P1.11 NWS CLOUD-TO-GROUND LIGHTNING THREAT ANALYSIS

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1. INTRODUCTION

The 25 million cloud-to-ground (CG) lightning flashes each year in the United States are the number two cause of weather related deaths and result in five billion dollars of economic impact (www.lightningsafety.noaa.gov). These statistics show that CG lightning poses a significant threat to life and property. The National Weather Service's (NWS) mission statement asserts that forecasts and warnings are issued 'for the protection of life and property.' Therefore, a CG lightning threat assessment can help the NWS fulfill its mission to protect life and property by making the public aware of the danger posed by all thunderstorms.

This paper will describe how the NWS Weather Forecast Office (WFO) in Tulsa is using CG lightning density to develop a five-tiered lightning threat analysis. This lightning threat will be conveyed to the public through both web-based and text products that will indicate where the greatest potential threat from CG lightning exists. These products are applicable to both severe and non-severe thunderstorms that occur in WFO Tulsa's county warning area.

2. DATA

The county warning area (CWA) of the NWS Weather Forecast Office (WFO) in Tulsa was divided into a 0.10° x 0.10° grid, shown in Figure 1. In order to maximize the CG lightning flash density within any 0.10° x 0.10° area, four passes are made through the data, as illustrated in Figure 2. This method eliminates potential errors that could occur if a thunderstorm spanned more than one grid box. It also provides a more stable and consistent representation of the actual lightning threat. The computational method uses the original 0.10° x 0.10° grid for the first pass. This original grid is then shifted by a 0.05° to the east for the second pass. The third pass through the data uses the original grid shifted to the south by a 0.05°. For the final pass, the original grid is shifted by a 0.05° to both the east and south. This shifting results in four overlapping 0.10° x 0.10° grid boxes that have one 0.05° x 0.05° area in common.

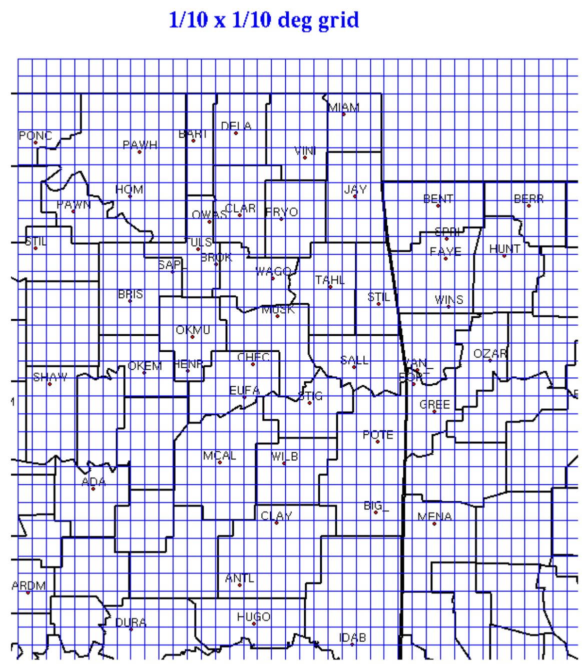

Figure 1. 0.10° x 0.10° grid over a map of the WFO Tulsa CWA (Eastern Oklahoma and Northwest Arkansas).

The location of CG flashes are reported using latitude and longitude. For ease of computation, it was therefore decided to use a grid based on latitude and longitude. However, it is acknowledged that the grid used actually covers about 4% more land area in the southern portion of the Tulsa CWA than in the northern portions due to the gradual spreading of the longitude lines from north to south. For the purposes of this study, it is believed that the small differences in areal coverage are not significant. For reference, the approximate center of the Tulsa CWA is 35.5° N latitude. At that latitude, each 0.10° x 0.10° grid box is roughly 10 km by 10 km (about 39 mi^2).

