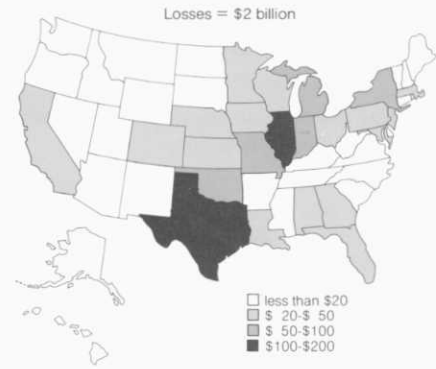


TORNADO





PROJECTED ANNUALIZED LOSSES FROM
TORNADO BY STATE UNDER 1980 CONDITIONS
(1978 dollars in millions)



Although Illinois would suffer the greatest dollar damage, because it is the most densely populated of the nation's tornado-prone states, 21 different states sustain tornado losses to buildings in excess of \$20 million 1978 dollars during a typical year.

Accurate damage assessments are unavailable in many sections of the country because destruction to areas outside of the center of a tornado's path is sometimes ignored. However, of all the natural hazards, it is the biggest killer on an annualized basis

Wind Patterns Reviewed

Computer projections reveal that nation-wide tornado damage to buildings during a typical year, under 1970 conditions, averages at least 1.5 billion 1978 dollars. This estimate stems from a comprehensive review of tornado strikes by frequency and intensity over many years and projections of likely damage from them

Because of rising building value and population growth in the Central States' "Tornado Alley," twister damage to buildings across the nation will probably increase more than 130 percent between 1970 and the year 2000, hitting 3.5 billion 1978 dollars by 2000. Many regard the estimate as low, but there is no way to be certain because of the current state of the art

If the 1973 Uniform Building Code were strengthened 50 percent in all categories pertaining to wind resistance and was employed nationally beginning in 1980, a computer model indicates that, by the year 2000, tornado losses to new construction could be reduced about 45 percent. Overall building losses would drop 15 percent

Chicago Scenario Created

Turning to a computerized scenario: If a 4 Fujita Magnitude tornado, with winds up to 250 mph, cutting a swath of 29 square miles, hit certain sections of the Greater Chicago area in the year 2000, it could cause building damage of approximately \$6 billion and almost 2,000 deaths. The level of devastation

would, naturally, vary, depending upon the area of the city hit. This is not an unthinkable scenario in that two such tornadoes *have* hit the Chicago area since 1934. All told, 29 tornadoes of varying intensities have struck the Windy City in this 44-year period

A totally accurate forecast of potential damage to Chicago's Loop is not possible at this time. At least one school of thought, as yet unproven, holds that the impact of a high velocity tornado striking downtown might conceivably be lessened by heat welling up between tall buildings during the tornado season deflecting some of the winds upward. Others theorize that skyscrapers might shield one another. Regardless of whether or not this is the case, an "average" scenario reveals that if all buildings constructed in Chicago after 1980 were 50 percent more tornado-resistant, annual losses from such a 4 Fujita tornado after 2000 could be reduced almost 15 percent

ACKNOWLEDGEMENTS

List Of Acknowledgements For The Report Entitled: National Losses And Mitigation Effects For Air, Earth And Waterborne Natural Hazards

Overall Review

Ad Hoc Review Committee—American Society of Civil Engineers

Chairman—D. Earl Jones, Jr., *Department of Housing & Urban Development*
Davis, Donald R., *Assistant Professor, University of Arizona*

Friedman, Don G., *Director, Corporate Research Division, The Travelers*

Jens, Stifel, W., *Reitz & Jens, Inc Consulting Engineers, St. Louis, Mo.*

Kiesling, Ernst W., *Professor & Chairman Dept. of Civil Engineering, Texas Tech University*

Levin, Theodore H., *Chief Economist, Federal Insurance Administration*

Lytton, Robert L., *Civil Engineering Department, Texas A & M University*

McDonald, James R., *Associate Professor, Institute for Disaster Research, Texas Tech University*

Swift, Walter D., *Vice President, American Insurance Association*

White, Gilbert F., *Director, Institute of Behavioral Science, University of Colorado at Boulder*

Worthington, Charles, *U. S Geological Survey*

Wright, Kenneth R., *Wright-McLaughlin Engineers, Denver, Colorado*

Providers of Source Material

U. S. Government Organizations

Department of Agriculture, Soil Conservation Service

Ackerson, K. T.

