees: Softwood (TS) | |

**Table 4: EF Scale Degree of Damage Single Family Residence Example[9]**

| DOD | Damage Description – Framed House | EXP | LB | UB |
|---|---|---|---|---|
| 1 | Threshold of visible damage | 63 | 53 | 80 |
| 2 | Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding | 79 | 63 | 97 |
| 3 | Broken glass in doors and windows | 96 | 79 | 114 |
| 4 | Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward or outward; failure of porch or carport | 97 | 81 | 116 |
| 5 | Entire house shifts off foundation | 121 | 103 | 141 |
| 6 | Large sections of roof structure removed; most walls remain standing | 122 | 104 | 142 |
| 7 | Exterior walls collapsed | 132 | 113 | 153 |
| 8 | Most walls collapsed except small interior rooms | 152 | 127 | 178 |
| 9 | All walls collapsed | 170 | 142 | 198 |
| 0 | Destruction of engineered and/or well constructed residence; slab swept clean | 200 | 162 | 220 |

Notes:

EXP = exposure C

LB = lower bound wind speed

UB = upper bound wind speed

[9] NOAA, W.D.T.B. (2007) *Introducing the Enhanced Fujita Scale.*

## 2.2 Summary of General Damage Observations

Figures 3 through 10 present characteristic damage observed by the PMAT. The assigned wind speeds are based on Exposure C measured at 33 feet above the ground. Most of the structures shown in these figures had at least one open exposure to the southwest, the direction from which the supercell approached. The EF numbers and wind speeds were assigned by the Texas Tech investigators based on field observations and compared to the EF Scale criteria. The PMAT only documented storm damage in and around shelter locations, and therefore exact determination of the EF Scale of the total storm strength could not be determined for the entire breadth and length of the tornado.

**Figure 3: Hillcrest Baptist Church, Yazoo City, MS, EF-3, 157 mph**

**Figure 4: Roberson Funeral Home, Yazoo City, MS, EF-3, 145 mph**

**Figure 5: Massey Ferguson Implement Co., Yazoo City, MS, EF-3, 138 mph**

**Figure 6: Remaining Portion of Ebenezer Baptist Church, Holmes County, MS, EF-3, 145 mph**

**Figure 7: Rolled Manufactured Home, Ebenezer, Holmes County, MS, EF-2, 110 mph**

**Figure 8: Vaulted Manufactured Home, Ebenezer, Holmes County, MS, EF-2, 110 mph**

**Figure 9: Sanctuary and Fellowship Hall (Left), Mills Spring Missionary Baptist Church (Bottom Right), Choctaw County, MS, EF-2, 120 mph**

**Figure 10: Typical Pine Tree Damage, Choctaw County, MS, EF-2, 100 mph**

## Section 3: Safe Room Observations

Given the large number of safe rooms constructed in the State of Mississippi, the PMAT was interested in finding safe rooms both in and around the path of the storm. The goal was to evaluate the FEMA-funded safe rooms in order to determine how they performed and also how the safe rooms were used, operated, and managed during the event.

### 3.1 FEMA 320 Residential Safe Rooms

FEMA 320 safe rooms are residential or small community safe rooms that may house up to 16 people. Safe rooms meeting the FEMA 320 criteria may be constructed or installed below ground, partially below ground, and completely above ground. Although information from MEMA indicated that subsidies had been provided for all types of shelters, only belowground safe rooms were found by the PMAT.

As the team investigated the tornado damage track, items of interest included:

- Type and location of safe room
- Safe room builder or installer
- Cost of the safe room
- Compliance with the FEMA 320 safe room criteria
- Use at the time of the storm
- Performance of the safe room during the storm

A total of nine residential safe rooms were observed by the PMAT. Of those nine safe rooms, six were occupied during the tornado. Tornado damage to the areas around the safe rooms was observed at two of the nine safe rooms. Five different types of underground safe rooms were observed; these were constructed and installed by four different producers. None of these safe rooms contained a National Storm Shelter Association (NSSA) label.

**National Storm Shelter Association (NSSA) Storm Shelter Quality Verification:**

NSSA manufacturers and installers affix a seal to each shelter unit attesting that their products have passed engineering and testing requirements of ICC-500, the International Code Council (ICC) and NSSA Standard for the Design and Construction of Storm Shelters. While FEMA does not approve, adopt, or endorse products or standards, the Agency acknowledges that shelters complying with ICC-500 meet all FEMA criteria as stated in FEMA 320 and FEMA 361 for tornado safe rooms.

**Safe Room #1:** The first residential safe room (Figure 11) observed by the PMAT is located in Yazoo City, Yazoo County. The owner was unavailable for an interview, but the installer of the safe room and owner of Life Saver Storm Shelters, accompanied the team on the first day to answer questions. Life Saver Storm Shelters installed this safe room at a cost of approximately $5,350. This safe room was unoccupied at the time of the storm event, but was in the storm path and seemed to have fared particularly well during the storm. The safe room is constructed completely of steel and includes a three-lock heavy duty door. It appeared that a tree had fallen onto the hatch to the safe room, but by the time the PMAT visited the site, the resident had already cleared the debris off the hatch. The hatch was in good working condition, despite the minimal damage. Life Save Storm Shelter claims their shelter meets or exceeds FEMA standards, and though untested, the shelter appears sufficiently robust to comply with FEMA 320 guidelines. The damage to the surrounding area was equivalent to approximately an EF-3 tornado. The safe room was funded under HMGP, DR-1604.

**Figure 11: Safe Room #1, Yazoo County, MS**

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**Safe Room #2:** The second safe room/shelter (Figure 12) is also located in Yazoo City, Yazoo County. The owner rents out this property and was unable to recall the manufacturer, installer, or price. Through initial observations, the PMAT concluded that this shelter does not comply with FEMA 320 guidelines because the door contains only two locks, which are gate fencing latches. This shelter was unoccupied at the time of the storm event, but was in the storm path. Although the safe room appeared to be undamaged, the adjacent trees and manufactured homes were damaged. Damage included torn and removed siding and roofing materials, broken trees, and scattered debris, equivalent to an EF-2 tornado. The safe room was funded under HMGP, DR-1604.

**Figure 12: Safe Room/Shelter #2, Yazoo County, MS**

**Safe Room #3:** The third safe room (Figure 13) is located in Yazoo County and was manufactured and installed by Life Saver Storm Shelters at a cost of approximately $5,350. The owner of this safe room is also one of the owners of Life Saver Storm Shelters. The safe room was constructed with steel and includes a three-lock heavy duty door. It was occupied by neighbors at the time of the storm event, but was not directly in the storm path. There was no damage to the safe room or surrounding area. The safe room was funded under HMGP, DR-1604.


**Figure 13: Safe Room #3, Yazoo County, MS**

**Safe Room #4:** The fourth safe room (Figure 14), located in Benton, Yazoo County, was installed by Life Saver Storm Shelters at a cost of approximately $5,350. The owner was unavailable for an interview. This belowground, steel safe room includes a three-lock heavy duty door. This safe room was in the direct path of the storm, but was unoccupied at the time of the event. The porch and trees surrounding the house were damaged, but there did not appear to be any damage to the safe room. The observed damage was equivalent to an EF-1. The safe room was funded under HMGP, DR-1604.

**Figure 14: Safe Room #4, Yazoo County, MS**

**Safe Room #5:** The fifth safe room (Figure 15) is located in Durant, Holmes County. Life Saver Storm Shelters installed this safe room at a cost of approximately $5,350. This belowground, steel safe room includes a three-lock heavy duty door. It was occupied at the time of the storm event by the owner and his wife, but was not directly in the storm path. The owner stated that they had approximately a 20-minute warning to access the safe room. There was no damage to the safe room, nearby houses, or in the general vicinity. The safe room was funded under HMGP, DR-1604.

**Figure 15: Safe Room #5, Holmes County, MS**

**Safe Room #6:** The sixth safe room (Figure 16) is located in Ackerman, Choctaw County. Bost Tornado Shelters manufactured and installed this safe room at a cost of approximately $3,500. According to the Building Inspector Shelter Checklist, the safe room meets or exceeds the FEMA 320 guidelines. This belowground, concrete, cast-in-place, three-lock safe room was occupied at the time of the storm event, but was not directly in the storm path. There was no damage to the safe room or the adjacent area. The owner stated that there had been some broken branches in their yard after the tornado. The safe room was funded under HMGP, DR-1604.

