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The Parkersburg, IA Tornado: 25 May 2008

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1. Introduction

A large, destructive tornado moved across Butler and Black Hawk Counties in northeast Iowa traveling through the south end of Parkersburg on 25 May 2008 (Fig. 1). The tornado damaged or destroyed more than three hundred residences in addition to two bank buildings, a high school, and many other buildings. Seven people died.

Soon after the event, ground and aerial surveys were conducted by the authors in order to map the damage path and determine EF-scale ratings. Aerial photographs of Parkersburg damage from the Civil Air Patrol also were studied. We found that the maximum damage intensity to homes and other buildings was EF-5 with three second wind gusts at 10m estimated to be around 92 ms^{-1}. This paper will present how the EF-scale ratings were determined from the analysis of building damage. Difficulties in rating homes arose since several homes were not anchored and slid off their foundations. Also, there was significant clean-up of debris within one to two days after the tornado, even in the midst of inclement weather. Correlations were made between the degree of building damage and the performance of vehicles in order to provide information on whether vehicles should be incorporated as a damage indicator in future revisions of the EF-scale.

Our damage survey revealed the tornado traveled east-northeast for approximately 70 km with 98 percent of the track traversing rural farmland. Spiral ground marks were observed in many fields where corn stubble had been gathered indicating this was a multi-vortex tornado. Complex flows were recorded in the corn stubble revealing sudden changes in the tornado's path and even one loop. Also, the diameter and shape of the spiral ground markings changed dramatically within a few tens of meters.

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Figure 1. Large "wedge-shaped" tornado east of Parkersburg. Photograph courtesy of Rod Donovan NWSFO/DSM.

2. Weather Situation

The supercell that produced the Parkersburg tornado developed late on the afternoon of 25 May 2008. The storm formed south of a surface low located over northern Minnesota, and beneath moderate west-southwesterly flow aloft. Forecasters originally focused near a triple point in south central Minnesota, but that focus quickly expanded south after 2000 Universal Time Code (UTC) as the environment became increasingly favorable for tornadoes over north central Iowa. Surface weather features of interest included a north-south oriented warm front through central Iowa (Fig. 2), and a cold front/dryline extending from the triple point into western Iowa and southeast Nebraska.

Weather conditions over central Iowa rapidly changed from cool, cloudy and humid during the morning, to the warmest, most humid afternoon of the spring season. Parkersburg residents commented that May 25th was the first humid, summerlike afternoon of the year. Marshalltown, Iowa (60 km south of Parkersburg) for example, changed from a temperature of 15 °C and a dew point of 13°C at 1200 UTC, to 29°C over 21°C at 2100 UTC with a south wind gusting to 13 ms^{-1}.

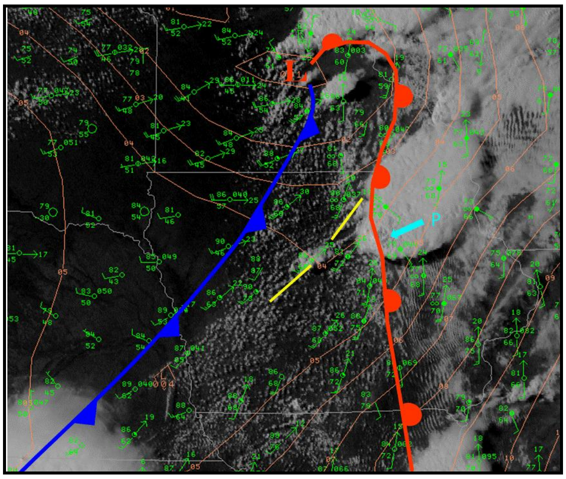

Figure 2. Visible satellite image at 2200 UTC with surface observations and fronts depicted. The supercell that produced the Parkersburg, IA tornado is shown by the blue arrow.