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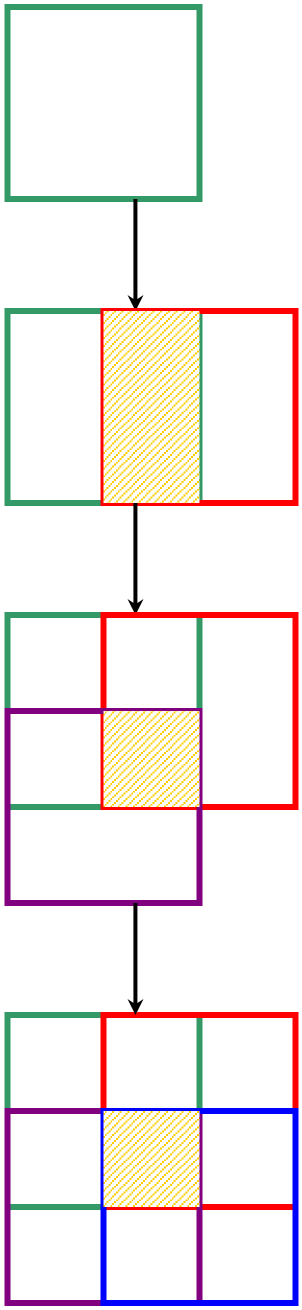

Figure 2. Illustration of the method used to maximize the CG lightning flash density within any 0.10° x 0.10° area. The green, red, purple, and blue boxes are each 0.10° x 0.10°. The orange hatching indicates the area shared by more than one 0.10° x 0.10° box.

One minute CG lightning data from the National Lightning Detection Network (NLDN) (Cummins et al., 1998a,b) are received by the NWS through the Advanced Weather Interactive Processing System (AWIPS) (FSL, 1997). AWIPS combines the one minute data into fifteen and sixty minute data. The fifteen and sixty minute CG lightning flashes are plotted on the 0.10° x 0.10° grid based on the latitude and longitude of each flash, as determined by the NLDN. The individual flashes are then added up to determine the number of flashes in each grid box during both the fifteen and sixty minute periods. The 0.10° x 0.10° grid is then shifted as described above. The 0.05° x 0.05° grid box is assigned a LT based on the maximum flash density in any one of the four 0.10° x 0.10° grid boxes.

3. WEB PRODUCT

A web-based graphic is produced indicating the CG lightning threat (LT) for both the previous 15 minutes and the previous hour (see Figs. 3-5 for examples of these graphics). Each 0.05° x 0.05° grid box uses color coding based on the LT level. The specific colors and threshold values for each of the five LT levels are shown in Table 1. The lowest threshold, Minor, was subjectively set with a minimum of 40 CG flashes/hour (10 CG flashes/15 minutes), which equates to approximately one CG flash per square mile during a one hour period. Each subsequent category is defined by a multiple of 40 CG flashes/hour.

These grids overlay a map of the WFO Tulsa CWA, with city names and county borders for reference. These graphics automatically update every fifteen minutes with the latest LT information. A legend indicating the threat level and its corresponding color are provided.

LT Category	**Threshold** CG flashes/hour	**Color**
	1 ≤ < 40	White*
Minor	40 ≤ < 80	**Green**
Moderate	80 ≤ < 120	**Yellow**
Elevated	120 ≤ < 160	**Orange**
High	160 ≤ < 200	**Red**
Extreme	≥ 200	**Purple**

*CG Lightning is present but the CG lightning density is below the minor threat category.

Table 1. Lightning threat levels.

4. TEXT PRODUCTS

An automated text product is generated when a grid box within the CWA has reached the Minor category. This product is a Special Weather Statement (SPS), defined by the NWS as “a priority disseminated product that can increase awareness and inform the public about significant, but less than severe weather” (NWS directive 10-517, SR supplement 05-2003). Lightning is not a criteria for issuing a severe thunderstorm warning; however, frequent to continuous lightning is one of the NWS criteria for defining a strong, non-severe thunderstorm.