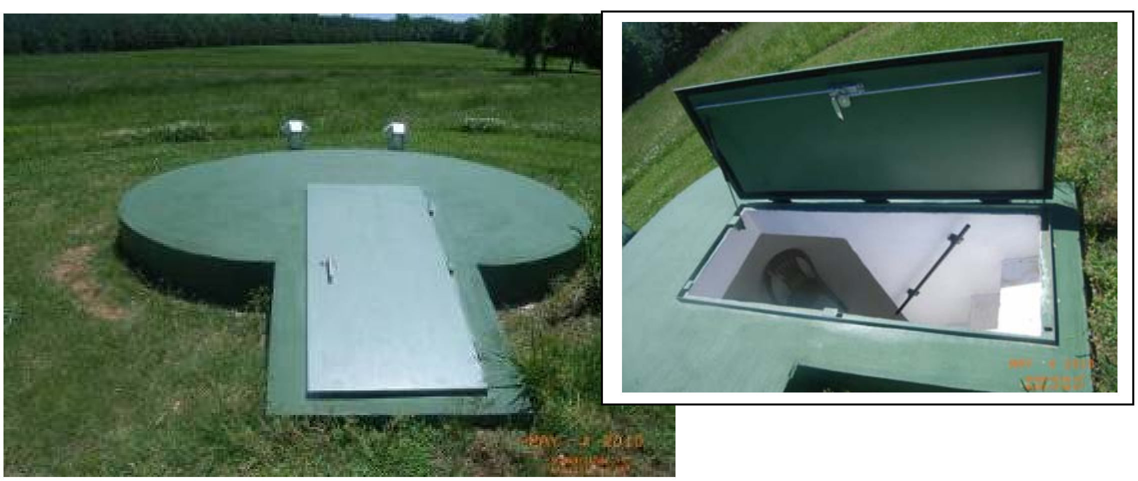


**Figure 16: Safe Room #6, Choctaw County, MS**

**Safe Room #7:** The seventh safe room (Figure 17) is located in Starkville, Oktibbeha County. The safe room was manufactured by Domes International and installed by the homeowner, who was also the dealer for the safe room company. The door assembly was tested by Texas Tech in 2001. The cost of manufacturing and installing this type of safe room is approximately $4,700. This belowground, fiberglass safe room includes a three-lock steel door. The safe room was unoccupied at the time of the storm event and was not directly in the storm path. The homeowner was not available for an interview and access to the safe room was limited due to fencing. The safe room was funded under HMGP, DR-1360.

**Figure 17: Safe Room #7, Oktibbeha County, MS**

**Safe Room #8:** The eighth safe room (Figure 18) is located in Starkville, Oktibbeha County. The safe room was manufactured by Domes International, and the door was tested by Texas Tech in 2001. The cost of manufacturing and installing this type of safe room is approximately $4,700. This belowground, fiberglass safe room includes a three-lock steel door. The safe room was unoccupied at the time of the storm event and was not directly in the storm path. There was no damage in the nearby vicinity of the safe room. The owner was at work at the time of the tornado and his wife stayed at a relative's home since one of the hinges on the safe room door was broken. The owner stated that he is very pleased with his safe room and has used it multiple times during other tornados. The safe room was funded under HMGP, DR-1360.

**Figure 18: Safe Room #8, Starkville, Oktibbeha County, MS**

**Safe Room #9:** The ninth safe room (Figure 19) is located in Starkville, Oktibbeha County. The safe room was manufactured by Domes International, and the three-lock steel door was tested by Texas Tech in 2001. The cost of manufacturing and installing this type of safe room is approximately $4,300. This belowground, fiberglass safe room was occupied by the homeowner at the time of the storm event and was in the path of a weakening tornado. The homeowner survived a direct hit by the tornado. The safe room was funded under HMGP, DR-1360.

The owner stated that news reports indicated that the tornado was approximately 1 mile away, but less than a minute later the wind picked up and he “heard the familiar sound” of a tornado. At that time, he and his girlfriend ran to the safe room just as a tree fell on his manufactured home. There was significant damage to the surrounding trees and nearby homes. The owner’s home appeared to have shifted on its foundation in addition to receiving damage from the fallen tree. The observed damage was equivalent to an EF-1. Originally, the homeowner was going to install a concrete safe room, but the necessary equipment could not access the site so he opted for a lighter, belowground safe room instead.

**Figure 19: Safe Room #9, Oktibbeha County, MS**

### 3.2 FEMA 361 Community Safe Rooms

Several FEMA 361 Community Safe Rooms in Mississippi have been funded by FEMA over the last 5 years. FEMA funded 56 community safe rooms under DR-1360 alone (Figure 20). Some of the safe rooms included two side-by-side, FEMA 320 safe rooms to create larger sheltering areas. Only a few of these were located within the storm path and none were occupied during the storm.

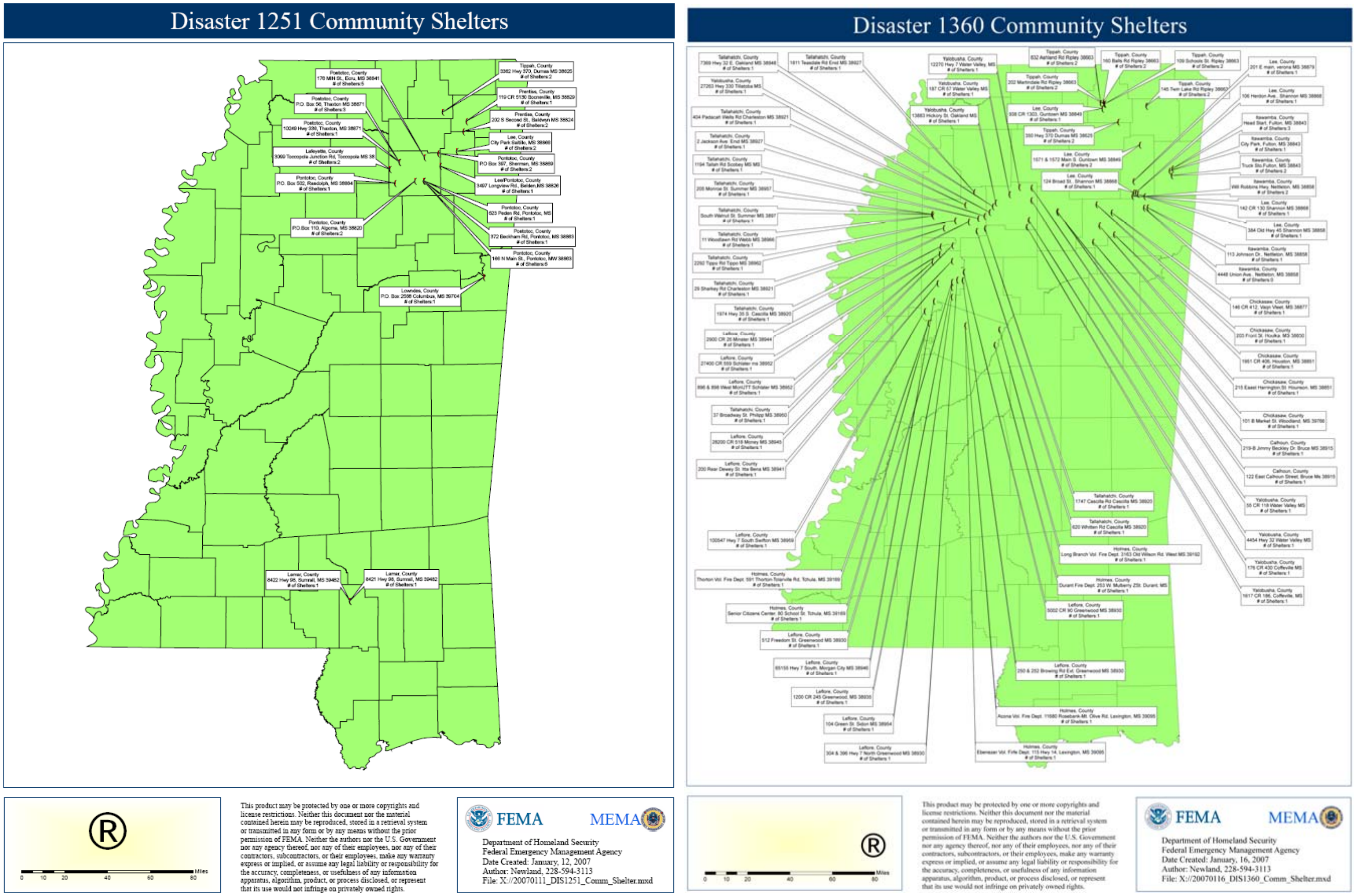



**Figure 20: FEMA 361 Community Safe Rooms Funded by DR-1251 and DR-1360 (also included in Appendix B)**

The PMAT located two community safe rooms: one community safe room was located at the Ebenezer Fire Department and the other was located at the Durant Police Station (Figures 21 and 22). The two community safe rooms are identical. According to Ebenezer Fire Department, people were afraid to use the safe room, and instead took refuge in the fire department building; a pre-engineered metal building. Both these community safe rooms appear to be two FEMA 320 residential safe rooms positioned directly next to one another for the purposes of providing safe space for more than 16 occupants. Since each location has two residential safe rooms, as a pair they were considered as community safe rooms by MEMA.