Christenson, J.

Flickinger, Arthur

Klingelhofer, Karl R.

Leicher, Richard

Lloyd, G.

Stearns, C. E.

Department of Air Force

Wayco, D.

Department of the Army, Corps of Engineers

Bucalo, Sal

Budlewski, Robert

Bouknight

Carter, C. R.

Chatry, F. M.

Chueung, Kisuk

Cooper, Sal

Dement

Garcia, Andrew W.

Graham, D. T.

Hamblen, William

Hobbs, Andrew

Houston, James R.

Karpowitz, Charles

Kerr, A. W.

Lasseran, Jack

Lee, Gerry

Leslie, J. W.

Lipski, L. J.

Long, E. G., Jr.

Matthias

Nerseian, G. K.

Ogle, Robert

Phippen, George

Platt, Robert

Salmen, A. J.

Schilling, Walter B.

Soileau

Smethen, D. R.

Tam, W. H.

Trieschman, W. E. Jr.

Whalin, Robert W.

Wilson, H. S. Jr.

Department of Commerce, National Bureau of Standards

Culver, Charles

Lew, H. L.

Department of Housing & Urban Development

Blaser, H. D.

Department of Interior, U. S. Geological Survey

Brabb, E. E.

Campbell, R. H.

Colton, R. B.

Davies, W. E.

Flemming, R. W.

Gray, H. H.

King, T. B.

Olive, W. W.

Radbruch-H

Schuster, R. L.

Sheldon, R. P.

Wallace, R. E.

Wentworth C. M. Jr.

Department of Transportation

Royster, D. L.

U. S. Weather Bureau

Tom, H. C. S.

Webster, B.

Universities

California State University of Northridge
Court, A.

Baylor University

Hayward, O. T.

Georgia Institute of Technology

Sowers, G. F.

Hawaii, University of

Chiu, A.

Los Angeles Valley College

Enderson, H. G.

Mexico Highlands University

Bejnar, W.

New Mexico, University of

McKeen, R. G.

Purdue University

Yao, J. T. P.

Southern Methodist University

Allen, P.

Texas Tech. University

Minor, J.

Metha, K.

Texas, University of

Dodge, C. F.

Foot, A. R.

Washington State University

Perry, D. C.

Private Organizations

Almuti, A. — *Bechtel Corp*

Chieruzzi, R. — *LeRoy Crandall & Associates*

Evans, L. T. Jr — *L. T. Evans, Inc*

Moran, D., *Engineering Geologists*

Reed, J. — *John A. Blume & Associates*

Vellozzi, J. — *Ammann & Whitney*

State Organizations

Alabama

Guthrie, R. L., State Soil Scientist

La Moreaux, P. E., State Geologist

Arizona

Guernsey, C. W., State Soil Scientist

Moore, R. T., Geologist, Bureau of Mines

Arkansas

Bush, W. V., Geologist

McGrew, C. W., State Soil Scientist

California

Broger, W., Department of Bldg. & Safety,

City of Los Angeles

Cleveland, G. B., Division of Mines

& Geology

Clover, R., Soil Scientist
Cobarrubias, J. W. Dept of Bldg
& Safety
Gay, T. E., Jr. Acting State Geologist
Gray C. H., Jr. Division of Mines
& Geology
Pulley, Rodger
Colorado
Gromko, G. J. Civil Engineer
Holder, T. J., State Soil Scientist
Rold, J. W., State Geologist
Connecticut
Haurter, E. H., State Soil Scientist
Delaware
Jordan, R. R., State Geologist
Florida
Johnson, R. W., State Soil Scientist
Hendry, C. W. Jr., State Geologist
Georgia
Pickering, S. M., State Geologist
Shaffer, M. E., State Soil Scientist
Hawaii
Butchart, John N.
Idaho
Bond, J. G., State Geologist
Gallup, D. L., State Soil Scientist
Illinois
Simon, J. A., State Geologist
Voss, E. E., State Soil Scientist
Indiana
Sinclair, H. R. Jr. State Soil Scientist
Iowa
Brune, W. J., State Conservationist
Kansas
McBee, C. W., State Soil Scientist
Wilson, F. W., State Geologist
Kentucky
Daniell, R. E., State Soil Scientist
Hagan, W. W., State Geologist
Noger, M. C., Geologist
Louisiana
Hough, L. W., State Geologist
Maine
Ferwerda, J. A., State Soil Scientist
Lanctot, E. M.
Maryland
Lee, W. K., III, Highway District
Engineer
Shields, R. L., State Soil Scientist
Weaver, K. N., State Geologist
Massachusetts
Grice, E. G., State Soil Scientist
Sinnott, J. A., State Geologist