A cluster of thunderstorms rapidly developed at 2000 UTC near Fort Dodge, Iowa (KFOD) within the northern end of the axis of highest instability. At this location, the 100 mb mixed layer Convective Available Potential Energy (CAPE) was near 3000 J kg^{-1}. This development was not anchored on the warm front or cold front, but appeared to be associated with a pre-frontal trough dividing much of the warm sector from a zone of deeper mixing and decreasing surface dew points to its northwest. Storms at the southern end of the cluster quickly moved to the instability gradient at the northeast periphery of the instability axis. Interaction with the north-south oriented warm front began after 2100 UTC. The ensuing supercell thunderstorm remained tied to the north-south boundary as the tornado reached EF-5 intensity around 2200 UTC.

Mesoanalysis fields from 25 May 2008 showed that numerous thermodynamic and wind shear values were well within the range of concern for strong and violent tornadoes, according to the research of Rasmussen (2003), Edwards et al. (2003), Davies (2002) and others. For example, 100 mb mixed layer CAPE in the vicinity of Parkersburg increased from 2300 J kg^{-1}at 2000 UTC to 3000 J kg^{-1}at 2200 UTC as the tornado was occurring (Fig. 3). Convective Inhibition (CIN) was less than 30 J kg^{-1} and the Level of Free Convection (LFC) heights were less than 1500 m. Bulk shear in the 0-6 km layer was 28 m s^{-1} (55 kt), and in the 0-1 km layer the shear increased to 14 m s^{-1} (25-30 kt) by 2200 UTC.

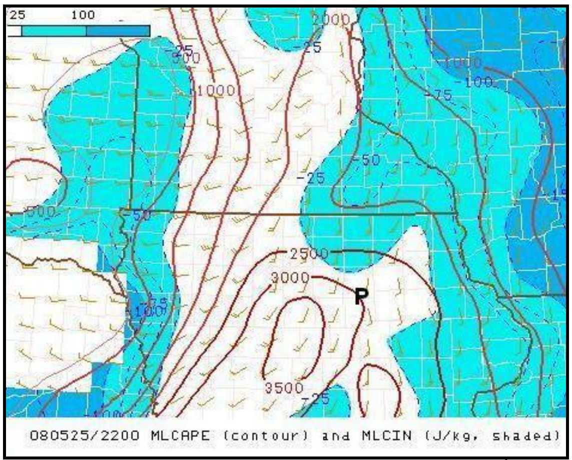

Figure 3. Plot of mean layer CAPE in J kg^{-1} over northern Iowa at 2200 UTC, at the time of the Parkersburg ("P" on diagram) tornado.

Storm-relative helicity (SRH) in the 0-1 km layer increased from 140 m^2 s^{-2} at 2000 UTC to over 210 m^2 s^{-2} at 2200 UTC due to backing in the surface layer winds ahead of the Parkersburg supercell (Fig. 4). In addition, a rapid update cycle (RUC) model proximity sounding for the grid point nearest Parkersburg at 2200 UTC exhibited steep low-level and mid-level lapse rates, and a hodograph with strong speed and directional shear below 1-3 km (Fig. 5). Southeast winds at the surface veered to west-southwest aloft.

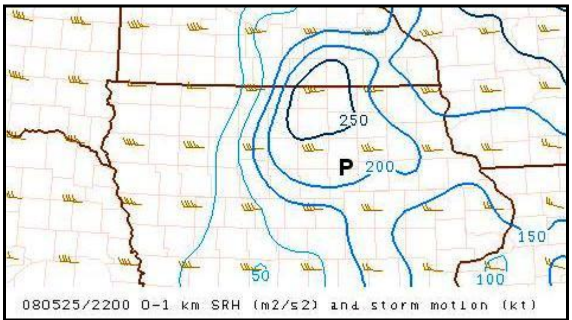

Figure 4. Plot of SRH in m^2 s^{-2} over northern Iowa at 2200 UTC, the time of the Parkersburg ("P" on diagram) tornado.

