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ABSTRACT

Tornadoes and extreme winds cause heavy loss of life and property damage throughout the United States. Most buildings offer significant protection from this danger, and building administrators should know the areas where this protection is available. This booklet presents a review of three schools, all of which were struck by tornadoes on April 3, 1974. Damage to these buildings from the tornadoes was examined by teams of specially trained architectural and engineering faculty, the various building administrators, and representatives of the architectural firm that designed the buildings. From these studies, guidance has been developed on selecting best-available shelter from high winds in existing buildings. Information in the brochure can also be useful to architects and engineers in designing new buildings that would offer protection from high winds. (Author/MLF)

TORNADO PROTECTION

SELECTING and DESIGNING SAFE AREAS in BUILDINGS

TR-83B / DEFENSE CIVIL PREPAREDNESS AGENCY / APRIL 1976

FOREWORD

The effects of severe winds generated by storms may be compared to the low-level blast effects of nuclear weapons. Therefore, increasing the protection in a building from the effects of high winds or tornadoes can provide increased protection in the building in case of nuclear attack.

Tornadoes and extreme winds cause heavy loss of life and property damage throughout the United States. Most buildings offer significant protection from this danger, and building administrators should know the areas where this protection is available.

This booklet, prepared for DCPA by Professor James J. Abernethy, School of Architecture, Lawrence Institute of Technology, presents a review of three schools: the Meadowlawn Elementary School in Monticello, Indiana; Monroe Central School in Parker, Indiana; and the Xenia Senior High School in Xenia, Ohio; all of which were struck by tornadoes on April 3, 1974. Damage to these buildings from the tornadoes was examined by teams of specially trained architectural and engineering faculty, the various building administrators, and representatives of the architectural firm which designed the buildings. From these studies, guidance has been developed on selecting best-available shelter from high winds in existing buildings, and is presented here. Information in this brochure can also be useful to architects and engineers in designing new buildings which would offer protection from high winds.

I urge architects, engineers, and building administrators to apply this guidance so that property losses will be reduced—and safety for the occupants increased.

John E. Davis

John E. Davis
Director

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introduction

Tornado damage to buildings is predictable.

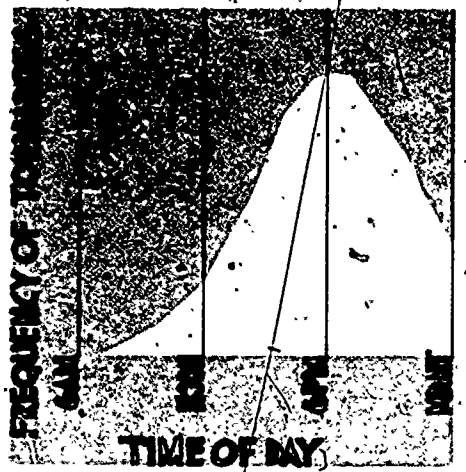
Administrators of buildings should know the safest places in their buildings—the portions that would offer protection if a tornado strikes. Most buildings offer a significant amount of protection for normal occupancy of the facility.

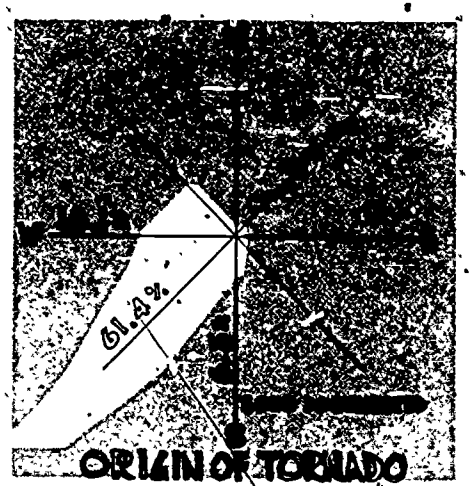
A trained architect or engineer can determine those portions of a building which will offer the greatest protection to occupants when a tornado strikes. This was concluded following on-site examinations and research of building damage by teams of specially trained architectural and engineering faculty.

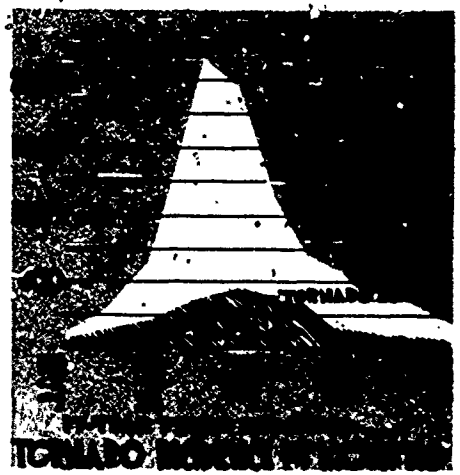
Architects and engineers should be able to use the information in this brochure to design facilities which offer higher levels of protection against high winds caused not only by tornadoes, but also by hurricanes and other severe storms.

The Institute for Disaster Research at Texas Tech University provided much of the substance of this brochure. Dr. Joseph Minor and Dr. Kishor Mehta of the Institute assisted in preparation and review of the material. Invaluable assistance was rendered also by the architects and engineers of the buildings presented as case studies, and by the school administrators.

TORNADO profile 1







The National Weather Service defines a tornado as a *violently rotating column of air pendant from a thunderstorm cloud and touching the ground.*

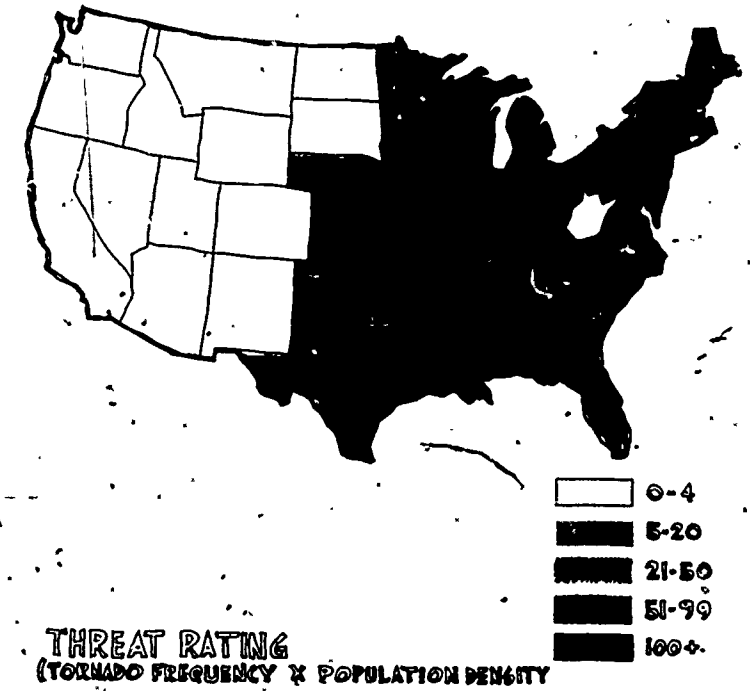
From a local perspective, a tornado is the most destructive of all atmospheric-generated happenings. In an average year, over 600 tornadoes hit various parts of the United States. About half of them occur in the period April through June.

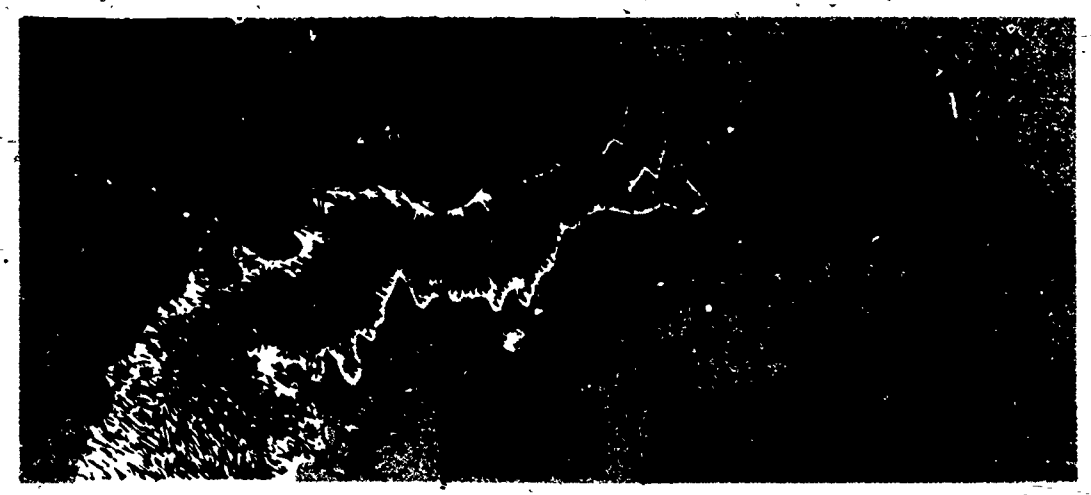
TORNADO CHARACTERISTICS

TIME OF DAY during which tornadoes are most likely to occur is mid-afternoon, from 3 to 7 p.m.

DIRECTION OF MOVEMENT is predominantly from the southwest to the northeast. Tornadoes associated with hurricanes may move from an easterly direction. About 85 percent of all tornadoes come from the southwest, plus or minus 45 degrees. Directions may vary significantly in local areas.

LENGTH OF PATH averages 4 miles, but some have exceeded 100 miles.





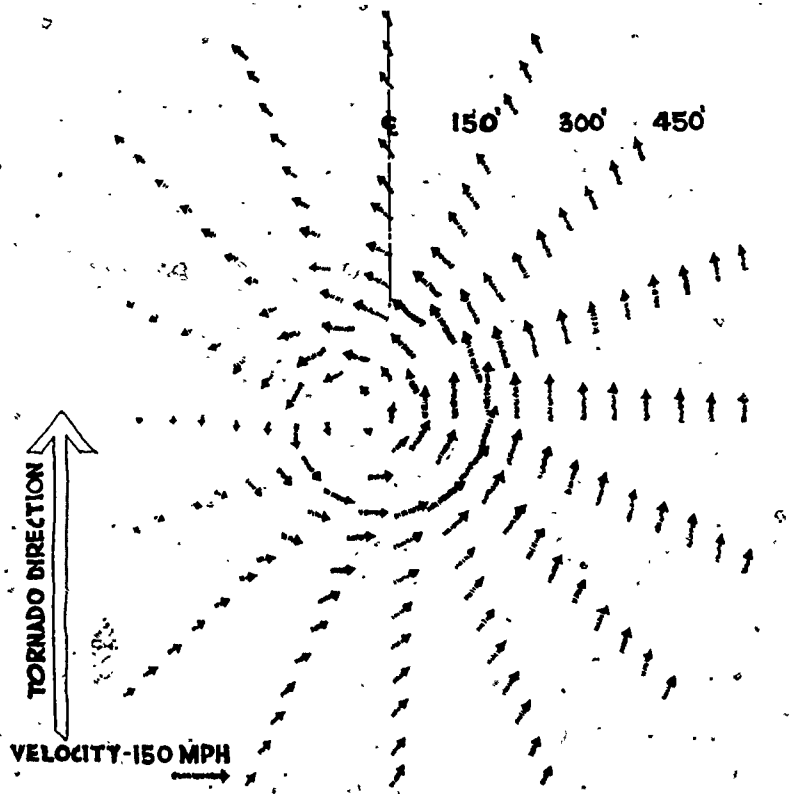
WIDTH OF PATH averages 300-400 yards, but may reach up to 1 mile.

