1.4 **COLLABORATIONS BETWEEN METEOROLOGISTS AND EMERGENCY MANAGERS: THE OKLAHOMA TORNADO OF 3 MAY 1999 PART 1: THE HISTORICAL FOUNDATION**

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1. INTRODUCTION

The OK-FIRST Program was developed, beginning in October 1996, as a formal educational outreach program of the Oklahoma Climatological Survey. The goal of OK-FIRST was to develop a transportable, agency-driven information-support system that helped public safety agencies harness the information age. The desired impact of OK-FIRST was documentable improvements in how public safety agencies (fire, police, and emergency management) responded to weather emergencies.

Today, over three years later, more than 100 public safety agencies (Figure 1) — in support of their respective missions — have received formal training in how to access and use many new forms of environmental information via OK-FIRST and a companion program known as ONALERT (*e.g.*, data from the Oklahoma Mesonetwork, volume-scan data from 15 WSR-88Ds, and other data from the modernized National Weather Service [NWS]). By design, most communities served by OK-FIRST represented rural areas of Oklahoma (e.g., ~50% have populations of 5,000 or less). As a result of having been "modernized" by OK-FIRST, public-safety agencies across Oklahoma have achieved numerous success stories from the application of OK-FIRST data.

The most revealing testimonials about the effectiveness and robustness of OK-FIRST occurred on 3 May 1999 — a day of unparalleled killer tornadoes that impacted central and northern Oklahoma (Figures 2-3). Because the meteorological community of Oklahoma (including the NWS and the broadcast media) performed superbly in dealing with the well-over 50 tornadoes, the death and injury toll was amazingly limited to 44 fatalities and 700+ injuries. This tornado outbreak was responsible for damage to or destruction of nearly 10,000 houses and buildings across the state. The impact of the storms on several rural towns was immense. The town of Mulhall lost most of its buildings including its churches, school, and post office. In a matter of minutes, one tornado eliminated over 50% of the tax revenue for the town of Stroud by destroying the town's three major employers — who decided not to rebuild their facilities.

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However, as major media outlets properly focused on the widespread death and destruction across heavily-populated central Oklahoma, the OK-FIRST system passed a major, critical test. For example, OK-FIRST servers shared over 36,000 files of WSR-88D information with public-safety users on 3 May. In addition, many significant, life-saving success stories from rural Oklahoma — *which did not make the national headlines* — provided convincing evidence that OK-FIRST played an important role in saving the lives of many Oklahomans on 3 May 1999. The purpose of these two companion manuscripts is to share some of these "untold stories". This manuscript focuses on the problem that OK-FIRST addresses; the second manuscript (Morris *et al.* 2000a) provides anecodotal evidence of the benefits that accrue to rural communities through the proper application of modernized weather information during a disaster situation.

2. HISTORICAL CONTEXT

During the recent past, Oklahomans have contended with lengthy droughts, severe flooding, bouts of damaging thunderstorms, and significant tornado outbreaks. Even in "more normal" periods, "non-severe" weather regularly affects human activities such as outdoor entertainment events. In addition, responses to wildfires, hazardous materials incidents, and acts of terrorism are impacted by environmental conditions. Before OK-FIRST, Oklahoma was a microcosm of the entire country in how agencies responded to emergencies in that *local decision-support systems generally suffered from a near-complete lack of current and relevant environmental information*. With OK-FIRST, Oklahomans have made great strides in local responses to weather-impacted emergencies; these manuscripts document some of this progress.

