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TORNADOES AND INDUSTRY

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TORNADOES AND INDUSTRY

The reported property loss from tornadoes in the United States since 1916 has totaled close to a billion dollars. Perhaps half, or even more of this billion dollars represents damage to industrial property.

In addition to the damage to real property and equipment, industry has suffered other less obvious, but very important losses.

1. The loss of production during the period of replacement and repair.
2. The loss of trained personnel because of death or injury.
3. The loss of personnel efficiency during periods of tornado potential.

Windstorn insurance may cover the loss of property, but it doesn't compensate for these hidden losses that are part of every tornado disaster.

The precise action which should be taken to meet the tornado problem must be decided locally. The frequency as well as the nature of tornadoes must be considered. The kinds and arrangements of buildings, the size of the work force, the nature of the products, the volatility of materials, and other non-meteorological considerations are all important to this decision.

The objective of this article is to present the known facts and opinions on tornadoes as a contribution to a better understanding of the tornado problem. It is hoped that this will enable industrial management to take action to reduce the financial loss from tornadoes as well as diminish the number of tornado deaths and injuries.

The Path to Reduced Tornado Losses

Although the problem of weather modification is being examined, no tenable proposal has as yet been offered for the prevention of tornadoes. Therefore, the best approach toward the reduction of tornado damage and casualties and loss of efficiency is through:

1. stronger buildings, and actions to make a building more likely to survive tornado forces,
2. an effective tornado emergency plan for personnel safety, and
3. the reduction of tornado apprehension during periods of tornado potential.

The first reaction to this list is likely to be one of futility, for it has been said so many times that tornado forces are irresistible. But, in general, this is not so. TORNADO FORCES CAN BE SUCCESSFULLY RESISTED. Whether or not it is practical to consider tornado forces in building practices depends upon the kind of building it is and where it is being constructed.

The Character of Tornado Forces

Tornado forces are of two kinds. There are the forces of the wind, and a force resulting from the low pressure in the center of the tornado.

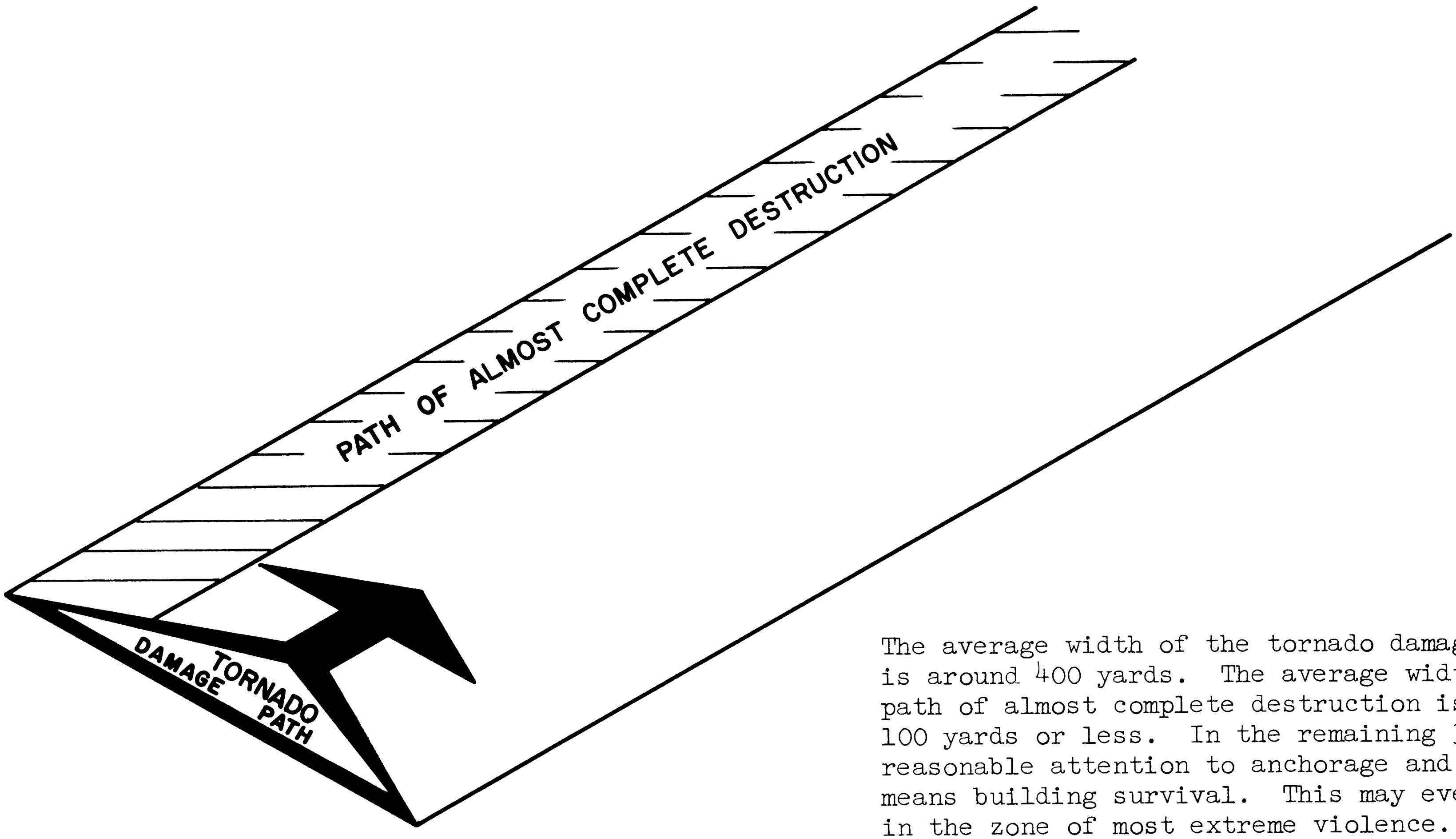
The forces of the wind are of two kinds. Some of the wind's momentum is transferred to any object it meets. This results in a pushing force. Very often this pushing force becomes magnified by flying debris. Flying debris has been a primary cause of tornado damage and casualties.