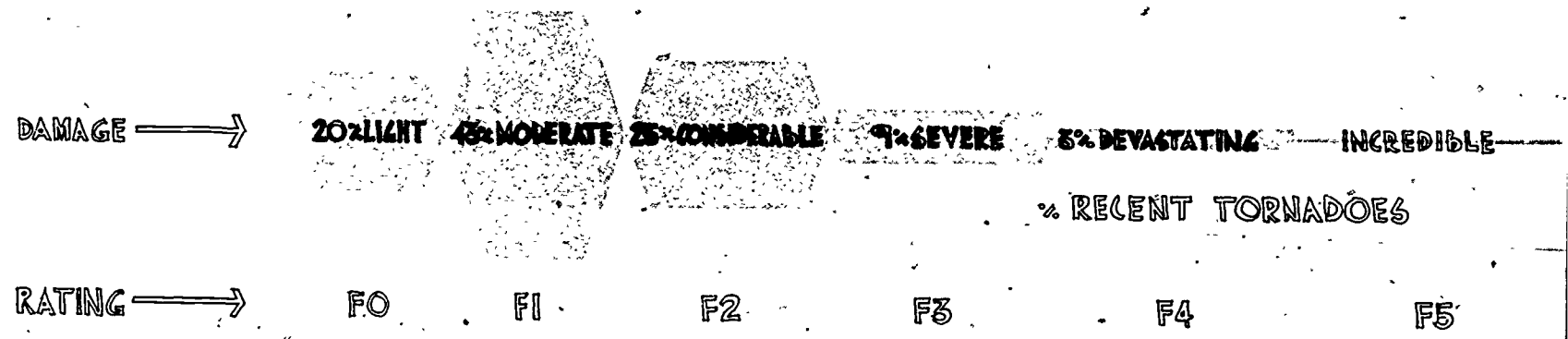
SPEED OF TRAVEL (TRANSLATIONAL) averages from 25 to 40 m.p.h., but speeds from 0 to 70 m.p.h. have been recorded.

SPEED OF TRAVEL (ROTATIONAL) is assumed to be symmetrical. The maximum rotational velocity occurs at the edge of the tornado core. Speed reduces rapidly as the distance from the edge increases.

The simplified example tornado shown here combines the translational and rotational wind speeds. The drawing is based upon a maximum rotational velocity of 110 m.p.h., and at 150 feet from the funnel's center, a 40-m.p.h. translational velocity is assumed. Therefore, the maximum combined velocity is 150 m.p.h. This example tornado *is more severe than 85 percent of all tornadoes.*

Note the highest velocities are found on the right side of this counterclockwise rotating tornado. This direction of [illegible] is characteristic in the Northern Hemisphere.





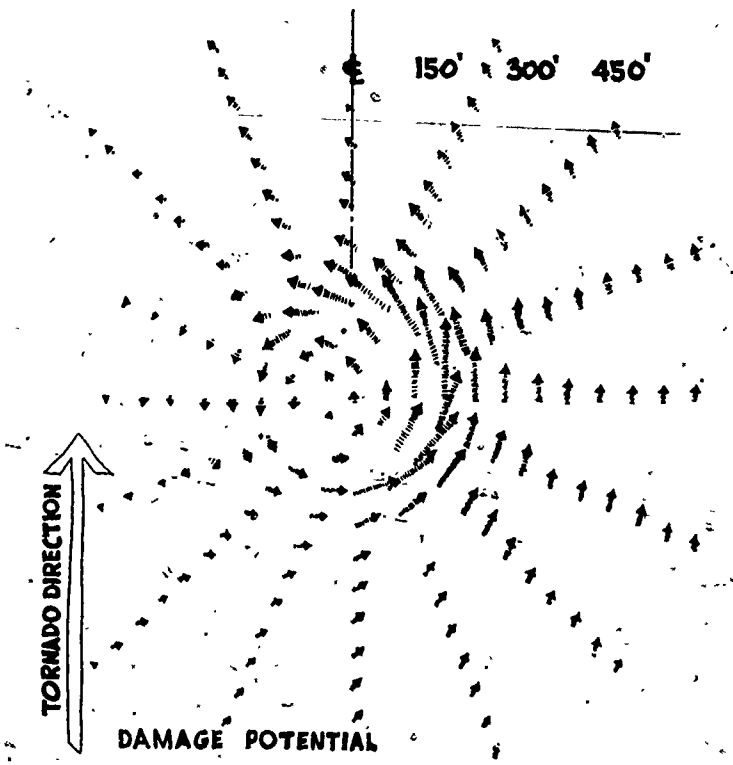
INTENSITY OF DAMAGE from a tornado is related to wind-speed (assuming consistent building construction).

The *F rating* scale was developed by Dr. T. Theodore Fujita. It is based upon trained meteorologists' evaluation of damage following tornadoes.

Eighty-eight percent of recent tornadoes have been rated at F0, F1, or F2.

Building damage is caused by a buildup of pressure on building surfaces, caused by the effects of high winds. This pressure is related to *wind velocity squared.*

The *damage potential* of the example tornado is shown graphically. Note that the greatest damage potential is on the right side. If the storm came from the southwest, the maximum damage potential would be on the south side of buildings.



effects of high winds 2

In buildings, the threat to life caused by tornadoes is due to a combination of effects which happen at almost the same time. Expert interpretations of building damage establish the following tornado effects, *in order of importance:*

EXTREME WINDS

Even the most modern building codes do not require buildings to withstand the winds of a tornado. Many buildings have been erected without the requirement to meet any building code. As a result, it isn't surprising to see that almost all buildings are no match for a tornado.

These extreme winds almost always rotate in a counterclockwise direction. Entire buildings are affected by the severe winds. The wind speed increases with height, causing maximum damage potential on the top floor of a building.

WINDWARD WALLS usually face south and west. However, east and even north walls can be windward, depending on the size and location of the storm and the building.

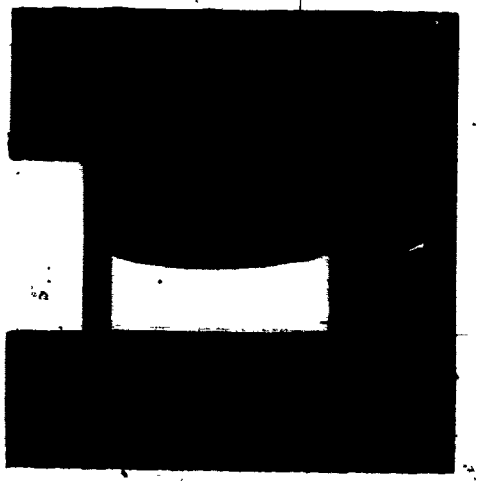
The glass, bricks, and block that make up these walls will be blown into the interior of the building.

LEEWARD WALLS usually face north and east. The winds tend to pull these sides outward. The pressures here are much smaller than on the windward side. The net result is therefore less damage to the leeward walls. The windows on these walls usually blow *out.*

Severe damage can occur to the leeward walls if the windward walls are penetrated. This *filling-the-balloon* effect is an added powerful force which can blow out the back walls.

ROOFS, especially flat roofs and those with a slight slope, tend to be lifted up and carried away. Overhangs and eaves on the windward side are the most vulnerable, and compound the uplift problem. Roofs with steep slopes are somewhat less vulnerable to uplift, but can be blown sideways.

Lightweight roofing materials, such as gravel, wood, insulation, shingles, and steel deck, often are lifted and thrown hundreds of feet in all directions by tornadoes. The weight of concrete roofs tends to resist uplift.



MISSILES

The high-speed whirling winds of a tornado can turn almost anything or anyone into a missile. Automobiles, buses, and tractor trailers can be tumbled about. Portions of buildings become airborne at high speed. Exterior wall materials on the windward sides often are thrown into building interiors.

Missiles move much faster horizontally than vertically. Also, many more missiles move horizontally. Therefore, it is more serious to have a wall missing than a roof insofar as protection from missiles is concerned.

Missiles are a major threat to life. Fortunately, they usually are stopped by substantial, somewhat massive interior partitions. Buildings without such interior partitions can be death traps.

COLLAPSE

Portions of buildings may fail during a tornado and collapse upon other spaces in a building. Chimneys collapse frequently, spilling their massive debris onto the roofs of adjacent spaces.

Higher portions of buildings may collapse onto adjacent lower spaces, adding extreme loads to already weakened roof systems.

PRESSURE DIFFERENCE

A tornado usually is a localized low-pressure storm in an overall low-pressure system. The atmospheric pressure inside a building exceeds the outside pressure, causing the building to tend to *explode*. Little is known about the magnitude of the pressure drop, since operating barographs rarely have survived a tornado.

Building *explosions* due to atmospheric pressure differences have probably been greatly overstated. Almost all damage can be explained from the extreme winds, missiles, and collapse. Since the pressure difference does occur, however, it is proper to open windows, especially on the leeward sides, to help equalize the pressures.

The somewhat predictable action of the winds, missiles, collapsing elements, and pressure differences make possible the identification and design of protected spaces for human occupancy. These *best-protected spaces can be identified and should be occupied during a storm.* People should not be randomly distributed throughout a building. They should move to preselected locations offering best-available protection. This does not mean that the best available shelter in all buildings is good enough to protect life. Some single-story lightweight buildings, especially modular houses and classrooms, should be evacuated and the *occupants should seek shelter elsewhere.*

POTENTIALLY HAZARDOUS ELEMENTS

Every building contains some vulnerable elements that cannot be counted upon effectively to withstand a tornado. Portions of buildings which contain one or more of these elements should be avoided whenever possible. *They are presented in order of importance for life safety:*

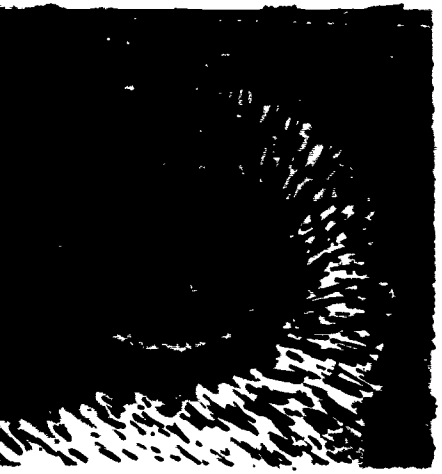
WINDOWS are no match for the extreme winds or missiles of a tornado. They usually break into many jagged pieces and are blown into interior spaces from the windward walls. Tempered glass will break into thousands of small, cube-like pieces. Windows in interior spaces also break, usually from missiles.

Acrylic or polycarbonate plastics are more resistant to impact than glass, but large panes may pop out.

Windows at the ends of corridors, particularly those facing south and west, are very dangerous. They probably will be blown down the corridor.

LONG-SPAN rooms almost always have high ceilings. The exterior walls are therefore much higher than the typical one-story wall. These higher walls often collapse. Sometimes they collapse into the long span, and roofs depending on the walls for support then fall in.