The SPS includes a description of up to three grid boxes with the highest CG flash rates. This description includes the location of the grid box from the nearest town; a reference to the nearest ‘large city’ (populations on the order of the county seat); the county or counties within which the grid box falls; the LT; and the 15 minute flash rate (in number of CG flashes per square mile). The three grid boxes with the highest CG flash rates must be at least 0.30° (approximately 30 km) apart in an attempt to capture multiple cells. A default setting will allow for a manual input of storm motion. It may be possible to use the Storm Cell Identification and Tracking (SCIT) algorithm (Johnson et al., 1998) to determine the storm motion of a particular high flash rate grid box by using the SCIT calculated storm motion of the nearest identified cell. The length of time the SPS will be valid (i.e. how far the storm is extrapolated into the future) will generally vary between 30 and 45 minutes, depending on the convective mode. Shorter times will be used for ordinary thunderstorms and longer times for squall lines, supercells, and mesoscale convective systems (MCS). Call-to-action statements included in the SPS will give the public suggested actions to take in order to protect themselves and their property. Possible call-to-action statements are listed in Appendix 4. The SPS will be disseminated through the NWS Family of Services, NOAA Weather Wire Service, the Internet, the Emergency Managers Weather Information Network (EMWIN), NOAAPORT, and the NOAA All Hazards Radio. Once a thunderstorm becomes severe, the lightning threat may be included in the severe thunderstorm warning with an appropriate call-to-action statement.

5. EXAMPLES

Three examples have been provided to illustrate the utility of the LT. These cases consist of ordinary thunderstorms that produced heavy rainfall, thunderstorms along a boundary, and an isolated severe supercell. All dates and times are in Universal Coordinated Time (UTC). The National Weather Service defines a severe thunderstorm as one that meets one or more of the following conditions: (1) hail with a diameter of 0.75 inch or greater, (2) surface wind gusts of 50 knots (58 mph) or greater, and (3) the occurrence of a tornado (NWS directive 10-511).

5.1 Ordinary Thunderstorms/Heavy Rainfall – May 1, 2004

Figure 3a is the one hour LT and 3b is the fifteen minute LT ending at 0300 UTC on May 1, 2004 for ordinary thunderstorms that produced heavy rainfall. Note in Fig. 3b that the highest LT is occurring across Benton County, AR, Adair County, OK, and Pushmataha County, OK. The LT for the entire life of the storm is shown in Figure 3c. The SPS for this event is shown in Appendix 1.

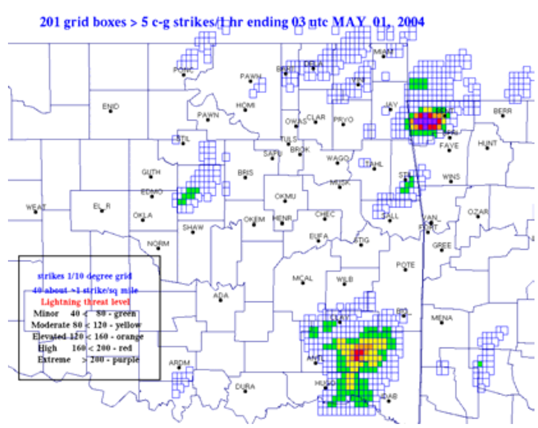

Figure 3a. 1 hour LT ending at 03 UTC May 1, 2004.

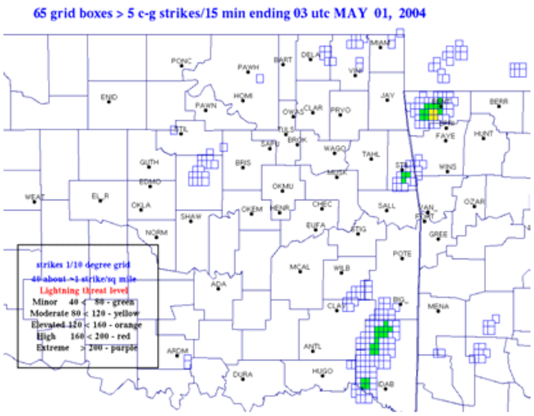

Figure 3b. 15 minute LT ending at 03 UTC May 1, 2004.