In addition, as the wind blows around an object, pockets of low pressure are created.[1,2] These add to the low pressure resulting from the character of the storm itself. Such dynamically created low pressures are especially large on the lee side and over low pitch roofs. The lee side is the side toward which the wind is blowing. More details about this effect can be obtained by reading references 1 and 2.

Tornadoes are defined as very violent, narrow-pathed windstorms. Traditionally, the tornado includes a funnel cloud. In the Northern Hemisphere, the classical definition calls for rotation in a counter-clockwise sense, looking down at the clock, around a vertical or nearly vertical axis. Many storms have been called tornadoes without proof of this rotation. Others which have been violent and narrow-pathed have been called "freak winds" instead of tornadoes, because rotation has not been immediately evident. In other words, the reporting system has not been consistent.

Whether or not there has been rotation is an academic rather than practical matter. In any event, at a given instant, the wind at a point is straight. If a building can withstand the classical tornado forces, it can withstand these so-called "freak" windstorms, too.

Neither very violent nor narrow-pathed are clearly defined. The average width of the tornado damage path is about a quarter of a mile. The reported width of path has varied from 9 feet to 4 miles.



The average width of the tornado damage path is around 400 yards. The average width of the path of almost complete destruction is probably 100 yards or less. In the remaining 300 yards, reasonable attention to anchorage and joints means building survival. This may even be true in the zone of most extreme violence.

The Tornado Force-Balance Picture

Although some attempt has been made to define very violent in terms of the size of limbs which are broken, the effort has been unsuccessful. At the present, there is no precise lower or upper limit to very violent.

The maximum wind speeds in a tornado are an unknown quantity. In the past it has been quite common to estimate tornado wind speeds as being from "300 to 700" miles per hour. It is felt that tornado wind speeds are in general less than 200 miles per hour. A calculation of 340 miles per hour was made for the Worcester tornado of June 9, 1953[3]. The limiting assumptions necessary in making any such computation require caution in accepting the resulting value as a true representation. The assumptions in this case are definitely suspect. However, the estimate could be of the right order of magnitude. Although some of us doubt it, no one has proved that it isn't.