Building administrators must resist the temptation to gather large segments of the building population into large spaces to facilitate control. *Often these large spaces receive maximum damage and if large groups of people*



are present, major loss of life and numerous injuries could occur.

Lightweight roofs such as steel deck, wood plank, and plywood usually will be lifted up and partially carried away, with some roof debris falling into the room below. The roof opening then allows other flying debris to be thrown into the interior space.

Heavier roofs, especially precast concrete planks, may lift up and move slightly and then fall—but not always exactly to the same supporting place. If the support has collapsed, the heavy roof may fall onto the floor below, causing almost certain death or injury to anyone there.

WIND TUNNELS occur in unprotected corridors facing the oncoming winds, which usually come from the south or west. Openings facing these directions allow the winds to penetrate into interior spaces. The winds apparently occupy almost the entire volume of such a wind tunnel, as debris marks have been found to cover the full height of the walls.

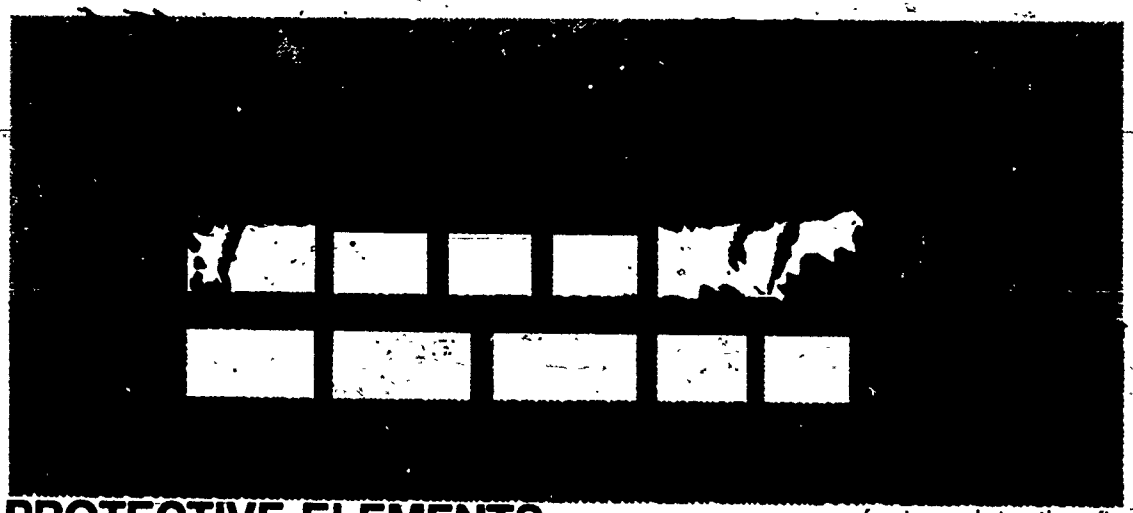
If entrances are baffled with a solid, massive wall, this effect is much less serious.

WINDWARD SIDE walls, which usually are on the south and west, receive the full strength of the winds. It is assumed that windows on these sides will be broken and blown into the rooms on the windward side. This often results in increased air pressure which aids in raising the roof.

LOAD-BEARING WALLS are the sole support for floors or roofs above. If winds cause the supporting walls to fail, part or all of the roof or floors will collapse. The most dangerous locations of a building are usually along the south and west sides, and at all corners.

Masonry construction is not immune to wall collapse. Most masonry walls are *not* vertically reinforced, and can fail when high horizontal forces such as caused by winds or earthquakes occur.

Masonry exterior walls higher than 10 feet are potentially hazardous.



PROTECTIVE ELEMENTS

Each building contains a number of elements which can help provide safe spaces for occupancy. The best spaces are those with two or more of these protective elements, and with no potentially hazardous elements. The protective elements are presented here *in order of importance for life safety:*

The LOWEST FLOOR is usually the safest. Upper floors receive the full strength of the winds. In some cases, tornado funnels hover near the ground, but hit upper floors only.

Belowground space is almost always the safest location for shelter. If a building has but one floor and no basement, seek out the remaining protective elements.

INTERIOR SPACES often form a protective core. A completely interior room protects against missiles and the *wind tunnel* effect.

The best interior partitions are somewhat massive, fit tightly to the roof or floor structure above, and are securely fastened to the floor or roof. Avoid interior partitions that contain windows.

SHORT SPANS on the roof or floor structure usually remain intact. This is due to the fact that short spans limit the amount of uplift caused by the winds.

While short structural spans are best, small rooms, even those with walls that do not support the roof, are usually quite safe. If the roof rises and then collapses, the interior walls may *become* supporting walls and thereby protect the occupants.

FRAMED CONSTRUCTION usually remains intact. Any structural system that is rigidly framed together is superior to load-bearing walls.

Poured-in-place reinforced concrete usually remains after the storm; and rigidly connected steel frames also are usually still in place after a tornado passes. However, in both these cases, the floor or roof system must be securely connected to the supports. Gravity connection of roof deck to frame is inadequate.

Generally, the heavier the floor or roof system, the more resistant it is to lifting and removal.

case studies 3

The three school buildings selected for examination in this brochure were picked for the following reasons:

a. All were hit by different, but intense tornadoes.

b. The three structures varied in size, age, and type of construction.

c. All were relatively new structures, designed by different architects and engineers to national building codes.

d. All had to be partially or totally destroyed later due to the extent of the tornado damage.

The building damage was examined by teams of specially trained architectural and engineering faculty, the building administrators, and the responsible architects.

Determination of best-available shelter in the three buildings was based on three sources of information, *in this order of importance:*

a. Persons in each building during the particular tornado.

b. Building examinations by architects and engineers.

c. Aerial photographs taken shortly after the storms.

The tornado-shelter quality of portions of these buildings has been divided into two categories: Primary and secondary. *PRIMARY SHELTER was the best available in each of the three buildings when the storms occurred. SECONDARY SHELTER was those additional spaces which would have offered some protection, but where possibly some injuries would have been sustained.*

Hopefully, these case studies will help building designers and administrators to locate accurately *what would be left after a tornado*—before it strikes; and help architects and engineers design facilities which offer the occupants excellent tornado protection at little or no additional cost.

MEADOWLAWN ELEMENTARY SCHOOL

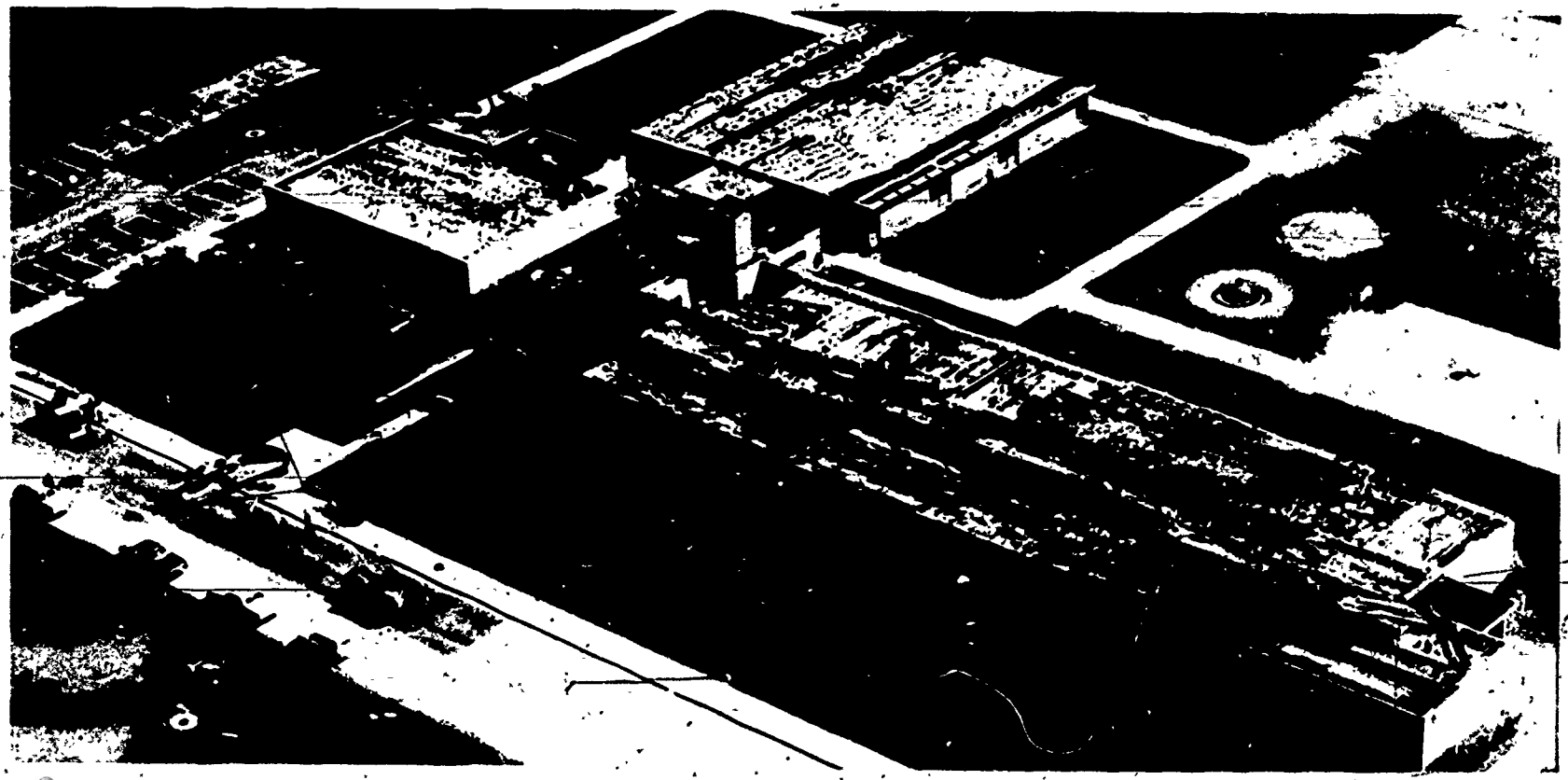
MONTICELLO, INDIANA

Building population:	*540, including staff;*
	No one in building during storm.
Tornado direction:	*From southwest.*
intensity:	*F3.*
wind speed:	*120-140 m.p.h.*
time:	*5:16 p.m.*
date:	*April 3, 1974*

The Meadowlawn Elementary School is typical of thousands of educational facilities built in the 1960's. The single-story, no-basement school is located on the southwest edge of Monticello, Indiana.

Conscious of the danger of tornadoes, and aware of an approaching severe weather system, the school administrators conducted a tornado drill on the morning of April 3, 1974.

Fortunately, the storm hit after school hours.