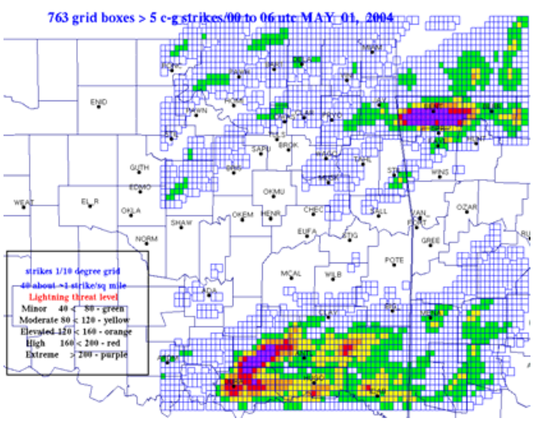

Figure 3c. Storm Total LT ending at 06 UTC May 1, 2004.

5.2 Thunderstorms along a Boundary – April 22, 2004

Figure 4a is the one hour LT and 4b is the fifteen minute LT ending at 2400 UTC on April 22, 2004 for thunderstorms along a boundary. Note in Fig. 4b that the three highest LT cells are occurring across Washington County, AK, Wagoner County, OK, and Seminole County, OK (Seminole Co. is outside of the WFO Tulsa CWA). The LT for the entire life of the storm is shown in Figure 4c. The SPS for this event is shown in Appendix 2.

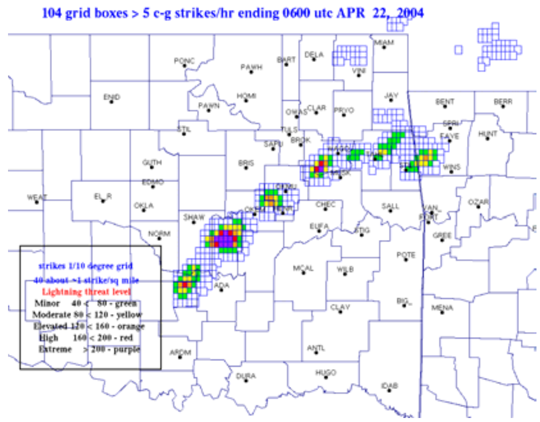

Figure 4a. 1 hour LT ending at 24 UTC April 22, 2004.

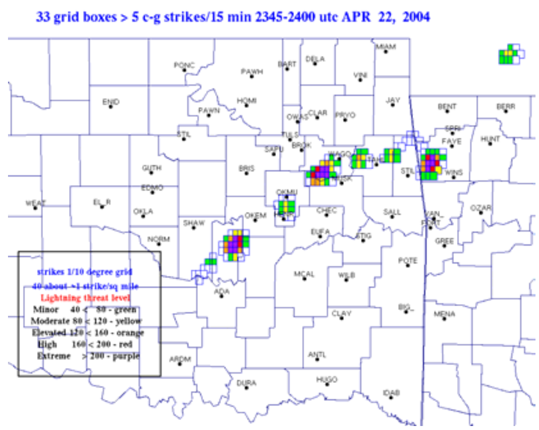

Figure 4b. 15 minute LT ending at 24 UTC April 22, 2004.

