National Conference on Earthquakes and Related Hazards

- Earthquake Prediction
  - Reaction and Response to Prediction
    - Hazard Reduction
      - Public Policy

An Invitational Conference

Sponsored by

The Council of State Governments

with the cooperation of

The Natural Hazards Research and Applications Information Center
Institute of Behavioral Science, University of Colorado

Held at Boulder, Colorado

November 16 - 18, 1977

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This conference was part of a two-year project aimed at identifying policy issues which public officials may face as a result of an anticipated increasing ability of scientists to predict earthquakes. The project was concerned not just with earthquakes, but with related hazards such as floods, fires, ground failures, and tsunamis. It looks at earthquake problems in the context of a comprehensive approach by public officials to natural and manmade hazards as well as emergencies of other kinds. It also considers intergovernmental roles and relations and the role of the private sector in its examination of policy issues and potential efforts to reduce hazards. The conference program is given in this volume and summaries of conference presentations and discussions are presented, covering earthquake prediction, validation of earthquake predictions, issuance of warnings and anticipated reactions, risk assessment, and hazard reduction. A progress report on implementation planning for an earthquake hazard reduction program of the federal government also is included.

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FOREWORD

As scientists increase their capabilities to predict the location, time, magnitude, and probability of earthquakes and related hazards, the resultant policy issues to be faced by public officials will be greatly multiplied. Public officials at the state level--governors, legislators, and administrators--may bear the major decisionmaking task in how to face these policy issue problems. Some states, such as California and Utah, have begun to address these problems. Other states have shown interest and concern. All states have the potential of being presented with the problems.

The Council of State Governments has worked with the states in the area of disaster preparedness through such means as developing suggested state legislation and providing technical assistance. The Council is pleased to be devoting some of its efforts in the research area of earthquakes and related hazards as part of its program devoted to governmental concerns with environmental problems. The conference which this publication reports is the beginning phase of these efforts.

Lexington, Kentucky
October 1978

Herbert L. Wiltsee
Executive Director
The Council of State Governments

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PREFACE

Achieving an understanding of earthquakes and related hazards and how they affect public policies and programs presents a complex challenge. The organization of the National Conference on Earthquakes and Related Hazards reflected this complexity. Representatives from federal, state, substate, and local governments attended, along with a number of nationally known scientists from the academic and private research communities and others from public interest groups and the private sector. The conference provided a needed opportunity for interaction among these participants. The Council of State Governments is especially appreciative of the time given by the participants to come to Boulder and for their willingness to raise questions, express views, and impart knowledge.

The conference was part of a two-year project being conducted by the Council of State Governments and financed by a grant from the National Science Foundation. The project is aimed at identifying policy issues which public officials may face as a result of an anticipated increasing ability of scientists to predict earthquakes. Associated with the Council in this project are three committees of state officials, organized, respectively, by the National Association of Attorneys General, the Council of State Planning Agencies, and the National Association of State Directors for Disaster Preparedness. Members of these committees are listed in the appendix to this report. Information provided through the project, issues identified, and potential policies and programs will be discussed with these associations, also with members and staff of the National Governors' Association and with representatives of federal and local government agencies. Additional committees of representatives from federal agencies and public interest groups have been formed for liaison purposes. Finally, an advisory council has been invited by the Council to monitor these efforts. A further report will be produced on the state role in dealing with natural hazards, concerned with broad range of problems involved in hazard assessment, warning and response, mitigation, and recovery.

The project is concerned not just with earthquakes but with related hazards such as floods, fires, ground failures, and tsunamis. It will look at "earthquake problems" in the context of a comprehensive approach by public officials to natural and manmade hazards as well as emergencies of other kinds. It will also look at intergovernmental roles and relations and the role of the private sector in its examination of policy issues and potential efforts to reduce hazards.

The Council's director for this project, Hirst Sutton, was chief organizer for the conference and editor of these proceedings. He was assisted by Council staff Charles Manning and Margaret Schrader. Valued assistance in Boulder came from the Natural Hazards Research and Applications Information Center of the University of Colorado. Gilbert F. White, director of the center and members of its staff advised in the development of the conference, also provided the initial notes for this report on conference proceedings. Portions of the final draft of the proceedings were reviewed by a number of conference panelists. Council staff member Emily Adams assisted in preparing the material for publication.

H. Milton Patton
Associate Director for
Environmental Resources

I. CONFERENCE PROGRAM

Tuesday, November 15, 1977

4 p.m. (Lobby) — Reception desk opens

6 - 7 p.m. (Century Room) — Reception for participants (cash bar)

8:30 - 9:30 p.m. (Century Room) — Predictable Disaster

A Public Broadcasting Service film on earthquake prediction, produced by WGBH, Boston

Wednesday, November 16

8 a.m. (Lobby) — Reception desk opens

9 - 9:15 a.m. (The Penthouse) — Opening Session - Schedule, Plans, Arrangements

Gilbert F. White, Director, Natural Hazards Research and Applications Information Center, University of Colorado

Hirst Sutton, Project Director, the Council of State Governments

9:15 - 10:30 a.m. (The Penthouse) — Earthquake Prediction

State of the art of earthquake prediction; foreign experience with earthquake prediction; prediction in the eastern and western parts of the United States; production and use of precursor data; aftershocks; role of the U.S. Geological Survey, of state and local governments; the future of prediction technology.

Chairman: Clarence R. Allen
Professor of Geology and Geophysics
California Institute of Technology
Pasadena, California
Chairman, National Research Council's Panel on Earthquake Prediction

Panel: Thomas V. McEvilly
Professor of Seismology
University of California
Berkeley, California

Robert E. Wallace
Chief Scientist, Office of Earthquake Studies, U.S. Geological Survey
Menlo Park, California

10:30 - 10:45 a.m.	Morning break
10:45 - Noon (The Penthouse)	Earthquake Prediction (continued)
12:15 - 1:30 p.m. (Century Room)	Lunch
1:30 - 2:45 p.m. (The Penthouse)	Validation of Earthquake Predictions, Issuance of Warnings, and Anticipated Responses

Responsibility for validation of earthquake predictions and issuance of warnings; roles of scientists and public officials; responsibilities of U.S. Geological Survey; legal implications and issues; community reaction to earthquake prediction and warning; socio-economic implications of an earthquake prediction and/or warning.

Chairman: Robert B. Rigney
Administrator, Environmental Planning
San Bernardino County
San Bernardino, California
Chairman, California Seismic Safety Commission

Panel: Robert E. Wallace
Chief Scientist
Office of Earthquake Studies
U. S. Geological Survey
Menlo Park, California

Dennis S. Mileti
Assistant Professor of Sociology
Colorado State University
Fort Collins, Colorado

Denise Heller Paz
Co-Investigator on Study of Response to Earthquake Threat in Southern California
University of California at Los Angeles

E. L. Quarantelli
Co-Director, Disaster Research Center
Ohio State University
Columbus, Ohio
Member, National Research Council's Panel on the Public Policy Implications of Earthquake Prediction

2:45 - 3 p.m.	Afternoon break
3 - 5 p.m. (The Penthouse)	Validation-Reaction (continued)

6 - 8:30 p.m. (The Penthouse) — Dinner (preceded by cash bar reception)

Presiding: Honorable Mike O'Callaghan
Governor of Nevada
Chairman, National Governors' Association Subcommittee on Disaster Assistance

Speaker: Philip M. Smith
Assistant Director
Office of Science and Technology Policy
Executive Office of the President
Washington, D.C.

Subject: Progress in Implementation Planning for an Earthquake Hazard Reduction Program of the Federal Government

Thursday, November 17

9 - 10:30 a.m. (The Penthouse) — Risk Assessment and Hazard Reduction

Delineation of earthquake and related hazards (tsunamis, floods, fires, ground failures);
Land use planning and regulation;
Engineering measures for loss reduction
--building technology to reduce risk in general construction (new and existing structures);
--lifelines (utilities, highways, communications, etc.);
--critical facilities (dams, nuclear reactors, other);
Disaster response: steps to increase readiness;
Other mitigation measures;
--insurance (liability protection, incentive for hazard reduction, public-private roles);
--financial incentives (tax policy, government grants-insured loans, conditions for public-private grants and loans);
--other uses of police power;
Long-range reconstruction and recovery;
Implementation of hazard reduction programs;
--federal-state-local roles;
--intergovernmental aids and relationships;
Dissemination of knowledge, education and training;
Adequacy of legislation.

Co-Chairmen: Carl Kisslinger
Director
Cooperative Institute for Research in Environmental Sciences
University of Colorado

Robert V. Whitman
Professor of Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

Panel:

Delineation of Hazards	John Wiggins, Jr. President, J. H. Wiggins Company Redondo Beach, California
Land Use Planning	George G. Mader Wm. Spangle and Associates, Inc. Portola Valley, California
Building Technology	Charles G. Culver Office of Housing and Building Technology National Bureau of Standards Washington, D.C.
Lifelines	James E. McCarty Director of Public Works, Oakland, California President, American Public Works Assn.
Disaster Response	Charles S. Manfred Director, California Office of Emergency Services Sacramento, California
Implementation of Hazard Reduction	Robert A. Olson Executive Director Seismic Safety Commission Sacramento, California

10:30 - 10:45 a.m.	Morning Break
10:45 a.m. - Noon (The Penthouse)	Hazard Reduction (continued)
12:15 - 1:30 p.m. (Century Room)	Lunch
1:30 - 2:45 p.m.	Hazard Reduction (continued)
2:45 - 3 p.m.	Afternoon Break
3 - 5 p.m.	Hazard Reduction (continued)
Evening	Brief meetings for members of committees of attorneys general, planners, and disaster officials--to discuss subsequent meetings and considerations for their committees

Friday, November 18

9 - 10:30 a.m. (The Penthouse)	Hazard Reduction (continued)
10:30 - 10:45 a.m.	Morning Break
10:45 a.m. - Noon (Century Room)	Wrap-up Session: Summary Presentation and Discussion Gilbert F. White, University of Colorado
Noon	Adjournment

II. SIGNIFICANT BRIEFS - Selections from Remarks by Conference Participants*

The optimism of the early 1970s about the imminent possibility of reliable earthquake prediction is gone...there is, however, hard evidence that there are useful precursors of large earthquakes.

While the present state of prediction should be viewed conservatively, it is still reasonable to take an optimistic view which supports an expectation that a capability to predict earthquakes, at least within short-term periods prior to an event, could come within the next ten years...A few years ago scientists in the earthquake field would have been more sanguine. Now they're more judicious.

Eastern earthquakes are not even understood by experts. USGS and NSF are working on new projects to deal with eastern earthquakes, but problems won't be identified for a few years. Eastern earthquakes in the United States could be bigger but less frequent than California ones. Risk is less understood but perhaps is as great in the east.

An earthquake prediction is an invisible problem. Local levels of government prefer not to handle it and will put it off on a higher level.

Prediction is the business of scientists. Long-term predictions for earthquakes will have a stronger and different socio-economic impact on a community than relatively short-term weather, fire, flood, and wind predictions. Issuance of warnings is a state-local responsibility.

There should be one warning system for all hazards to avoid confusion; a warning needs to be accompanied by suggested actions the public can take.

While California is the center of most earthquake discussions, other states have very different problems.

A case hasn't yet been made that it is cost beneficial to spend much time and effort to prepare just for earthquakes; if preparedness actions are helping a community deal with other problems as well, then a much stronger case can be made.

An all-hazards approach can lend vital support for mitigating hazards from earthquakes as well as other natural hazards. We need now to find out how to get together people having concerns for mitigation of particular hazards in order to maximize our hazard reduction efforts for mutual advantage and to achieve a better all-round result.

Traditional types of measures for preparedness (i.e., responding to the event of a disaster after it occurs) are an important part of what happens if a long-term earthquake prediction is issued, but they are only a small part of an effective, comprehensive mitigation program.

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*These statements are not direct quotes nor do they necessarily represent consensus points of view. From the editors' standpoint, however, they are worthy of special attention by those interested in the subject matter of the conference.

Effective hazard reduction measures are critical for emergency preparedness. City planning directors, attorneys, and others will make as many of these decisions, likely more, than disaster directors.

Choosing the right mix of tools which can be applied to earthquakes and other hazards is a major area of concern.

There must be consideration of the social impacts of hazard mitigation. When hazard mitigation is added to other things, some activities may affect poorer people most.

III. SUMMARY OF CONFERENCE PRESENTATIONS AND DISCUSSIONS*

*As is often the case at conferences such as this, time ran out before attention could be given to a number of subjects listed in the conference program.

A. EARTHQUAKE PREDICTION

From Members of the Panel:

Clarence R. Allen, California Institute of Technology - Chairman
Thomas V. McEvilly, University of California (Berkeley)
Robert E. Wallace, U.S. Geological Survey

Optimism. Optimism in the field of earthquake prediction means that a prediction shortly before the event of an earthquake may be possible within ten years. Such a prediction would allow time after the prediction for short-range protection measures but not longer-term measures such as building code changes, land-use restrictions, etc. There is a wide spectrum of opinion about the possibility of prediction, but it is clear that earthquake prediction is not just around the corner.

Some earthquakes have been predicted. We know something about successes and failures that the Chinese have had. In this country a prediction was also made of an earthquake that occurred at Blue Mountain Lake in New York State in 1973.[1]

Physical precursors of earthquakes have been observed, which some day we will be able to measure effectively for the purpose of making predictions. Examples which have been seen are changes in uplift (particularly as seen in Niigata, Japan) and random anomaly noted in local ground water in southern Russia. Rock when squeezed has shown certain precursors before failure. Such ground failure observed and measured is not the result of a random process; it obeys physical laws, and these can be ascertained.

The Chinese earthquake of February 4, 1975 at Haicheng was preceded by identified precursors, including an increase in measured seismicity and magnetic changes. In June of 1974 measurable effects increased in severity and led to the prediction of an earthquake within one to two years of a Richter magnitude of 5 or more. That summer, anomalies in well water and in the behavior of animals were observed. On January 13, 1975, a prediction was made that an earthquake would occur within six months. In February foreshocks built up, then cut off. These events provided a clear observational basis for a valid prediction--one which led to saving many lives.

But we also know the Chinese have failed to predict devastating earthquakes.

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[1]Following several magnitude 2 to 3 earthquakes on July 14 and 15, 1973 at Blue Mountain Lake, located in upstate New York, portable seismographs were installed which enabled analyses of seismograms monitoring variations in travel-time ratios between compressional and shear waves in underground rock. When velocity decreases similar to those preceding several 1971 events in the same area occurred, a prediction was made on August 1, 1973 that an earthquake of magnitude 2.5 to 3 would occur in a few days. On August 3 an earthquake of magnitude 2.6 occurred.