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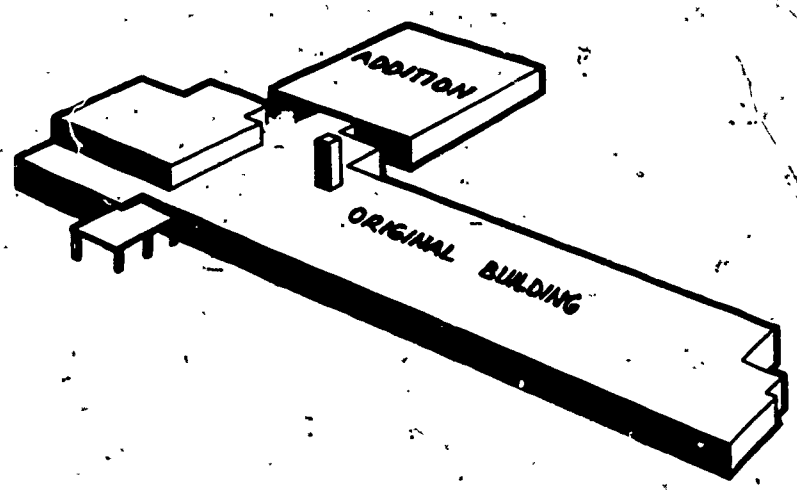


TORNADO DAMAGE

HAZARDOUS ELEMENTS

Unrepairable damage occurred to the original classroom wing when the south exterior walls failed. The *WINDOWS* blew into all of the *WINDWARD SIDE* classrooms. All south and west windows were broken. Wind entering these rooms caused a ballconing effect. Some of the metal roof deck was lifted, and was scattered through an open field northeast of the school.

The winds blew into the classrooms facing west, throwing furniture around and piling it into the center of the rooms.

Glass in the unbaffled south entranceway blew through the corridor. The winds in this corridor created a *WIND TUNNEL*, causing some of the roof decking to uplift.

The original 12 classrooms and library were demolished. The boiler room, multipurpose room, offices, and the six-classroom addition were repairable.

CONSTRUCTION

ORIGINAL BUILDING

exterior walls: *glass and metal curtain wall. End walls 4" brick, 8" block.*

interior walls: *plaster on metal studs. Block in multipurpose and boiler rooms.*

roof system: *steel frame. Steel open-web joists, with metal decking and insulation.*

ADDITION

exterior walls: *non-loadbearing 4" brick, 8" block, minimal glass.*

interior walls: *same as original building*

roof system: *same as original building.*

PROTECTIVE ELEMENTS

The *STEEL FRAME* remained intact.

The *INTERIOR PARTITIONS* stopped incoming missiles from reaching adjacent rooms or corridors.

North and east classrooms received little damage.

Roof fans lifted off the multipurpose room, helping to equalize the pressure differences.

The gymnasium did not collapse. This is partially due to the fact that it is located in the northeast corner of the building.

The office spaces, workroom, lockers, and storage spaces were undamaged due to *SHORT ROOF SPANS*.

COMMENTS

"The important thing as far as I'm concerned in reference to the structure of this building is that we had two support walls going down the middle. Now, in my opinion, if we would have had some form of open-type construction such as I've seen with open concept building, I'm afraid that we would have had a severe loss of kids if we had been in the building.

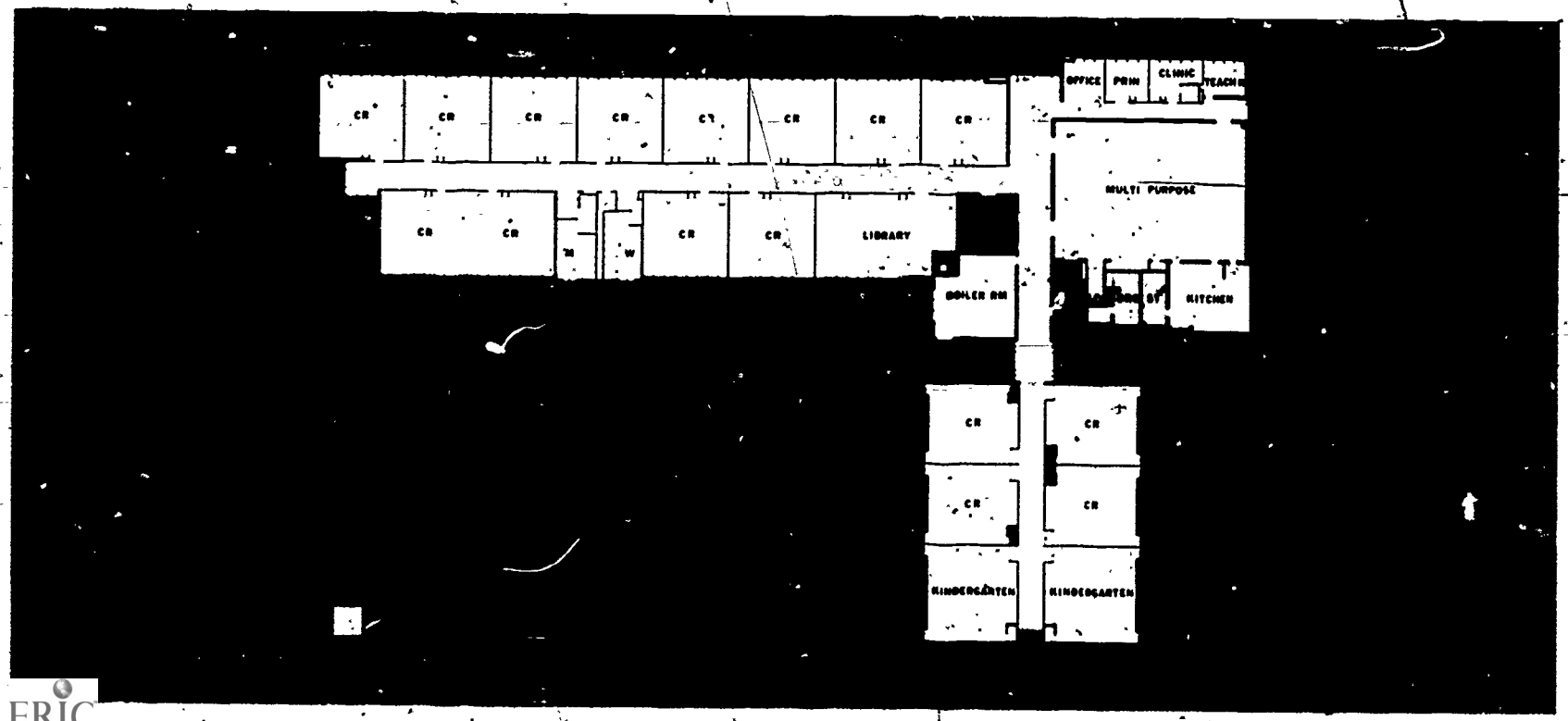
"With the structure as it is we would have had no major injury, and we're talking about probably 400 kids along this east-west corridor."

PRINCIPAL

"We are aware of the fact that Indiana is prone to tornadoes. Therefore, each year we formulate plans, and I might say that in the morning of April 3, all of the buildings within the Twin Lakes School Corporation conducted tornado drills. We had quite a sophisticated plan for placing students in what we feel are the safest areas within the school.

"As a result of this tornado, we have been able to go back into the buildings that were hit by the storm and evaluate the tornado drills that we have. In most cases we have found areas that we had earlier identified as being safe areas appear that they would have been safe had the tornado hit during the school day, with a couple of exceptions."

SUPERINTENDENT OF SCHOOLS



MONROE CENTRAL SCHOOL

PARKER, INDIANA

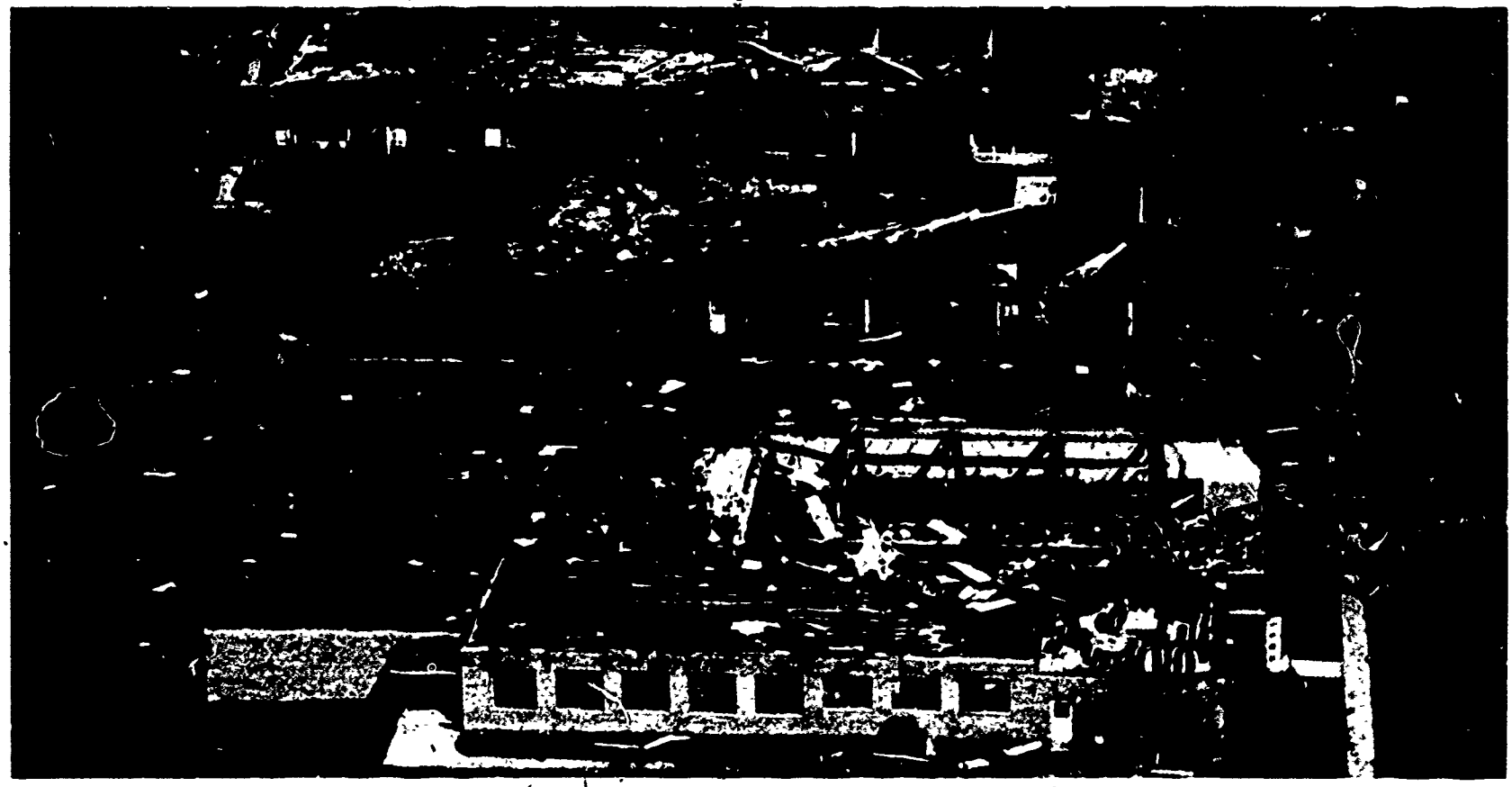
Building population:	*690, including staff;*
	14 staff present during tornado
Tornado direction:	*From south-southwest.*
intensity:	*F3*
wind speed:	*110-130 m.p.h.*
time:	*3:46 p.m.*
date:	*April 3, 1974.*

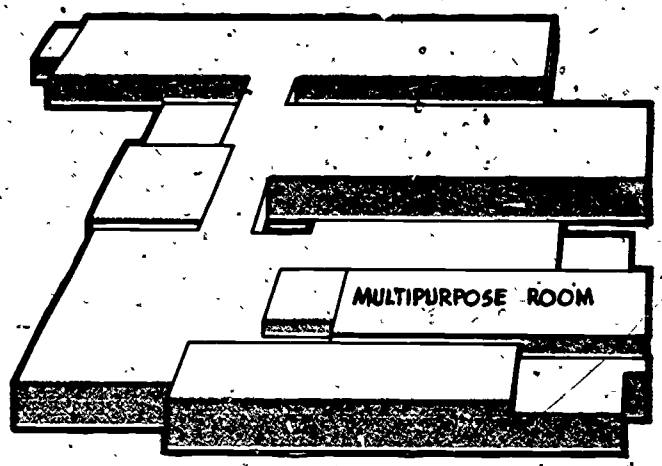
This single-story, no basement, slab-on-grade school building was located in rural eastern Indiana. The building contained a junior and senior high school, plus the administrative offices of the school corporation (district).

