GIS DISASTER MAPPING TO UPDATE WARNING SYSTEMS

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ABSTRACT

The National Weather Service (NWS) of the United States maintains a technological warning system to assist the populace in their response to swiftly-forming tornadoes. Installed about twenty years ago, this Severe Weather Alert Radio System was designed to serve a much smaller population than exists today. One hint of the resulting inadequacy of the system came on March 27, 1994 when a series of killer tornadoes tore through Alabama and Georgia. In spite of warnings issued by the National Weather Service before these tornadoes touched down, little action was taken by the general public as indicated by the relatively high death toll of forty people and extensive property damage.

Warning systems for human response to the tornado hazards of the United States present a unique problem in spatial distribution. Radio sending stations must be located strategically in relation to the topography for the most efficient transmission of signals and must be near large population clusters. This spatial problem was addressed by application of a geographic information system (GIS) which overlaid various data sets to identify where stations are needed. When population density was correlated with historical distribution of tornado events, the resulting analysis of the maps disclosed that a significant number of highly populated areas in Alabama were out of the range of the NWS Severe Weather Alert Radio signals. This beneficial use of GIS analysis for disaster mapping could be extended to survey the expanded American population's access to radio warnings for other fast-acting natural and technological disasters that require quick warning. In line with the current National Weather Service modernization program titled Modernization and Associated Restructuring, new systems may be implemented for use of advanced equipment and scientific methods, but the traditional radio warning system has unique advantages and is still essential.

1. BACKGROUND

Threats from natural disasters require a variety of coping approaches. As outlined by Perry, Lindell and Greene [1], the three main tactics for handling

natural disasters include: 1) control of the hazardous physical event, 2) restrictions on land use, or 3) identification and improvement of forecasting methods and warning systems that produce a positive response by the people under threat. Issues connected to the third alternative as applied to fast-acting natural disasters are the focus of this paper, particularly, the implementation of geographical information systems (GIS) to increase preventive, pre-impact evacuations that lower losses of life and property. Some fast-acting natural threats which require efficient early warning systems are tornadoes, hurricanes, flash floods, and natural fires; human-induced technological threats would include dam breaks.

2. NEED FOR SEVERE WEATHER ALERT SYSTEMS

Threats from tornadoes are part of everyday life in many parts of the United States. In these areas, tornado watch and warnings are accepted messages throughout the year but especially during tornado season in the spring when the likelihood of tornado touchdowns is much higher than during other times of the year. However, tornadoes can develop at any time of the year, and often the ones costing most lives occur during the winter season or during the night when victims are asleep. Tornadoes that touch down during the night expose victims to their fury with little warning.

All tornado touchdowns in the United States are recorded by the National Severe Storms Forecast Center in Kansas City, Missouri. Records exist for the past 44 years. A major portion of the midwestern United States, where there is a higher frequency of tornadoes than in other parts of the US, is called Tornado Alley. While most of the states in this region report high frequencies of touchdowns, these incidents are not distributed equally throughout each state. In Alabama, for example, the range of touchdowns varies between 4-54 by county, while in the neighboring state of Georgia the range is between 0-21 touchdowns per county.

The National Weather Service is moderately successful in predicting tornado occurrences, especially if monitoring systems such as meteorological forecasting, spotter networks and, in more recent years Doppler radar are utilized. After a tornado is spotted, information about its activity is reported and transmitted through a complex network of Severe Weather Alert Systems. However, the placement of these Severe Weather Alert Systems was questioned March 29, 1994 after tornado warnings were issued. None of the people worshipping at a Church in Piedmont, Alabama [2] sought shelter because they did not receive any prior warnings of the coming tornadoes.

3. CURRENT PLACEMENT

Most Severe Weather Alert Systems were sited in the mid-seventies. Their placements were based on Federal Emergency Management Agency (FEMA) guidelines [3] and the United States demographics at that time. This radio system is maintained by the National Oceanic Atmospheric Administration (NOAA) in conjunction with state and local governments [4]. However, major shifts in population distribution occur every five to seven years according to the Bureau of Census [5]. Consequently, the present Severe Weather Alert System sending stations may not be placed at the most appropriate sites.
By using Alabama as a case study, this research project addressed the following:

1) where are the Severe Weather Alert Systems in Alabama currently placed?
2) does the placement correlate with existing demographics?
3) do incidence of tornado patterns within each county correlate with both of these variables?