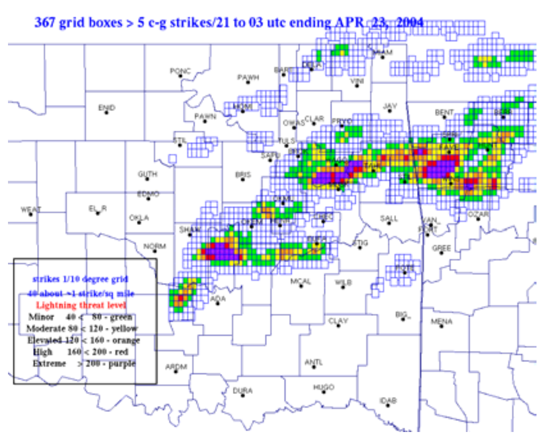

Figure 4c. Storm Total LT ending at 03 UTC April 23, 2004.

5.3 Isolated Severe Supercell – May 30, 2004

Figure 5a is the one hour LT ending at 05 UTC on May 30, 2004 for a severe supercell that moved through Sapulpa (Sapu) into south Tulsa (Tuls). Note that the highest CG flash density is occurring from Sapulpa to Tulsa. The fifteen minute LT ending at 05 UTC is shown in Fig. 5b. The LT for the entire life of the storm is shown in Figure 5c. Appendix 3 gives a tornado warning, including a statement about the LT, for this thunderstorm.

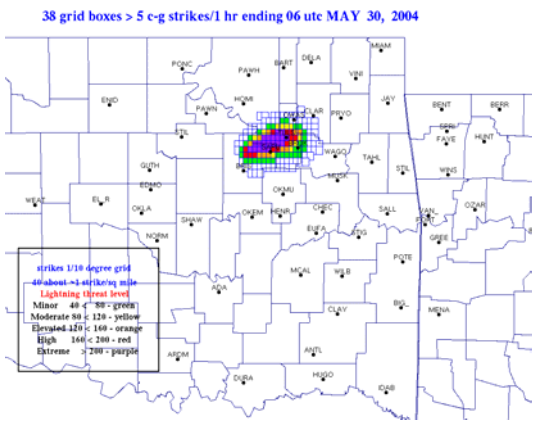

Figure 5a. 1 hour LT ending at 06 UTC May 30, 2004.

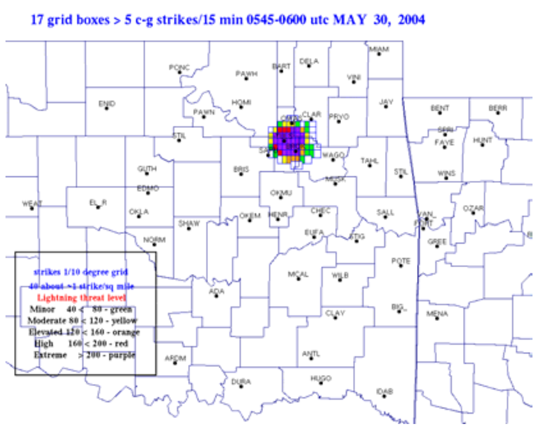

Figure 5b. 15 minute LT ending at 06 UTC May 30, 2004.

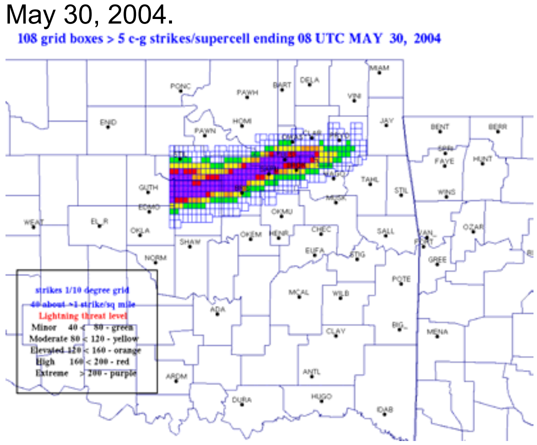

Figure 5c. Storm Total LT ending at 08 UTC May 30, 2004.

6. Summary and Future Work

Cloud-to-ground lightning is a threat to life and property. Therefore, an analysis of the lightning threat should help the NWS accomplish its mission to protect life and property. This lightning threat will be conveyed to the public through both web-based and text products issued by the NWS WFO in Tulsa, utilizing a five-tiered threat assessment. Users of this product might include emergency managers, school officials, and businesses and organizations with outdoor interests.