To further earthquake prediction in this country there is need for funding of prediction research at a level adequate, among other things, to provide necessary instrumentation. A considerable period, many years in fact, will be needed to test forecasting techniques; unfortunately, this can be done only with the occurrence of earthquakes.

Considerable instrumentation exists in California but not in other states where seismic activity is known to occur, such as Massachusetts and New York. Testing is possible in California because of the larger number of earthquakes taking place; exploration is needed as to which techniques usable in California are transferable to other parts of the country.

The Conservative Outlook. The optimism of the early 1970s about the imminent possibility of reliable earthquake prediction is gone. The basis for this loss of enthusiasm is that greater study and evaluation of successful predictions have yielded no evidence of fool-proof prediction tools.

There is, however, hard evidence that there are useful precursors of large earthquakes (e.g., magnetic field changes, earth deformations). Problems in the utilization of these precursors which face scientists and others fall into several categories:

1) Temporal relationships. The temporal relationship between precursors and events has not been identified. For example, the Southern California uplift is thought by many seismologists to be a possible precursor, but what the deformation means in terms of time scale is not known.[2] More will be learned as a result of current studies. (See Appendix, page 70, "Scientists Recheck California 'Bulge' for Earthquake Signs.")

2) Velocity changes. Although predictions have been made as a result of velocity change precursors, we find no consistency of velocity changes before all earthquakes.

3) Foreshock identification. Although some major earthquakes are preceded by foreshocks, not all are; in fact, there is presently no way to distinguish a foreshock from an actual quake.

4) Selection of areas for instrumentation. Decisions on instrumentation efforts raise questions of geographic sampling, presenting both spatial and temporal problems. Seismicity occurs in many parts of the United States, and earthquakes can affect large areas in the United States. There is neither manpower nor instrumentation enough to monitor all areas. There is a good chance that the U.S. Geological Survey will not be monitoring the area where the next significant earthquake occurs.

Consequences of these problems in techniques and in the spatial and temporal sampling processes are that (a) within the next few decades there may

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[2] A number of conference participants used the vernacular term "the Palmdale Bulge" to describe what many now prefer to call the Southern California Uplift. These two titles are used interchangeably throughout this report.

well be one or more sleeper earthquakes--not even guessed at; (b) earthquakes will occur which have been predicted only in very general terms (e.g., earthquake "predictions" associated with the Southern California uplift anomalies); and (c) predictions will be made that are absolute misses.

It will be a challenge to maintain credibility in light of trying to practice this new, imperfect technology.

The three-year program authorized by the Earthquake Hazards Reduction Act, which became law on October 7, 1977, will not solve the problems which the act addresses. Hopefully, Congress and others do not think it will.

There is a real danger that public attention and support will have waned during the three-year program, especially if there are no major earthquakes during that period. Public recognition is needed that earthquake research is more like cancer research than it is like technologic projects which got man to the moon.

Future of Earthquake Prediction Research. Future earthquake research is warranted in a number of areas. More specific knowledge is needed about the effects of different intensities of earthquakes. Much knowledge is now available (e.g., about creeping sections and locking sections found between the North American and Pacific tectonic plates along the San Andreas fault). We know something now about mechanisms for different areas and are learning more.

Research can provide information which engineers need to know about the effect of earthquakes and related hazards on structures--such as knowledge as to how long vibrations will last, the frequency of waves and their vibration effects. More needs to be known about ground stability, liquefaction possibilities, potential for landslides, and tidal wave action or tsunamis.

Risk and hazard maps are needed. If these are used in our microzonation processes, what will be the local effects on nuclear reactors, lifelines, and fire danger?[3]

Prediction research must seek to develop each of the four main elements of prediction: time, place, magnitude, and probability.

Scientists can help public officials by developing scenarios for them. These will be helpful in translating earthquake prediction technology into policy and will involve evaluation of predictions, when and how to issue warnings, and ways in which public awareness to earthquakes and related hazards can be heightened. Public administrators will need the help of scientists in the val-

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[3]Microzonation is a term developed in earthquake engineering and doesn't apply to the term "zoning" as used in a legal sense to regulate land use. It does, however, involve the procedure of bringing together data on various systems (transportation, waste disposal, etc.) as well as geologic information useful in detailed land use and construction criteria studies and decisions.

idation of earthquake prediction. Political motivation must be kept separate, and, at the same time, a scientist must realize the impact of his statements. There should probably be guidelines on these points from scientific organizations, as well as means for peer review of scientists' statements about prediction of earthquakes.

Attention should be given to developing the potential of long-range prediction of earthquakes. The U.S. Geological Survey is undertaking work on "prehistoric earthquakes" in several parts of the United States; these studies can contribute to the construction of historical records which will be useful in assessing probabilities.

In summary, there are opportunities for helpful research in earthquake prediction, research which will increase knowledge needed by both scientists and administrators. While the present state of the art should be viewed conservatively, it is still reasonable to take a more optimistic view, which supports an expectation that a capability to predict earthquakes, at least for short-term periods prior to events, could come within the next ten years.

Discussion.

Question. Is there any research on modifying an earthquake itself?

Response. U. S. Geological Survey scientists say that there are no current programs which are actually trying to relieve stress. In Rangely, Colorado, there has been some experience which leads to optimism. However, there are problems, especially legal ones. There might be a place with small faults, far from populated areas, where it would be practical to experiment with fluid injection to relieve stress.

Question. Do you agree with the Stanford Research Report that there is a trend toward earthquake control rather than prediction?[4]

Response. That is a long way off. It would be a secondary objective but might be possible some day. At the present time the answer is no. There are, for example, legal bars to pumping water into the San Andreas fault. Furthermore, earthquake control efforts will not likely be funded from federal sources.

Comment. A member of a scientific team invited to China reported that the Chinese admit that their predictions have been partly luck and that they have had a lot of failures. During his trip to China it was impossible to ascertain how they were doing in a statistical sense.

We should be optimistic about our own emerging knowledge of precursors. A University of Colorado project in the Aleutian Islands is revealing much about foreshocks. Evidence is emerging that there might be a lot of activity years before a quake, followed by a long quiet period. The Aleutian Islands network just had a 6.5 magnitude earthquake and hopefully a careful re-examination of past records will yield significant information.

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[4]"Earthquake Prediction, Uncertainty, and Policies for the Future," Stanford Research Institute, Menlo Park, California 94026, January 1977

We will not know that we have the capability to predict a large earthquake until we have one. At present we do not know whether techniques for predicting a magnitude 6 earthquake are the same as those for predicting earthquakes of magnitude 8 and larger. We might be able to go overseas in order to instrument and study areas more likely to have large events. The Congress included this possibility under the Earthquake Hazards Reduction Act.

Earthquake prediction technology has the need for 1) more data, 2) earthquakes, and 3) public awareness that development of earthquake prediction capabilities will be a slow process with many failures.

Question. Earthquakes on the east coast are different from those in the west. Is there work on impact and attenuation rates on the east coast?

Response. Attenuation is very different in the two sections of the country; seismic waves propagate for long distances in the east. There is some work in east coast areas now funded by the Nuclear Regulatory Commission and the U. S. Geological Survey. A lot of people are looking at the problem.

Additional Response. The Nuclear Regulatory Commission has extensive risk evaluation efforts in 20 states, backed up by $5 million worth of support. NRC seismic maps working toward risk assessment will be published.[5]

Comment. Engineers prefer to deal with intensity rather than magnitude scales. Intensity is much more understandable both to public officials and to building professionals.

Added Comment. This question of the different scales is an on-going concern, but there really should be no problem. Both the magnitude (Richter) scales and the intensity (Modified Mercalli) scales are useful. Unfortunately, most statistics are based on magnitude, and it is very difficult to convert from one scale to the other. Both scales have their inadequacies.

Question. Can you explain the magnitude scale?

Response. While seismologists disagree somewhat, Richter defines magnitude measure as the size of the earthquake at its source. Size here is intentionally vague. Magnitude is assessed in a logarithmic scale; thus a large earthquake is so very much larger. What determines limits? An upper limit is not defined--the largest to date in historical record is about 8.9. The lower end reaches into a minus scale. A large earthquake would register 6, a great earthquake 7 or 8. Also, it is now realized that destruction is dependent on duration, type of ground motion, and, of course, distance from source.

The Modified Mercalli scale measures the effects of ground motion at a point. It is purely subjective, e.g., window shaking, cracks in ground, occurrences determined by observation. Of course, it too varies with distance. The Modified Mercalli scale goes from I to XII, the latter being classed as "complete destruction."

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[5]This program is under the direction of the Office of Research, Seismic Intensity Mapping, Nuclear Regulatory Commission, Washington, D.C. 20555.

An accurate analogy of these two scales can be compared generally with a light bulb whose wattage is a measure of magnitude (Richter) and to a light meter reading at some distance which is a measure of intensity (Mercalli).

Comment. Concern was expressed that the scientific community is promising more than can be delivered in earthquake prediction. Therefore the public is expecting something and so are public officials.

Some communities have mapped hazards in the past--for example, for landslide and avalanche hazards--and have stated only that in the foreseeable future certain areas will experience these hazards. Such communities must recognize these risks and plan for them. Seismologists shouldn't give probability estimates and predictions so much emphasis; they should just say: "If you build in certain areas, do it with earthquake-resistant structures." But for collapse-hazard and other non-conforming older buildings prediction offers an alternative to possibly impossible strengthening.

Question. There are four elements of a prediction. Three are physical aspects--size, magnitude, and place; but one--probability--has political implications. What are now considered reasonable confidence levels for issuing a prediction?

Response. It is very important that the public know about every prediction, but each prediction must be accompanied by an estimate of its probability. A recent study shows that the public would rather not know about low-probability predictions, but the U.S. Geological Survey has a responsibility to tell them anyway. The problem is how do public officials respond to a prediction that is at a 25 percent confidence level?

Added Response. There are some positive responses to low-confidence predictions, e.g., public education programs which would enable individuals to take wise steps for their own survival. If the level of confidence is high, actions would be taken like lowering water levels in dams, evacuating dangerous buildings, etc.

Question. Is there any formal international effort on earthquake prediction?

Response. There are on-going cooperative programs with Japan, China, and the U.S.S.R. The program with the U.S.S.R. is very successful. There is continued communication with Japan. The exchange of information with China has been mainly through delegations to China--not a very open sharing. China's unique contribution is its widespread amateur network.

Question. Would there be more payoff if earthquake research centered on defining areas where there could be damaging earthquakes and doing microzonation in areas of active faults? Also research is needed on whether or not active faults present hazards.

Response. The Earthquake Hazard Reduction Act includes a "balanced approach" for prediction, hazard assessment, consequences, etc. But "prediction" is the only one of these which deals with the situation already existing (non-conforming buildings, etc.). Hazardous buildings have to be remedied or evacuated before an event to save lives. Certainly prediction is not the only part of the earthquake hazards program which this country should undertake, but it was the spectacular part used to sell the legislation to Congress. The money which will be made available, however, will not be directed only to prediction.

Question. The interest of the states hinges on mitigation rather than prediction. Will the states be involved in prediction?

Response. State and local governments properly have a major role in mitigation partly through their land use planning, building codes, etc. Yet, because prediction is still in a research phase, state scientists should be involved, particularly in their universities, as they are in California and elsewhere. Also with respect to prediction, state and local governments may well be concerned with evaluating a prediction before issuing warnings to their constituencies; issuance of a warning is comparable to the act of declaring an emergency or a disaster area. This has to be a state or local government role.

Question. What about remote sensing?

Response. All of geophysics is remote sensing. Satellite imagery is useful for faults, especially in certain areas of China and Russia that are so inaccessible. It has, on occasion, been misused without reference to "ground truth." U2 flight data and side-looking radar have also been useful. Infra-red is not very useful. Distance and location measuring capacity (geodosey) is useful at present for movement rate and may become more so. There is great promise for a fixed satellite station in the Aleutians. This is an area which has many earthquakes but is inaccessible.

Question. Does a community have a capacity and funds to develop scenarios for different earthquake conditions? Are there enough geologists? Any sense of cost?

Response. Many states are doing it now. There has to be a political response in terms of how much money will be put into such efforts. Geologists can do generalized mapping for relatively low costs, and local communities can upgrade their work for various purposes.

Added Response. It cost $180,000 for San Francisco to analyze liquefaction, landslide, and ground-shaking hazards and to conduct a building construction analysis.

A risk map implies a sense of probability which we don't have. We have only a poor handle on the probability of risk for many specific sites.

Question. Have we had an inventory on population related to structures at risk? Economists worry about cost-benefit assessment. How much should be invested in this area? Is this an inter-generation transfer?

Response. Maps have been issued, such as the U.S. Geological Survey acceleration map, for a 90-year return period. Some people wanted intensity maps, but it is difficult to determine the effects on population or buildings on a national scale. With respect to cost-benefit assessment, our earthquake research efforts have had socio-economic input for only about five years. This aspect needs more attention.

Added Response. A national inventory of buildings at risk from earthquakes reaches a value of $2 trillion, and by the mid-1980s will amount to more than $4 trillion. Structural damages from natural hazards now reach an annual loss of almost $6 billion, but a single earthquake could produce damages of $20 billion to structures alone. Mitigation costs for all structures at risk could not be justified, but if social dislocation were taken into account, cost-benefit studies of mitigation measures could be justified.

Added Response. Lacking precise probability means precise cost-benefit ratios couldn't be developed. We have to move ahead with risk mapping without full knowledge.

B. VALIDATION OF EARTHQUAKE PREDICTIONS, ISSUANCE OF WARNINGS, AND ANTICIPATED REACTIONS

From Members of the Panel:

Robert B. Rigney, Chairman, San Bernardino County Environmental Improvement Agency; Chairman, California Seismic Safety Commission
Robert E. Wallace, U.S. Geological Survey
Dennis S. Mileti, Colorado State University, Fort Collins
Denise Heller Paz, University of California (Los Angeles)
E. L. Quarantelli, Ohio State University (Columbus)

What constitutes a valid prediction? Are there credibility quotients so that we know when a realistic prediction has actually been made? Credentials of predictors are very important if predictions are to be taken seriously by the public.

There will be few predictions in the foreseeable future. At present predictors are stuck in the gray zone. They just aren't sure. What has been said about the Southern California uplift is not a prediction but a carefully written geologic message from the U.S. Geological Survey. What should USGS do? What should governmental jurisdictions and the public do? Just note possible danger and update disaster plans? Watch for changes in the uplift? There are changes occurring now, and clearly the seismic danger has increased, but no one knows how directly these changes affect the probability of an earthquake.