The tornado hit 30 minutes after school dismissal and caught the remaining staff by surprise.

Fortunately, a tornado drill had been conducted on April 2, 1974; and when this actual storm hit, the staff went quickly to a preselected area and escaped with slight injuries.

The building was so badly damaged it was deemed a total loss and later was completely demolished.





TORNADO DAMAGE

The tornado center passed slightly to the right of the center of the building, and caused major damage to all three wings. The enclosure walls failed, allowing the winds to enter interior spaces, lift roofs, and toss debris throughout the building.

HAZARDOUS ELEMENTS

(Multipurpose Room)

The *WINDWARD* (south) high *LOAD-BEARING MASONRY WALL* of this *LONG SPAN* room collapsed, and the winds blew brick and concrete blocks throughout the room.

Winds entering the room caused a ballooning effect. The lightweight roof deck was blown off. Some of the deck and the steel bulb tees fell on the floor; and the remainder blew onto adjacent roofs and open spaces.

The high leeward (north) wall of the multipurpose room *COLLAPSED* onto the locker room roof below.

CONSTRUCTION

MULTIPURPOSE ROOM

exterior walls: *4" brick, 8" concrete block.*

structure: *Rigid steel frame, load-bearing south end wall, 2" pressed-fiber-board roof deck on steel tees.*

MAJORITY OF BUILDING

exterior walls: *Glass and metal curtain wall, 4" brick, 8" block.*

interior walls: *8" block.*

structure: *Precast concrete frame, precast concrete hollow-core roof plank (not rigidly connected).*

HAZARDOUS ELEMENTS

(Majority of building)

The winds blew into the building from the south and east. The *WINDWARD* (east) *GLASS CURTAIN WALLS* blew in, allowing a ballooning effect, which caused the *LOAD-BEARING* end walls to blow out. The precast concrete roof planks were lifted up. Some fell back into the rooms, and others blew on top of the remaining roof. The north-south corridors became *WIND TUNNELS* throughout their entire length.

Automobiles on the adjacent south parking lot were rolled and tumbled against the building.

PROTECTIVE ELEMENTS

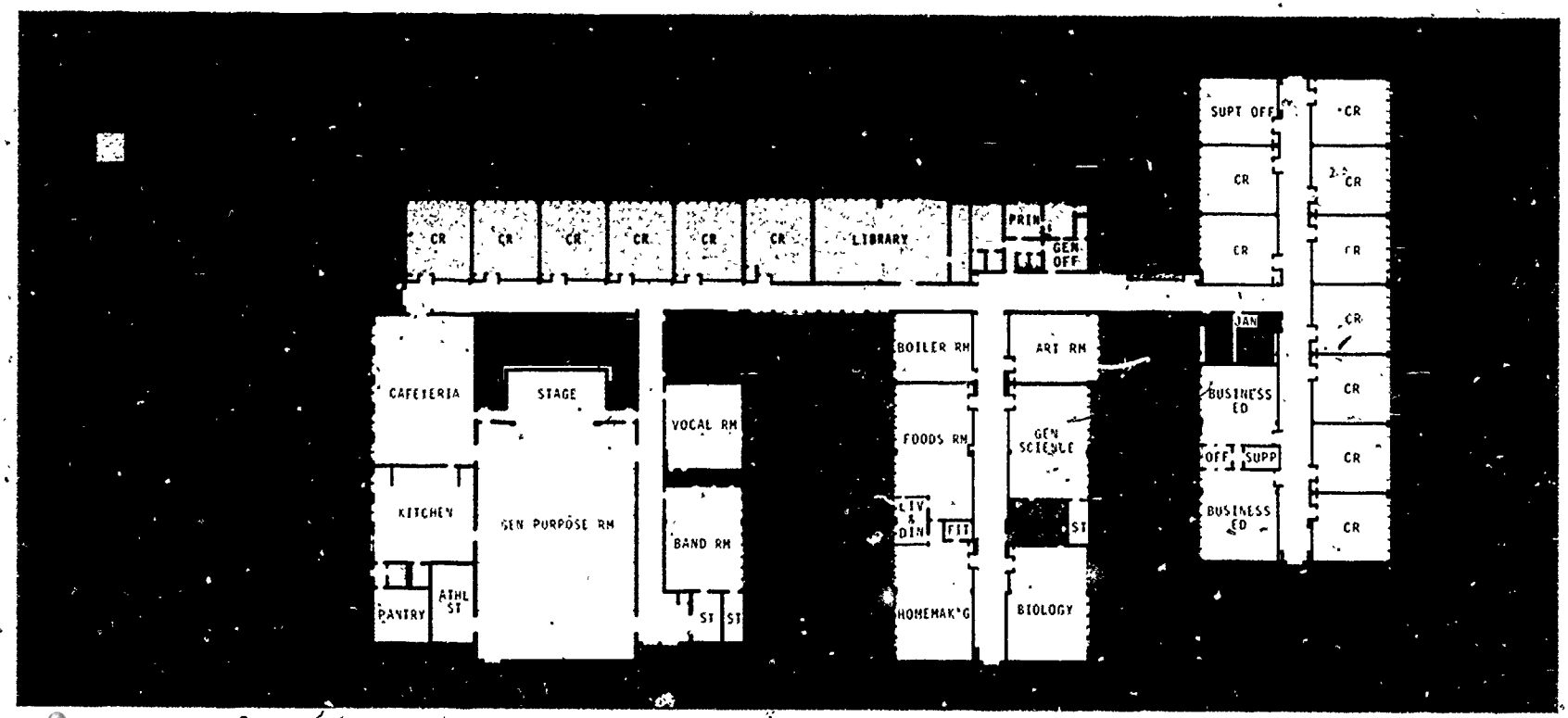
The completely *INTERIOR SPACES* remained intact, offering protection against incoming missiles such as glass, brick, gravel, and block. This was particularly true of the *SHORT SPANS* or smaller spaces such as toilet rooms, work rooms, and storage spaces. Rooms on the leeward (north) side received least damage. Only one north window was broken. The *STRUCTURAL FRAME* remained intact. However, the roof deck was not rigidly connected to these frames, and for the most part depended upon their weight to resist wind uplift. The *HEAVY CONCRETE ROOF* remained intact over most of the building.

COMMENTS

"Those in the building had about 2 or 3 minutes prior warning before the tornado struck. I walked about 50 feet and was approaching my car. I heard this terrific noise. It sounded like 50 jet airplanes treetop high. I glanced over my shoulder to the southwest and saw this mammoth black cloud rapidly approaching. I froze for an instant. Then, realizing it was a tornado, I ran back into the building yelling and shouting to others of the approaching danger.

"We took cover in the north-south corridor beside the boiler room against a west wall lined with lockers. We all kneeled side-by-side in a line, with our hands over our heads for protection. The corridor darkened, doors on the south end of the corridor banged, opened and closed, and a wastebasket blew from an east room west across the corridor into another room facing west. There was some glass breakage. The damage didn't appear to be too great. At the conclusion of this there was a period of calmness, I would say 2 to 5 seconds, and then the storm really hit. Debris was flying down the corridor. This consisted of mud, sticks, stones, glass, plastering, pieces of brick and cement block. Everyone ducked their heads just a little bit farther when this occurred. The terrific suction moved us in the corridor a short distance. One custodian was being sucked around a corner and he grabbed for others to keep from being blown away."

SUPERINTENDENT OF SCHOOLS



XENIA SENIOR HIGH SCHOOL

XENIA, OHIO

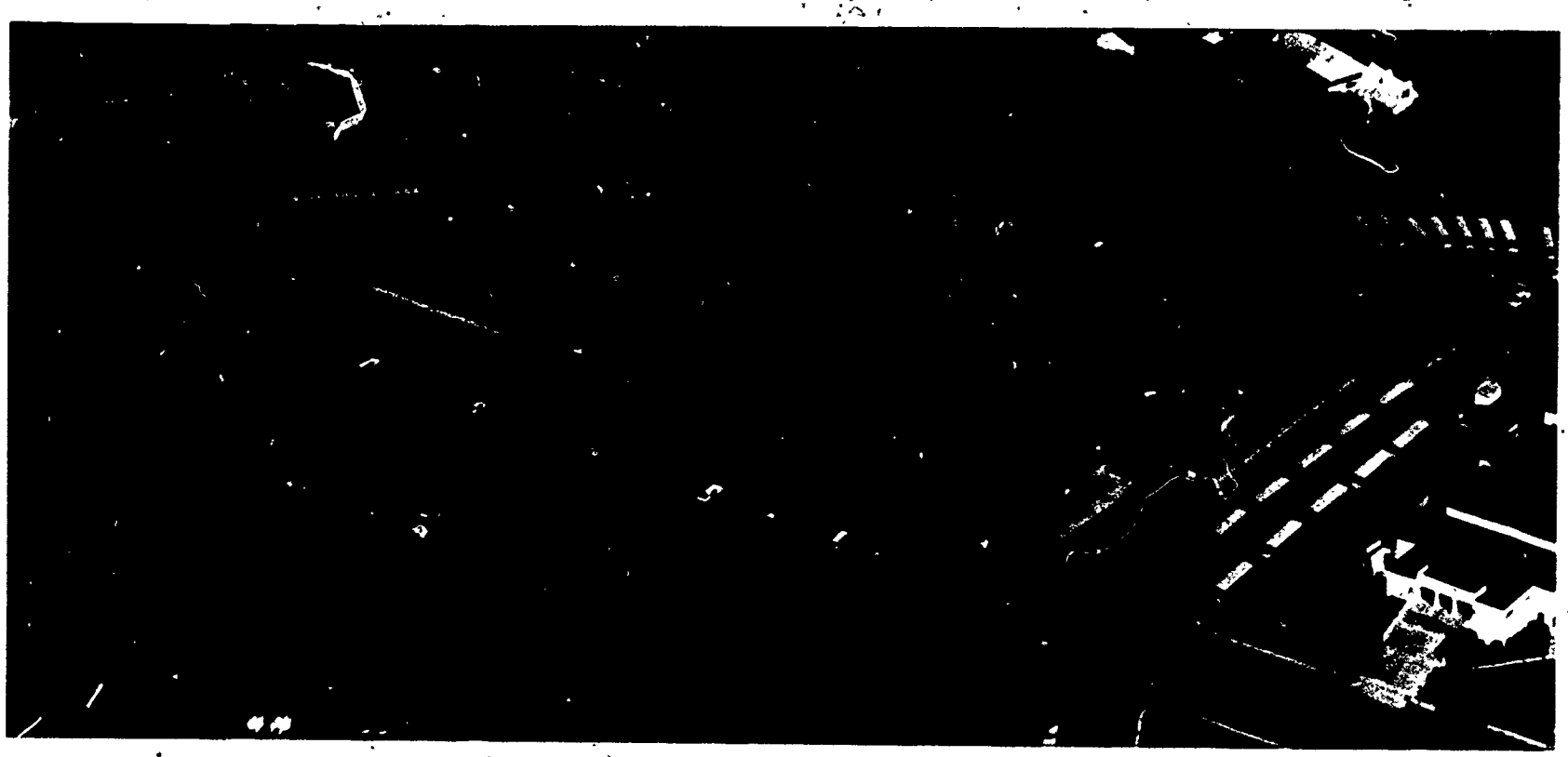
Building population:	*1450, including staff; 12 students, 3 staff in building during storm.*
Tornado direction:	*From southwest*
intensity:	*F5.*
wind speed:	*140-160 m.p.h.*
time:	*4:45 p.m.*
date:	*April 3, 1974.*