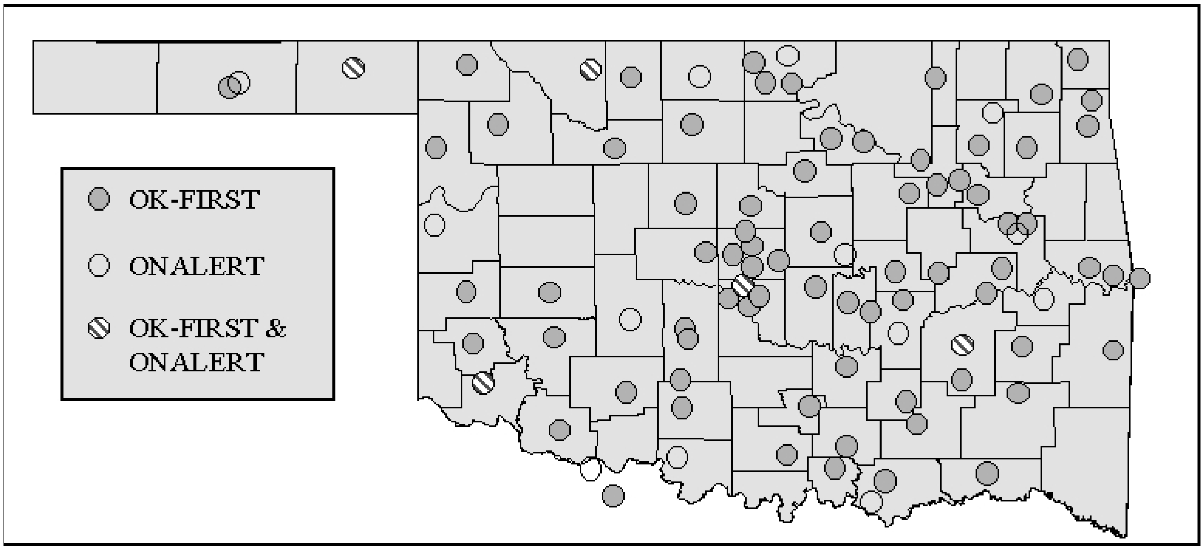

Figure 1. Communities served by the OK-FIRST and ONALERT programs.

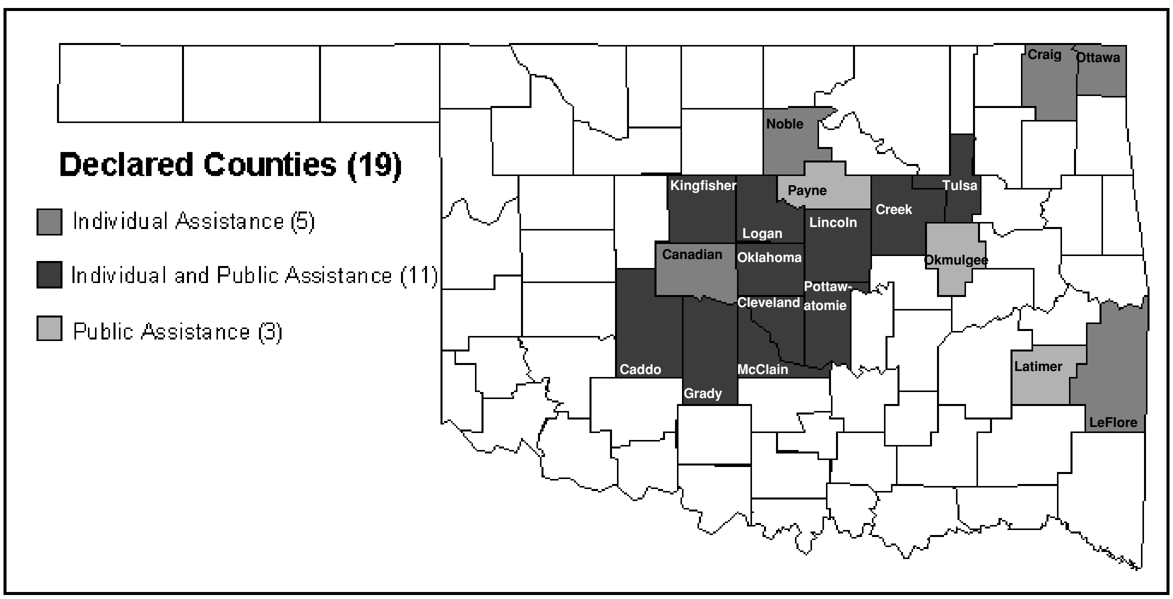

Figure 2. Counties in Oklahoma declared disaster areas by President Clinton and the Federal Emergency Management Agency for the severe weather that occurred on 3-4 May 1999. The declarations were made because the amount of damage in these counties was beyond the ability of local governments to respond and provide help to individuals or to repair public infrastructure (*i.e.,* public assistance).