Validation and certification are not pleasing terms. The USGS has said in the federal regulation issued April 12, 1977 that the purpose of the regulation is to describe the Geological Survey's capability and limitations for advance recognition and warning of various kinds of geologic-related hazards and the procedures proposed to carry out the responsibilities delegated under the Disaster Relief Act. The terms "notice of potential hazard, hazard watch, and hazard warning" refer to the issuance of technical information to officials responsible for public safety and to the news media; recommendations or orders to take defensive actions are issued by officials of state and local governments, where the police power and public safety responsibility and authority rests in our governmental system.

An earthquake prediction and evaluation panel and a public policy response panel have both been created by California, which is the most advanced state in dealing with earthquake prediction.

The recent USGS statement last April was the first attempt to show how it will perform in respect to predictions and warnings. Each level of government should have its own plan; there is a need for both redundancy and flexibility. Responsibility for warnings after predictions have been made is strictly a local one, or should be. Governors make determinations as to emergencies, and with presidential affirmation or declaration of an emergency the Federal Disaster Assistance Administration can allocate federal dollars for local preparedness. We will want to see what the President reports to Congress on the federal role as a result of the implementation plan now being developed in response to the

Earthquake Hazard Reduction Act of 1977.

Now tourists are attracted to take a look at the Palmdale bulge. A few people see it for its dollar-making possibilities. Most see it as a reason for declining land values. An earthquake prediction is an invisible problem. Local levels of government prefer not to handle it and will put it off on a higher level. Local levels of government can't deal with invisible problems. They are more comfortable solving concrete, visible problems, even post-disaster problems. Local leaders prefer to suggest solutions to solve earthquake problems but they don't want to be a part of the prediction problem themselves. Locals don't want to touch prediction. They will react to predictions and attempt to solve the problem effectively, but only after someone else makes the prediction. They do not have the resources to make predictions with any confidence and the consequences of errors are too enormous for local determination.

There is a good bit of difference between scientists on the one hand and community leaders on the other. Their approaches and their time frames are different. A short time frame exists for local leaders and a very long-term one for scientists. How can a politician be concerned with a 10,000-year time frame? Their communication problems must be bridged.

California communities are angered that the state's Seismic Safety Commission designated certain areas as high-risk, and communities turned against the idea of government study. State and local governmental entities tend to say, "The heck with too much effort to determine risk; we live with greater risk on the highways; the people don't want it; it is very costly for their investment, so forget it."

For example, in the past we have been forced to pass legislation to determine acceptable risk when a problem exists, problems, for example, such as air and water quality. Earthquake prediction will face the same kind of problem. Administrators will seek to force scientists to define levels of risk when they believe a seismic problem exists.

These remarks do not mean that local government is not willing to prepare for responding to disasters and, in fact, city agencies in southern California are responding to Palmdale warnings (retrofitting buildings, etc.). Some local governments have their in-house planners, and these will generally seek land use solutions to earthquake problems. Builders point out that building codes don't bother trying to delineate specific geographic problem areas, and a little higher standard will be cost-effective because most damage is due to ground-shaking.

Social scientists can't put communities into labs and squeeze them as geologists do rocks. What will people do following an earthquake prediction? They won't run for the hills. They think the walls where they are may crack if there is a serious earthquake, but they probably won't die. Others may die, but they won't. They're safe, 'though others may not be. Residents in many seismic areas say it is no news that an earthquake is coming, but they believe they'll be all right. However, whether a prediction is long or short-term heavily influences what people will do.

The traditional types of measures of preparedness (i.e., responding to the event of a disaster) are an important part of what will happen in the event a long-term prediction is issued, but they are only a small part of an effective, comprehensive mitigation program. Effective hazard reduction measures are critical for emergency preparedness. City planning directors, attorneys, and others will make as many of these decisions, likely more, than disaster directors. Many officials will do their jobs well. Residents will do less, are less likely to take action. Bureaucracies will make the decisions which influence what state residents do.

Long-term predictions for earthquakes will have a stronger and different socio-economic impact on a community than relatively short-term weather, fire, flood, and wind predictions. Issuance of warnings is a state-local responsibility.

What will business firms do after an earthquake prediction? They will take very traditional, prudent, self-interest actions. Affluent corporations will "think" during the first six months after a prediction before taking action. First, they will turn to consulting engineers to see how their structures are, assess their risk, and then they will move to limit loss and economic disruption to themselves.

Asking what people will do, when scientists don't even know what people will be faced with, is speculative.

There are four sociological concepts which govern why some organizations do something, some others do a little, and some do nothing.

1) Control. If the organization can determine how many people are willing to buy their products or use their services, the economic context will be altered. An organization which knows its market well will survive. Organizations that lose control over sales and services are particularly vulnerable.

2) Security. Well-established institutions would be secure. For example, drought would not affect the existence of the University of Colorado, but nearby dry farmers, on the other hand, are in terrible straits due to droughts.

3) Flexibility. Organizations which are experienced in addressing change and having greater flexibility will be better able to deal with events after a prediction.

4) Linkage. Those who are linked to systems which provide them with information will have more time to decide what to do and more information on which to base decisions. Hermits won't find out in advance. Further attention should be given to the linkage between decisions people make at their workplaces and those they make at home.

It is well to not be too concerned about distinguishing between valid prediction and warning. In the first blush predictions bring response; we shouldn't assume that only warnings bring response. People who get predictions or warnings will make decisions on what businesses do, and businesses will decide what to do based on predictions as well as warnings.

UCLA has been conducting a project on community response to earthquake threat in Southern California. That project has monitored media since January 1976, examined government and private organizational response, and surveyed community response. Its goal was to determine what people are aware of, what they hear and remember. These are factors important for scientists and public officials to know.

Over half of the sample in the UCLA project had heard about the Palmdale bulge; nearly three fourths understood it to mean a coming earthquake; over half who heard about it took it seriously; less than one fifth assumed it would not have an effect where they lived.

Most people had heard of psychics' predictions; many attributed these to scientists. Many such predictions are not taken seriously. The Southern California uplift carried more weight as scientific evidence and more people took it seriously, but in a general survey of California problems, less than six percent of the project's sample mentioned earthquakes as a problem in California.

Most see earthquakes as frightening but not sufficiently so to alter their behavior. Few would leave California because of fear of an earthquake.

The second objective of the project was to identify perceptions and attitudes of leaders regarding predictions of earthquakes. Over half believe scientists cannot accurately predict earthquakes at the present time; over three fourths expect there will be a future ability to predict earthquakes. A majority believe only scientists can predict, but nearly one third believe scientists are not the only ones able to predict, with many believing psychics and religious leaders can predict earthquakes, and nearly all want information if it seems very certain a quake will occur. They believe government officials should announce predictions.

A third objective of the project was to determine what people are doing to reduce danger; who should be responsible for doing things? Over two thirds suggest that some member of local government should be responsible for children, the elderly, the handicapped, etc.; they believe state and federal government have specific responsibility. Over two thirds of those with children have instructed them as to what to do in the event of an earthquake.

The project's conclusion is that the public sees government officials as playing an important role in issuance of warnings, reducing damage, etc. They definitely see the government in a leadership role.

We are not yet locked in on fixed ideas regarding public policy implications of earthquake prediction. Ideas and traditions are evolving and laws are still being written. There is opportunity to think through what policies should be adopted.

The term "prediction" itself is not a good one. More standard terms like "watch" or "warning" should be preferable.

The U.S. Geological Survey will issue information on potential hazardous events. It's then up to local governments. USGS won't suggest action. USGS regulations published in the Federal Register of April 12, 1977 (copies made available to all conference participants) set forth definitions of prediction, warning, watch, etc. They take into account the difference between earthquakes and other phenomena. For instance, there is a difference where the National Weather Service can track a storm visually; this cannot be done yet for earthquakes.

If earthquakes are lumped with other hazards, problems may result. Earthquake hazard reduction requires long lead time, and no other disaster causes as widespread and extreme damage as high-magnitude earthquakes. So we shouldn't assume that general hazard response planning will suffice.

There should be one warning system for all hazards in order to avoid confusion, reduce costs, and maximize resources. The issuance of a warning needs to be more than just a statement that a hazard may be a problem. A warning needs to include suggested actions which people can take, a factor especially important with warnings having a short time frame during which action should be taken. A better approach is to seek to reach "groups" rather than "individuals" or "the public." "The public" is diverse in knowledge, values, beliefs, etc. It is better to take advantage of groups and their own special interests. It is easier to change groups, and group actions have consequences for individuals. Many factors need to be taken into account in order to get response. Mass media should be involved. The scientific community cannot control what people pay attention to. There is a growing negative view of science as well as of increasing governmental involvement. This negative trend in society will affect response to prediction as well as prediction itself.

We should assume rationality of response. People act in ways that make sense to them at the time. It's crucial to adjust plans to people, not people to plans. Don't try to get people to take actions radically different from actions that make sense to them and that they are accustomed to taking.

A case hasn't yet been made that it's cost-beneficial to spend much time and effort to prepare just for earthquakes. If preparatory actions will help a community deal with other problems as well, then a much stronger case can be made for it.

Discussion.

Comment. Earthquake prediction is different from weather service prediction where direct responsibility is placed with local governments. It seems that locals are being forced by USGS to issue earthquake warnings.

Response. No, you have a misconception. In the Palmdale instance, USGS checked out all possible predictions but the only message transmitted by the agency was a passive, scientific one related to the uplift. Experts predict, but state and local governments carry the message to the people.

Question. Are there maps showing earthquake hazards? Do real estate people inform prospective buyers about such hazards?

Response. There are some maps. Individual faults are not well understood, but we are making progress.

Added Response. Citizens observe that their property values have been lowered by announcing the existence of the Palmdale bulge. On the other hand, many uplifted properties in Northern California have a lovely view of the ocean and are highly-valued properties.

Added Response. Real estate agents should get involved in disclosure.

Comment. It is vexatious that governments have lawsuits against them. There are reasons and laws on liability of government. There are some big legal issues which should be dealt with. Government may be sued for not taking action as well as for taking action. Predictions and warnings must be looked at from a legal perspective. Is a prediction just informational?

Question. What would happen if there were a valid prediction and local government did not respond? Would local government be in a position to suffer a class action suit?

Response. Probably, but a suit won't prevail where a decision is made to take no action on a discretionary act even if it's wrong, unless it is shown that negligence was present in exercising the discretion.

Comment. There is a very low probability of a big earthquake affecting an individual. How do we get people to take action if it appears rational to them to take no action? Some actions should be taken by individuals so that society is not harmed?

Comment. The media is so important in affecting people's attitudes. The media have been good in some instances, bad in others. TV is particularly influential but lots of misinformation is passed along. For example, animal behavior, which is a questionable way for predicting earthquakes, has been mentioned so very often on TV. In California the State Emergency Services Agency has developed spot programs for TV to better inform residents accurately about the Palmdale bulge.

Question. What are the differences between what citizens expect of government versus what government expects from citizens? People do expect relief after a disaster. What is the proper mix between paying for preparation ahead of time rather than cleaning up afterward? Why do people buy insurance after an event rather than before?

Response. Congress allocates dollars inequitably for cost-benefit studies but equitably from the stance of utilities. Government will spend more in preparing for and preventing giant accidents. This is known as the maximum regret theory.

C. RISK ASSESSMENT AND HAZARD REDUCTION

Members of the Panel:

Carl Kisslinger, University of Colorado, Co-chairman
Robert V. Whitman, Massachusetts Institute of Technology, Co-chairman
John H. Wiggins, Jr., J. H. Wiggins Company, Redondo Beach, California
George G. Mader, William Spangle & Associates, Inc., Portola Valley, California
James E. McCarty, City of Oakland, California
Charles G. Culver, National Bureau of Standards
Charles S. Manfred, California Office of Emergency Services
Robert A. Olson, California Seismic Safety Commission

1. Delineation of Hazards (Earthquakes and Other Natural Hazards)

From the Panel:

A member of the panel dealing with this subject based his remarks and presentation on information being compiled in a current study of natural hazard loss aimed at developing a reasonable projection of estimates of national annual building losses that might be experienced during a specific 30-year period, from 1970 to 2000.[1] The hazards covered in the study are the nine most destructive of the natural hazards--namely, earthquakes, expansive soils, landslides, hurricanes, tornadoes, severe winds, riverine floods, storm surges, and tsunamis.

"Risk" (i.e., degree of loss expectancy) as used in the study equals the chance of annual average loss effected by the type of hazard, including vulnerability, location, and response. Loss figures are given in 1970 dollars.

Included in the following pages and in the appendix to this report are tables and maps developed by the panelist. (Some of these were not presented at the conference but are included in the appendix to this report because they depict states' presumed exposure to each of the nine hazards, information deemed to be of special interest to state officials.)

Tables 1 and 2 summarize annual building losses by state in 1970 and 2000, respectively, for each of the nine hazards (in 1970 dollars).

Table 3 presents, in its first column, total dollar losses for all nine hazards in 1970 and 2000 with states listed in rank order of loss expectancy for the year 2000; a second column of Table 3 indicates state ranking in terms of damage rate.

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[1]Only summary information was reported at the conference; these notes are based on the panelist's remarks, also on a draft of his study report still in preparation. For additional information, interested readers should be on the look out for the final report being prepared by the J. H. Wiggins Co., 165 South Pacific Coast Highway, Redondo Beach, California 90277.