Both safe rooms consist of a pair of 6-foot, 6-inch wide x 12-foot long x 6-foot tall concrete septic tanks adapted for use as safe rooms. The safe rooms were anchored to the ground with ties and anchors typically used to secure manufactured housing units. The adequacy of this anchor system was not verified or documented. Neither of the safe rooms contained backup lighting and the steel doors and locking system did not appear very robust. Recent impact testing by Texas Tech of an identical door and locking system failed. Neither safe room locations were in the direct path of the storm or sustained any damage. However, the town of Ebenezer sustained significant damage at a nearby church; manufactured home damage and tree damage was also prevalent.

**Figure 21: Durant Police Station (Left) and Ebenezer Fire Department (Top Right), Holmes County, FEMA 361 Community Safe Rooms**

**Figure 22: Durant Police Station, Holmes County, FEMA 361 Community Safe Room**

## Section 4: Key Findings and Recommendations

Key findings based on observations related to residential safe rooms in Yazoo, Holmes, Choctaw, and Oktibbeha Counties, MS, are provided below.

- After the PMAT survey was completed, the team concluded that a full Mitigation Assessment Team (MAT) is not needed.
- Only belowground residential safe rooms/shelters were observed by the PMAT. These safe rooms/shelters appear to be the prevailing choice by homeowners due to cost, availability of installers, and difficulty of placing an in-home safe room in existing homes.
- Belowground safe rooms are considerably easier for homeowners to construct and install (or have installed). Most of the homeowners interviewed stated that the installation time for their belowground safe room was 1 to 2 days.
- Many safe room owners were unfamiliar with aboveground safe room options or were skeptical of their safety.
- Due to the necessity of digging a hole for belowground safe rooms, safe room locations varied from 10 feet to 100 feet from the primary residence.
- The contractors for all the observed safe room installations were Mississippi residents; however, most of the products were constructed outside of Mississippi.
- Mississippi typically has a high water table. It is unclear how the belowground safe rooms were installed to resist the potential for hydraulic lift.
- MEMA reported that a few contractors are starting to build in-home safe rooms during new homes construction.
- The observations and recommendations from the PMAT report should be considered when updating the FEMA 361 and FEMA 320 publications.

**Table 5: General Findings Summary**

| | Total Observed | Residential | Community |
|---|---|---|---|
| | | 9 | 2 |
| **Location** | Belowground | 9 | |
| | Aboveground | | 2 |
| **Funding Source** | DR-1360 | 3 | 2 |
| | DR-1604 | 6 | |
| **Installer / Manufacturer** | Life Saver | 4 | |
| | Bost | 1 | |
| | Fiberglass Creations | 3 | |
| | Unknown | 1 | 2 |
| **Equivalent EF Rating at Location** | 0 | 6 | 2 |
| | 1 | 2 | |
| | 2 | 1 | |
| | 3 | 1 | |
| | 4 | | |
| | 5 | | |

A few of the key findings based on observations related to community safe rooms in Holmes County, MS, are provided below.

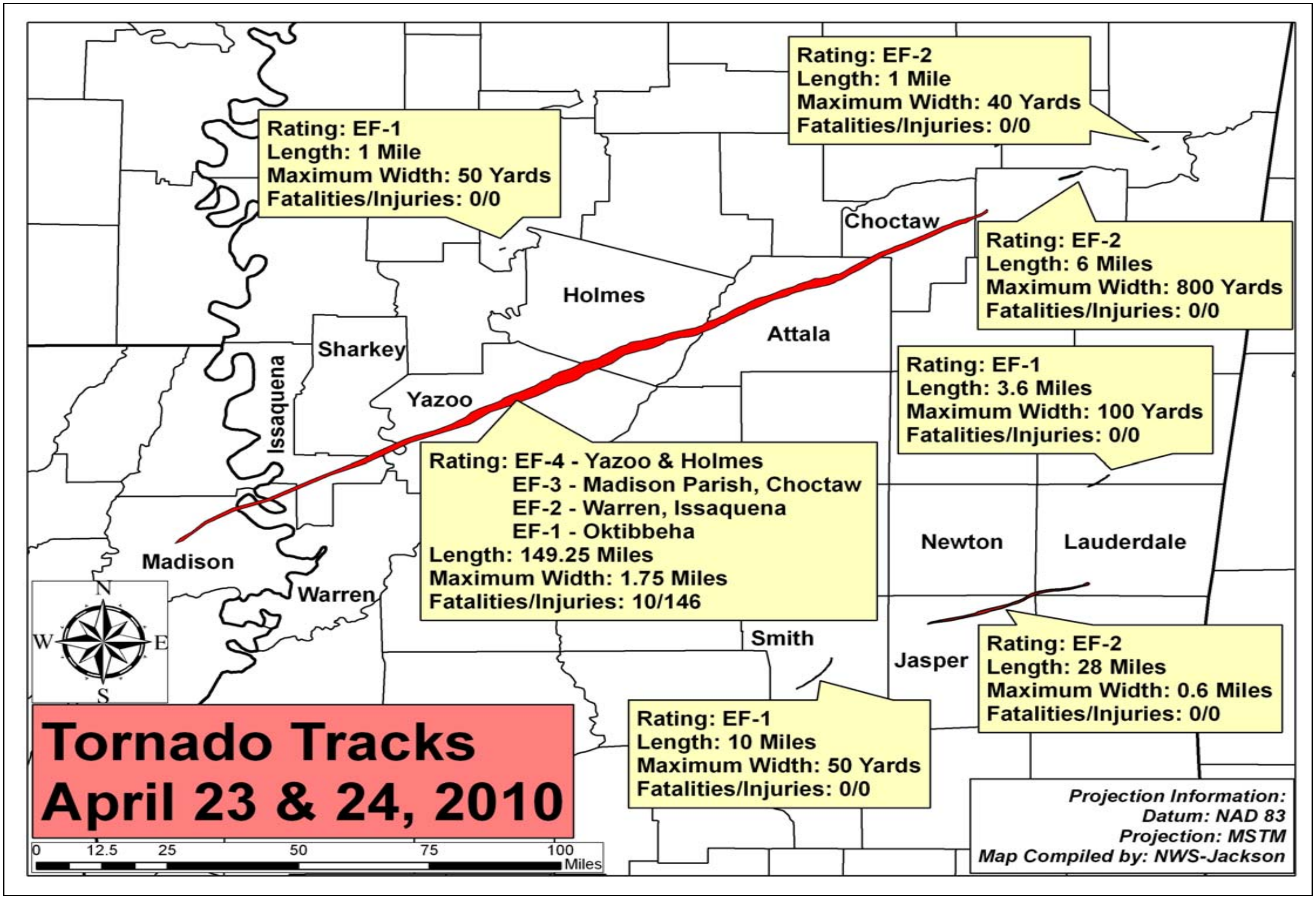
- There are a limited number of community safe rooms in the central part of the State. Information provided by MEMA shows that the majority of community safe rooms are in the northern and southern parts of the State.
- Though the concrete septic safe rooms would have provided some level of safety to occupants, the lack of lighting, the difficulty of door locking, and the inconsistent use of anchors resulted in a lack of confidence by the potential users.
- Based on interviews with officials and people in the area, the PMAT believes that the presence of the community safe rooms is unknown to the local populace.
- No information could be found regarding the existence or location of the operations plan for the community safe rooms.
- The observed community safe rooms appear to be two residential FEMA 320 safe rooms placed side by side.