Over the past thirty years, much evidence has accumulated to suggest that the National Weather Service (NWS) was disconnected from outside agencies due to outmoded dissemination policies. Access to NWS information by local officials nationwide was cumbersome, expensive, non-intuitive, and lacked critical details. In addition, the NWS occasionally did not *receive* critical storm or flood reports and thus could not produce appropriate warnings. Morris *et al.* (2000b) documented thirty years of this evidence, including:

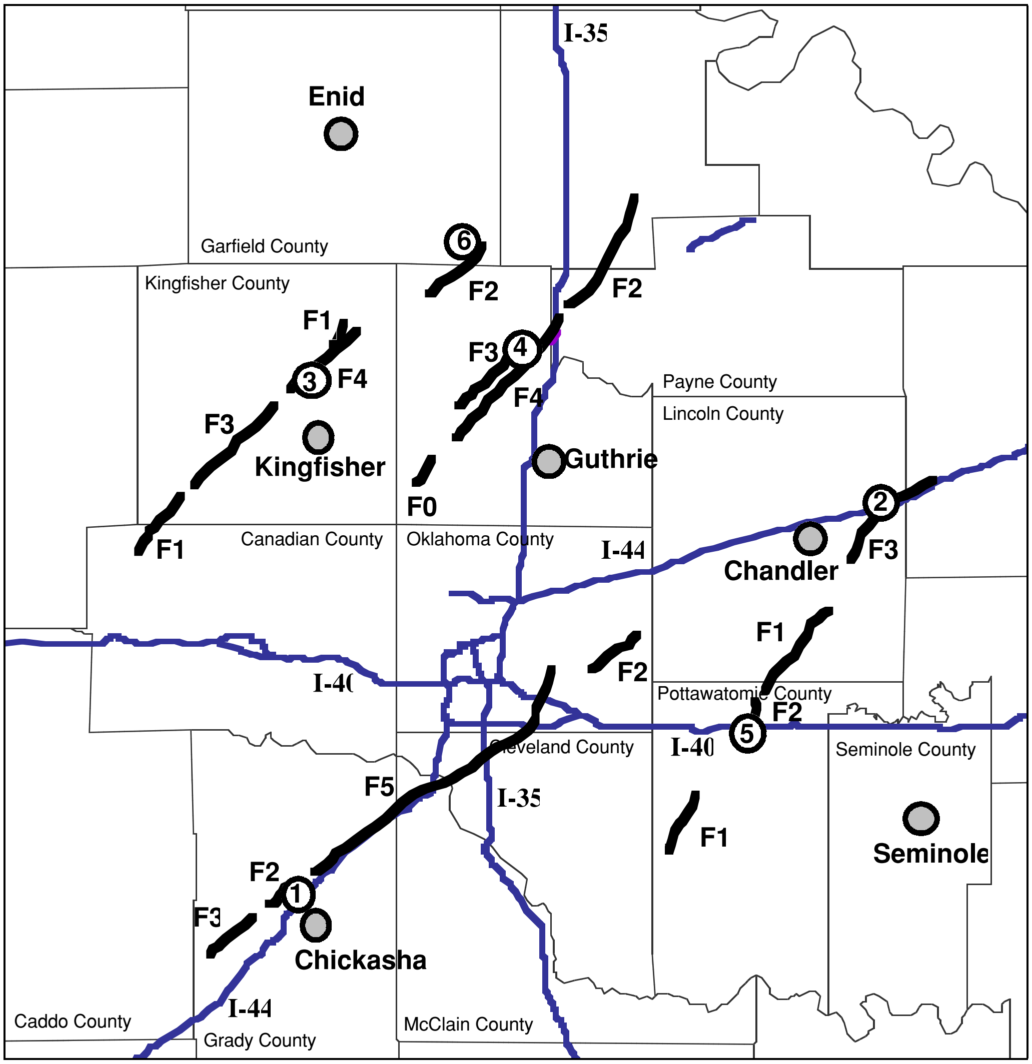

Figure 3. Approximate damage paths and Fujita damage scale ratings for many of the tornadoes in central Oklahoma on 3 May 1999. Numbered circles denote areas impacted by decisions based on OK-FIRST: 1. Chickasha Municipal Airport; 2. Town of Stroud and Tanger Outlet Mall; 3. Town of Dover; 4. Town of Mulhall; 5. I-40 exit near Shawnee. Adapted from NOAA (1999).