TABLE 1

Summary by States of Annual Building Losses Due to Natural Hazards in 1970
(Millions of 1970 Dollars)

1970 BASELINE % DAMAGE	STATE	TOTAL STRUCTURE VALUE ($BILL.)	POPULATION (MILLIONS)	EARTH HAZARDS			WATER HAZARDS			WIND HAZARDS			ALL HAZARDS
				EQ	ES**	LS	FL*	SS	TS	TO	HU	SW	
.309	AL	26.7	3.44	.0	14.45	4.6	28.9	4.3	0	18.4	11.9	0	82.6
.164	AK	3.9	0.27	3.6	0	0	2.4	0	0.4	.0	0	0	6.4
.130	AZ	16.9	1.77	0.7	2.3	2.29	14.7	0	0	1.9	0	0	21.9
.299	AR	13.6	1.92	3.3	7.01	2.98	20.0	0	0	7.3	0	0	40.6
.375	CA	226.0	19.96	439.6	182.59	36.83	178.5	0	3.5	13.8	0	0.6	855.6
.319	CO	22.7	2.21	20.2	17.77	6.27	18.4	0	0	9.4	0	0.4	72.3
.284	CT	35.0	3.03	0.8	7.08	10.30	21.8	9.7	0	5.7	43.6	0.4	99.4
.184	DE	5.7	0.55	0.1	.64	1.59	4.5	0.5	0	1.4	1.8	0	10.5
.087	DC	12.6	0.76	0.1	.79	.82	6.3	0	0	1.1	1.9	0	11.0
.825	FL	61.1	6.79	1.0	14.60	3.91	56.9	195.0	0	41.8	190.4	0.2	503.8
.223	GA	41.5	4.59	0.5	17.17	5.12	38.5	4.4	0	18.6	8.4	0	92.7
.114	HI	10.0	0.77	0.3	0	0	6.9	0	4.1	.0	0	0.1	11.4
.179	ID	6.3	0.71	1.5	2.42	1.01	5.9	0	0	0.4	0	0.1	11.3
.274	IL	126.8	11.12	1.0	28.69	33.16	132.2	0	0	152.2	0	0.8	348.0
.252	IN	48.8	5.20	0.1	6.31	6.80	61.8	0	0	47.7	0	0.4	123.1
.291	IA	25.8	2.83	.0	14.69	5.21	36.4	0	0	18.6	0	0.3	75.2
.423	KS	21.5	2.25	0.2	25.88	3.41	28.9	0	0	32.3	0	0.2	90.9
.192	KY	25.6	3.22	1.3	8.58	5.96	25.4	0	0	8.0	0	0	49.2
.721	LA	30.3	3.64	1.9	26.29	5.95	37.8	84.5	0	13.3	48.6	0.1	218.4
.233	ME	8.3	0.99	.0	2.30	2.12	7.1	0.5	0	1.0	6.3	0	19.3
.155	MD	49.2	3.92	0.1	6.66	11.97	32.2	4.0	0	8.6	12.8	0.1	76.4
.272	MA	63.4	5.69	1.7	4.83	13.21	40.8	12.5	0	35.3	63.6	0.8	172.7
.230	MI	90.8	8.88	0.9	42.31	19.47	105.6	0	0	40.1	0	0.1	208.5
.215	MN	37.7	3.80	.0	5.87	5.52	48.8	0	0	20.3	0	0.4	80.9
.477	MS	14.6	2.22	0.4	13.19	2.76	23.1	13.2	0	8.4	8.7	0	69.7
.396	MO	45.1	4.68	15.3	37.22	10.75	60.1	0	0	55.2	0	0.2	178.8
.202	MT	6.4	0.69	1.4	4.02	1.18	5.8	0	0	0.4	0	0.1	12.9
.391	NE	14.3	1.49	0.2	21.33	2.64	19.2	0	0	12.3	0	0.2	55.9
.153	NV	5.8	0.49	2.7	1.12	.64	4.1	0	0	0.2	0	0.1	8.9
.220	NH	7.4	0.74	0.2	.70	1.47	5.3	0	0	2.8	5.8	0	16.3
.159	NJ	83.7	7.17	3.4	7.47	10.70	49.7	11.5	0	26.2	23.1	0.8	132.9
.182	NM	9.1	1.02	1.2	3.81	.82	8.5	0	0	2.2	0	0.1	16.6
.166	NY	229.6	18.24	20.2	14.76	29.36	126.5	50.0	0	10.7	129.4	1.0	381.9
.310	NC	40.0	5.08	0.1	18.92	9.76	41.8	7.7	0	12.7	32.	0.2	124.1
.277	ND	4.8	0.62	.0	1.88	1.13	8.0	0	0	2.2	0	0.1	13.3
.194	OH	106.3	10.66	1.0	14.57	21.87	126.8	0	0	41.9	0	0.3	206.4
.338	OK	23.1	2.56	0.5	4.86	2.16	26.6	0	0	43.5	0	0.4	78.0
.151	OR	19.9	2.09	1.7	4.97	4.19	18.7	0	0.1	0.4	0	0	30.1
.136	PA	116.1	11.80	0.4	14.84	24.91	81.8	0	0	20.1	15.7	0.4	158.2
.284	RI	9.3	0.95	0.1	.74	.60	6.8	7.1	0	0.5	10.4	0.2	26.4
.311	SC	19.6	2.59	1.9	8.66	3.21	21.7	7.0	0	7.9	10.5	0	60.9
.311	SD	5.3	0.67	0.1	3.49	1.31	8.6	0	0	2.9	0	0.1	16.5
.210	TN	30.8	3.92	15.1	6.67	2.00	30.9	0	0	10.0	0	0	64.7
.398	TX	103.7	11.20	0.8	143.69	11.36	116.5	15.7	0	92.6	30.6	1.0	412.3
.286	UT	10.6	1.06	12.2	5.53	3.13	8.8	0	0	0.5	0	0.1	30.3
.137	VT	3.8	0.44	.0	.44	.54	3.2	0	0	.8	0.2	0	5.2
.220	VA	48.8	4.65	0.4	8.87	8.94	38.2	13.5	0	8.5	28.8	0.3	107.5
.404	WA	35.6	3.41	96.9	4.71	10.41	30.5	0	0.7	.4	0	0.2	143.8
.166	WV	14.2	1.74	0.1	3.87	4.88	13.7	0	0	1.0	0	0	23.6
.213	WI	41.2	4.42	.0	6.28	10.43	52.6	0	0	18.2	0	0.2	87.7
.200	WY	3.2	0.33	.0	2.27	.71	2.8	0	0	0.5	0	0.1	6.4
.279	U.S.	2064.5	203.24	655.2	798.1	370.3	1901.0	441.1	8.8	880.2	685.4	11.3	5751.4

*Flood is estimated with a different model.
**Only residential expansive soil losses,

August, 1978

TABLE 2

Summary by States of Annual Building Losses Due to Natural Hazards Projected for the Year 2000 (Millions of 1970 Dollars)

2000 BASELINE % DAMAGE	STATE	TOTAL STRUCTURE VALUE ($ BILL.)	POPULATION (MILLIONS)	EARTH HAZARDS			WATER HAZARDS			WIND HAZARDS			ALL HAZARDS
				EQ	ES**	LS	FL*	SS	TS	TO	HU	SW	
.213	AL	65.0	4.17	.0	17.51	10.8	30.2	9.6	0	43.9	26.8	.0	138.81
.124	AK	8.6	0.34	7.1	-	-	2.2	0	1.4	0	0	.0	10.7
.063	AZ	47.8	2.78	1.6	3.61	6.2	13.3	0	0	5.5	0	.1	30.31
.163	AR	32.4	2.18	6.3	7.96	7.4	14.5	0	0	16.8	0	.0	52.96
.232	CA	539.8	26.03	748.8	238.10	88.7	135.5	0	8.8	31.8	0	1.9	1253.6
.219	CO	56.1	2.86	44.5	22.99	15.7	15.7	0	0	23.2	0	.9	122.99
.227	CT	82.6	4.05	1.6	9.47	24.4	16.9	22.0	0	13.2	98.6	1.0	187.17
.121	DE	14.4	0.75	.1	.87	4.0	4.2	1.3	0	3.3	4.6	.1	18.47
.062	DC	42.4	1.49	.1	1.55	2.7	12.1	0	0	3.5	6.3	.0	26.25
.781	FL	198.8	11.61	2.2	24.97	12.7	91.9	647.4	0	132.8	639.1	.6	1551.67
.147	GA	116.0	6.32	.9	23.64	14.2	53.8	9.8	0	49.9	18.7	.0	170.94
.056	HI	26.2	1.11	.3	-	-	6.6	0	7.5	0	0	.2	14.6
.093	ID	13.5	0.79	3.0	2.69	2.1	3.6	0	0	1.0	0	.1	12.49
.197	IL	286.8	13.60	1.7	35.09	74.9	119.1	0	0	333.3	0	1.7	565.79
.157	IN	118.2	6.56	.3	7.96	16.6	49.0	0	0	110.9	0	1.0	185.76
.157	IA	53.4	3.03	.1	15.73	11.0	19.3	0	0	37.2	0	.5	83.83
.264	KS	47.0	2.51	.3	28.88	7.8	17.0	0	0	69.7	0	.4	124.08
.099	KY	65.8	4.04	2.6	10.77	15.4	15.7	0	0	20.4	0	.0	64.87
.569	LA	66.4	3.91	3.9	28.24	13.1	29.6	171.0	0	28.3	101.2	.2	377.54
.156	ME	17.0	1.05	.1	2.44	4.5	3.6	1.1	0	2.0	12.7	.0	26.44
.105	MD	133.3	5.71	.3	9.70	31.0	38.1	9.4	0	22.4	29.6	.1	140.6
.220	MA	151.3	7.48	3.3	6.35	31.3	30.8	31.1	0	81.5	146.1	1.9	332.35
.131	MI	206.6	10.89	1.7	51.87	43.3	85.8	0	0	88.4	0	.2	271.27
.113	MN	91.8	4.80	.0	7.41	13.1	33.2	0	0	48.8	0	.8	103.31
.307	MS	33.0	2.36	.8	14.02	6.4	14.5	28.5	0	18.8	18.4	.0	101.42
.252	MO	101.2	5.40	28.2	42.95	24.5	36.6	0	0	122.4	0	.3	254.95
.106	MT	12.3	0.68	2.2	3.96	2.2	3.6	0	0	.8	0	.3	13.06
.217	NE	31.2	1.67	.3	23.91	6.0	11.3	0	0	25.8	0	.4	67.71
.094	NV	17.7	0.84	7.1	1.92	2.2	4.8	0	0	.5	0	.2	16.72
.142	NH	18.1	0.97	.4	.92	3.6	3.6	.1	0	6.9	13.6	.1	25.62
.114	NJ	199.2	9.53	6.5	9.93	25.8	46.5	25.0	0	61.0	50.7	1.8	227.23
.092	NM	20.2	1.15	2.3	4.29	1.8	5.4	0	0	4.6	0	.2	18.59
.125	NY	511.3	22.55	36.1	18.24	66.2	119.1	106.2	0	23.2	267.0	2.0	638.04
.199	NC	103.0	6.53	.2	24.31	25.6	29.6	17.1	0	32.0	75.7	.3	204.81
.126	ND	8.9	0.57	.0	1.73	2.1	3.2	0	0	4.0	0	.2	11.23
.108	OH	242.5	12.82	2.0	17.53	48.4	100.9	0	0	92.3	.0	.6	261.73
.255	OK	55.8	3.08	1.2	5.85	5.2	24.8	0	0	104.1	0	1.0	142.15
.069	OR	45.1	2.49	3.2	5.92	9.6	11.4	0	.1	.8	0	.1	31.12
.082	PA	252.0	13.49	.7	16.96	53.2	58.6	0	0	42.8	32.9	.9	206.06
.218	RI	20.4	1.14	.1	.89	1.3	4.2	14.8	0	1.0	21.9	.3	44.49
.213	SC	48.0	3.20	3.8	10.70	7.8	22.4	15.1	0	18.6	23.6	.1	102.1
.150	SD	10.4	0.65	.1	3.39	2.6	3.7	0	0	5.5	0	.3	15.59
.115	TN	80.0	5.04	33.6	8.58	5.2	19.0	0	0	25.9	0	.0	92.28
.261	TX	261.0	14.37	1.4	184.35	28.5	115.5	38.4	0	229.0	80.8	2.1	680.05
.191	UT	27.2	1.39	27.3	7.25	8.1	7.9	0	0	1.1	0	.2	51.85
.066	VT	8.6	0.51	.0	.51	1.2	1.8	0	0	1.8	.4	.0	5.71
.150	VA	133.0	6.46	.8	12.32	25.3	38.1	29.9	0	21.5	71.1	.6	199.62
.305	WA	78.5	3.99	187.7	5.51	23.1	19.7	0	1.9	.8	0	.5	239.21
.078	WV	29.5	1.73	.1	3.85	10.1	7.0	0	0	2.1	0	.0	23.15
.119	WI	89.5	5.10	.0	7.25	22.8	36.9	0	0	39.6	0	.4	106.95
.106	WY	6.4	0.33	.1	2.29	1.4	1.8	0	0	1.0	0	.2	6.79
.196	US	4925.2	256.10	1177.0	997.13	871.28	1594.0	1177.8	19.7	2055.7	1739.8	24.8	9657.2

*Flood is estimated with a different model
**Only residential expansive soil losses

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TABLE 3

Dollar Losses by State in Millions for 1970 and 2000.

FL	503.8	1551.67
CA	855.6	1253.6
TX	412.3	680.05
NY	381.9	638.04
IL	348.0	565.79
LA	218.4	377.54
MA	172.7	332.35
MI	208.5	271.27
OH	206.4	261.73
MO	178.8	254.95
WA	143.8	239.21
NJ	132.9	227.23
PA	158.2	206.06
NC	124.1	204.81
VA	107.5	199.62
CT	99.4	187.17
IN	123.1	185.76
GA	92.7	170.94
OK	78.0	142.15
MD	76.4	140.6
AL	82.6	138.81
KS	90.9	124.08
CO	72.3	122.99
WI	87.7	106.95
MN	80.9	103.31
SC	60.9	102.1
MS	69.7	101.42
TN	64.7	92.28
IA	75.2	83.83
NE	55.9	67.71
KY	49.2	64.87
AR	40.6	52.96
UT	30.3	51.85
RI	26.4	44.49
OR	30.1	31.12
AZ	21.9	30.31
ME	19.3	26.44
DC	11.0	26.25
NH	16.3	25.62
WV	23.6	23.15
NM	16.60	18.59
DE	10.5	18.47
NV	8.9	16.72
SD	16.5	15.59
HI	11.4	14.6
MT	12.9	13.06
ID	11.3	12.49
ND	13.3	11.23
AK	6.4	10.7
WY	6.4	6.79
VT	5.2	5.71

Damage Rate by State, 100ths of a Percent, for 1970 and 2000.

FL	825	781
LA	721	569
MS	477	307
WA	404	305
KS	423	264
TX	398	261
OK	338	255
MO	396	252
CA	375	232
CT	284	227
MA	272	220
CO	319	219
RI	284	218
NE	391	217
AL	309	213
SC	311	213
NC	310	199
IL	274	197
UT	286	191
AR	299	163
IN	252	157
IA	291	157
ME	233	156
SD	311	150
VA	220	150
GA	223	147
NH	220	142
MI	230	131
ND	277	126
NY	166	125
AK	164	124
DE	184	121
WI	213	119
TN	210	115
NJ	159	114
MN	215	113
OH	194	108
MT	202	106
WY	200	106
MD	155	105
KY	192	099
NV	153	094
ID	179	093
NM	182	092
PA	136	082
WV	166	078
OR	151	069
VT	137	066
AZ	130	063
DC	087	062
HI	114	056

NOTE: The first figure in each pair of figures is for the year 1970, the second for the year 2000.