One improvement of this product will be the inclusion of a vector on the web graphic that would indicate the average storm motion based on the SCIT algorithm. This vector would than allow users to estimate the future lightning threat.

The authors also plan to combine the CG flash density/LT with other mesoscale data, such as vertical integrated liquid (VIL), precipitable water, upward vertical velocity, and convective available potential energy (CAPE), to determine if such combinations will provide a useful index for severe thunderstorm forecasting. Other aspects of CG lightning, including polarity, number of strokes, and strength of the flashes, could also be analyzed for the development of additional hazardous weather products.

7. Bibliography

Cummins, K. L., E. P. Krider, and M. D. Malone, 1998a: The U.S. National Lightning Detection Network and applications of cloud-to-ground lightning data by electric power utilities. *IEEE Trans. Electromagn. Compat.*, **40**, 465-480.

Cummins, K. L., M. J. Murphy, E. A. Bardo, W. L. Hiscox, and R. B. Pyle, A. E. Pifer, 1998b: A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network. *J. Geophys. Res.*, **103**, 9035-9044.

FSL, 1997: *WFO-Advanced Display 2-Dimensional User's Guide*. NOAA/ERL/FSL, Boulder, Colorado, 235 pp.

Johnson, J. T., P. L. MacKeen, A. E. Witt, E. D. Mitchell, G. Stumpf, K. Thomas, 1998. The storm cell identification and tracking algorithm: an enhanced WSR-88D algorithm. Weather Forecast. 13.

8. APPENDICES

8.1 Appendix 1

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE
945 PM CDT FRI APR 30 2004

ARZ-010-010300
BENTON AR-
945 PM CDT FRI APR 30 2004

THE NATIONAL WEATHER SERVICE IN TULSA HAS ISSUED A SIGNIFICANT WEATHER ALERT…FOR LIGHTNING…EFFECTIVE UNTIL 1000 PM CDT FOR:

THE AREA NEAR HEALING SPRINGS IN BENTON COUNTY. THIS AREA IS ABOUT 7 MILES SOUTH OF BENTONVILLE.

AT 945 PM THERE WAS A MODERATE THREAT OF CLOUD TO GROUND LIGHTNING…WITH APPROXIMATELY 2 CLOUD TO GROUND FLASHES PER SQUARE MILE. THE STORM PRODUCING THIS LIGHTNING WAS MOVING EAST AT 20 MILES AN HOUR AND WILL AFFECT CAVE SPRINGS AROUND 1000 PM.

THIS STORM MAY ALSO AFFECT ROGERS AND LOWELL IN BENTON COUNTY BEFORE 1015 PM.

AVOID CONTACT WITH CORDED PHONES AND WITH ELECTRICAL EQUIPMENT OR CORDS. IF YOU PLAN TO UNPLUG ANY ELECTRONIC EQUIPMENT, DO SO WELL BEFORE THE STORM ARRIVES. STAY TUNED TO NOAA WEATHER RADIO…FOR THE LATEST WEATHER INFORMATION.

8.2 Appendix 2

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE
645 PM CDT THU APR 22 2004

OKZ070-ARZ-010-230001-
WAGONER OK-MUSKOGEE OK-
WASHINGTON AR-
645 PM CDT THU APR 22 2004

THE NATIONAL WEATHER SERVICE IN TULSA HAS ISSUED A SIGNIFICANT WEATHER ALERT…FOR LIGHTNING…EFFECTIVE UNTIL 700 PM CDT FOR:

THE AREA NEAR TAFT IN MUSKOGEE COUNTY. THIS AREA IS ABOUT 10 MILES WEST OF MUSKOGEE.