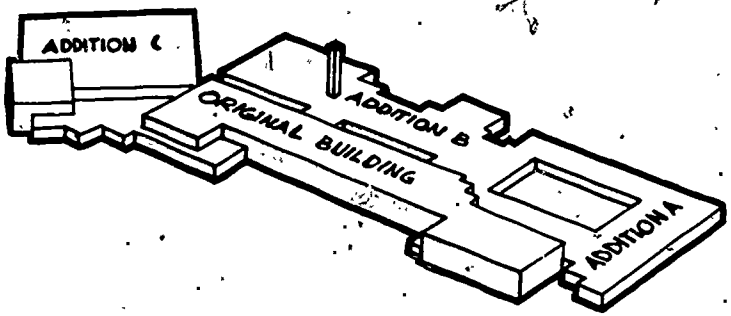
This two-story, no-basement, slab-on-grade school building was located on the near north side of Xenia, Ohio. It faced Shawnee Park to the west.

The massive storm hit 1 hour 45 minutes after school dismissal. It was spotted by a student who was leaving the school. She alerted drama students who were rehearsing in the auditorium. The students ran and dove for shelter in a nearby corridor.

The tornado passed directly over the school. Two school buses came to rest on the stage where the students had been rehearsing. Some of the students were treated at a nearby hospital for injuries.

The building was unsafe to enter and was demolished.





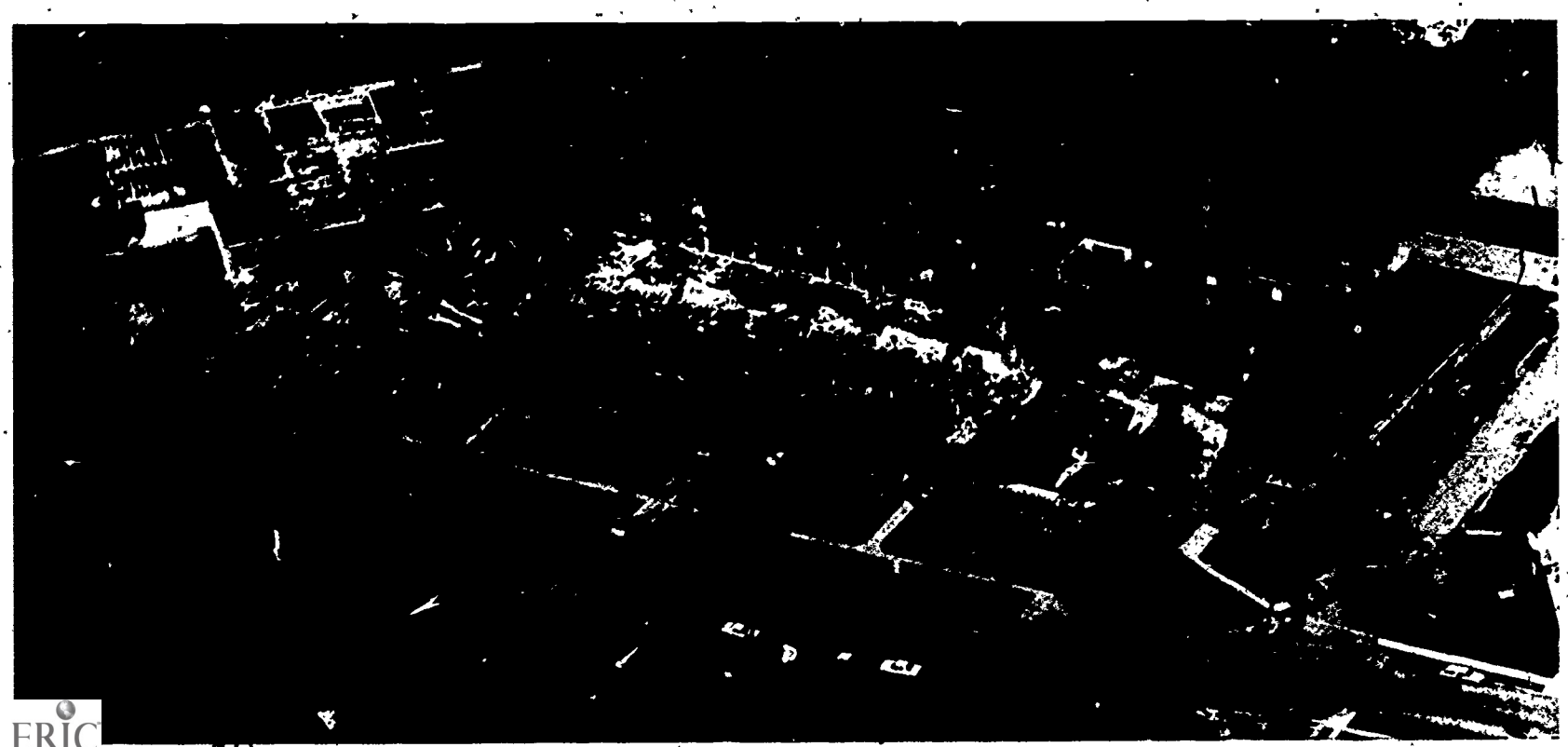
CONSTRUCTION

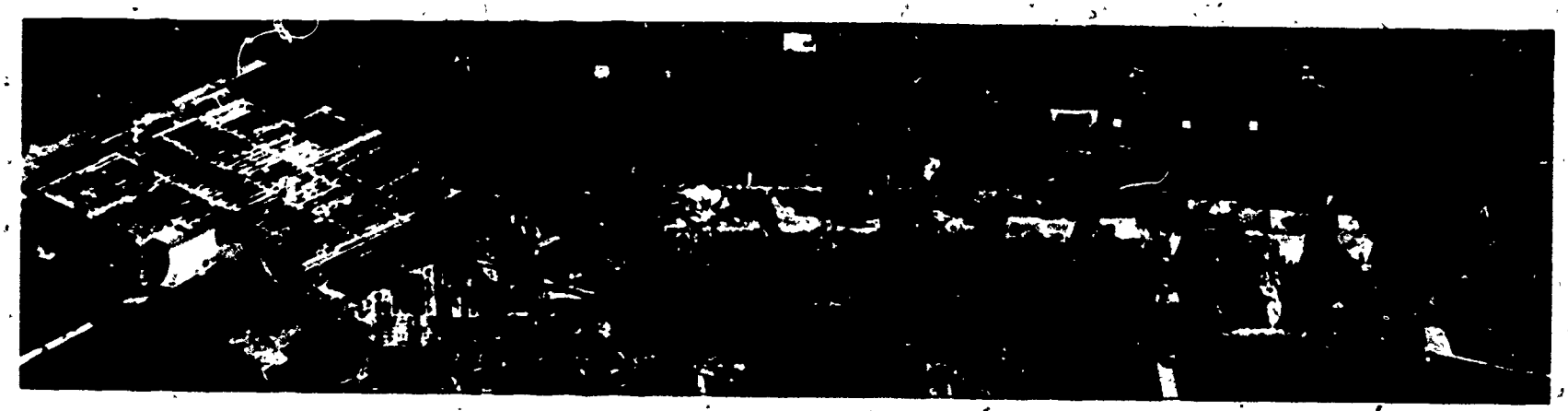
structure: *Lightweight steel frame, open-web steel joists, 2" gypsum roof deck (original building and addition B).*

Loadbearing masonry walls, hollow-core precast concrete roof planks (addition A).
Precast concrete frame, double-tee floor/roof beams (addition C).

Loadbearing masonry wall, precast concrete tee beams (girls' gym).

Loadbearing masonry walls, steel trusses (auditorium and boys' gym).





TORNADO DAMAGE

The tornado passed directly over the school. It engulfed the entire building, plus the adjacent fieldhouse to the south.

The enclosure walls failed on the west and south sides, allowing the winds to enter the building. The roofs collapsed over the three large spans—the auditorium, the boys' gym, and girls' gym. The lightweight roof over the original two-story building was removed.

HAZARDOUS ELEMENTS

All *WINDOWS* on the *WINDWARD SIDES* (west and south) were blown into the interior. The high single-story, *LOAD-BEARING MASONRY WALLS* of the *LONG-SPAN* rooms failed, allowing the roofs to fall in. The unbaffled west entrances allowed the east-west corridors to become *WIND TUNNELS*.

Debris from nearby homes, vehicles, and the park became *MISSILES* which hit and entered the school.

The 46-foot-high masonry chimney *COLLAPSED*. A non-loadbearing second-floor wall on the leeward (north) side *COLLAPSED* onto a lower roof.

PROTECTIVE ELEMENTS

The only portion to offer shelter in the original building was the *LOWEST FLOOR* (first floor). The completely *INTERIOR SPACES* remained intact, especially the *SMALLER SPACES*.

Most of the corridors which were perpendicular to the storm path offered considerable protection.

The concrete *STRUCTURAL FRAME* of addition C remained intact. As a result, interior portions of the second floor provided shelter for some custodians.

The *HEAVY CONCRETE ROOF* remained in place wherever the supports were rigid frames. It also remained intact in addition A, with its loadbearing walls.

The concrete block interior partitions stopped incoming missiles from reaching adjacent interior spaces.

As a result of combinations of the above protective elements, considerable shelter space existed in scattered locations throughout the building.

COMMENTS

"The cast had just done the big dance number from the show. They had done a sloppy job and I was just getting ready to tell them to do it again when a girl yelled, 'Hey, you want to see a tornado? There's a funnel cloud outside.' I came very close to telling everyone to forget it and do the dance again. That would have been a fatal mistake.

"Instead, I jumped off the stage and told everyone to follow me so that we could get a view of it. We ran out the front doors of the school nearest the auditorium. It looked like a lot of dirt or smoke swirling around. We couldn't see anything that looked like a clearly defined funnel cloud. We were looking out at the park across from the school. The mass of wind, dirt and debris was somewhere, I would say, between 100 and 200 yards away. Cars parked in front of the school started to bounce around a bit from the force of the winds. It was really beyond belief.