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These data indicate, for example, that California was the most hazard-prone from the standpoint of annual loss expectancy in 1970, with Florida the most risky per dollar exposed. California ranked tenth in terms of riskiness or severity. Similarly, New York ranked fourth in annual losses but much lower (35th) in severity.

Two maps, Figures 1 and 2, show, respectively, national distribution of total annual loss for the nine hazards and annual losses as a percentage of the building assets in each state, both for 1970 conditions.

Table 4 presents major findings for the study quantifying for the year 2000 annual building loss reductions, based on effective mitigation measures against the nine natural hazards.

The loss information presented to the conference is assumed to be of use in delineating natural hazards of various kinds in a general way, with more specificity to be determined for given locations based on efforts of appropriate federal, state and local agencies to apply the information to specific areas and undertake related analysis, a job for planners and other professionals.

Of the nine natural hazards included in the panelist's data, the following quantitative structural loss information (average annual losses over the 30-year period) and the most vulnerable states are listed below:

Earthquakes, projected at $655 million average annual loss nationally; California followed by Washington.
Landslides, $370 million; California, followed by Illinois, New York, Pennsylvania, and Ohio.
Expansive Soils, $798 billion; California and Texas.
Hurricanes, $685 million; Florida and New York, followed by Massachusetts, Louisiana, Connecticut, North Carolina, Texas, Virginia and New Jersey.
Tornadoes, $880 million; Illinois and Texas, followed by Missouri, Indiana, Oklahoma, Ohio, Florida and Michigan.
Severe Winds, $11 million; New York and Texas, followed by New Jersey, Massachusetts, Illinois and California.
Riverine Floods, $1.9 billion; California, Illinois, Ohio, New York, Texas and Michigan.
Storm Surges, $440 million; Florida followed by Louisiana and New York.
Tsunamis, $8.8 million; Hawaii, followed by California.

Adding all structural losses together on an annual basis, the hurricane and storm surge states of Florida and Louisiana lead in terms of loss as a percentage of building structure value, but the greater potential sudden loss (described earlier in the report as that from events falling in a "maximum regret" category) is quite definitely larger for earthquakes than for any of the other hazards. However, if effective building codes were adopted and warnings heeded, storm surges and hurricanes would lead, with earthquakes dropping to third, based on the amount of mitigation possible.

Discussion.

Question. Is this type of information useful for state officials?

Response. Speaking as a state decision-maker, these kinds of things as

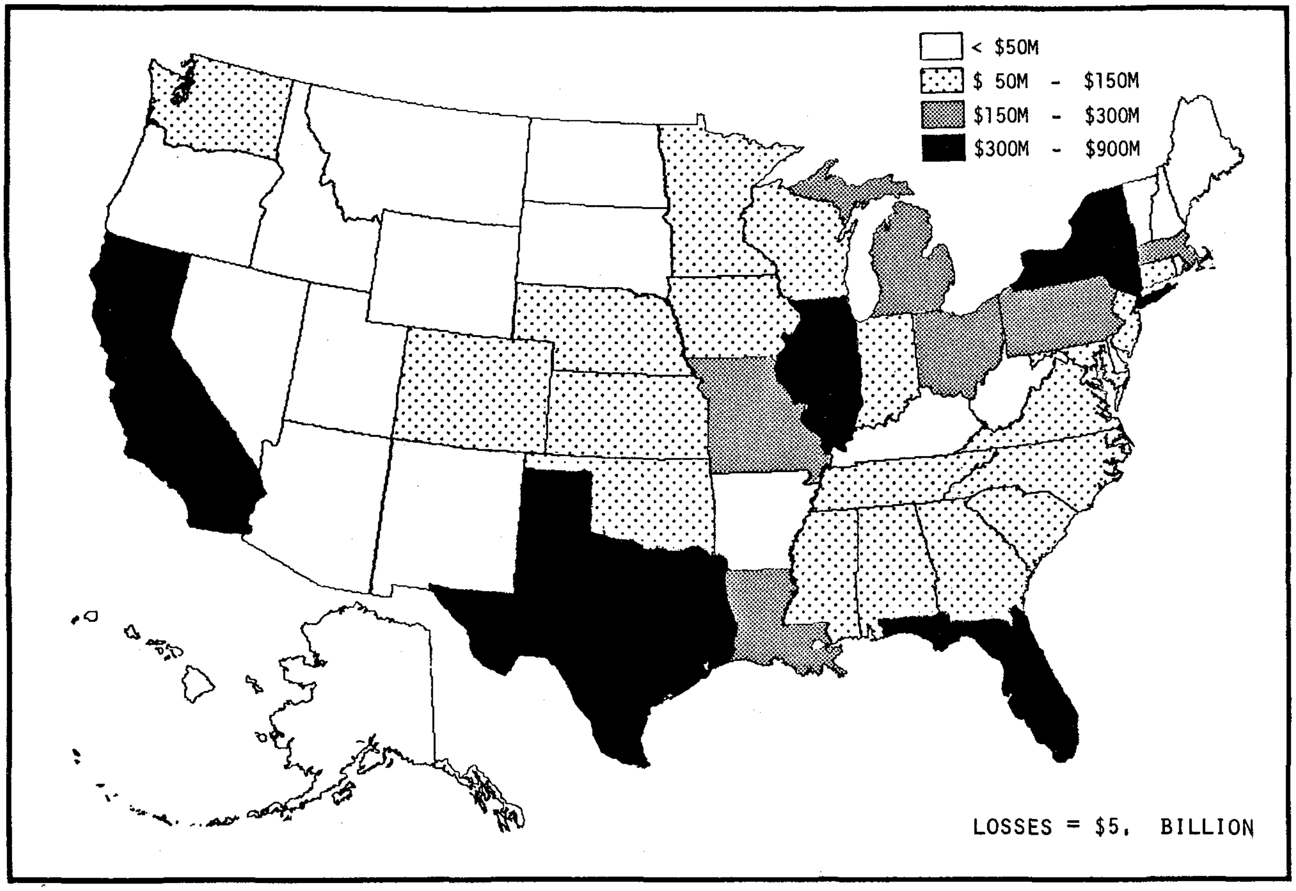

Figure 1. Annual Losses by State for the Nine Natural Hazards Considered for 1970 Conditions

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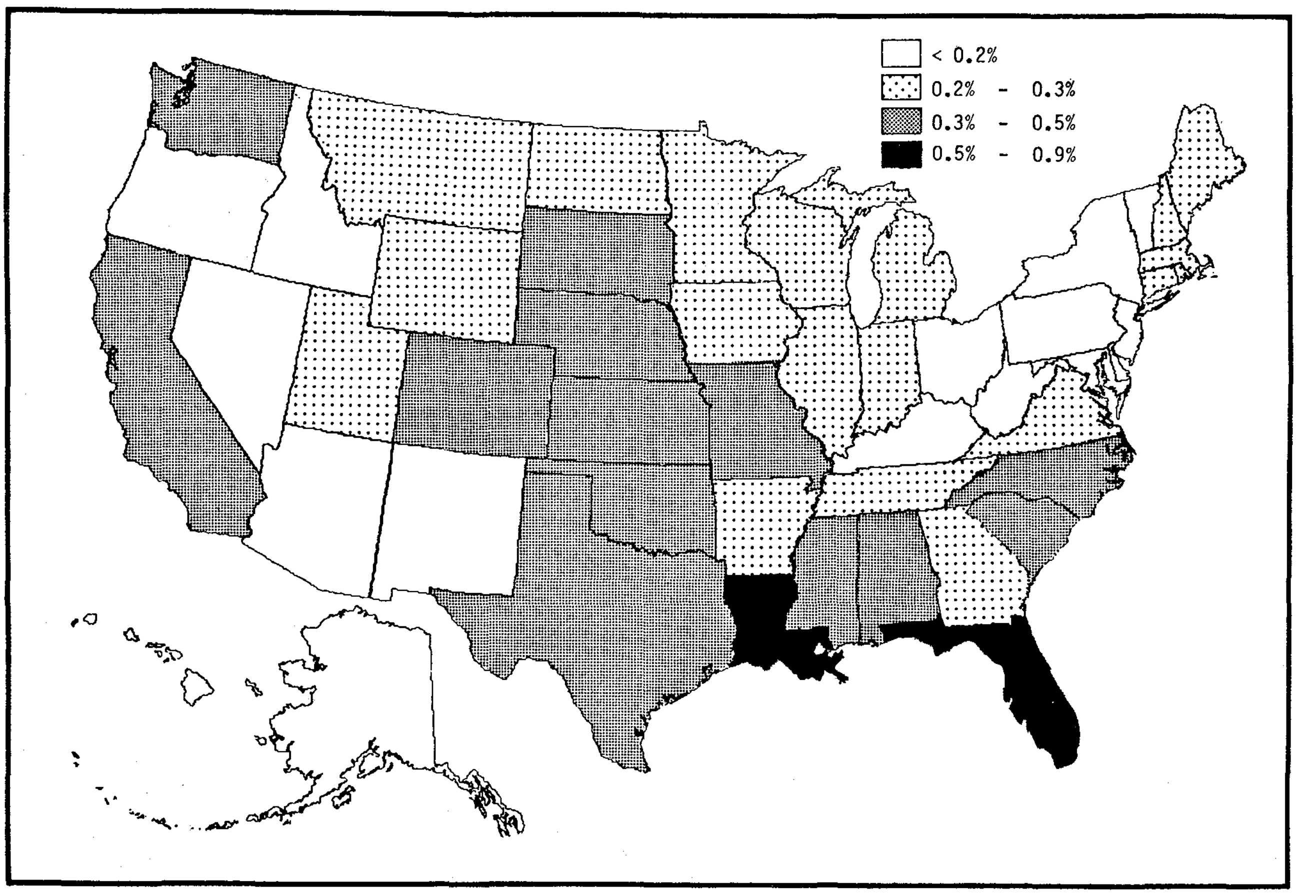

Figure 2. Ranking of Each State for the 9 Natural Hazards-Annual Losses as a Percentage of the Building Assets in Each State for 1970 Conditions

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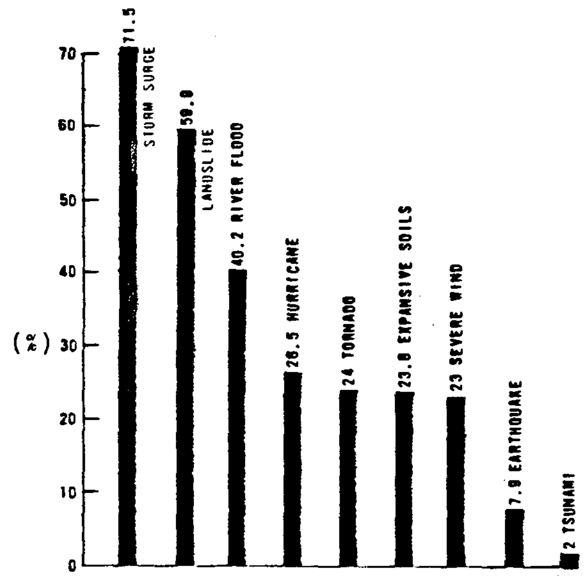
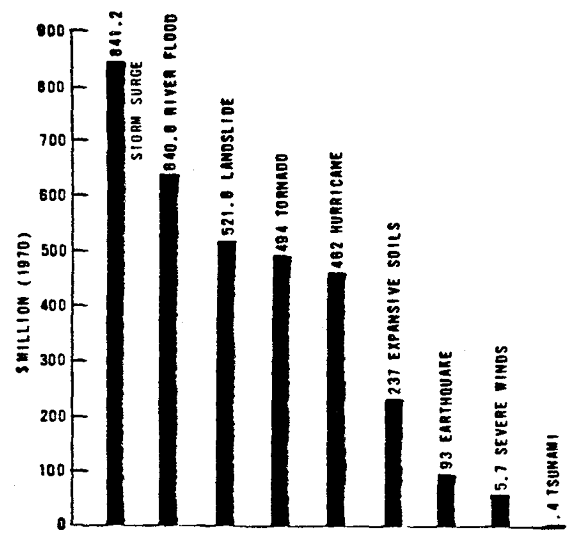
TABLE 4

Maximum Annual Building Loss Reduction by the Year 2000, Assuming Effective Mitigation



Percentage Reduction



Dollar Reduction

such are useless. They need to be more specific, in order to determine actions at specific locations, but it is helpful to know which areas may be the most vulnerable. It is also important to recognize that risk follows population migration.

Comment. Except for riverine flood information, the data are available on a country-wide basis. (For riverine flood information, the researchers broke the nation into eight sub-regions; the effects in these sub-regions were then averaged for each county. One cannot look at floods on a county-by-county basis but losses for all other hazards were constructed on a county-by-county basis.)

Question. Where should responsibility for preparation of risk delineation data lie?

Response. Initially, at the federal level.

Added Response. This type of information is of enormous benefit to state and local officials. For example, it can help NSF decide where grants should go or help state officials develop proof of risk for additional funding. Accuracy needs to be improved.

Comment. This is probably good enough evidence. It might be difficult to be more specific on hypothetical projections.

Question. In the last ten years my state has had five earthquakes. Can we take these loss data and use them to predict what will happen?

Response. This is an estimate of losses, not a prediction.

Question. Are these loss projections simply straight-line projections, based on past history?

Response. Yes.

Question. If you look at hurricanes or earthquakes, isn't the potential for loss of life much greater for hurricanes? Also, remember that often indirect cost is much larger than direct losses.

Comment. There is a lot of concern about the population increase occurring in coastal communities at a time when there is a lull in hurricanes. The population at risk is two million in Texas and 1.3 million in Florida.

Response. This should show up in the projected losses.

Question. Did you vary the degree of mitigation on a macro level?

Response. Building codes were applied nationally as of, say, 1981. With other measures, we assumed a warning in time to take mitigation action.

Question. Since the study included central costs but not lifelines, etc., what would be the change in relationship if all costs were included--for example, the effect of an earthquake on the electronics industry in San Jose?

Response. Secondary losses--homelessness, jobs, recovery materials were included but not the others--it would have been too big a job. The maps are not intended to be used as a planning tool, but to give an idea of where the losses are or are likely to be.

Question. Are people too sensitive for local maps? My city uses landslide maps, and people accept the information.