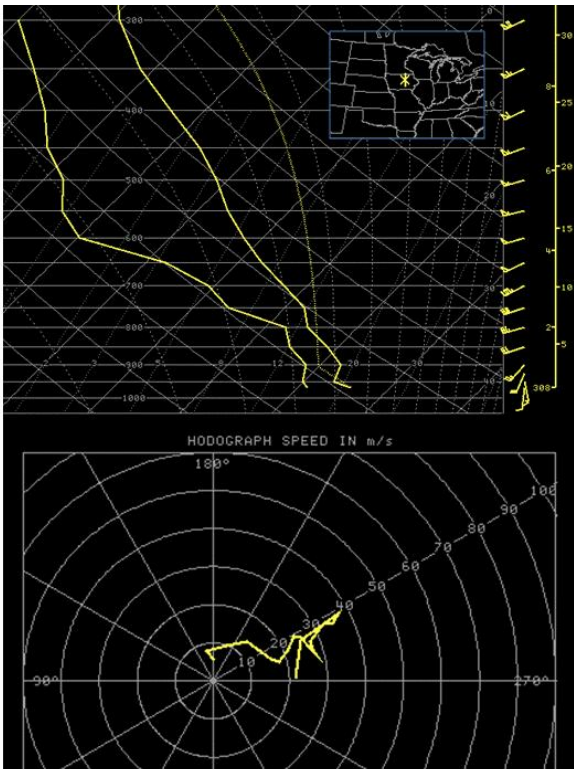

Figure 5. 2200 UTC RUC 00 hour analysis proximity sounding near Parkersburg, Iowa from the NWS AWIPS system.

3. Tornado Damage Path

Aerial and ground damage surveys revealed the tornado traveled east-northeast for approximately 70 km with 98 percent of the track traversing rural farmland (Fig. 6) and the remaining two percent going through the south end of Parkersburg. The initial touchdown occurred near the Butler and Grundy county lines, two miles south of Aplington and quickly grew in size and intensity as it approached Parkersburg. Spiral ground marks were first detected in an open field about 1 km west of Parkersburg. Corn stubble and other debris had been gathered in wind rows. The oblong shaped spirals were approximately 150 m long in the north-south direction. Fujita and Smith (1992) have documented numerous examples of such ground marks in corn fields.

The tornado entered the southwest corner of Parkersburg around 2156 UTC traveling eastward along Highway 57/14 destroying residences, businesses, two banks, and the high school along a 2 km path. The intensity of the tornado damage increased toward the east end of town as more and more debris was ingested into the tornado. A wind row of debris was noted in open corn fields east of town. The tornado then struck large grain silos filled with corn just east of Parkersburg before traveling through river bottoms uprooting and breaking hundreds of trees (Fig. 7).