"Someone said we'd better take cover, so we turned around and ran from the hallway we were in into the center hall that ran north and south. Before we could reach the center hall, the lights went out.

"I only opened my eyes a couple of times. When I did, I saw large pieces of dirt and wood flying through the air. Lockers clanged open and shut and several sections of lockers were actually pulled from the wall and thrown onto the floor. One section barely missed some of my students when it came out of the wall.

"I was sitting directly across from one of the restrooms and a metal door kept flying open and shut constantly during the time that the tornado was on us. That was my greatest fear."

—ENGLISH/DRAMA TEACHER

"I was watching the sky and the lightning seemed to get worse. The minutes went by and it at first had been going vertically and slowly it started to go on angles.

"The black cloud looked like it was about 2½ miles away from the school. As I watched, the lightning came concentrated into the middle of the cloud and began going on angles until it was horizontal.

"For a few seconds, I didn't know that the shrinking cloud was forming a tornado funnel. The funnel was a whitish-grey color more in the shape of a column than it was a funnel. I realized it was tornado when I saw air currents began to swirl. At first I was not afraid. Instead, I was fascinated that you could really see air currents in it.

"I went to the main office to get the principal, but the office was locked and everyone was gone. Just as I started to move, the drama cast started to rehearse a song in the auditorium, so I headed for the auditorium.

"I walked down the aisle past 24 rows of seats to one of my friends in the second row and said, 'Hi Paul, have you ever seen a tornado?' He said 'Ya' and put his arm up on the back of a chair like he's getting ready for a long conversation. I said, 'Neat, there's one across the street.' He looked up at me. The kids up front and to the side looked up at me. Then they all stood up and started to walk out. They got about halfway out and started running.

"All the kids were yelling, 'Hey neat, look at that' and things like that. All of a sudden everyone was dead silent for about 4 seconds. Then everyone started screaming and yelling at once. Julie yelled, 'Get to A-1.' I said, 'Get to the southwest corner.' Mr. Heath turned around and yelled, 'Go to the main hall.' So all the cast started to rush out of the doors and promptly got stuck, so they had to wait and go slow and go out one or two at a time."

—STUDENT (SPOTTER)

"When we were warned about the tornado, we all ran to the door to look at it. I was about the last one to arrive there and I stood there very long until someone yelled from around the corner to get over there. The last thing I saw the tornado doing, was picking up my car which was parked out on the street.

"I then ran around the corner and found everyone already lying along each side of the wall and some around the corner. I then ran to the intersection of the two halls and laid alongside the wall.

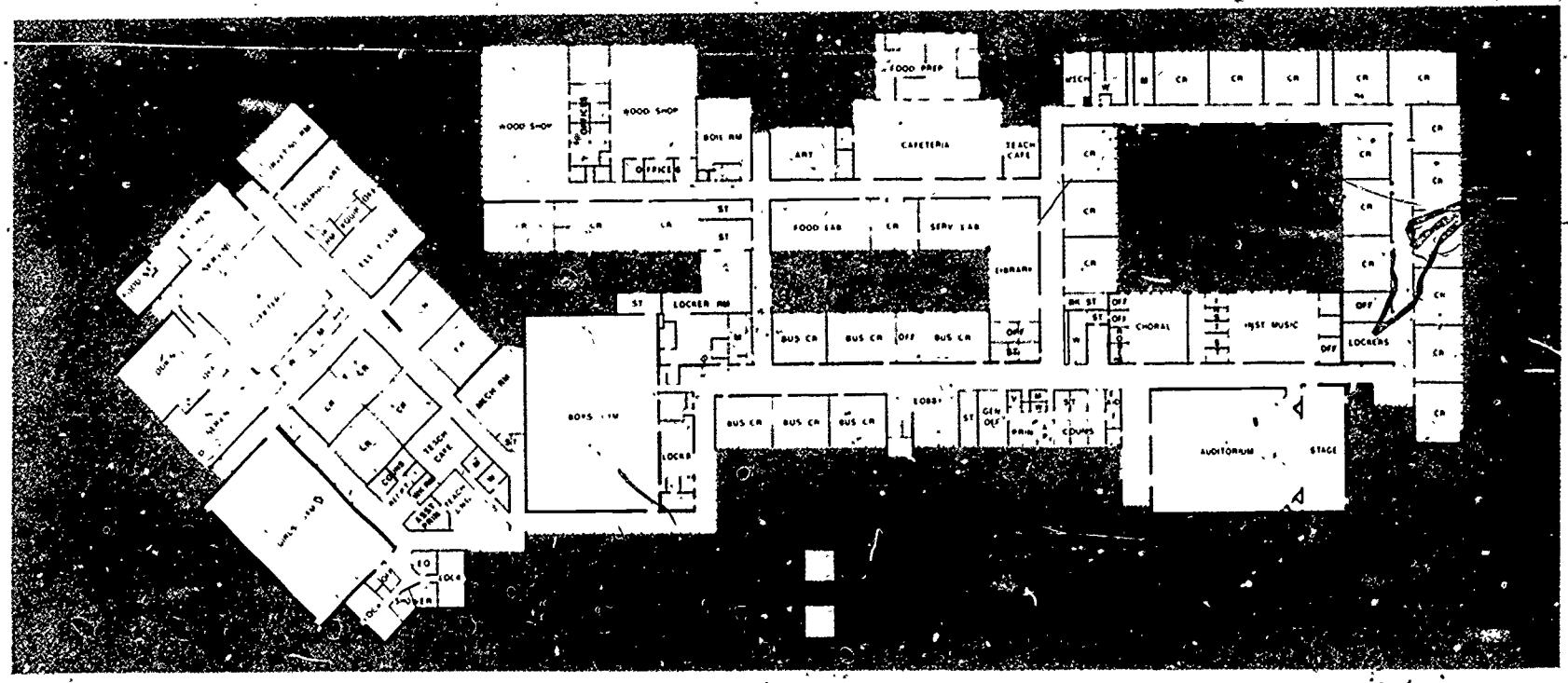
"When it was all over, I was buried from the waist down in little pieces of gravel, boards and a lot of water from the lake across the street in the park."

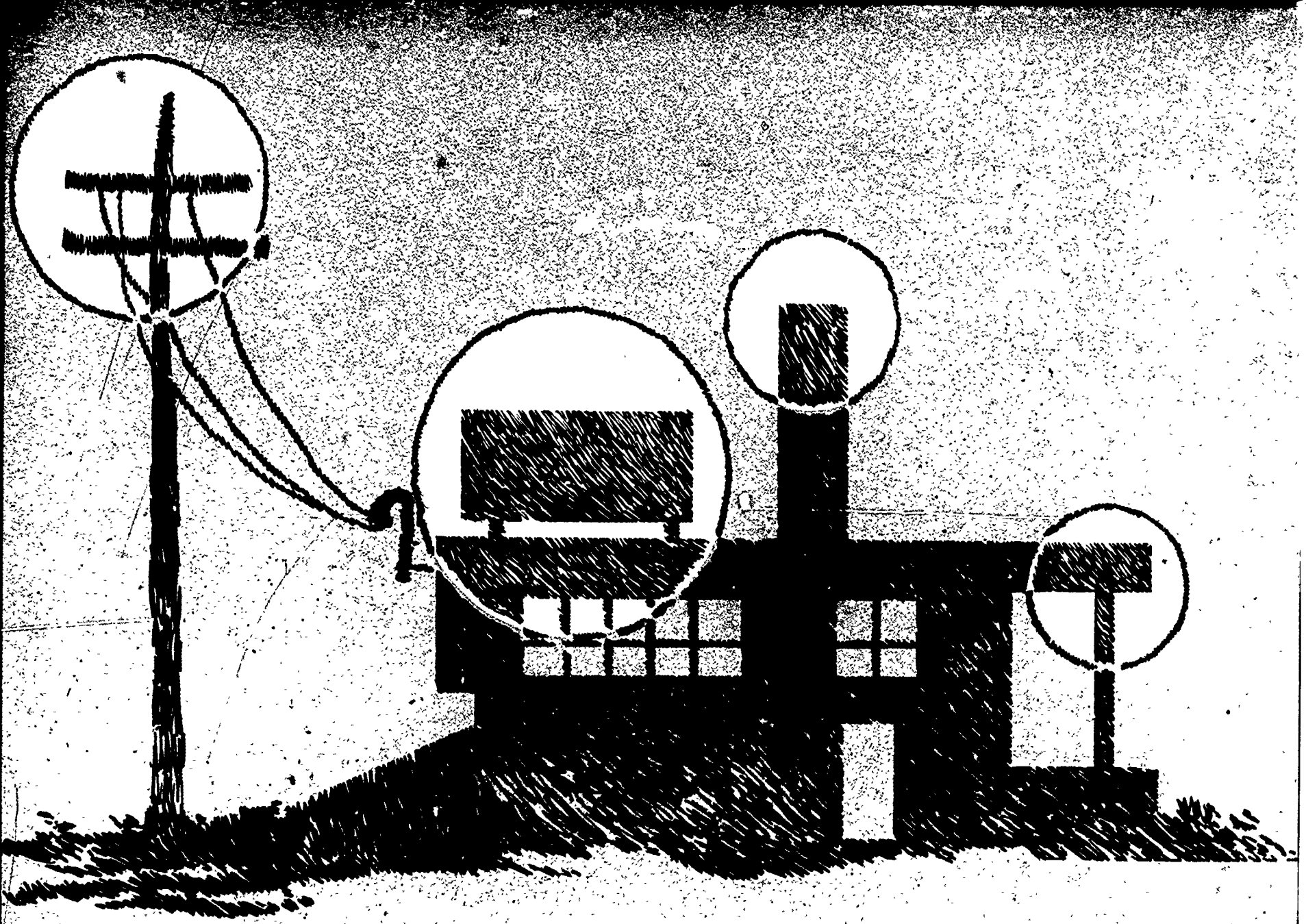
—STUDENT

"The first place I ran to was this little cubbyhole right in front of the girls' restroom door. If I had stayed there, I would have been splattered across the hall, because it blew so hard it almost came off its hinges. For some reason, which I cannot account for, I dived across the hall right after the lights went out and got to the other side of the hall just as the front doors were breaking.

"I kept my eyes open which was stupid on my part. I was looking down at the floor rather than out and I could see big chunks of wood and debris flying down the hall by my feet. It was incredible."

—STUDENT





This procedure is designed to assist in a systematic review of a building to find best available shelter space against severe winds. It is not intended to imply that these spaces guarantee safety during a storm, but that they are the *safest available* in the building.

There are some facilities such as *lightweight modular houses, offices, and classrooms which must be presumed to be death traps. THEY SHOULD BE EVACUATED!*

ADVANCE PREPARATION

Obtain the following equipment: Compass, flashlight, and tape measure.

Know tornado history for the geographic area. Consult the nearest National Weather Service office.

Obtain plans for each floor of the building. Ideal plans are small, to scale, with sufficient detail. If the drawings are not available, have someone prepare a simple, accurate drawing of each floor. Check the drawings against the actual building.