Response. Specific buildings were left out in mapping San Francisco. This says something about local attitude.

Added Response. The mayor's earthquake task force in Los Angeles considered damage maps. While some thought the maps would be harmful, it was believed they'd be useful to business firms which can plan measures such as sending employees home and achieving some mitigation by individual decisions. Maps need to be detailed enough so that individuals can take action to protect themselves. The task force decided benefits outweighed problems.

Comment. The loss figure for Colorado is larger than any losses ever realized in the past.

Response. The dollar loss in the early period was very small, but the exposure in the year 2000 will be much greater. Losses were calculated for the year 2000 based on estimated exposure; therefore, the losses would be greater than any yet experienced. On a regional basis, the east is growing (population and real property values) at 2½ percent annually. Growth is not very high in the north central and southern areas. On the west coast and in the Rocky Mountain states people are migrating to hazardous areas.

Question. Any projections on loss of life?

Response. Compared to 46,000 deaths from traffic accidents in 1976, roughly 1,000 people die from natural hazards per year, with tornadoes the major killer.

2. Land Use to Reduce Hazards

From the Panel:

Changes in land use policy to minimize seismic risk must be weighed against and in conjunction with other approaches such as engineering, insurance and warning systems, for example. Nonetheless, land use planning can do a lot to reduce seismic hazards.

As a first step, government should be prudent in the location of its own projects. This will be a way of providing leadership to communities. Construction of roads, for example, will impact decisions on building location and construction. Government has responsibility for its own land use.

Local land use planners need more good information properly interpreted to assist them in designating land uses for hazardous areas. The U. S. Geological Survey has been a leader in getting useful information to locals and will continue in this role. The Department of Housing and Urban Development can do more to be of help to urban planners. State geologists also have an important role in providing data. Most detailed information needed at local levels, however, is beyond the capability of federal and state governments to provide. There must be mapping at local levels for fine-grain information. Population concentration and potential growth patterns should indicate where good data are most needed.

Federal officials can help in the preparation and implementation of local plans to reduce hazards. A-95 reviews by state and regional clearinghouses can be useful in federal decisions to make sure that federal funds are used so as to help ensure seismic safety.[2]

To what degree can state growth and land use planning take seismic and geological hazards into account? Implications of hazards may be at a micro level--so how do states deal with this problem? Critical areas in many states are being identified by state agencies. A state's role, while not site-specific, is broad and can be helpful in guiding local government.

What should a state mandate local government regarding land use planning? In California, all cities and counties are required to prepare and adopt a general plan, which includes at least the following elements: land use, circulation, housing, conservation, open space, seismic safety, noise, scenic highways, and safety. California law further requires that zoning and subdivision of land be consistent with the adopted general plan. The seismic safety element was specified under a requirement enacted soon after the 1971 San Fernando earthquake; thus, all cities and counties have been required for at least six years to include a seismic safety element in their general plans; this requirement calls for identifying and appraising hazards and taking results of geologic and other studies into account.

What have been the effects of this requirement?

1) There is a greatly heightened awareness of hazards. By 1977, 87 percent of the localities had incorporated seismic safety provisions in their plans.

2) Cities and counties are more likely now to utilize geologists; this is a big step forward.

3) The requirement has brought different levels and branches of government together to talk about seismic hazards.

4) Local regulations restricting unsafe development have been adopted.

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[2]Federal grant reviews carried out under the provisions of Circular A-95 of the Office of Management and Budget

Seismic safety elements incorporated in local plans vary throughout the state. This variety has been salutory because it has led to many different approaches in a field where no one claims to have the perfect approach. Some form of quality control, however, is still needed.

States should take direct action to obtain mapping of at least the major hazards, with state requirement for local compliance. It is becoming more common for states to designate areas of critical environmental concern. An example, again from California, is the Special Studies Zones Act under which the State Geologist has delineated major active fault zones. The zones are ordinarily less than a quarter-mile wide unless special considerations indicate the need for a wider zone. Zone maps are officially issued by the Division of Mines and Geology, after which local jurisdictions must require geologic reports prior to approval of any new real estate development or major additions to existing structures within the zones. Certain minor residential developments are excluded. Criteria adopted by the division include the prohibition of construction of structures for human occupancy across active fault traces.

Once the fault zones are mapped, local governments must administer the law. The law may be a step toward discouraging development not only over active faults but also in areas susceptible to other hazards such as groundshaking and landslides. Since land use decisions are made at the local level, involvement of the right kind of professionals is extremely important in advising local authorities. States should set up regulations and conditions which assure a good job at the local level.

Examples of some of the approaches taken by California jurisdictions in their seismic safety elements include:

1) Oakland's maps show the range of seismic hazards, and the text sets forth general policies for mitigating hazards.

2) Santa Barbara County has a unique ranking system on the severity of hazards, mapped on a 90-acre grid system for the entire area, which serves as a basis for its element.

3) Santa Clara County did a background study and mapped three zones--areas where geologic investigations are required, areas where they may be required, and areas where they are not required.

4) San Jose's maps show areas which are good or bad for high intensity use, based in part on potential landslides and liquefaction.

5) San Francisco, with a problem of many old buildings, has mapped areas with old buildings and started a program to reduce hazards in those areas.

6) San Bernardino County has developed a strong public education program. Also, matrices have been developed to correlate land uses with areas of increasing relative risk. Greater restrictions then apply in higher risk areas. Very clear maps show local government plans for limiting growth in hazardous areas.

Discussion.

Question. Have studies been done on the effects of hazard disclosure on the buyers of property? Is there a measurable response?

Response. Studies of flood plain designation indicate that disclosure is not a detriment to property values. Communities have a right to zone against development in flood plains.

Added Responses. But communities are less inclined to zone against development in potential earthquake areas than in flood plains.

People too often respond to earthquake risk as though it presents an "acceptable level of risk;" they perceive little hazard to individuals.

California's Association of Realtors has just prepared a handbook for realtors on disclosure.

Question. Does California have "planned unit development?"

Response. Local government decides whether to have planned unit development. Planned unit development (PUD) is important in dealing with areas which contain geologic hazards but also have portions suitable to development.

Question. What constitutes a good "seismic safety element?"

Response. It needs to be based on accurate information. It should not misconstrue or misinterpret. A good "element" should be multi-disciplinary, be based on the views of all who studied the situation.

Question. The federal flood insurance program mandates through financial sanctions? What can the federal government do to accelerate hazard reduction?

Question. How does the Coastal Zone Act work in regard to coastal flood plains? It requires consistency with states. How is it enforced?

Response. As an example, the state of Washington can't build an oil port where it wishes because the state can't overcome federal coastal zone regulations.

Question. Why not tie enforcement to federal money sanctions as was so often done in the past?

Response. A review of 115 federal programs involving land use requirements showed only eight related to hazards.

Added Response. The Feds need to get their own house in order.

Comment. A regional or metropolitan area planning association (i.e., substate planning agencies) can provide land use information and services to member governments, including provision of hazard maps at a detailed level. For example, the Association of Bay Area Governments participated with USGS in providing data to member jurisdictions. Such agencies also can review state and local projects in their A-95 clearinghouses. They can take some of the review pressure off the states. Regional planning agencies can also advocate worthwhile legislation for member communities.

Question. What can we say to other governments which have not had the experience of requiring inclusion of seismic safety in community plans?

Response. It is surprising how much can be accomplished by requiring communities to develop a seismic safety plan. This should be considered at the national level for all disaster planning.

Added Response. California has no sanction against locals if they don't adopt seismic safety zoning. All local plans must have a seismic safety element but they are not required to develop zoning by the general plan.

Comment. Nebraska communities may zone for flood plains. If the locals don't, the state will.

Added Comment. California doesn't go that far, but a locality would be open to suit if it does not comply with state requirements.

3. Construction Regulation

From the Panel:

Construction codes are one of many mitigation measures. Manmade structures account for most of the loss from earthquakes and other natural hazards. In the past 90 percent of lives lost and a major percentage of economic loss from earthquakes have been due to damage to structures.

However, earthquake-resistant structures can be built. A 1972 report of the Office of Emergency Preparedness says that the greatest mitigation will come through safe construction.

Most regulation authority is vested in state government, and that responsibility is passed on to local government. Over 5,000 building codes exist throughout the country. Many do not consider earthquakes, including those in areas where earthquakes have occurred in the past.

22 states now have statewide building codes, most of which are mandatory. Building codes generally include minimum safeguards for fire safety and prevention of collapse, and also health standards.

Most codes are developed through adoption or modification of model codes. The first model code was developed in 1927. In the United States there are now four model codes, termed "Standard," "Basic," "Uniform," and "National," developed by the model code organizations, one of which is represented at this conference. There is a move for more uniformity between these model codes, likely to be sought or urged through the newly-established National Institute of Building Sciences now being organized in Washington.[3]

Earthquake code requirements have been developed mostly in California. In 1948, comprehensive lateral force requirements were developed in California. The San Fernando earthquake awakened new interest, and the need for a more coordinated national-oriented approach was recognized. In 1973, a project to develop criteria, national in scope, was organized through the National Bureau of Standards; two groups were formed: 1) a seismic design review group to discuss the technical aspects, composed of earthquake engineers, seismologists and geologists; and 2) a building code consultant group. The technical provisions for earthquake design will be ready (although in tentative form) in the summer of 1978.[4] They need to be tested to establish their technical viability and economic impact.

The federal government can have an impact on construction in two significant ways:

1) Through construction of its own buildings, dams, etc. For example, the federal government currently owns or utilizes approximately 450,000 buildings.

2) Through requirements specified in grants for federally-assisted construction; this is a subject under consideration in the Federal Implementation Plan being developed under the Earthquake Hazards Reduction Act.

Discussion.

Comment. Earthquake prediction can aid officials by setting priorities for improving existing structures.

Added Comment. A seismic safety committee established by California's Seismic Safety Commission held a workshop on existing buildings. The engineering problems, while costly to correct, are actually more simple than the social problems which would result from stricter engineering requirements, especially as applied to existing structures. The conference included representatives of insurance, banking, mortgage investment, community groups, etc., who considered such social problems.

A special life-safety code is needed to protect people from hazards in existing buildings and to allow them to get out of buildings when there is a quake--whether the building survives or not. The financial community has an interest in such a code if the mortgage situation is firm, with a view to protecting investments.

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[3]The National Institute of Building Sciences is now located at 1730 Pennsylvania Avenue, N.W., Washington, D.C. 20006; (202) 347-5710.

[4]"Tentative Provisions for the Development of Seismic Regulations for Buildings," NBS Special Publication 510, June 1978 (for sale by the Superintendant of Documents, U.S. Government Printing Office, Washington, D.C. 20402; Stock # 603-003-01939-9, $6.75).

Proceedings of this workshop are due in the spring of 1978.

Added Comment. The sort of thing a city needs is analysis of: 1) the increase in safety with such a code as compared to other existing codes, and 2) relative costs in construction with each code.

Response. The first is difficult, and the second is easier.

Comment. Building codes apply to existing structures in only a limited way, usually covering only major improvements. This presents a tough problem--both political and technical.

Question. Any more ideas about existing structures?

Response. In 1969 San Francisco passed a retroactive ordinance on parapets. It was unenforced for six years. The problem was to find a way of retrofitting at a cost that was not prohibitive.

Added Response. Long Beach's code includes a provision based on a time frame; for example, the most hazardous buildings have the highest priority. It is based on voluntary compliance. The key to the success of the Long Beach code was that the idea was sold before it was legislated, with citizen participation, a concerted public relations effort, and an attempt to take differences into account.

Added Response. Los Angeles is embarking on a program to retrofit or condemn 14,000 unenforced buildings. Originally scheduled to be an ordinance with across-the-board effect, owners were given two years from the time of citation to submit a plan for approval and two years to carry out the approved plan. There was no priority ranking. The ordinance, to be revised, is now in committee.

Comment. Cities could be carving out a whole new area of liability by lax enforcement of codes. In California, there was a case in which the court held that one of the state's own traffic codes was not met by the state, and so California was held liable for an accident caused by an overburdened intersection. If a state does not implement its own building code, it could be liable for subsequent injuries.

Added Comment. Massachusetts set up a study group on building code provisions for seismic safety, and a statewide building code recently developed included provisions to deal with seismic hazards. Massachusetts has people knowledgable about earthquakes. The American Concrete Institute and others were interested in hearing what engineers thought about their structures.

A lack of enthusiasm among planners, engineers, and builders doesn't lead to stricter codes. We must change the attitudes of professional societies.

Question. Massachusetts' building code developments are cheering. Who enforces these codes?

Response. The Massachusetts Building Code Commission adopted it, and it hasn't been overridden. Enforcement is local. If local inspectors don't enforce it, the locals are open to suits. While such cases haven't arisen over earthquake provisions, they have in the case of lead-painted buildings.

Added Comment. The professional level of building officials must be raised to obtain enforcement of regulations which do exist.

4. Lifelines (Utilities, Transportation, Communications)

From the Panel:

Lifelines, those systems for water, waste disposal, energy, transportation, and communication which play essential roles in a community's existence, make up half of the value of all facilities exposed to earthquakes. The American Society for Civil Engineers has set up a special unit to study lifelines problems. Its Technical Council of Lifeline Earthquake Engineering has committees for 1) gas and liquid fuel; 2) transportation (including harbors and airports); 3) water and sewage; 4) power and communication facilities; plus additional committees dealing with risk, research, and other subjects. ASCE held a conference at the University of California at Los Angeles in August 1977, which produced a comprehensive report on "The Current State of Knowledge of Lifeline Earthquake Engineering."[5]

Lifelines engineering for earthquakes and related hazards is applicable to a number of linear systems (rather than single structures) crossing many geologic hazards and combinations of risk. Because of this factor, needed analysis of lifelines as related to hazards is complex. Concern for lifelines engineering came along later than that for structures; it has been given special emphasis since the San Fernando earthquake in 1971.

The goal of lifelines engineering is to review facilities in order to 1) devise methods for upgrading existing structures (a retrofit program) and 2) design future facilities that will reduce probable loss. Some upgrading measures are simple, e.g., securing heavy equipment such as generators and assuring safe storage of laboratory materials. Others are more complex, including those affecting dam safety, pipeline design, valves, etc.

In the San Francisco Bay area local groups are working actively on various lifelines systems, including studies by telephone and power companies and by highway agencies. New studies of seismic risk are needed.

Guidelines for lifelines protection must be reasonable and must recognize regional differences. Research is needed. Unfortunately, funding for such research is more likely to be available after a catastrophic event.

Discussion.