- In a U.S. Weather Bureau report entitled "The National Research Effort on Improved Weather Description and Prediction for Social and Economic Purposes" (1964), a select panel concluded that "informed decisions on the part of users of weather information are needed if such information is to be translated into beneficial actions." The panel also found that research in improving the link between meteorological service and the users of weather information was markedly deficient. The report stated that several major user groups received little or no attention from the meteorological community (U.S. Weather Bureau 1964).

- In 1970, another panel determined the situation reported in 1964 had not appreciably changed, and that the recommendations were more valid and urgent than ever (National Academy of Sciences, Committee on Atmospheric Sciences 1970).

- After the Johnstown, PA, flash flood of 19-20 July 1977 which killed 76 persons, a Natural Disaster Survey Report stated that "neither the National Weather Service component of the Flash Flood Warning System nor that part of it involving local communities and Civil Defense did much good for anyone in the Johnstown, Pennsylvania, area." (National Oceanographic and Atmospheric Administration 1977).

- While the Wichita Falls and Oklahoma City NWS offices provided "excellent warning services" during the 10 April 1979 tornado outbreak, over 40 people perished in Wichita Falls. Many of the deaths resulted from people who were caught in automobiles. In the Kansas City flash flood of 12-13 September 1977, seventeen deaths were car-related. Even today, weather conditions are rarely transmitted automatically to automobiles although technological advances permit. After the Wichita Falls tornado, it was revealed that the ability of the broadcast media to relay critical weather information was hampered by rate increases to the NOAA Weather Wire Service (National Oceanographic and Atmospheric Adminstration 1977, 1980).

- A National Research Council report stated that "for many years, the National Weather Service ... operated on the assumption that if they produced a good product, someone would come to get it and use it. ... Users are currently left largely to their own devices in determining what is available and how to use it; many are unaware of the information available." (National Academy of Sciences 1980).

- In June of 1990, a localized area of rain with amounts between 3 and 4 inches occurred in a 45 minute period upstream of Shadyside, Ohio. This flood caused 26 fatalities and the destruction of 80 residences. The NWS issued a flash flood watch for the affected county, but no flash flood warning was issued because the NWS received no information indicating that a flood was imminent. The NWS did not receive real-time flood information from local officials; they did not find out about the flood until four hours after the peak of the flood. In addition, the flash flood watch only reached Shadyside officials through the broadcast media. County officials received notification of the flash flood watch but did not relay this information to local officials in Shadyside (National Oceanic and Atmospheric Administration 1991).

- While local NWS offices issued tornado warnings with adequate lead time, 42 lives (20 at one church) were lost during the 27 March 1994 Palm Sunday Tornado Outbreak. Though warnings were disseminated using NOAA Weather Radio, local officials and citizens at risk did not receive notification because of the "limited resources many rural county emergency managers and law enforcement officials had at their disposal for receiving the emergency messages and enacting their response plans" (National Oceanic and Atmospheric Administration 1994).

The $4.5 billion modernization of the NWS during 1990s exacerbated this data-telecommunications problem by producing vast amounts of high-quality, county-scale information with no viable delivery mechanism to those ultimately responsible for making life-and-death decisions. In addition, rural areas — traditionally under served by telecommunications and technology — were at especially high risk. Consequently, local officials made weather-impacted decisions without adequate information (*e.g.*, storm spotters were deployed precariously because coordinators lacked information about storm location, movement, and intensity).