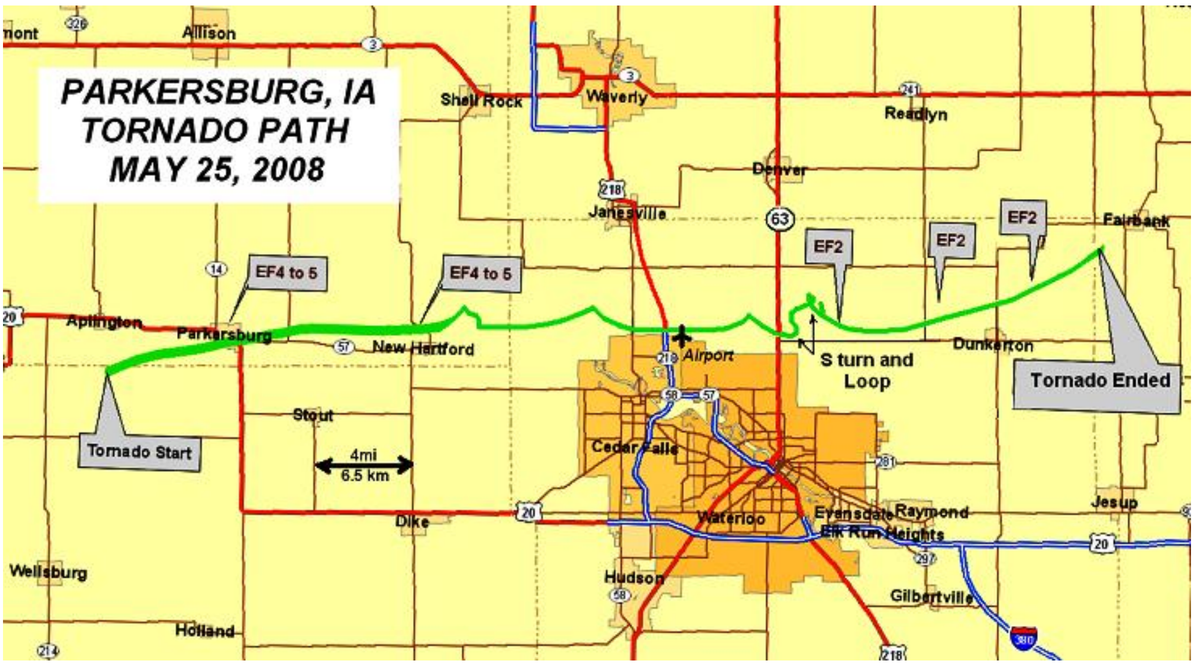

Figure 6. Track of the Parkersburg, IA tornado. Note the irregular shape to the path east of New Hartford.

Figure 7. Damage to grain silos filled with corn just east of Parkersburg.

The tornado maintained its size and intensity as it traveled just north of New Hartford completely destroying more than a dozen homes. Circular spiral ground marks were again observed in the corn stubble between Parkersburg and New Hartford and continued east of New Hartford. Then about 5 km east of New Hartford, the tornado path narrowed to about 100 m, then turned abruptly south, before resuming its east-northeast track. The tornado made two more abrupt turns to the southeast prior to reaching Highway 63 passing just north of the cities of Cedar Falls and Waterloo. After crossing the highway, the ground spirals tightened, and became oblong in shape. Then the tornado made an "S-shaped" turn to the north, before heading northeast (Fig. 8). Suddenly, the tornado widened, made a loop, and was joined by a satellite vortex, before heading southeast (Fig. 9). The tornado then resumed its east-northeast heading finally dissipating southwest of Fairbanks.

Figure 8. Aerial view showing the abrupt "S-shaped" turn in the tornado path to the north, just east of Highway 63. The tight spirals in the fields were made visible by the accumulation of corn stubble.

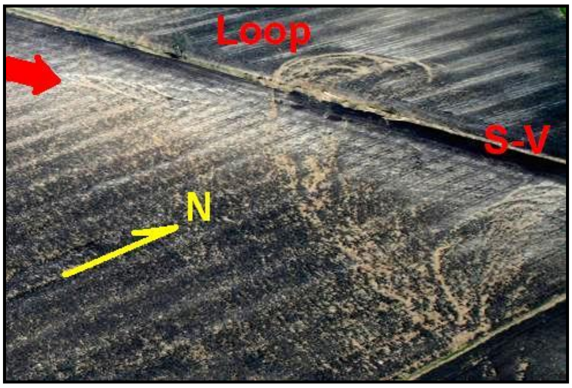

Figure 9. Aerial view showing a loop in the tornado path and merger of a satellite vortex (S-V) made visible by the accumulation of corn stubble.

4. Performance of wood-framed housing

EF-scale numbers were assigned to 370 houses based on increasing severity of the damage (Figs. 10 and 11). Degree of damage (DOD) descriptions were followed in accordance with those developed by the Wind Science and Engineering Center (2006). Homes were rated EF-0 if they had some damage to their roof coverings and/or lost some of their vinyl or metal siding (DOD=2). A rating of EF-1 was assigned to those homes that lost most of their roof covering and/or had minor structural damage to the roof such as displaced gable ends or loss of some roof decking (DOD=4). Homes were rated EF-2 if they had lost most of their roof structure but the walls remained standing (DOD=6). A rating of EF-3 was given to homes that lost most of their walls (DOD=8). An EF-4 rating was given to those homes that had all walls down and a pile of debris remaining on their foundations (DOD=9). EF-5 ratings were given to homes that were swept clean above their anchored floor platforms (DOD=10). These homes were found in the eastern portion of the damage path. The damage path did widen as the tornado exited town.

Figure 10. EF-scale ratings to wood-framed houses within the Parkersburg tornado damage path.