Comment. There is an analogy in highway law which raises concern about

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[5]Available from ASCE's Publication Department, 345 East 47th Street, New York, New York 10017 (price $10 to members; $20 to non-members).

preparing guidelines. If you have a code and don't live up to it, the government may be liable for damages.

Added Comments. In fire standards, a lot of case law says you may already be liable.

The problem of liability might keep you from doing anything. As to cost, you have to look at cost to whom. Building code restrictions are not "no-risk" provisions; there can always be a "bigger" earthquake.

Question. How uneasy are you over the prospect of fires from earthquakes?

Response. Fires at industrial plants are a problem. Special valves which turn off with earthshaking may be a possibility where a gasoline line, for example, crosses the Hayward fault. The ability to fight fire also depends on the location of reservoirs.

Comment. This is not the problem it used to be.

Added Comment. Be careful. In Boston, for example, water lines are likely to be knocked out in the soft soil, and this soil is in congested areas.

Comment. Also remember the impact which one large power failure had on New York City. That experience underlines the importance of looking at a whole geographic area.

Added Comment. Redundancy in lifelines is always an important element for consideration in lifelines engineering.

Comment. Nuclear reactors can be shut down during an earthquake, but the cooling towers probably will not survive so there may be no power after an earthquake. The towers take a long time to repair. Fossil fuel plants face a similar problem because their boilers are especially vulnerable. One must conclude that you can't count on power from either nuclear or fossil fuel plants after an earthquake.

Question. What is the relative risk of underground vs. above-ground lines? What do you do with existing lifeline systems?

Response. There is no easy way to upgrade these facilities. There is not much difference between overhead and underground facilities. They have different designs, and both are vulnerable in certain respects.

Question. Has there been any work on the value of small power systems? It seems that communities with their own smaller power plants have gotten back into service faster than large-grid systems.

Response. I know of no such study. It is mostly in California that this question is being examined now.

Added Comment. The economics of scale lead us to larger facilities.

Added Comments. Major lifelines, such as those for electric power and pipelines for gas, have a tendency for the structures to get more complex as need increases. The repair record of today's complex transmission lines may differ from historical repair records (e.g., 20 months for some new ones in Kansas vs. six weeks for the older facilities). There is a need to consider rulings of state and other regulatory officials to put multiple power lines in fewer corridors, thus increasing risk and complexity. There is a need for an integrated approach in considering all hazards and lifelines. Consistent and reasonable requirements are needed.

Added Comment. All lifelines are exposed to multiple hazards. We need to look at all of them. We need to look at the distribution of facilities as related to population. As an example, in earthquake engineering, not all facilities should be put on the opposite side of a fault from where the population resides.

Question. Should special focus be put on lifelines serving especially vulnerable groups such as elderly people?

Response. The program should address this specifically.

Question. Is there enough interest by industries in parts of the country other than California?

Response. Actions are often taken not so much on a state basis, but by groups or industries. The American Association of Highways is developing a code for bridges and earthquake hazard. Bell Telephone is taking action to reinforce racks against earthquake hazard. Some electric power companies in the east are taking action. Water systems offer great difficulties; there is a need for pilot studies in the east to get a sense of cost-benefit, as has already been developed in California.

Added Response. Some studies made in San Francisco have found that a Pennsylvania gas company was way ahead of many other public utilities in retrofitting. If there were an earthquake in San Francisco, the Water Department estimates there could be as many breaks in water mains as there were in 1906; alternatively, the high pressure fire fighting system is very well equipped.

5. Emergency Response Systems

From the Panel:

Experience with fires, floods, earthquakes and tsunamis have resulted in a firm legal base for emergency relief and services in California. The responsibility for these services is shared between the governor, county executives, and city mayors.

A mutual aid system has been developed whereby manpower and materials can be massed in order to combat effects of disaster throughout the state. For example, in the Santa Barbara fire, 1,000 men and 100 pieces of equipment from city, county, state and federal sources were mobilized to fight the fire. Mobilization can be accomplished at different government levels depending on the nature of the emergency.

After the San Fernando earthquake in 1971 studies were made to determine what the effects of another 1906 earthquake in San Francisco would be. Estimates showed from 3,000 to 10,000 killed, with losses of $15 to $20 billion. It would be a national as well as a state disaster.

California has recently completed a new earthquake response plan specifying government agency roles and responsibilities after big earthquakes. Copies are available from the state's Office of Emergency Services.

Weaknesses were identified in particular parts of the plan. A large quake woule isolate communities, and we're now trying to improve mobile communication. New equipment needs to be developed for "heavy rescue." Medical care needs better coordination. Improvements are needed in public education.

Reliable earthquake prediction would most certainly accelerate public interest, would focus immediate effort on rehabilitation and reconstruction of unsafe buildings, and would lead to the development of a new warning system.

After the 1971 earthquake, California took steps to institutionalize state approaches to earthquakes, resulting in a joint legislative commission on earthquakes, a seismic safety commission, and an advisory council on earthquake prediction evaluation.

The California Office of Emergency Services has a full-time person for public information, involved with such things as films, mail-outs in utility bills, etc. He's trying to establish an earthquake information center, able to deal with subgroups in the society (schools, chambers of commerce) as well as with the public at large. The policy is not to hire state employees for this purpose, but to utilize contractual sources in order to reach specific groups.

Implementation of the Earthquake Hazards Reduction Act will influence intergovernmental relationships among the federal, state, and local levels of government. There needs to be a single point of contact at the federal level, and the federal effort needs to be coordinated. State emergency service directors must be kept informed.

To other states: use research results to develop new tools in your emergency preparation effort and make appropriate changes in your emergency procedures. Cooperate with your state planning officers with open exchange of research results.

Discussion.

Question. How long can a high interest level be sustained in the absence of big earthquakes?

Response. No question, it is a problem to maintain high public interest. Have programs ready to go, and jump in immediately after an earthquake.

Question. How much use is made of volunteers?

Response. Volunteers can distribute public information materials, also serve as "watchers" as they've been used for prediction purposes in China.

Comment. We need ideas on how to use volunteers. The more involved the public is, the more awareness and responsiveness will be achieved.

Added Comment. In Los Angeles, a series of articles and a booklet on local self-help and volunteer efforts have been developed dealing with earthquake safety in the home. Some groups have begun to work with the Red Cross to distribute these on a large scale.

Question. If 40 percent of Palmdale never heard of the bulge, weren't there public education programs there? Why so low an awareness?

Response. There has been media coverage and two programs prepared by the Seismic Safety Commission. Still, it is a problem to reach everyone. We can continue with public "seismic safety" spot announcements, school education programs, etc. People in California appear to keep the earthquake threat in perspective; over-reaction doesn't occur.

Added Response. UCLA's study in the Palmdale bulge area indicated that a greater number (than 40 percent) knew about the bulge. 86 percent of those interviewed had heard of the bulge.

Question. Is there a school curriculum dealing with earthquakes, and is there a "hot line" for watchers?

Response. A schoolteacher safety training grant expired two years ago. We may possibly be able to use volunteers, but they must be able to relate to a governmental entity, and they need to be trained. Use of volunteers to watch and report on animal behavior merits cautiousness.

Comment. The Stanford Research Institute has an on-going research effort on animal behavior. UCLA is also involved with work in this area.

Added Comment. Greater use should be made to get information in the hands of groups such as engineering societies. Public officials may get information but too often it doesn't get to people who can make use of it.

Question. Should other states, including those in the midwest and the east, develop response plans specific to earthquakes?

Response. A western state has expressed interest in developing a specialized seismic plan because the state has much low-key seismic activity.

Added Response. States with less likelihood of an earthquake should concentrate less on preparedness keyed to earthquake prediction and take a long-term coordinated hazard approach based on land use and research.

Comment. USGS has asked every state and territory to designate a representative to work with it on earthquake and other geologic hazards. In answer to the USGS request, 15 states named their geologists, 21 their disaster directors, six an assistant in the governor's office, six named persons in other state agencies (environmental quality, natural resources, planning, etc.) 10 states and three territories have not responded. USGS is willing to hold regional meetings of USGS and NOAA representatives with state designees and state disaster directors. (Note: a program of such meetings is now underway and several regional or state meetings have been held.)

6. Implementation of an Earthquake Hazards Reduction Program

From the Panel:

The transfer of technical knowledge about earthquakes into effective implementation programs for hazard reduction is difficult. The relationship between technical expertise and policy and program development is a new field. The process involved results in social and organizational change. Many physical scientists are just learning that this is the case. Also, earthquake research has created a vast amount of new knowledge, some of it on the policy and social science aspects of earthquake prediction and hazard reduction.

Successful implementation depends upon influential elements of the social system, which have a voice as to whether knowledge is translated into action. Because the social system is pluralistic and diverse, citizens and public bodies are frequently being exposed to a wide range of knowledge, pressures, and information which will influence their behavior.

Design and implementation of earthquake hazard reduction policies and programs are influenced by: 1) the occurrence of earthquakes; 2) activities of advocate organizations; 3) activities of opinion leaders; 4) increased concern about the environment and its relation to human activities; 5) amount of funds allocated to research and implementation, and 6) publicity about earthquake prediction.

Impediments to improved seismic safety policy include: 1) absence of earthquakes; 2) existence of other high-priority problems; 3) an inability to define earthquake risk in precise enough terms for local jurisdictions to integrate into their programs; 4) negative reaction to hazard reduction efforts which, in the absence of earthquakes, begin to be questioned, and 5) inability to demonstrate the effectiveness of existing hazards reduction knowledge and programs, especially in the absence of earthquakes.

Subsequent to adoption, most difficulties arise over operational questions--rules, regulations, and procedures. Fewer difficulties arise in adopting basic policy as time passes.

Policy decisions are needed with respect to land use, buildings, lifelines, critical facilities, support programs, and other hazard reduction measures. Procedures will vary, as will intergovernmental relationships.

Current examples of major policy issues involve such different questions as: 1) what to do with structurally unsafe existing buildings; 2) socio-economic implications of earthquake prediction; 3) standards for lifelines and related services; 4) role of building codes in seismic safety (and in achieving other goals as well); 5) development of increased governmental coordination; 6) learning to utilize knowledge, and 7) need for policy research leading to stronger public programs and understanding of the policy process.

Discussion.

Question. We're focusing heavily on California's conditions and experiences relative to earthquakes, but other states can't proceed in the same way as California. What do other states think they can do?

Response. The seismic safety model in California is hard to export. Planning for earthquakes in areas where the earthquake hazard is not as well perceived is difficult. Organizational forms and experiences should not be exported to places where they might not fit. The idea of a seismic safety commission, such as that in California, would seem applicable only to areas with a high degree of earthquake risk and a high level of perception. Legislation authorizing the California commission insures its existence only through 1981; this makes it more responsive and accountable to the legislature.

Added Response. Washington state is looking at natural disasters, also at possible disasters arising due to new technology. It has a new contract with the Federal Disaster Assistance Administration to improve its disaster plan, and the new governor is interested in planning for the mitigation of hazards. State legislation mandates disaster planning. Cross-state correlation must be considered. For example, in 1962 a tropical storm in California leveled forests in Washington.

Added Responses. It is not possible that there will be a seismic safety commission in Illinois. Public awareness of present and past seismicity is very low. Drought actions were taken when drought occurred, but once rain came, efforts ceased.

In Missouri, efforts were made to elicit comprehensive state support for earthquake programs but no interest brewed.

The idea of a seismic safety commission is a haphazard approach and would not be pursued in Nebraska. Its state emergency service could take more leadership within the framework of the state's organization. The state government should be able to cover the earthquake hazard without formulation of a new commission.

Question. South Carolina is concerned with both hurricanes and earthquakes. Where are the faults? How are they different from those in California? There was an intensive earthquake at Charleston in 1886, but people today need more information.

Response. Eastern earthquakes are not even understood by the experts. USGS and NSF are working on new projects to deal with eastern earthquakes, but problems won't be identified for a few years.

Eastern earthquakes in the United States will be bigger but less frequent than California ones. Risk is as great in the east.

Comment. In implementing hazard mitigation efforts, the cure should not be worse than the disease.

There must be consideration of the social impacts of hazard mitigation. When hazard mitigation is added to other things, some activities may affect poorer people most. It affects structures least able to be upgraded and therefore affects persons least able to compete for alternative housing. It could add one more threat to those already having difficulty surviving, e.g., the elderly.

Historic structures may also be affected and viable neighborhoods disrupted without adequate precautions.

7. Additional Contributions from Conference Participants

a. Role of Volunteer Organizations

Red Cross looks at 37,000 disasters a year and gains a lot of information and experience. Here are some instances in last winter's storms which might also be applicable to earthquake response:

1) The Red Cross was asked to open buildings not heated by natural gas. These buildings can be identified ahead of time.

2) Social Security checks couldn't get through even in areas not directly affected. In earthquakes, too, the elderly in areas not impacted might not have money for food; there aren't emergency plans to deal with this.

3) In Florida, 10,000 migrant workers were out of work. A similar situation could occur in California's central valley if a dam should break during an earthquake.

There needs to be a mechanism for sharing this kind of information and experience.

A recent meeting of volunteer organizations on earthquake problems revealed a tremendous constituency through volunteer church groups. Church leaders believe hazard mitigation is a moral issue; at their annual meeting in January they will discuss what they can do. We should begin to depend on this "born again" interest in mitigation.

The Red Cross is beginning to take a position of advocacy. Its new operational manual states that Red Cross will push for land use, insurance, and other mitigation efforts.

b. National Governors' Association Preparedness Project

A one-year NGA disaster preparedness project is just getting underway. An analysis of strengths and weaknesses of state disaster preparedness programs will be conducted from a perspective of broad social concerns as well as the immediate needs of the disaster situation. The study will complement the Administration's disaster reorganization effort by surveying selected programs to assess how well federal programs respond to state and local needs. A comprehensive manual for governors will be prepared outlining problems and suggesting methods of strengthening state emergency preparedness programs. Governor O'Callaghan is chairman of the NGA Disaster Assistance Subcommittee and will have a lot of input.

NGA is sending out a questionnaire to all states to elicit experience with emergencies in the last three years.

Discussion.

Comment. There have been no earthquakes in the past five years, so the questionnaire will not gain any information on earthquakes.

Added Comment. A University of Massachusetts project under Dr. Peter Rossi has been looking at hazards experience for the period 1960-70, including an inventory of all events in four classes of natural hazards during that 10-year period.

c. A Strategy for Financing Hazard Reduction Efforts

When considering taxes as a means of stimulating capital expenses for business purposes, losses, research, etc., related to hazards reduction, 1) the federal route is more lucrative than the state route since the tax rate is higher and so are the returns; 2) increasingly states follow federal law and benefits are likely to come from both; and 3) federal law is easier to deal with. So far as natural hazards in general are concerned, it would apply to all states and not just to those primarily concerned with earthquakes.