One major component of the NWS modernization was the deployment of an advanced, nationwide Doppler radar network. Local officials around the country expected to reap many of the benefits of this NEXRAD system because the network employed computer algorithms to automatically detect significant weather phenomena including rotational signatures, hail, and excessive rainfall. At the same time, the NWS out-sourced the *exclusive* dissemination of NEXRAD data among four private weather data vendors who provided the data to all entities outside the NWS. Known as NIDS (NEXRAD Information Dissemination Service), this arrangement was based upon management and logistical problems inherent in the radar-data distribution system used by the NWS during the pre-NEXRAD era; it was based upon federal policy of the 1980s which encouraged the privatization of government information services. Each of the NIDS vendors licensed the data from the NWS and constructed a variety of dissemination mechanisms which ranged from dial-up access to satellite delivery. The vendors also maintained dedicated dial-up connections to each of 154 radars, provided various levels of customer service, and created "value-added" products like regional mosaics. As a result, market forces and the cost of doing business made access to NEXRAD data prohibitively expensive for most public-safety and other government users nationwide. Yet, in Oklahoma, as a result of OK-FIRST, rural users statewide have routinely accessed the NIDS data stream through a public-private partnership with one of the NIDS vendors — this situation is a NIDS success story (Crawford *et al.* 1999).

Meanwhile, the NWS was working to improve its infrastructure to take advantage of modern computer workstations. Despite these improvements which dramatically improved forecasting and warning capabilities and produced tremendous data resources *within* the federal government, many of the associated benefits were beyond the financial reach of local public safety officials. Time after time during the past 15-20 years, the NWS made correct decisions involving the issuance of severe weather warnings based upon timely and modern information. Yet, because adequate dissemination systems *designed for local officials* did not exist, decisions affecting the protection of citizens frequently were made without the benefit of critical and local information.

3. HISTORY OF OK-FIRST

The OK-FIRST "information support system", introduced by Crawford *et al.* (1998), was intended to fill a recognized "service void" in Oklahoma's weather-warning system by building information bridges between the modernized NWS and the unmet, but critical need for information in rural areas during emergencies. It was built upon successes in implementing the Oklahoma Mesonetwork (Brock *et al.* 1995) and its K-12 educational outreach program known as EARTHSTORM (McPherson and Crawford 1996).

Critical design decisions included evolving OK-FIRST into a "web-based" decision support system (Morris 1998) built around Internet browsers, plug-in software (Wolfinbarger *et al.* 1998a,b), and extensive feedback from front-line users (Morris *et al.* 1999). Yet, mere *access* to modern weather information was not the *total* solution to the data void problem for public safety users; OK-FIRST staff have supported these users through regular instructional workshops which maintain and improve data interpretation and software skills. Morris and Duvall (1999) provided a subjective evaluation while James *et al.* (2000) provided and objective and independent evaluation of impact that OK-FIRST was beginning to have. In addition, the crowning evaluation-achievement to date has been the finalist-status accorded to OK-FIRST by the John F. Kennedy School of Government at Harvard University and the Ford Foundation (Morris *et al.* 2000b). Their "Innovations in American Government" program placed OK-FIRST in the top 25 of 1,609 innovative programs reviewed during 1999.

4. SUMMARY

The historical record documenting weather disasters and their impact on the citizens of our world has one consistent thread running throughout — and that is the fact that the citizens under the greatest risk from an impending weather event often did not know it. Such scenarios were especially true for those who lived in more remote locations.

This common thread does not imply that the meteorologists who made critical warning decisions or the meteorologists who broadcast news of impending events did not perform in a highly professional manner. Rather, this scenario unfolded time and again, partially because rural communities had limited resources devoted to public safety prior to environmental emergencies (often they devoted zero resources). More likely, the scenario occurred because the telecommunications technologies used during prior decades were simply not up to the challenge of communicating life-saving but highly perishable information into remote areas where local officials were trained and ready.

Clearly, the modernization of the National Weather Service has opened new doors of opportunity to eliminate the weakest link in our nation's weather-warning system. As a result of having a firm foundation upon which to work (*i.e.,* the modernized NWS) to benefit citizens and clients, the flow of life-saving information (observed data and information processed by meteorologists in both the public and private sectors) can now be assured to reach remotely-located public safety officials. Even so, much work remains to eliminate "holes in the floor" whereby some communities fail to receive and/or react to life-saving information.

OK-FIRST represents an attempt by the State of Oklahoma to build information bridges between the modernized NWS and the information needs in rural communities. Because OK-FIRST tackled the difficult problem of weather-data telecommunications in rural areas, the public safety in both rural and metropolitan areas alike stands to benefit. We believe the need for "an OK-FIRST-like system" was conclusively demonstrated during the massive tornado outbreak of 3 May 1999.

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