Michigan
Harner, R. F., State Soil Scientist
Slaughter, A. E., State Geologist
Minnesota
Moore, E. B. Jr. Director Power
Plant Citing
Scillely, F. M., State Soil Scientist
Walton, M., State Geologist
Mississippi
Carter, R. C., State Soil Scientist
Moore, H. M., State Geologist
Missouri
Howe, W. B., State Geologist
Martin, J. V., State Conservationist
Montana
Groff, S. L., State Geologist
Rogers, J. W., State Soil Scientist
Nebraska
Culver, J. R., State Soil Scientist
Dreeszen, C. H., State Geologist
Griss, O. B., Sr. Geologist
Nevada
Nathan, E. A., State Soil Scientist
Trexler, D. T., Res. Assoc., Nevada
Bureau of Mines & Geo.
New Hampshire
Pilgrim, S., A. L., State Soil Scientist
New Jersey
Markley, M. L., State Soil Scientist
Widmer, J., State Geologist
New Mexico
Kottlowski, F. E., State Geologist
Seay, B. D., State Soil Scientist
New York
Gilbert, F. L., State Soil Scientist
North Carolina
Conrad, S. G., State Geologist
Hatfield, W. F., Assistant Soil Scientist
North Dakota
Arndt, M., Geologist
Ekart, S. C., State Soil Scientist
Ohio
Collins, H. R., State Geologist
Post, G. J., State Soil Scientist
Steghitz, R. D., Head Regional
Geology Section
Oklahoma
Fuchs, W. W., State Soil Scientist
Luza, K. V., Engr. Geo.
Oregon
Allen, J. M., State Soil Scientist
Corcoran, R. E., State Geologist
Pennsylvania
Adams, W. R., Engr. Geo.
(Allegheny County)
Briggs, R. P., Prof. Dir. Greater
Pittsburgh Reg. Studies
Latshow, G. J., State Soil Scientist
Socolow, State Geologist

South Carolina
Gerald, T. R., Acting State Soil Scientist
Olsen, N. K., State Geologist
Wells, R. D., State Soil Scientist
South Dakota
Bannister, D. L., State Soil Scientist
McGregor, D. J., State Geologist
Tennessee
Bowers, C., Soil Scientist
Hersehy, R. E., State Geologist
Miller, B., Geologist
Sims, R. P., State Soil Scientist
Texas
Groat, C. S., Acting State Geologist
Gustavson, T. C., Acting Coordinator,
Bureau of Economic Geology
Thompson, C. M., State Soil Scientist
Utah
Hutchins, T. B., State Soil Scientist
McMillan, E. T., State Geologist
Vermont
Watson, B. G., State Soil Scientist
Virginia
Calver, J. L., State Geologist
Googins, R. L., State Soil Scientist
Washington
Mitchell, R. F., State Soil Scientist
Thorsen, G. W., Geologist
West Virginia
Lessing, P., Geologist
Schmude, K. O., State Soil Scientist
Wisconsin
Klingelhoets, A. J., State Soil Scientist
Roshardt, M. A., Geologist
Wyoming
Breckenridge, R. M., Staff Geologist
Kronenberg, R. C., State Soil Scientist
Miller, D. N., Jr., State Geologist
Sherman, W., Chief, Geologist,
Hwy. Department

Other

Miller, Gaylord R., Dir., Joint Tsunami
Research Effort
Wilson, CALTRANS, Maintenance
Planning, Sacramento
Yelverton, C. A., Risk Analysis
Insurance, Whittier

Exposure Model

Gordon, Peter, Department of Economics,
University of Southern California

REFERENCES

The following personnel contributed to the development of this investigation in the areas indicated

J. H. Wiggins Company:

Jon D. Chrostowski
Storm surge and earthquake

Ronald T. Eguchi
Tsunami and storm surge

Gary C. Hart
Hurricane, tornado and severe wind

T. K. Hasselman
All hazard models

Joseph G. Hirschberg
Exposure models

Jerrold Isenberg
Wind models

Dorothy Kennedy
Statistics and demography

Larry T. Lee
Flood, storm surge, tsunami and local flooding

John H. Wiggins
Earthquake, landslide and expansive soils. Overall project direction