A geographic information system (GIS) was used to analyze existing patterns and to identify whether or not discrepancies exist.

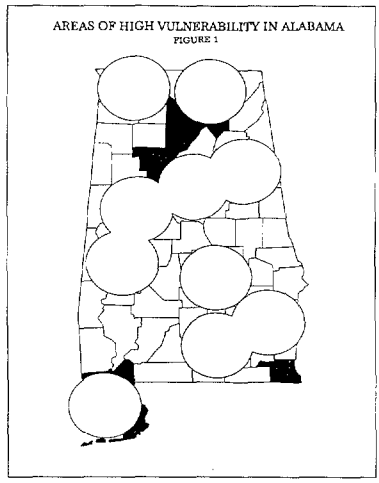
4. GEOGRAPHIC INFORMATION SYSTEM APPLICATION

The placement of the existing Severe Storm Alert System Stations was the first variable to be manipulated within a GIS. Next, the range of transmittal facilities was established. Each station has an approximate range of 30 miles.

The next step was to select historical averages of tornado incidents by county over the past 44 years. The information was mapped, and patterns of a high number of tornado incidents became apparent.

Mapping of 1990 population density followed. Comparing the recent population density data with average tornado incidents, it became apparent that there were some areas which had high population density and also high incidence of tornadoes.

In the final step, all three maps were combined to synthesize on a map areas which had high tornado incidence and high population density that was not covered by the Severe Weather Radio Alert Systems. Figure 1 demonstrates that there are large areas of high vulnerability in Alabama.



5. NEW TECHNOLOGIES TO IMPROVE ACCURACY

For the 1990s, the U.S. National Weather Service plans to update its operation through a process of change called Modernization and Associated Reconstructuring [6]. Major new technologies to be implemented include a new radar based Doppler effects and named the Next Generation Weather Radar (NEXRAD). The development and movement of severe storms is detected and monitored by NEXRAD through advances in remote sensing, data processing and display, and the application of mesoscale meteorological knowledge. This technology will provide more accurate short-term forecasts, but more important, it will lengthen the leadtime for issuance of tornado warnings. A second technology to assist in severe weather, flash floods, and river flood forecasting programs is the Automated Surface Observing Systems (ASOS) which, when installed, operates 24 hours a day with or without human attendants. One thousand ASOS systems are planned for country-wide installation.

6. VALUE OF TRADITIONAL RADIO WARNING SYSTEM

With today's technology, tornado warnings are usually only issued after visual sightings have been reported. When the National Weather Service completes its total modernization program, it is expected that there will be fewer false alarms of severe weather than experienced in the past. More importantly, it may be possible to give as much as 30 minutes of warning time for major tornadoes as compared with warnings of less than ten minutes average today. With all these planned National Weather Service high tech improvements, it might be expected that today's radio warning systems for the public could retire. However, in

severe weather conditions, radio communication provides a distinct advantage. In most households, the television screen often loses power during storms. With battery-powered radios in houses or cars, severe weather warnings can still be monitored by the public, a basic rationale for improving the spatial distribution of the Severe Weather Alert System sending facilities.

7. CONCLUSIONS

GIS is an ideal tool to be applied in the siting of Severe Weather Alert System radio stations in the United States. By using Alabama as a case study, it was highlighted that there is a lack of coverage in some high risk zones. Currently only 75-80% of the U.S. is covered by these systems in a systematic manner, and plans are underway to upgrade the system to 95% coverage. A model which includes other parameters such as topography and direction of the prevailing winds etc., can be a useful tool for future placing of Severe Weather Alert Systems not only in Alabama but throughout the entire United States. While this research provided only a small glimpse into the wider problem of siting of radio sending stations, through GIS analysis and synthesis, cartographers can provide a model for placing these systems in a more effective manner.

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