Recommendations based on the PMAT observations include the following:

1. Documentation or labels should be provided by the designer to indicate that the safe rooms comply with the FEMA 320/361 safe room criteria.
2. Only products that have been tested to meet the FEMA 320/361 requirements should be accepted by the FEMA grant programs. Alternatively, only safe rooms that are constructed onsite using tested materials or materials identified in FEMA 320/361 should be accepted by the FEMA grant programs.
3. Documentation on the adequacy of foundations for pre-manufactured safe rooms could not be identified. This is a deficiency that should be addressed by the designer, as a safe room that would otherwise meet the FEMA criteria may be unable to withstand anticipated winds.
4. An effort should be made by FEMA and MEMA to conduct additional outreach and training for safe room owners, especially for belowground safe rooms, to coordinate in advance by letting other people (i.e., neighbors) and appropriate organizations (i.e., local police, fire, emergency management, etc.) know of the safe room's existence and having proper communications equipment such as a cellular phone or Citizen's Band (CB) radio in the safe room. In the event a safe room occupant is trapped, he or she can call for help from within.
5. An effort should be made by FEMA and MEMA to conduct additional outreach and training for homeowners and local officials of the benefits and safety of aboveground and in-home safe rooms. Existing FEMA educational references and programs could be beneficial in this effort.
6. An effort should be made by FEMA and MEMA to conduct additional outreach and training for local engineers, architects, manufacturers, installers, and sellers on the design and installation of all types of safe rooms.
7. Community shelters installed with Federal funding should meet the FEMA 361 criteria. FEMA 361 community safe rooms should be accessible, have proper lighting, and have locking devices that are easily operated. Citizens should be informed by MEMA and local communities of the location and availability of community safe rooms they can use.

# Appendix A

# Tornado Path




National Weather Service Map of Tornado Path and Damage Swath

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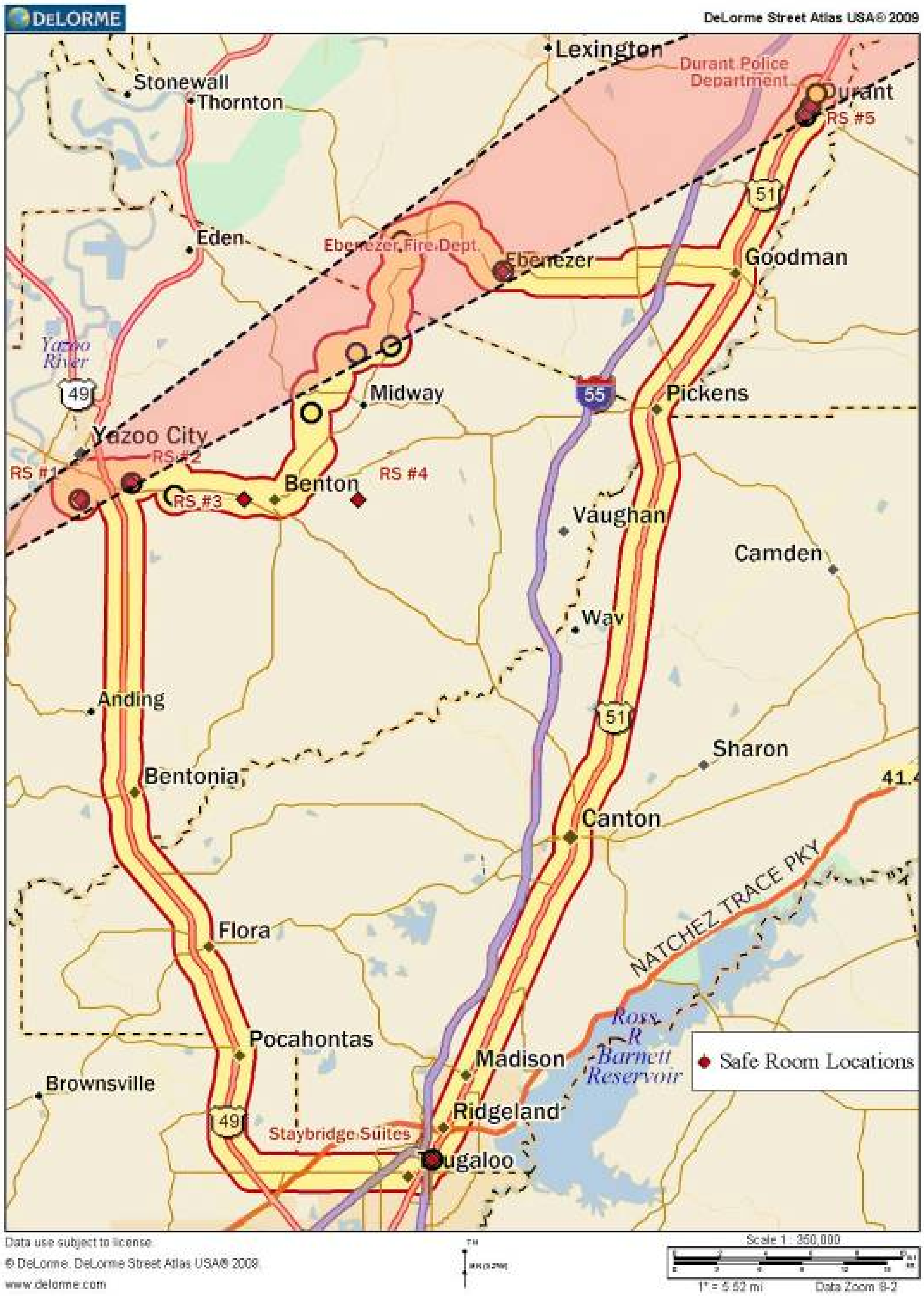
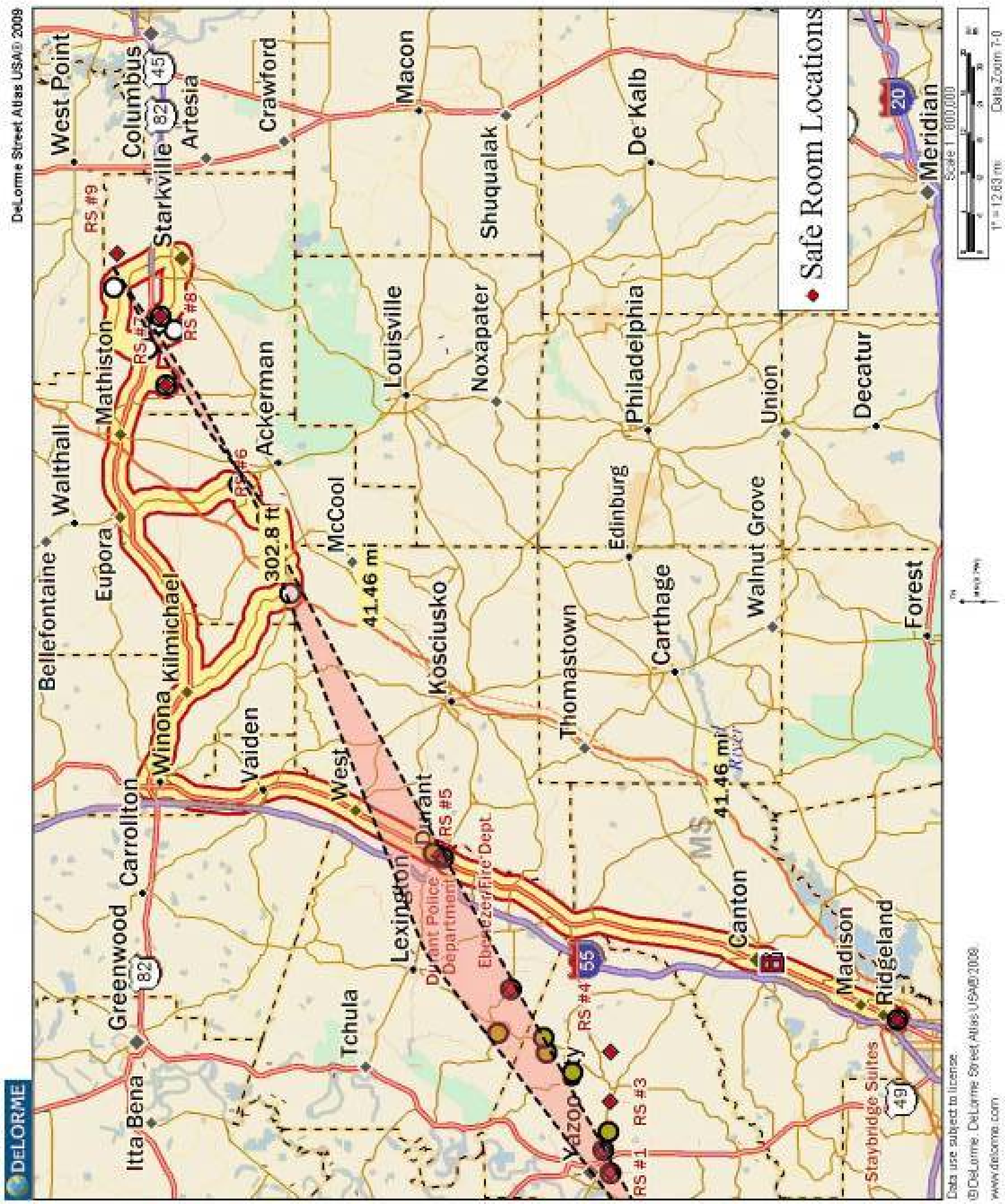
# Appendix B