AT 645 PM THERE WAS A MODERATE THREAT OF CLOUD TO GROUND LIGHTNING…WITH APPROXIMATELY 2 CLOUD TO GROUND FLASHES PER SQUARE MILE. THE STORM PRODUCING THIS LIGHTNING WAS MOVING NORTHEAST AT 30 MILES AN HOUR AND WILL AFFECT TULLAHASSE AROUND 700 PM.

A SECOND AREA OF SIGNIFICANT LIGHTNING WAS NEAR CYLDE IN WASHINGTON COUNTY ARKANSAS ABOUT 15 MILES SOUTHWEST OF FAYETTEVILLE…WITH ABOUT 2 CLOUD TO GROUND FLASHES PER SQUARE MILE. FAYETTEVILLE MAY RECEIVE SIGNIFICANT LIGHTNING BY 715 PM.

DO NOT TAKE COVER UNDER TREES…NEAR METAL OBJECTS…OR IN AN OPEN FIELD. FIND A SUBSTAINAL STRUCTURE OR SOLID ROOF CAR FOR SHELTER. STAY TUNED TO NOAA WEATHER RADIO…FOR THE LATEST WEATHER INFORMATION.

8.3 Appendix 3

BULLETIN – EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE TULSA OK
1207 AM CDT SUN MAY 30 2004

THE NATIONAL WEATHER SERVICE IN TULSA HAS ISSUED A

* TORNADO WARNING FOR
  EASTERN CREEK COUNTY IN NORTHEAST OKLAHOMA
  TULSA COUNTY IN NORTHEAST OKLAHOMA

* UNTIL 100 AM CDT

* AT 1207 AM CDT…DOPPLER RADAR INDICATED A DEVELOPING TORNADO 4 MILES SOUTHWEST OF KELLYVILLE. THIS DANGEROUS STORM IS MOVING EAST AT 20 MPH.

* SOME LOCATIONS NEAR THE PATH OF THIS STORM INCLUDE…BIXBY…BROKEN ARROW…MOUNDS…AND SAPULPA.

IF YOU ARE IN OR NEAR THE PATH OF THIS STORM…TAKE COVER NOW! IF NO UNDERGROUND SHELTER IS AVAILABLE MOVE TO AN INTERIOR ROOM ON THE LOWEST FLOOR.

IN ADDITION TO THE TORNADO THREAT…LARGE HAIL AND DAMAGING STRAIGHT LINE WINDS CAN BE EXPECTED WITH THIS STORM. THE LIGHTNING THREAT WITH THIS STORM IS EXTREME. GO TO A SAFE PLACE NOW!

8.4 Appendix 4

MOVE INDOORS IMMEDIATELY! LIGHTNING IS ONE OF NATURES NUMBER ONE KILLERS. REMEMBER…IF YOU CAN HEAR THUNDER…YOU ARE CLOSE ENOUGH TO BE STRUCK BY LIGHTNING.

WAIT 30 MINUTES AFTER YOU LAST HEAR THUNDER BEFORE RESUMING OUTDOOR ACTIVITIES.

DO NOT TAKE COVER UNDER TREES…NEAR METAL OBJECTS…OR IN AN OPEN FIELD. FIND A SUBSTAINAL STRUCTURE OR SOLID ROOF CAR FOR SHELTER.

AVOID CONTACT WITH CORDED PHONES AND WITH ELECTRICAL EQUIPMENT OR CORDS. IF YOU PLAN TO UNPLUG ANY ELECTRONIC EQUIPMENT, DO SO WELL BEFORE THE STORM ARRIVES.

AVOID CONTACT WITH PLUMBING. DO NOT WASH YOUR HANDS, DO NOT TAKE A SHOWER, DO NOT WASH DISHES, AND DO NOT DO LAUNDRY.

STAY AWAY FROM WINDOWS AND DOORS, AND STAY OFF PORCHES.

DO NOT LIE ON CONCRETE FLOORS AND DO NOT LEAN AGAINST CONCRETE WALLS.