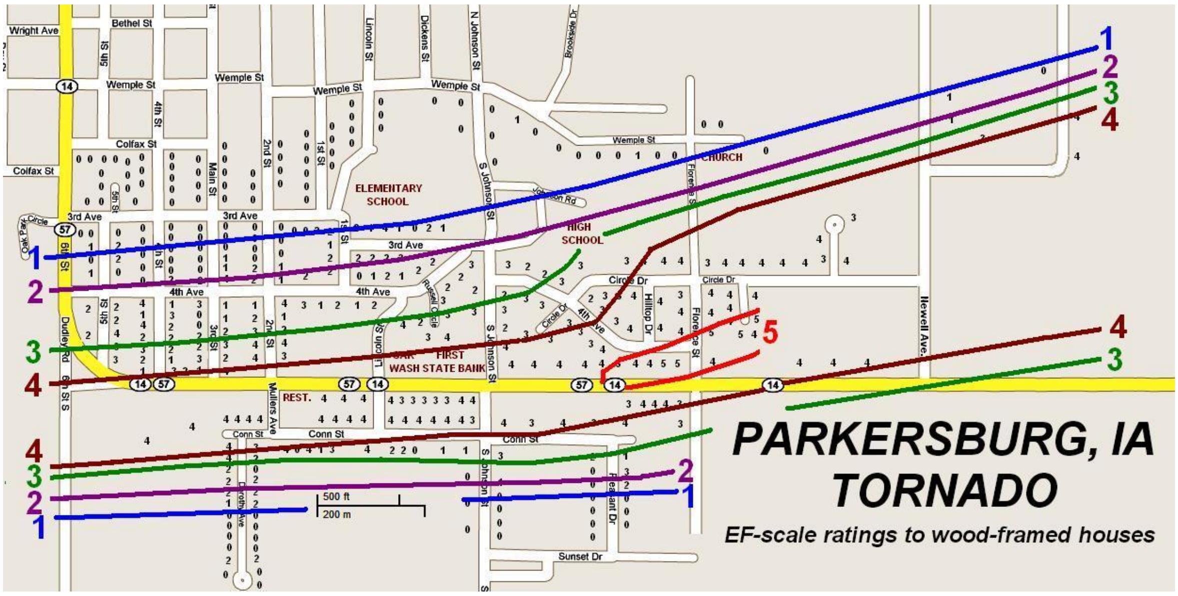

Figure 11. EF-scale ratings to 370 wood-framed houses in Parkersburg, IA.

Homes were typically built on top of concrete masonry unit (CMU) or poured concrete foundations (Fig. 12). A few old homes had rock foundations. Wood sill plates were usually secured to the foundation with J-bolts or straps. These bolts or straps were embedded into a grouted cell in the CMU. Wood floor joists were usually toe-nailed into the wood sills a plywood subfloor was nailed to the joists. Wood wall studs were straight-nailed to wood bottom plates; the plates were straight-nailed into the plywood subfloor. Failure of the home typically occurred where the wall studs and plates were straight-nailed into the floor leaving the floor platform intact. In some instances, the anchor bolts

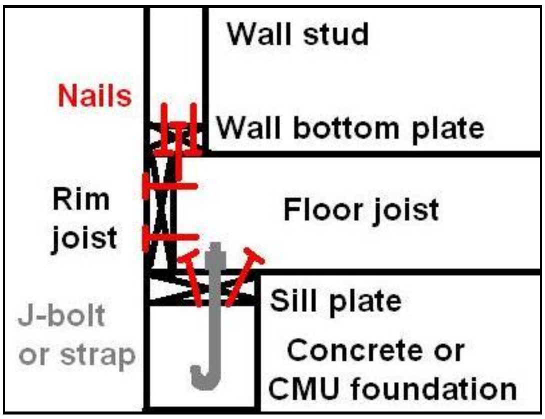

Figure 12. Typical foundation-wall cross section of Parkersburg home. Nails are indicated in red.

were pulled out of the CMU or the anchored CMU was dragged along with the floor. Such failures are common and have been described by Marshall et al. (2003). We found 33 homes that slid off their foundations. These homes were rated EF-2 or assigned an EF number of the adjacent home that did not slide off its foundation (Fig. 13).