The real hope does not lie in the minimization of the maximum velocities. No matter what the maximum velocities are in the worst of tornadoes, the speeds generally experienced across tornado paths are considerably under this value. That is, the fringe area of strong but not irresistible winds is much larger than the zone of maximum velocities. As a matter of fact, the results of several investigations have shown that most of the tornado damage is caused by wind speeds on the order of 125 to 150 miles per hour.[4,5] This makes it practical to consider tornadoes in building design. The probability of being in a tornado is small. The probability of being in an especially violent one is smaller. And the chance of being in the worst part of the especially violent one is smaller yet. So if a structure is built to withstand winds of 150 miles per hour, the likelihood of its being destroyed by a tornado is indeed remote.

It has been estimated that the pressure reduction within a tornado is as much as one half of an atmosphere.(6) On the other hand, the greatest officially observed drop has been .65 inch of mercury.(7) This amounts to a change of about 45 lbs per square foot. Doubtless, the greatest drop which has occurred has not been measured.

The tornado is relatively small horizontally. The average is perhaps one half mile across.* The average speed of the storm unit is about 40 miles per hour. This would place one in the center in about 20 seconds after he is reached by the forward edge of a directly approaching storm.

If the air pressure outside a building is suddenly reduced, there will be an explosive net force against the walls and roof, from the inside. This is true, unless air is lost from the building fast enough to compensate for the pressure reduction on the outside. If the pressure difference between the inside and outside were half an atmosphere, the explosive force would be around 1000 pounds per square foot. If the differential were on the order of .65 inch of mercury, the explosive force would be around 45 lbs per square foot.

The tornado pressure problem is discussed at some length in reference 8. This article includes an estimate that an effective venting area of one square foot per 1000 cubic feet of air space is sufficient for most, if not all, tornado situations.

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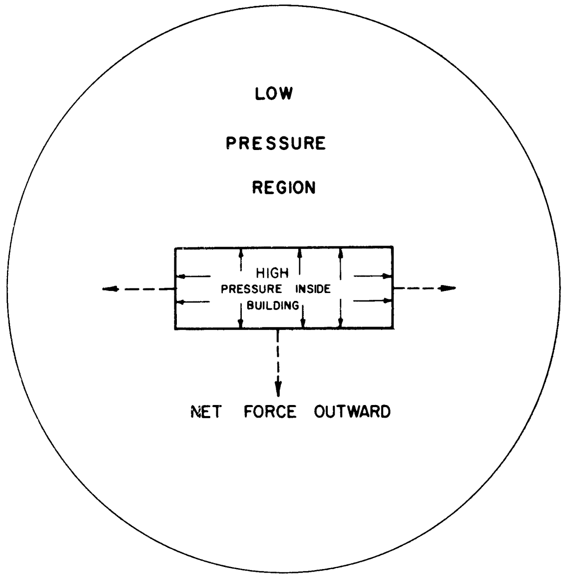
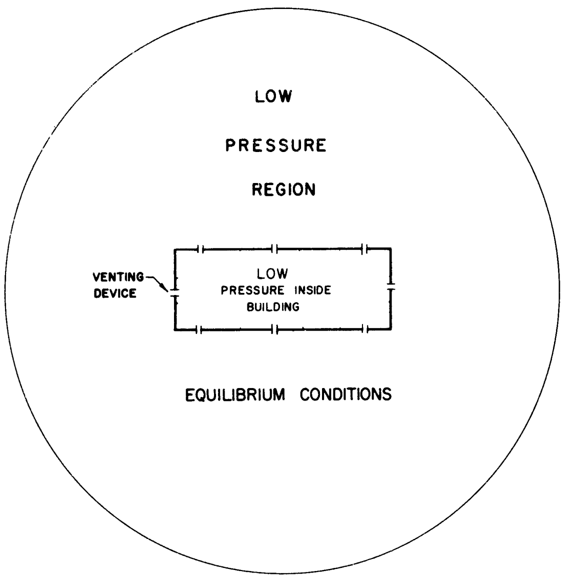
*The damage path is suspected to be only half as wide as the tornado itself.