# Sites Visit Map and Tables




**PMAT Day 1 – Route**

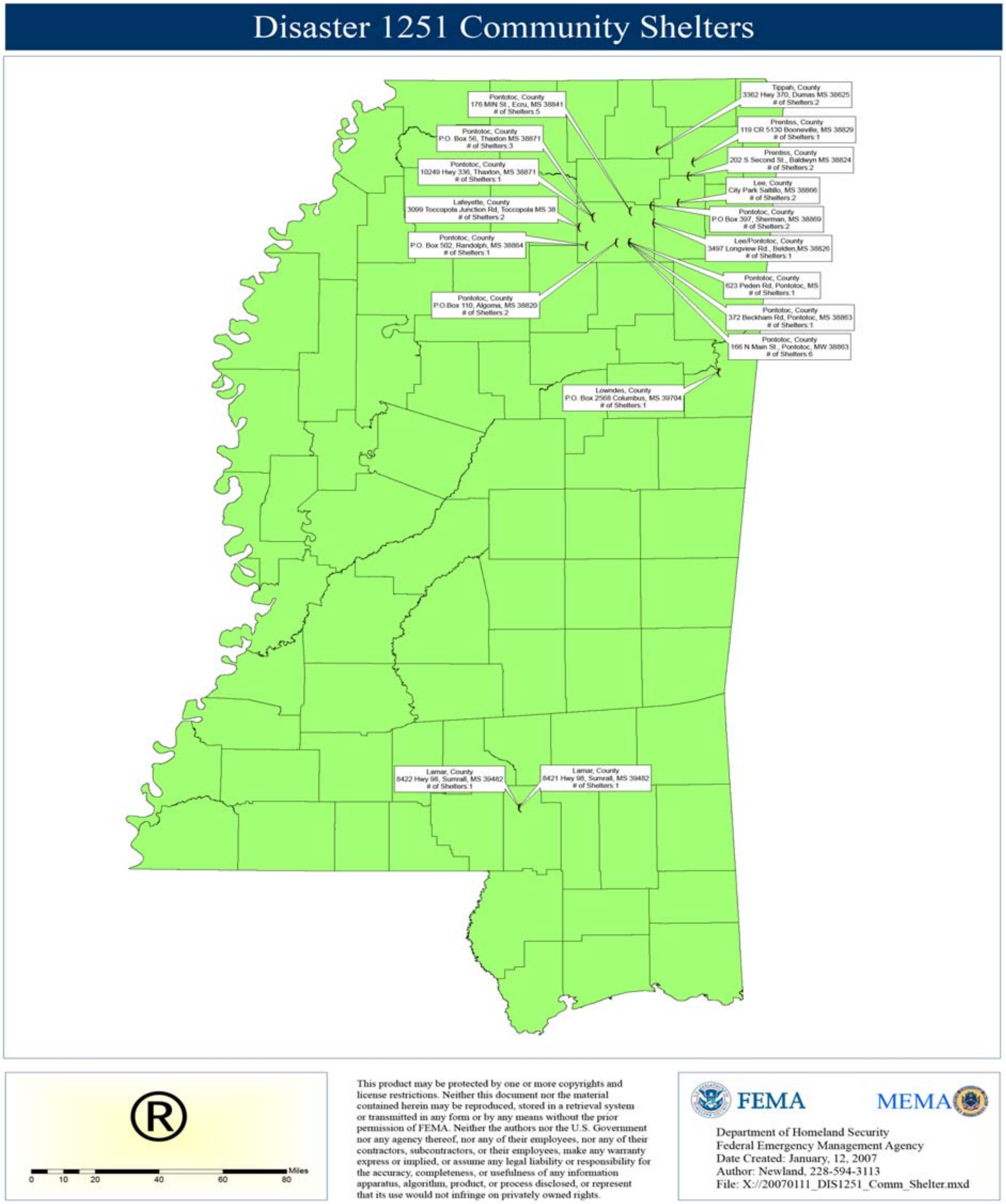



PMAT Day 2 – Route

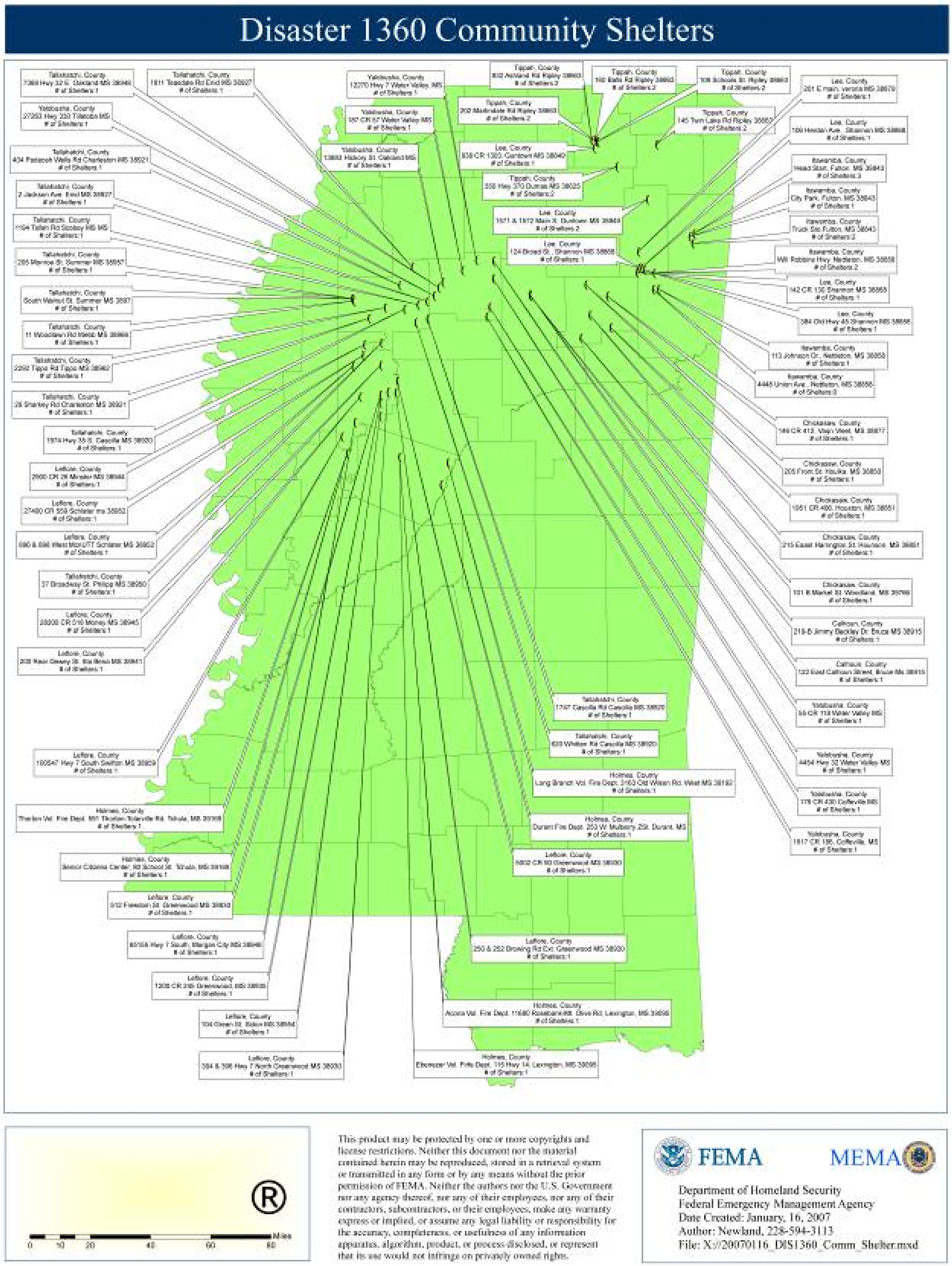
**Federally Funded Residential Safe Rooms for Choctaw, Yazoo, and Holmes Counties under DR-1604**

Page B-3 contains a list of addresses, latitude and longitude coordinates, and total and federal share values for residential safe rooms in Choctaw, Holmes, and Yazoo counties, funded under DR-1604.