Table 1 presents a summary of the EF-scale ratings to houses in the Parkersburg tornado. EF-0 damage occurred to 158 homes. These homes were located on the periphery along the north and south edges of the damage path. EF-1 damage occurred to 45 homes, while 66 homes had EF-2 damage. It was found that homes were more apt to lose the entire roof rather than a portion of the roof. A total of 57 homes were rated EF-3 and 96 homes were rated EF-4. Homes were more apt to have all walls down rather than a portion of the walls remaining upright. Seventeen homes had EF-5 damage.

TABLE 1
EF-SCALE RATINGS TO HOUSING

EF rating	Town	Rural	Homes	Percent
EF0	136	23	158	36
EF1	34	11	45	10
EF2	60	6	66	15
EF3	53	4	57	13
EF4	81	15	96	22
EF5	6	11	17	4
TOTAL	**370**	**70**	**440**	**100**

Figure 13. Unanchored home that slid off its CMU foundation was rated EF-2 due to loss of its roof.

The fact that homes were swept away did not by itself indicate EF-5 damage. Consideration was given to the type of foundation and anchorage, as well as the degree of the surrounding damage to homes and trees. We did notice that flying debris appeared to play a role in the degree of damage as the tornado traveled through town. Wind rows of fine debris were visible along the center line of the path which included bits of roof shingles, wood, corn stubble, and gravel (Fig. 14). Debris impact marks were observed on debarked trees in town. In rural areas, the tornado picked up wet top soil and corn stubble and plastered buildings, utility poles, and barbed wire fences up to 3 cm thick (Fig. 15).

Figure 14. Bits of roof shingles, wood, corn stubble, and gravel along the center line of the tornado damage path in Parkersburg. A quarter coin was added for size. Image from NWSFO/DSM.

Figure 15. Mud and corn stubble plastered barbed wire fence.

5. Vehicles

A total of 204 cars and "light" trucks were found within the damage path. Most of these vehicles had been parked adjacent to homes or along streets while other vehicles had been parked in garages. We compared the degree of damage to vehicles with residences. Refer to Table 2. Surprisingly, 103 vehicles, or 50 percent, had not moved. Even 29 percent of the vehicles had not moved when homes sustained EF-4 damage. However, the vast majority of vehicles had been breached by flying debris and would not have been safe havens in the tornado. Significant movement did occur in the majority of vehicles near homes that sustained EF-3 damage or greater. Rolled, tumbled, or lofted vehicles were rare.

TABLE 2
COMPARISION OF VEHICLE DAMAGE TO RESIDENTIAL DAMAGE

EF-rating of nearest house	No vehicle movement	Vehicle shifted laterally	Vehicle rolled or lofted
EF 0	15	2	0
EF 1	25	3	0
EF 2	28	9	0
EF 3	13	18	4
EF 4	22	46	9
EF 5	0	7	3
TOTAL	**103 (50%)**	**85 (42%)**	**16 (8%)**

6. Parkersburg Community High School

Parkersburg High School was a one-story structure that was oriented east-west except for the gymnasium which was two stories. Perimeter walls were constructed with CMUs with a brick masonry exterior. Open web steel roof joists were attached with steel straps to concrete bond beams atop the walls. The straps were welded to the tops of the joists (Fig. 16). The high school was located along the north edge of the tornado damage path with the strongest winds being from the north.

Two sections of the high school collapsed to the south. The north masonry wall on the west wing toppled inward at its base and the south masonry wall to fell outward (Fig. 17). A hinge line formed at the base of the both walls. In addition, the walls failed at window joints. Windows openings extended almost the full height of the walls and this interrupted the continuity of the walls. In addition, winds from the north broadsided the north wall loading the wall in its weakest direction.

Figure 16. Aerial view of the Parkersburg Community High School looking north. The west wing and gymnasium (outlined) collapsed.

Figure 17. Collapsed north wall on the west wing of the high school. The wall collapsed about a hinge line at the base of the wall. Tall window openings (circled) created weak vertical joints in the wall.

The gymnasium at the east end of the school collapsed in a similar manner. A hinge line developed where the north and south walls intersected the first story roof. Heavy steel trusses fell as the north wall fell inward and the south wall fell outward. The degree of damage to the high school would yield an EF-4 rating. However, a home north of the school had EF-0 damage and homes south of the school had EF-2 to EF-3 damage.