When the low pressure of a tornado suddenly surrounds a building, the pressure inside the building is still about the same as it was before the tornado hit. This results in a net force outward which may cause the building to explode, unless some means is provided for air to escape from the building.



If a building has a venting device which will allow the air to escape fast enough, the pressure on the inside and the outside of the building will be about the same. There will be no net outward force, and so the building will not explode.

The Relative Resistivity of Different Kinds of Buildings

The relative ability of various buildings to withstand tornado forces has not been thoroughly investigated. However, an investigation of 12 tornadoes and a survey of hundreds of reports on tornado damage has brought out the following facts and opinions:

1. The complete collapse of public buildings has accounted for a large per cent of tornado tragedies, e.g., 29 people were crushed to death in the Dennis Building during the Waco tornado of May 11, 1953.
2. No record has been found of more than superficial damage to rigid-frame steel reinforced concrete buildings. Several of this type have been reported to have survived in areas of otherwise complete destruction.
3. In some buildings the steel framework is one unit with the walls placed inside the framework. The Bryan, Texas courthouse is of this type. In such cases it is suspected that parts of walls might sometimes be destroyed without collapse of the building.
4. Old load-bearing brick wall structures are quite likely to collapse during tornadoes. The Dennis Building was of this type.
5. Insecure anchorage of a roof to a wall can result in its loss early in the tornado experience. This leaves the rest of the building more at the mercy of the wind. In addition, the structural strength added by the roof is gone.

6. Frame houses which are well-anchored to a solid foundation probably have a good chance for survival. This and other building problems are discussed in references 8 and 9.
7. Unanchored frame buildings, such as storage sheds are not good tornado risks. Further, they become flying missiles, often responsible for the destruction of a building that would have otherwise survived.
8. Flying tin roofing is deadly. It actually decapitated a man in the Vicksburg tornado of December 5, 1953.
9. Trash and lumber piles and the like furnish materials for flying debris which is a prime contributor to tornado casualties and damage.

Is the Number of Tornadoes Increasing?

In recent years there has been considerable discussion as to whether tornadoes are on the increase. The average number of tornadoes per year between 1916 and 1950 was 146. In 1957, 924 tornadoes were officially reported.

No one knows for sure whether there has been and will continue to be a systematic increase in tornado incidence. However, it is certain that most of this increase is the result of a change in the reporting system. The number of deaths has not been increasing, and 1954, 1955, 1956 and 1957 all have less deaths than the 227 average between 1916 and 1950. Part of this encouraging picture is the result of the tornado warning efforts of the United States Weather Bureau.

The Tornado Warning System

The function of the tornado warning system is not only to save lives but to reduce apprehension as well. Because the understanding of the system is incomplete, and perhaps because of an incomplete faith in weather forecasting agencies, the activation of the tornado warning system often results in lost efficiency of school children, working mothers, and even fathers and others. The awesome nature of tornado forces, coupled with the blackness of tornado headlines, has left some people practically paralyzed during periods of tornado potential.

The tornado warning system consists of three parts:

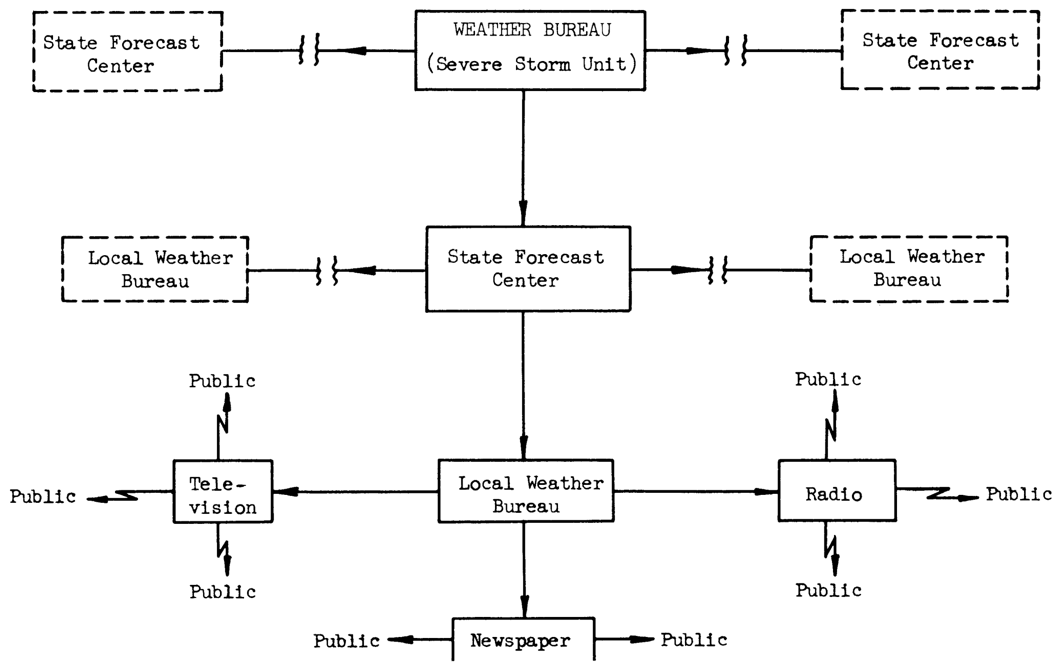
1. the tornado forecast,
2. the tornado alert,
3. the action taken as a result of the forecast and the alert.

The Tornado Forecast

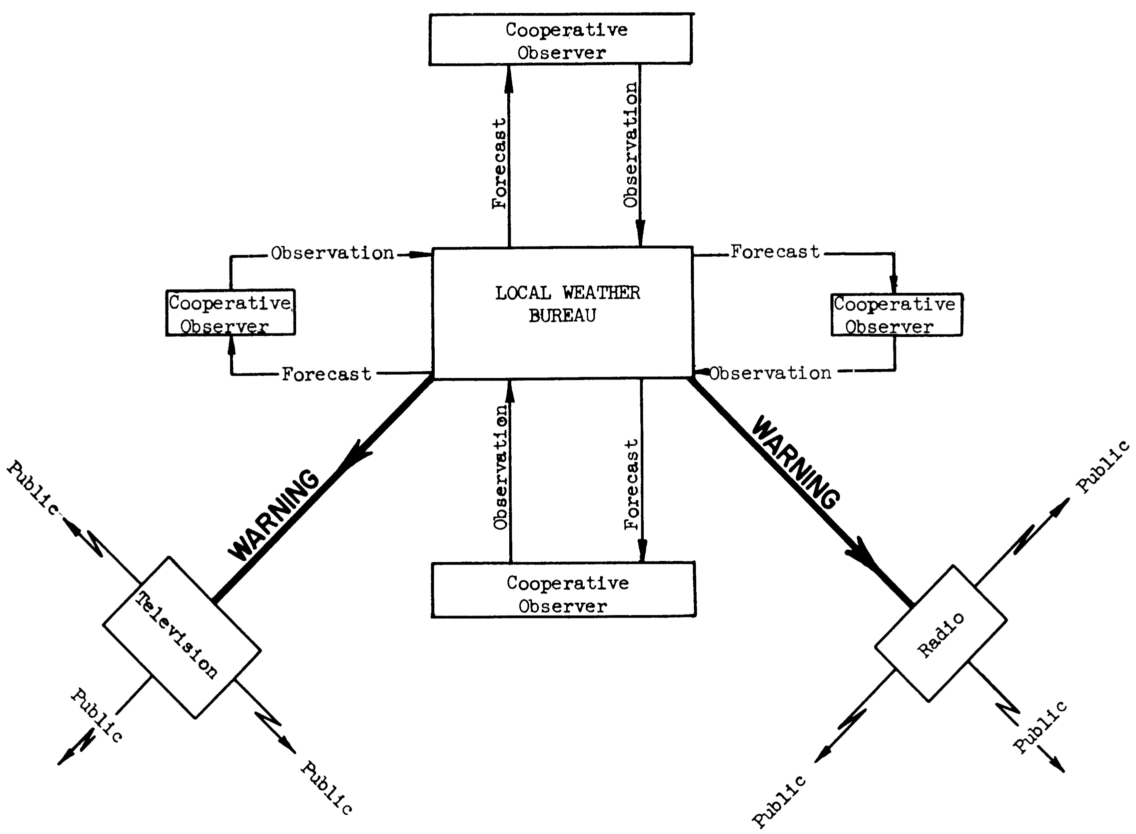
We are not yet able to pinpoint when and where a tornado will occur. However, it is now possible to delineate areas in which tornadoes CAN occur. This can be done a few hours in advance. When such a situation arises, the Weather Bureau issues a tornado forecast to the public through radio and television. This might be a typical forecast:

> "Tornadoes are possible in an area bounded by lines 50 miles on either side of a line from Springfield, Illinois to Indianapolis, Indiana between 3 PM and 9 PM."

This does not mean that this entire area will be under the threat of a tornado throughout the period. Tornadoes are inclined to be connected with a storm system. As the system moves across the area,



Tornado Forecast Information Flow



Tornado Warning Information Flow

the tornado potential moves with it. At a point within the forecast area the weather is often good during much of the forecast period and sometimes throughout the entire period.

The Tornado Warning

This is issued only after the tornado is known or strongly suspected to exist. Cooperative observers phone the Bureau as soon as a tornado is sighted, or if wind damage is observed. This is why THE INDIVIDUAL MUST NOT CALL THE BUREAU EXCEPT TO REPORT A SEVERE STORM. Unnecessary calls can only interfere with the flow of information to you through the Bureau.

Radar offers assistance in tornado tracking and identification. It is not, by itself, a completely dependable tornado tool.

What to Do

The most important thing is to have a plan. Although the odds against a tornado striking a specific point are great, the existence of a plan will help to soothe those with an inclination to press the panic button. Just what the plan should be will have to be decided locally.

The plan should probably include some system of sky-watching. It is better to have one man rather than an entire factory doing this watching. As long as no storm system is approaching, a look around the horizon every 15 minutes or so is plenty. Proper attention should be paid to communication between the observer and the plant authorities.

During these periods it is probably desirable to keep a radio turned on. If it is considered desirable, in some areas one can subscribe to the Conelrad disaster warning system. Subscribers to this set-up can arrange to receive a signal which tells them when to turn on the radio.

As a storm system approaches, the watch should become continuous. If the sky becomes sufficiently threatening or if the alert is received over the radio, the tornado emergency plan should be put into action. Just where people should go, what they should do, and what is done with gas, electric, and chemical lines, etc., should be decided by plant management, in advance, after talking the matter over with proper engineering personnel.

Some Tornado Misconceptions

At this point it should be mentioned that many tornado legends and rules of thumb are more fantasy than fact. The behavior of tornadoes is erratic. Sometimes there is no rain at all, sometimes rain before and not after, sometimes after and not before. Sometimes there is hail; sometimes not.

Waco had an Indian legend that a tornado couldn't strike there. There were 125 people killed in that storm. The 96 people killed in the Worcester, Massachusetts tornado of June 9, 1953 derived little comfort from the fact that their's was not a tornado-frequent area.

Perhaps most important is the observation of the funnel cloud. Whether or not one must exist in order to call a storm a tornado is academic. For many officially reported tornadoes no funnel cloud has been observed. It made no difference to the 5 people killed in the Wood River, Illinois tornado of May 21, 1949 that no funnel cloud was seen. THE VIOLENT CHARACTERISTICS OF A TORNADO CAN EXIST WITHOUT THE OBSERVATION OF A FUNNEL CLOUD. If the sky is really threatening, it is probably best to play the safe side. Efficiency is no doubt low during these periods, anyway.

In Conclusion

How much of the material discussed in this article you consider depends upon how serious the tornado problem is to you. It is likely that if you have read this far, tornadoes are of concern. Human life and misery, profit and loss, must all be balanced in the decision regarding the tornado problem.

It may be that you feel that the additional emphasis on tornadoes by creating a tornado emergency plan will do more harm than good. There is no direct rebuttal to such an attitude. Each responsible office must make its own decision. It is hoped that this material will be useful in making it.

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