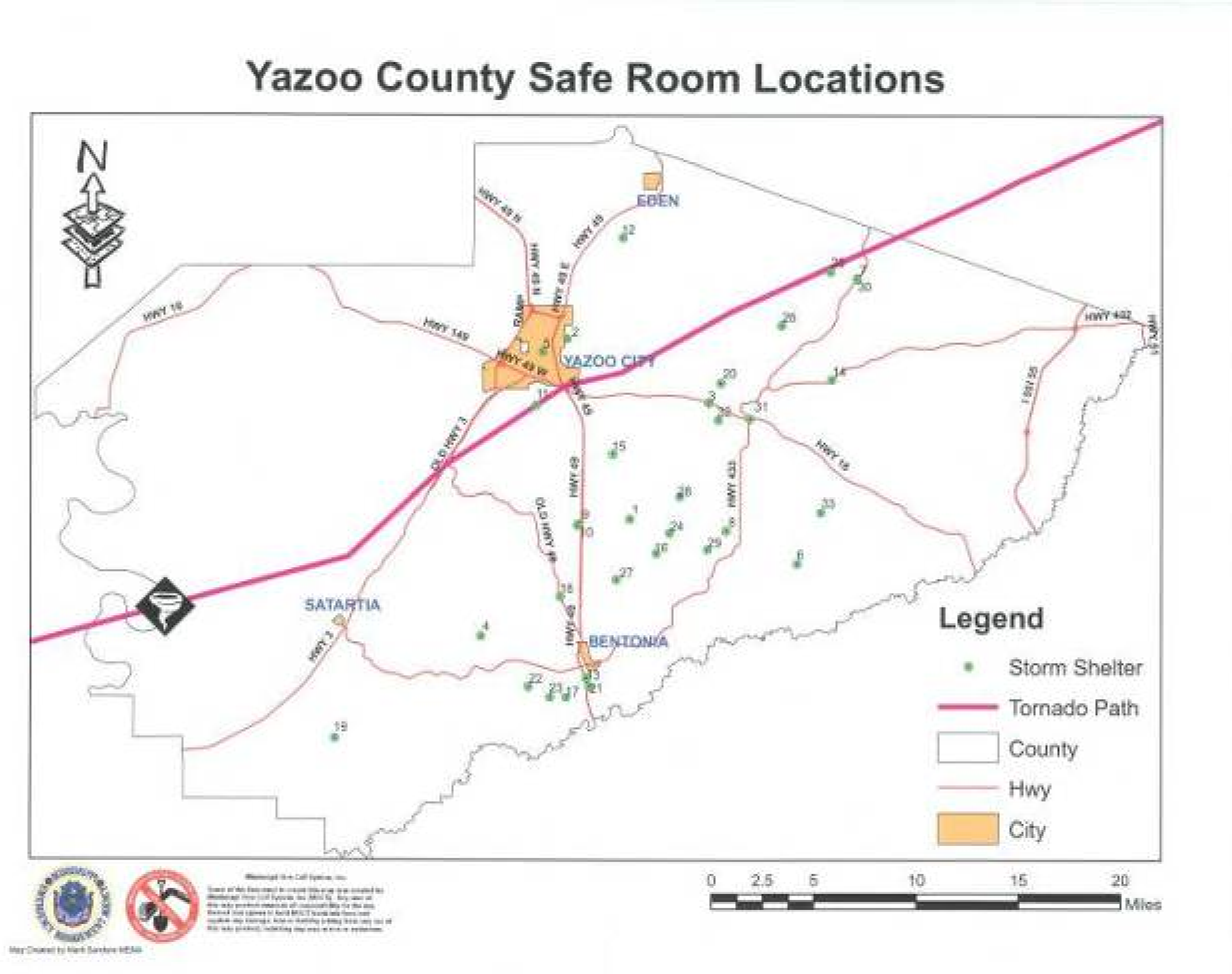
**PAGE B-3 IS NOT INCLUDED IN THE REPORT VERSION FOR PUBLIC RELEASE DUE TO PRIVACY ISSUES.**




**FEMA 361 Community Safe Rooms Funded by DR-1251**




**FEMA 361 Community Safe Rooms Funded by DR-1360**




**Residential Safe Room Locations in Yazoo County, Provided by MEMA**

# Appendix C

# MS Safe Room Details

# Summary of Safe Room Details

Appendix C contains a table outlining the safe room details for each residential and community safe room observed during the PMAT. The table includes the following characteristics about each safe room: disaster number, type, address, latitude and longitude coordinates, interior dimensions, construction material, above or below ground, approximate distance to home, door types, adequate ventilation, and flood zones.