SHELTER SPACE REQUIREMENTS

The space per person depends on the size of the people and their degree of mobility. Small children require only 3 sq. ft./person. Usually 5-6 sq. ft./person is adequate for adults. However, nursing home or hospital patients will require much more space.

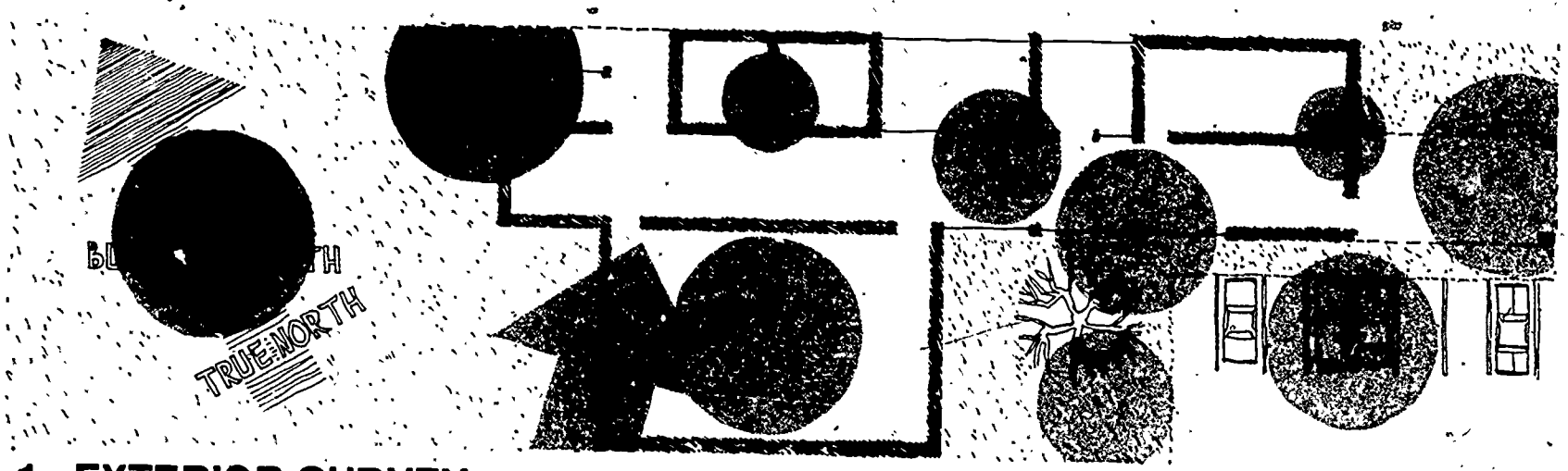
TEST AND RECORD

A plan is almost worthless if it is not tested and understood by the people it is intended to protect. A good plan has the following features:

a. It identifies one or more spotters who are responsible for prompt and accurate visual identification of an approaching storm. The National Weather Service will provide training.

b. It provides for a prompt, clear warning that will be readily understood by all.

The plan should be recorded and made known to all concerned—so all will know where to go and what to do in an emergency.



1. EXTERIOR SURVEY

Establish true north. Use a compass or compare the building to an accurate map of the locality. Place a north arrow on the floor plans of the building. Do not confuse true north with *BUILDING NORTH*, a direction sometimes used to simplify drawings

Check completely around the building, look for and record the location of the following:

a. Potential missiles, such as site equipment, nearby buildings, automobiles, and other debris especially on the south and west sides.
b. Ground embankment against the buildings.
c. Mechanical equipment on the roof
d. Electrical service entrance.
e. High building elements such as chimneys and high portions of the building.
f. Changes in roof level.

Take a long look from each direction, particularly from the south and west, noting building entrances, windows, and construction features.

2. AVOID!

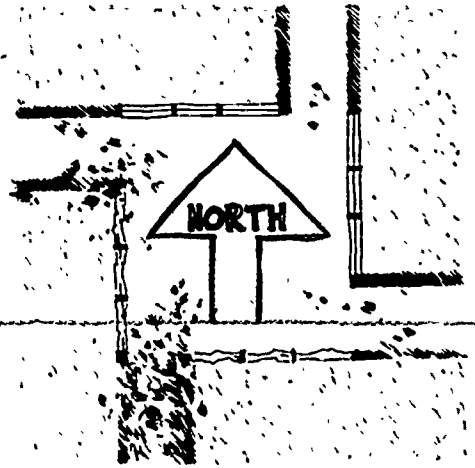
Carefully identify the following spaces as the most hazardous locations, *the spaces to avoid!*

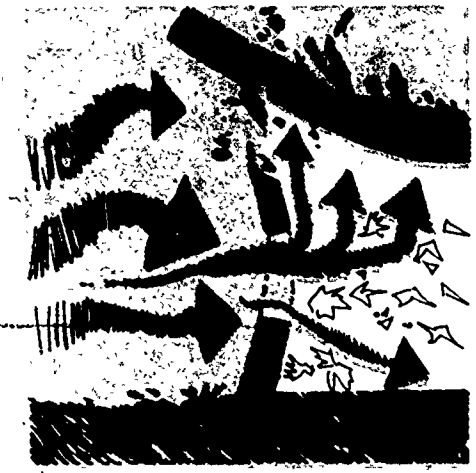
Avoid locations where roofs are likely to be blown off. They may fall in on the occupants. Missiles also have direct access to the interior. Portions of roofs most likely to be blown off are:

a. Windward edges (usually south and west).
b. Long spans.
c. Portions with loadbearing wall supports.
d. Portions with overhangs on the windward sides.

Avoid exterior walls that are most likely to be partially or completely destroyed The most likely damage will probably occur, in the following order, to these walls:

a. South.
b. West.
c. East.
d. North.





AVOID!

Avoid corridors that may become *WIND TUNNELS*. Examination of corridors after tornadoes revealed much debris, and evidence of very high speed winds. This was found in corridors with exterior doors allowing direct exit (no turns) to the following directions, *in order of severity of wind tunnel effects:*

a. South.
b. West.
c. East.
d. North.

Avoid locations with *WINDOWS facing the likely storm direction*. Assume that the windows will blow *IN* on the south and west sides of the building, and occasionally on the east and north.

Avoid, whenever possible, portions of buildings that contain loadbearing walls. If such a wall collapses, the roof or floor will fall in.

Examination of building failures after high winds reveals a pattern of remaining spaces. These should be considered for occupancy during a tornado:

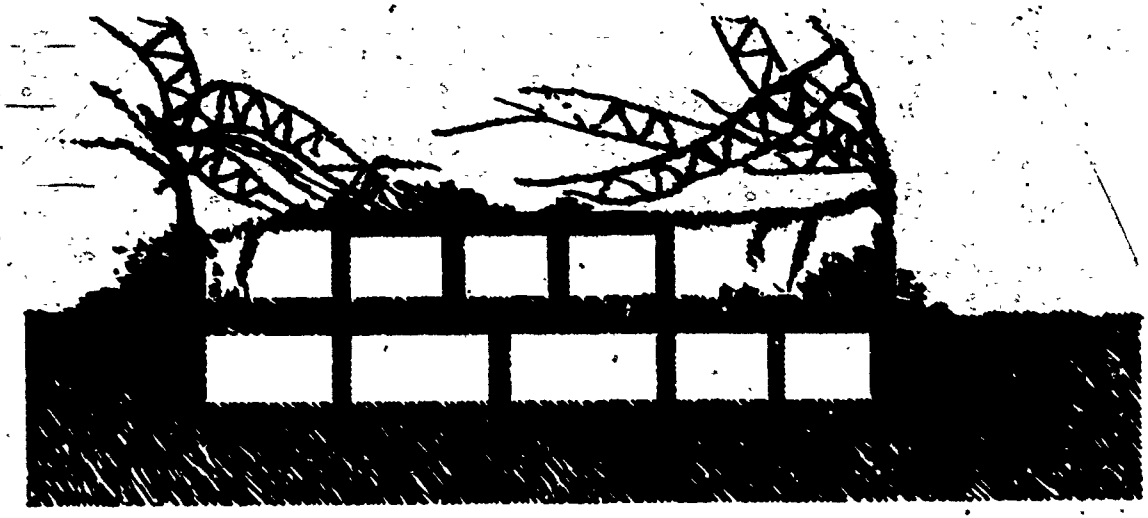
3. CONSIDER—but do not necessarily select . . .

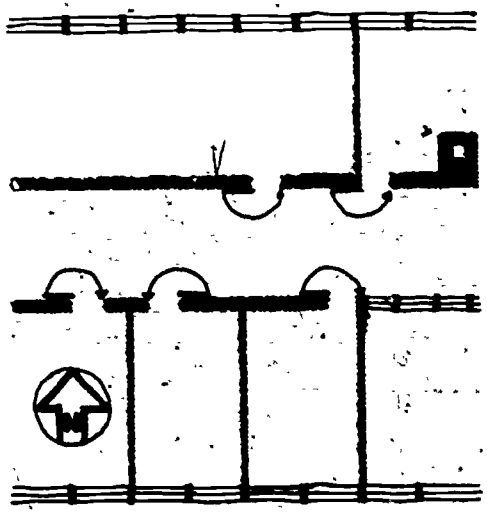
The *LOWEST FLOOR*. If a building has a basement, or a partial basement, it is probably the safest space in the structure.

INTERIOR SPACES. These are spaces that have no walls on the exterior of the building. However, avoid interior spaces with large spans.

SHORT SPANS. It is difficult to find one space, with the exception of a basement, that will offer a high degree of protection to all of the building occupants. Therefore, seek out a number of smaller spaces.

The portions of buildings supported by *RIGID STRUCTURAL FRAMES*, such as steel, concrete, or wood, rather than those portions that have loadbearing walls.





4. REFINE

It is essential that spaces selected be the very best available. Often poor (relatively hazardous) spaces exist within generally safe areas. These poor spaces must be avoided or occupied as a last resort.

Avoid spaces opposite doorways or openings into rooms that have windows in the exterior walls, particularly those facing south or west.

Avoid interior locations that contain windows such as display cases, transoms above doors, and door sidelights.

Avoid interior locations under skylights or clerestories.

Avoid locations where interior doors swing. When the storm hits, the doors are likely to swing violently.

Avoid spaces within the falling radius of higher building elements, such as chimneys or upper walls enclosing higher roof areas. Assume that the falling radius is approximately equal to the height of the higher building element above the roof.

5. OTHER CONSIDERATIONS

Often the best available shelter spaces in a building *CANNOT* be occupied during emergencies for various reasons. Consideration of the following will help determine if the spaces can be occupied:

What portion of the space is usable? Permanent equipment and furniture reduce the usable space.

Which good spaces are often inaccessible in emergency? Many fine spaces normally are locked, with few people having keys.

Which good spaces are unsuitable for occupancy due to operational reasons? Many secure spaces offer excellent protection, but operationally are *not good* to retain security over records, equipment, or money.

Where is the building first aid kit or medical supplies? They should be in one of the safest spaces.

Would protection levels increase significantly and movement time-to-shelter decrease significantly if people were jammed in at lower square-foot per-person ratios? This is a valid alternative in lieu of using a lower quality of protection, with more space per person.

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