Six, hollow spun, steel reinforced concrete light poles toppled to the west and northwest in a baseball field located just east of the high school. Each pole was about 30 m tall and was broken at its base. All six poles left impact marks in the ground. However, the wind was strong enough to push the top half of one pole along the ground to the south. Fine debris accumulated up to 3 cm deep upwind of this pole (Fig. 18). This example illustrated that strong inflow winds occurred very close to the ground.

Figure 18. Concrete light pole had impacted the ground, then the top portion was pushed to the south. Debris gathered on the upwind side of the pole. This indicated that strong inflow winds occurred very close to the ground.

7. First State Bank

The First State Bank was a large, one- and one-half story, wood-framed structure constructed on a concrete slab foundation. Exterior walls were clad with brick and stone masonry. The bank was rectangular in plan with the long dimension oriented east-west. The combination gable and hip style roof was covered with asphalt shingles. The bank was located just north of the tornado center line and experienced the strongest winds from the south and west (Fig. 19). The bank was well built with metal straps connecting the roof and walls. Wall studs were 3.8 x 14 cm (nominally 2 x 6 in) rather than the standard 3.8 x 11.4 cm (nominally 2 x 4 in) in cross section.

The bank building sustained considerable damage from the tornado but exterior walls remained. However, some of the south and west walls were pushed inward pivoting about their bases (Fig. 20). There was greater than 20 percent damage to the roof covering and some of the roof decking had been removed. The degree of damage to the bank was given an EF-2 rating. By comparison, homes north and south of the bank building were assigned EF-3 and EF-4 ratings.

Figure 19. Aerial view of the First State Bank building looking north. The bank was near the center of the tornado path and survived relatively intact.

Figure 20. A south facing wood-framed wall on the bank building had been pushed inward, pivoting about its base.

8. SUMMARY

A violent EF-5 tornado was produced by a classic supercell in northeast Iowa on May 25, 2008. The storm evolved from a cluster of cells that formed on a pre-frontal trough and quickly moved into an area of relatively high instability. The supercell became tornadic as it interacted with a warm front.

Aerial and ground surveys revealed the tornado traveled east-northeast for approximately 70 km through Butler and Blackhawk Counties with 98 percent of the track crossing rural farmland. The remaining two percent of the tornado traveled through the south end of Parkersburg.

EF-scale ratings were assigned to 440 wood-framed houses of which 370 homes were within the Parkersburg. The vast majority of wood-framed houses were built atop CMU or poured concrete foundations with the wooden floor platform secured to the foundations with anchor bolts. Walls were simply straight nailed into the plywood floors. Failure of the home typically occurred where the wall studs and plates were straight-nailed into the floor leaving the floor platform intact. We encountered 33 homes that slid off their foundations. These homes were rated EF-2 or assigned an EF number of the adjacent home that did not slide off its foundation

Our study of vehicles revealed that 50 percent of them had not moved. Even 29 percent of the vehicles had not moved when homes sustained EF-4 damage. However, significant movement did occur in the majority of vehicles near homes that sustained EF-3 damage or greater. Rolled, tumbled, or lofted vehicles were rare. Regardless, the vast majority of vehicles had been breached by flying debris and would not have been safe havens in the tornado.

Specific study of the damage to the Parkersburg High School revealed weak points in the construction of the unreinforced masonry walls. In particular, hinge lines formed at the bases of walls causing them to topple just above ground level. Elongated (floor-to-ceiling) windows in the walls also created weak vertical joints in the walls making it easier for wall sections to topple inward or outward when broadsided by the wind.

We found several interesting features with the tornado path. Spiral ground marks were observed in many fields where corn stubble was gathered indicating this was a multi-vortex tornado. There were sudden changes in direction and the sizes and shapes of the spiral ground markings changed dramatically within a few tens of meters. Wind rows of fine debris were visible along the center line of the path which included bits of roof shingles, wood, corn stubble, and gravel. In rural areas, the tornado picked up wet top soil and corn stubble and plastered buildings, utility poles, and barbed wire fences up to 3 cm thick.

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