**APPENDIX C IS NOT INCLUDED IN THE REPORT VERSION FOR PUBLIC RELEASE DUE TO PRIVACY ISSUES.**

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# Appendix D

# FEMA 361 Design Tables

## FEMA 361 – Wind Safe Room and Shelter Design Codes, Standards, and Guidance Comparison

| Title or Name of Document[1] | Code, Regulation, Standard, or Publication | Wind Hazard | Wind Map | Wind Design Coefficient Considerations[3,4] | Debris Impact Criteria[5] | Remarks |
|---|---|---|---|---|---|---|
| FEMA Safe Room Publications:<br>FEMA 320, *Taking Shelter From the Storm: Building a Safe Room For Your Home or Small Business* (2008)<br>FEMA 361, *Design and Construction Guidance for Community Safe Rooms* (2008) | FEMA guidance document, not a code or standard. "Best Practice" for extreme-wind safe rooms. | Tornado and Hurricane | **FEMA 320:** Hazard map, maximum wind hazard speed of 250 mph used for design.<br>**FEMA 361, Tornado:** Map with four wind speed zones for design (wind MRI[2] is 10,000–100,000 years). This map is often referred to as the "FEMA 361 map."<br>**FEMA 361, Hurricane:** Uses ICC-500 hurricane map. | FEMA 320: Use 250 mph and calculate pressures using ASCE 7-05 methods and use I=1.0, $K_d$=1.0, Exposure C, no topographic effects, $GC_{pi}$=+/-0.55 (this will account for atmospheric pressure change [APC]).<br>FEMA 361, Tornado: Use FEMA 361 wind speed map with four zones. Calculate pressures using ASCE 7-05 methods and use I=1.0, $K_d$=1.0, Exposure C, no topographic effects, $GC_{pi}$=+/-0.55 (this will account for APC).<br>FEMA 361, Hurricane: Use ICC-500 process, but also must use Exposure C and design building using $GC_{pi}$=+/-0.55. | FEMA 320: Test all safe rooms with the representative missile: a 15-lb 2x4 at 100 mph (horizontal) and 67 mph (vertical).<br>FEMA 361: Test safe rooms with representative missile (missile speed dependent on site design wind speed).<br>Tornado: 15-lb 2x4 at 80–100 mph (horizontal) and 2/3 of this speed (vertical). Hurricane: 9-lb 2x4 at 80-128 mph (horizontal) and 16-26 mph (vertical). | FEMA 320: Intent is to provide "near-absolute protection" with prescriptive designs that meet the highest hazard design criteria for both tornadoes and hurricanes.<br>FEMA 361: Intent is to provide "near-absolute protection" through appropriate design and construction guidance. Design criteria for features such as debris impact-resistance, flood hazard-resistance, and operational criteria are more conservative than criteria in the ICC-500. Safe room operations guidance is provided. Occupancy issues addressed. Wall section details provided. Building evaluation checklist provided.<br>Notes: (1) Does not require the design and construction of safe rooms, but provides criteria for doing so. (2) FEMA does not provide safe room certification or product approvals. |
| International Code Council/National Storm Shelter Association (ICC/NSSA) *Standard for the Design and Construction of Storm Shelters* (ICC-500, August 2008) | Consensus standard for shelter design and construction, tentatively available for adoption in 2008. To be incorporated by reference into the 2009 IBC and IRC. | Tornado and Hurricane | **Tornado:** Uses FEMA 361 map.<br>**Hurricane:** Uses revised ASCE 7-05 map with contours at 10,000-year MRI[2] with minimum shelter design wind speed of 160 mph, maximum approximately 255 mph. | Tornado: Use FEMA 361 wind speed map. Calculate pressures using ASCE 7-05 methods and use I=1.0, $K_d$=1.0, Exposure as appropriate, no topographic effects, $GC_{pi}$=+/-0.55 or +/-0.18+APC.<br>Hurricane: Use revised ASCE 7-05 map and methods and use I=1.0, special definitions for enclosure classification, all other items as per ASCE 7-05, no APC consideration required. | Test safe rooms with representative missile (missile speed dependent on site design wind speed):<br>Tornado: 15-lb 2x4 at 80–100 mph (horizontal) and 2/3 of this speed (vertical). Hurricane: 9-lb 2x4 at 64–102 mph (horizontal) and 16-26 mph (vertical) | Intent is to provide a standard for the design and construction of extreme-wind shelters. Will not use term "near-absolute protection." Occupancy, ventilation, and use issues are also addressed.<br>Notes: (1) The standard does not require the design and construction of shelters, but provides criteria for doing so. (2) The ICC-500 does not provide shelter or shelter component certifications, but rather defines the procedure by which testing must be performed to be certified and define what type of laboratory certification is required. |
| Florida State Emergency Shelter Program (SESP) – Florida Interpretation of the American Red Cross (ARC) 4496 Guidance. Note: shelters in this category will range from Enhanced Hurricane Protection Area (EHPA) recommended design levels, shown in this row, to the code requirement levels (next row), to the ARC 4496 requirements (see below). | Guidance in the FBC "recommending" above-code requirements for EHPAs. See also Appendix G of the SESP report for the detailed design guidance. | Tornado and Hurricane | **Florida Building Code (FBC)** map +40 mph recommended, based on ASCE 7-05 (maps basically equivalent); MRI is 50–100 years in coastal areas and adjusted with importance factor. | Recommends that designer add 40 mph to basic wind speed from map, Exposure C, I=1.15, $K_d$=0.85, $GC_{pi}$ as required by design (typically +/-0.18), but recommends +/-0.55 for tornado shelter uses. | In windborne debris region (120 mph+): Small – pea gravel; Large – 9-lb 2x4 at 34 mph (horizontal), up to 60 feet above grade, but recommends 15-lb 2x4 at 50 mph (horizontal). | The building, or a portion of a building, is defined as an essential facility and as a shelter. Designer is required to submit a signed/sealed statement to building department and state offices stating the structure has been designed as a shelter (EHPA plus added recommended criteria). |
| Florida Building Code EHPAs – code requirements for public "shelters" (FBC Section 423.25) | Statewide code requirements for EHPAs | Hurricane | **FBC map**, based on ASCE 7-05 (maps basically equivalent); MRI is 50–100 years in coastal areas and adjusted with importance factor. | Use basic wind speed at site as identified on FBC wind speed map, use exposure at site, use I=1.15, $K_d$=0.85, $GC_{pi}$ as required by design (typically +/-0.18). | In windborne debris region: Small – pea gravel; Large – 9-lb 2x4 at 34 mph (horizontal), up to 60 feet above grade. | The building or a portion of a building is defined as an essential facility and as an EHPA. Designer is required to submit a signed/sealed statement to building department and state offices stating the structure has been designed as an EHPA. |
| FBC 2000 and later International Building Code (IBC)/ International Residential Code (IRC 2000) and later/ ASCE 7-98 and later. | Building code and design standards for regular (non-shelter) buildings. Some additional guidance is provided in the commentary. | Hurricane | ASCE has its own wind speed map based on historical and probabilistic data; MRI is 50–100 years in coastal areas and adjusted with importance factor. | Method is the basis of most wind pressure calculation methods. All items in design process are site-specific. Use I=1.15 for critical and essential facilities. | In windborne debris region: Small – pea gravel; Large – 9-lb 2x4 at 34 mph (horizontal), up to 60 feet above grade.<br>Note: FBC, IBC, and ASCE 7-05 require the 9-lb 2x4 (large) missile to be tested at 55 mph for critical and essential facilities. | Code requires increased design parameters only for buildings designated as critical or essential facilities. For improved performance of residential buildings (but not life-safety protection), design criteria and prescriptive solutions can be found in ICC-6, *Standard for Residential Construction in High Wind Regions* (Fall 2008) |
| American Red Cross (ARC 4496) *Standards for Hurricane Evacuation Shelter Selection* | Guidance for identifying buildings to use as hurricane evacuation shelters | Hurricane | None | None | None | Provides guidance on how to select buildings and areas of a building for use as a wind shelter or refuge area during wind events. Does not provide or require a technical assessment of the proposed shelter facility. |
| Pre-2000 Building Codes | Building code and design standards for regular (non-shelter) buildings | Hurricane | Each of the older codes used their own published wind contour maps. | Typically these older codes provided a hurricane regional factor for design wind speeds, but little attention was paid to components and cladding. | Not required for all buildings. Where required, the Standard Building Code (SBC)[6] developed and recommended debris impact standards for use in hurricane-prone regions. | These codes specified limited hazard-resistant requirements. Some guidance was provided with SSTD 10 from SBCCI for the design and construction of buildings in extreme-wind and hurricane-prone regions. Buildings constructed to these early codes were not required to have structural systems capable of resisting wind loads. |
| Refuge Areas of Last Resort | Guidance from FEMA and others for selecting best-available refuge areas | Tornado and Hurricane | None | None | None | Best available refuge areas should be identified in all buildings without shelters. FEMA 431, *Tornado Protection: Selecting Refuge Areas in Buildings*, provides guidance to help identify the best available refuge areas in existing buildings. Because best available refuge areas are not specifically designed as shelters, their occupants may be injured or killed during a tornado or hurricane. |

Notes:

1. The wind shelter guidance and requirements shown here are presented from highest to least amount of protection provided.
2. Mean recurrence intervals (MRIs) for wind speeds maps are identified by the code or standard that developed the map. Typically, the MRI for non-shelter construction in non-hurricane-prone areas is 50 years and in hurricane-prone regions, approximately 100 years.
3. ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures* (2005) is the load determination standard referenced by the model building codes. The wind design procedures used for any shelter type in this table use one of the wind design methods as specified in ASCE 7-05, but with changes to certain design coefficients that are identified by the different codes, standards, or guidance summarized in this table.
4. From ASCE 7-05 method: I = importance factor; $K_d$ = wind directionality factor; $GC_{pi}$ = internal pressure coefficient.
5. Roof deck, walls, doors, openings, and opening protectives must all be tested to show resistance to the design missile for the FEMA, ICC, and FL EHPA criteria.
6. From the Southern Building Code Congress International, Inc. (SBCCI).