Engineering Geology Consultants, Inc.:

James P. Krohn
Landslide and expansive soils

James E. Slosson
Landslide and expansive soils

Principal Study Reports

Hart, Gary C., *Natural Hazard Tornado, Hurricane, Severe Wind*, J. H. Wiggins Company Report prepared for the National Science Foundation under Grant #ERP-75-09998 (December 1976) and #AEN-74-23993

Lee, Larry T., Chrostowski, Jon D., and Eguchi, Ronald T., *Natural Hazards Riverine Flooding, Storm Surge, Tsunami*, J. H. Wiggins Company report prepared for the National Science Foundation under Grant #ERP-75-09998 (June 1976) and #AEN-74-23993

Lee, Larry T. and Thomas L. Essex, *Urban Headwater Flooding Damage Potential*, J. H. Wiggins Company, Technical Report #1282 prepared for the National Science Foundation under Grant #ENV-76-24658 (October 1977)

Wiggins, John H., Slosson, James E., and Krohn, James P., *Natural Hazards: Earthquake, Landslide, Expansive Soil*, J. H. Wiggins Company report prepared for the National Science Foundation under Grant #ERP-75-09998 (October 1978) and #AEN-74-23993

Hirschberg, J., Gordon, P., and Petak, W. J., *Natural Hazards Socioeconomic Impact Assessment Model*, Redondo Beach, California, J. H. Wiggins Company, 1978, under Grants #ERP-75-09998 (June 1976) and #AEN-74-23993

Petak, W. J., Atkisson, A. A., and Gleye, P. H., *Natural Hazards A Building Loss Mitigation Assessment (Final Report)*, Redondo Beach, California, J. H. Wiggins Company, 1978, under Grant #ERP-75-09998 (June 1978)

Other References

Alfors, et al, *Urban Geology Master Plan for California—Phase I A Method for Setting Priorities*, California Division of Mines and Geology, open file report 72-2 (1971)

Friedman, D. G. and Bocaccino, M., *Computer Simulation of the Effects of Adjustment to the Inland Flood Hazard*, the Travelers Insurance Company originally published in 1966 (December 18, 1972)

Jones, D. E. Jr., *Natural Hazards Considerations, Problems and Questions*, (November, 1972)

Jones, D. E., Jr & Holtz, W. G., *Expansive Soils—The Hidden Disaster*, Civil Engineering, Volume 43, No. 8, Page 45-51 (1973)

Krohn, J. P. and Slosson, J. E., 1976, *Landslide Potential in the United States*, in *California Geology*, California Division of Mines and Geology, pp. 224-231.

Krohn, J. P. and Slosson, J. E., 1978, *Assessment of Expansive Soils Within the United States*, in *Proceedings of the Sixteenth Annual Symposium*, (paper presented on April 6, 1978)

NOAA, *Storm Data*, monthly publication of NOAA, U. S. Department of Commerce (1971)

Office of Emergency Preparedness, *Disaster Preparedness*, Volumes 1-3 prepared for the Office of Emergency Preparedness, Department of Housing and Urban Development (1972)

Smith, D. M. and Allen, D. M., *A Cost Benefit Analysis of Housing Foundation Failures*, Department of Economics, Southern Methodist University, Dallas, Texas (1974).

Sugg, A. L. et al, *Memorable Hurricanes of the United States Since 1873*, NOAA Technical Memorandum NWS SR-56 (1971)

White, G. F., *Changes in Urban Occupancy of Flood Plains in the United States*, Department of Geography, Research Paper #57, University of Chicago Press (1958).

U. S. Geological Survey, 1976 *Landslide Overview*, Conterminous United States, Miscellaneous Field Studies Map MF-771.

White, G. F. and Haas, J. Eugene, *Assessment of Research on Natural Hazards*, The MIT Press (1975)

The dedication and long hours spent by all personnel involved in the program are deeply appreciated

Support for this effort was provided by Dr. Charles C. Thiel, Dr. G. Patrick Johnson and Dr. Michael P. Gaus of the National Science Foundation

Special thanks are due Mr. D. Earl Jones Jr., Chairman of the ASCE Oversight Committee, for his many constructive comments and suggestions made throughout these studies