**FEMA 361 – Wind Safe Room and Shelter Design Values Comparison**

| Shelter Design Standard, Code, or Document | Data[1] | Example Location #1: Miami, Florida Tornado and Hurricane Hazards | Example Location #2: Galveston, Texas Tornado and Hurricane Hazards | Example Location #3: Greenburg, Kansas Tornado Hazards |
|---|---|---|---|---|
| FEMA 361 | Design wind speed | 200 mph (tornado)<br>225 mph (hurricane) | 200 mph (tornado)<br>160 mph (hurricane) | 250 mph (tornado) |
| | Pressure on windward wall[2] | 107 psf (tornado)<br>136 psf (hurricane) | 107 psf (tornado)<br>69 psf (hurricane) | 167 psf (tornado) |
| | Pressure on roof section[2] | 257 psf (tornado, suction)<br>325 psf (hurricane, suction) | 257 psf (tornado, suction)<br>202 psf (hurricane, suction) | 401 psf (tornado, suction) |
| | Test missile momentum at impact[2] | 62 $lb_f$-s (tornado)<br>46 $lb_f$-s (hurricane) | 62 $lb_f$-s (tornado)<br>33 $lb_f$-s (hurricane) | 68 $lb_f$-s (tornado) |
| ICC-500[3] | Design wind speed | 200 mph (tornado)<br>225 mph (hurricane) | 200 mph (tornado)<br>160 mph (hurricane) | 250 mph (tornado) |
| | Pressure on windward wall[2] | 107 psf (tornado)<br>136 psf (hurricane) | 107 psf (tornado)<br>69 psf (hurricane) | 167 psf (tornado) |
| | Pressure on roof section[2] | 257 psf (tornado, suction)<br>325 psf (hurricane, suction) | 257 psf (tornado, suction)<br>202 psf (hurricane, suction) | 401 psf (tornado, suction) |
| | Test missile momentum at impact[2] | 62 $lb_f$-s (tornado)<br>36 $lb_f$-s (hurricane) | 62 $lb_f$-s (tornado)<br>26 $lb_f$-s (hurricane) | 68 $lb_f$-s (tornado) |
| FBC EHPA/SESP Recommend Criteria (using basic wind speed + 40 mph) | Design wind speed | 186 mph | 130 mph | N/A |
| | Pressure on windward wall[2] | 91 psf | 44 psf | N/A |
| | Pressure on roof section[2] | 217 psf (suction) | 106 psf (suction) | N/A |
| | Test missile momentum at impact[2] | 34 $lb_f$-s | 14 $lb_f$-s | N/A |
| FBC EHPA (Required per FBC Section 423.25) | Design wind speed | 146 mph | N/A | N/A |
| | Pressure on windward wall[2] | 39 psf | N/A | N/A |
| | Pressure on roof section[2] | 117 psf (suction) | N/A | N/A |
| | Test missile momentum at impact[2] | 14 $lb_f$-s | N/A | N/A |
| ASCE 7-05/IBC 2006 (ASTM E 1996) | Design wind speed | 150 mph | 105 mph | 90 mph |
| | Pressure on windward wall[2] | 41 psf | 18 psf | 15 psf |
| | Pressure on roof section[2] | 124 psf (suction) | 52 psf (suction) | 44 psf (suction) |
| | Test missile momentum at impact[2] | 14 $lb_f$-s | Not required | Not required |
| ARC 4496 | Design wind speed | Not specified | Not specified | Not specified |
| | Pressure on windward wall[2] | Not specified | Not specified | Not specified |
| | Pressure on roof section[2] | Not specified | Not specified | Not specified |
| | Test missile momentum at impact[2] | Not specified | Not specified | Not specified |
| Pre-2000 Building Codes | Design wind speed | 140 mph and less | 90 mph and less | 90 mph and less |
| | Pressure on windward wall[2] | < 40 psf (varies) | < 15 psf (varies) | < 15 psf (varies) |
| | Pressure on roof section[2] | < 120 psf (varies) | < 45 psf (varies) | < 45 psf (varies) |
| | Test missile momentum at impact[2] | Not required by all codes | Not required | Not required |
| Refuge Areas of Last Resort | Design wind speed | Unknown | Unknown | Unknown |
| | Pressure on windward wall[2] | Unknown | Unknown | Unknown |
| | Pressure on roof section[2] | Unknown | Unknown | Unknown |
| | Test missile momentum at impact[2] | Not required | Not required | Not required |

Notes:

1. Wind pressures were calculated based on a 40-foot x 40-foot building, with a 10-foot eave height and a 10-degree roof pitch.
2. psf – pounds per square foot; $lb_f$-s – pounds (force) seconds.
3. ICC-500 Hurricane design criteria used the most restrictive case that may be appropriate, which results in the use of $GC_{pi}$=+/-0.55 and Exposure Category C at the site.

## FEMA 361 – Comparison of Debris Impact Test Requirements for Tornadoes and Hurricanes

| Guidance, Code, or Standard Criteria for the Design Missile | Horizontal Debris Impact Test Speed (mph) | Large Missile Specimen | Momentum at Impact ($lb_f$-s)+ | Energy at Impact (ft-$lb_f$)+ |
|---|---|---|---|---|
| **Tornado Safe Room Missile Testing Requirements** | | | | |
| DOE-STD-1020-2002 | 25 mph<br>75 mph<br>150 mph (maximum)<br>100 mph (minimum) | 3,000-lb auto<br>75-lb pipe<br>15-lb 2x4<br>15-lb 2x4 | 3,240<br>257<br>103<br>68 | 67,710<br>14,110<br>11,288<br>5,017 |
| FEMA 320/FEMA 361 | 100 (maximum)<br>80 (minimum) | 15-lb 2x4<br>15-lb 2x4 | 68<br>55 | 5,017<br>3,210 |
| ICC-500 Storm Shelter Standard | 100 (maximum)<br>80 (minimum) | 15-lb 2x4<br>15-lb 2x4 | 68<br>55 | 5,017<br>3,210 |
| IBC/IRC 2006, ASCE 7-05, Florida and North Carolina State Building Codes, ASTM E 1886/ E 1996 | N/A | None | N/A | N/A |
| **Hurricane Safe Room Missile Testing Requirements*** | | | | |
| DOE-STD-1020-2002 | 50 | 15-lb 2x4 | 34 | 1,254 |
| FEMA 320/FEMA 361 | 128 (maximum)<br>80 (minimum) | 9-lb 2x4<br>9-lb 2x4 | 53<br>33 | 4,932<br>1,926 |
| ICC-500 Storm Shelter Standard | 102 (maximum)<br>64 (minimum) | 9-lb 2x4<br>9-lb 2x4 | 42<br>26 | 3,132<br>1,233 |
| Florida State Emergency Shelter Program (SESP) Criteria and EOC Design Criteria | 50 (EOC recommended)<br>55 (EHPA recommended)<br>34 (EHPA minimum) | 15-lb 2x4<br>9-lb 2x4<br>9-lb 2x4 | 34<br>23<br>14 | 1,254<br>911<br>348 |
| IBC/IRC 2006, ASCE 7-05, Florida and North Carolina State Building Codes, ASTM E 1886/ E 1996* | 55<br>34 | 9-lb 2x4<br>9-lb 2x4 | 23<br>14 | 910<br>348 |

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# Appendix E

# Safe Room References, Links, and Resources

## Contacts:

FEMA Safe Room Helpline: saferoom@dhs.gov
866.222.3580

TTU Subject Matter Expert and Debris Impact Testing Lab: TTU Ernst Kiesling
Ernst.Kiesling@ttu.edu

## References:

American Red Cross: http://www.redcross.org

American Society of Civil Engineers (ASCE): http://www.asce.org/

Building Your Safe Room: http://www.fema.gov/library/viewRecord.do?id=1732

Department of Homeland Security (DHS) Emergency Planning and Preparation Guidance: http://www.Ready.gov

FEMA: http://www.fema.gov

FEMA 320, *Taking Shelter from the Storm: Building a Safe Room Inside Your House*, Third Edition: http://www.fema.gov/plan/prevent/saferoom/fema320.shtm

FEMA 361, *Design and Construction Guidance for Community Safe Rooms*, Second Edition: http://www.fema.gov/plan/prevent/saferoom/fema361.shtm

FEMA 431, *Tornado Protection: Selecting Refuge Area in Buildings*, Second Edition: http://www.fema.gov/hazard/tornado/fema431.shtm

FEMA 453, *Design Guidance for Shelters and Safe Rooms:* http://www.fema.gov/plan/prevent/rms/rmsp453.shtm

FEMA Flood Maps: http://www.fema.gov/hazard/map/flood.shtm

FEMA Safe Rooms: http://www.fema.gov/plan/prevent/saferoom/index.shtm

National Oceanic and Atmospheric Administration Coastal Services Center: http://www.csc.noaa.gov/

National Storm Shelter Association (NSSA): http://www.nssa.cc/

National Weather Service National Hurricane Center: http://www.nhc.noaa.gov/

Texas Tech University Wind Science and Engineering Research Center: http://www.wind.ttu.edu/