Spending is needed for hazard reduction as well as for relief to people hit by disaster. In Congress, the causes that succeed in getting authorizations and appropriations are those that some individual takes on for political reasons. The trick in getting federal funds is to find the right political backing in Congress at the right time.

Obtaining government financing is not an economic problem but a political problem.

The Advisory Commission on Intergovernmental Relations can be a useful body in identifying federal, state, and local intergovernmental problems and in suggesting programs to solve them. It includes governors, county officials, mayors, as well as Congressional representatives, plus three public members. Problems come to the commission mostly through its individual members. If a problem needs exposure and political clout, it may help to get the advisory commission's interest through one or more of its members.

8. Concluding Observations from the Co-chairmen of the Hazard Reduction Session

There is a lesson in the fact that when the sociologist who was to co-chair this session couldn't get away from his campus, a seismologist substituted for him.[6] This shows progress in interdisciplinary efforts, also that people from

[6]At the last moment Dr. Ralph H. Turner, UCLA sociologist who chaired the National Research Council's Panel on the Public Policy Implications of Earthquake Prediction, found that he would be unable to attend the conference. The Council of State Governments is gratefully indebted to Dr. Carl Kisslinger of the University of Colorado for responding to its eleventh-hour request that he serve as a co-chairman for the hazard reduction portion of the conference.

different fields can talk to one another.

When summarizing things to be done for earthquake hazard reduction, one caution should be made regarding earthquake prediction--namely that expectations concerning earthquake prediction may be too high. This is important because some implementation plans are nearer realization than others.

Among important things to be done are:

1) Earthquake site risks at state and local levels should be specifically located.

2) The federal government can provide coordination, information, and incentives--it should also set a good example in land use decisions.

3) There is still a gap between technical people and others such as planners and state-local decision-makers; they haven't known how each other thinks and works. The gap is closing but more needs to be done.

4) Many problems are international; in both economic and humanitarian terms, these need to be examined on an international level. There is a lot to be learned from other countries.

In this session we have discussed various aspects of construction and codes, lifeline systems, land use, and many other things. Unfortunately, we did not talk much about the role of insurance; perhaps, in this connection, we can learn from flood insurance experience.

There seems to be a tendency that possible liability for identifying a hazard is a reason to ignore it. Is this a real or imagined tendency?

The all-hazards approach can lend vital support for mitigating hazards from earthquakes as well as other natural hazards. We need now to find out how to get together people having concerns for mitigation of particular hazards in order to maximize our hazard reduction efforts for mutual advantage and achieve a better all-round result.

D. WRAP-UP PRESENTATION AND DISCUSSION

Chairman, Gilbert F. White

From the Chairman:

We have had a very lucid and balanced presentation on the state of the art of earthquake prediction. Distinguishing characteristics of earthquakes are that they are invisible and highly infrequent.

The tasks in prediction are difficult, and we don't understand much about the nature of earthquakes in the eastern United States, but there, too, as well as in the west, large social dislocation can result and many political issues are involved.

The last major earthquake was in 1971, for which losses are estimated at $500 million dollars. Although there was a sophisticated network of technical equipment, we couldn't call it in advance and couldn't get a warning out. We can expect more of these uncalled events.

A few years ago scientists in the earthquake field would have been more sanguine. Now they're more judicious. Scientists are soul searching, wondering what actually the public should know and when they should hear it.

Five themes developed in the conference:

1) Algebraic formula. California is not equal to the United States, not in experience, competence, scientific expertise, or innovative government. California dominates earthquake discussions due to experience and perspective but, as has been mentioned, other states have very different problems. The problems of other states deserve attention.

   Nor is California the world! So we must look to international experience for relevance.

2) Choosing right mix of tools. There are all kinds of tools for dealing with extreme events. There are various modes of mitigation and the problems are complex. What is the appropriate way to deal with particular hazards--in warning, prediction, insurance, building construction, and other pertinent elements for reducing risk? What are the various ways to distribute costs, not just to achieve the best emergency response but to meet mitigation needs too, with consideration of physical and social costs for research, warning, etc., to help our communities? We must choose among damage possibilities and integrate with other programs. The salient character of environmental quality and housing codes must be considered. As has been pointed out, almost no attention was given at this conference to insurance as one of the tools.

3) Which public-whose responsibility? So many organizations with special interest and expertise and so many different jurisdictions having varying commitments, legal rights and responsibilities are involved.

   Warnings, for example: how will all people in California respond?

That's too broad a question. We have to look at the responses of particular segments--business, citizens, voluntary agencies.

Education and awareness: there is much discussion about these programs, often targeted at particular audiences. The response of those affected by real estate disclosure may have high political and policy implications. The long term viability of programs must be considered. If earthquakes do not occur, maybe research monies will no longer be allocated. Interaction of implementation agencies is both intragovernmental and intergovernmental in nature and in some aspects can present jurisdictional problems.

4) In union there is strength. What are the best approaches to push for hazards legislation? Political expediency will probably guide us. Conference participants have pondered the practicality of supporting comprehensive hazards legislation or focusing attention on a particular hazard. An integrated approach should be taken in examining why a special seismic agency is necessary. We will need to work out a policy concerned with all hazards rather than just earthquakes.

5) Crisis as a springboard. Many times public actions have been adopted following disaster events. This was true following tropical storm Agnes, also the San Fernando earthquake.

We can predict policies will change following the next major disaster experience. Weaknesses will be exposed, and changes will be pushed through due to increased public interest.

What will we do when the next disaster comes? What actions should be taken in the following months? Be ready. We need to be thinking about the initiatives we should take. We need to have in mind practical programs and long-term projects to bring up following the next disaster when social conditions are ripe for new policies and programs.

Discussion.

Question. Where do forums exist to give consideration in national ways? The three committees of state officials in the CSG project should ask what can they recommend in the near future and what would they do if the social environment gave them leeway to propose what they would like, without thinking and worrying about political realities.

Response. This conference and the National Hazards Research Clearinghouse workshops are forums. We lack points of view, not forums. A question for the earthquake hazards implementation plan working group: what are the research fields and the implementation fields where we would really like to see substantial progress?

Comment. Another time for consideration of new ideas in the federal government is when a presidential transition occurs. This year's presidential transition has stimulated hopeful consideration. There will be similar opportunities in the future at various governmental levels.

Comment. Intergovernmental relations cause some of our frustrations. We need to use these forums for states to work with their constituents and the federal agencies. In New York, legislation was not enacted following Hurricane Agnes due to local constraints. The different perspectives of key actors must be considered an important part of the dialogue at these forums.

Added Comment. We in hazards love talking to ourselves. This conference has been a step forward because new people were involved.

Scientists point out problems where decisions must be made in situations of uncertainty. Business is getting better at this, and public administrators must improve. It's time that special efforts are made to inform and try to win over groups so often opposed to most hazard mitigation projects.

Response. Land use provisions of the Flood Insurance Act are now under political and legal attack. One reason is that FIA has not cultivated constituencies. It's been so defensive and hasn't identified with the public. It couldn't hold the line when challenged. We must involve the public more directly with the issues at stake.

Question. Who are the constituents for planners and others who have the job of developing and implementing mitigation programs?

Response. We may be on the verge of a number of helpful things. There is need for stronger state policy planning. Local planners often have ambitious general plans, but they are mostly involved with zoning and subdivisions, not policy development and program planning in a more comprehensive sense.

The Association of Bay Area Governments illustrates the trend toward and usefulness of regional planning. There is often opposition to regional planning but it is needed because so many problems are interjurisdictional in nature. Regional planning will survive.

Comment. It is disappointing that many agencies and public interest groups are seeing the same problems but dealing with them individually. We need to coordinate our efforts.

Response. So far as coordination among the public interest organizations is concerned, the former Public Administration Clearinghouse is a missing ingredient.

Comment. Earthquake problems can't be looked at in isolation or in laboratory experiments. They are real problems, and we must recognize issues such as those which, among other things, involve housing, risk allocation, effect of prediction on tax bases.

Added Comment. Bringing the state attorneys general into this conference has been a well-received innovation.

Response. They have been good participants. Their short-term goal is to be concerned with the preparation and dissemination of model statutes related to liability in hazard administration. They will be meeting during the winter in southern California, utilizing California's legal experience and expertise. Legal materials will later be distributed to state people. State initiative will be needed to use the information.

Concluding Comment from the Chairman.

This has been a propitious time for this conference. Geologists and seismologists are more realistic now about prediction. The prospect for earthquake prediction is large but as with cancer research, it needs great investment and there are no easy cures.

The Earthquake Hazards Reduction Act will add to our efforts, and the presidential task forces on federal disaster reorganization will change intergovernmental approaches to natural disasters.

A great deal will happen in the next six months, and in the future we must keep up work on other hazards. 11 years ago the federal government assured a major role in floods, but we're far from being advanced in planning for floods and now serious community questions have been raised that are major challenges.

So, there is much to be done.

IV. PROGRESS REPORT ON IMPLEMENTATION PLANNING FOR AN EARTHQUAKE HAZARD REDUCTION PROGRAM OF THE FEDERAL GOVERNMENT

(Note: As the conference program indicates, the paper which follows was presented at a conference dinner presided over by the Honorable Mike O'Callaghan, Governor of Nevada, and Chairman of the National Governors' Association Subcommittee on Disaster Assistance. The paper is that of Philip M. Smith, Assistant Director, Office of Science and Technology Policy, Executive Office of the President. Due to illness which kept Mr. Smith in Washington, it was delivered by Karl L. Steinbrugge, who chaired the OSTP Working Group on Earthquake Hazards Reduction.

Governor O'Callaghan was introduced by the project director, Hirst Sutton, who emphasized the special knowledge and experience which the Governor brought to the conference as a two-term governor of Nevada, as that state's first Director of Health and Welfare, and as a federal official with considerable disaster experience when he was Western Regional Director for the Office of Emergency Preparedness.)

Governor O'Callaghan introduced Karl V. Steinbrugge as "Mr. Earthquake," reflecting the Governor's personal knowledge of Mr. Steinbrugge's leadership role in efforts which led to the establishment by the California legislature of that state's Seismic Safety Commission in 1976. Mr. Steinbrugge served as the unpaid chairman of the commission from the time of its establishment until he recently resigned in order to chair the OSTP Working Group.

The Governor pointed out that the United States is getting more committed to reducing hazards. Passage of the Earthquake Hazards Reduction Act was cited as a major step. Recognizing that earthquakes are the most feared disaster, both California and Utah have established special seismic safety bodies. He referred to two relatively recent earthquakes in his own state: in 1932, one with a Richter magnitude of 7.3; and in 1964, one of 7.1. Nevada is renovating its state capitol building at a cost of $6 million. He said we know better now how to live with earthquakes, but as a realist, pointed out that it's not easy to talk with legislative bodies about what "might happen."

The paper presented by Mr. Steinbrugge on behalf of Philip M. Smith follows:

Progress in Implementation Planning for an Earthquake Hazard Reduction Program of the Federal Government

"There are some things that are inevitable, and we must cooperate with them." At this point in his text Dr. McGree of the First Methodist Church of Sikeston, Missouri, paused for emphasis. His dramatic pause was unexpectedly filled by the sudden and growing sounds of his church, which began shaking and groaning. The startled congregation stirred...Dr. McGree summoned all of his strength and presence and announced, "Everybody be calm...I don't know what it is, but just be calm." The shaking subsided and he proceeded with his sermon.

The occurrence was an earthquake...in southern Missouri...in 1963. Missouri, as you all know, is but one of the 39 states that are wholly or partially susceptible to major or moderate earthquake risk. It was this same area of Missouri which in 1811 and 1812 was the site of the largest earthquakes that have occurred during this country's life...quakes so large that they were felt over an area of more than two million square miles...so intense that the U.S. Capitol then under construction was damaged...so far-reaching that the quake rang church bells in Boston.*

Disasters and events preshadowing them have necessarily occupied our attention over the centuries. Today, we are at an interesting point in history. We might, in the near future, more accurately forecast several natural catastrophic events of nature--hurricanes, perhaps floods and hopefully earthquakes. The scientific revolution is tearing back the veil of mystery from earthquakes, taking them out of the realm of the metaphysical and into the realm of scientific inquiry and explanation. Research conducted during the past decade has revolutionized our knowledge of the nature of the earth's crust. It has provided, in the plate tectonic theory, not only a rationale for where earthquakes occur, but a beginning understanding as to <u>why</u> they occur. Now we anticipate a prediction capability.

The coincidental convergence of new scientific discoveries and improved engineering knowledge coming from research in several countries, the tragic loss of life in earthquakes around the world last year, and a large-scale earth uplift, the Palmdale bulge in southern California, brought the problem of earthquake hazards squarely before our federal government. After carefully reviewing scientific opportunities, an advisory group to the President's Science Advisor headed by Dr. Nathan Newmark prepared an option paper on earthquake prediction and hazard mitigation. The Congress was concurrently considering legislation, and with the support of the Executive Branch passed the Earthquake Hazards Reduction Act of 1977, which was signed into law by President Carter on October 7.

This act is interesting in several major respects.

- First, it provides a legislative framework for the accelerated research program recommended in the Newmark report. This is the research effort, now proceeding at about $50 million in 1978, a doubling of the funding previously available for earthquake research.

- Second, the act directs that an implementation plan to prepare for earthquakes in advance be developed and implemented; the implementation plan is to be developed around a series of specific time-oriented goals or milestones.

- Third, the act specifically directs that, for purposes of carrying out the act, the President, "shall provide an opportunity for participation by the appropriate representatives of state and local governments..." This is in complete accord with President Carter's desire to make government more responsive to the people's needs, and his desire to involve state and local governments as integral partners in formulating policy and carrying out programs.

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*Editor's Note: See Appendix D, page 76, "The Mississippi Valley Earthquakes of 1811 and 1812."

The Earthquake Hazards Reduction Act of 1977 outlines one of the most comprehensive programs of hazard mitigation and disaster preparedness ever undertaken in the United States. It provides a unique opportunity to test whether or not it is possible to achieve an effective state of protection and preparedness for disasters characterized by low probability but high potential destruction, damage, and disruption. This opportunity must be viewed as a special challenge because most hazard mitigation and disaster preparedness programs in the past have either failed or proved to be grossly inadequate.

The President's Office of Science and Technology Policy has been assigned responsibility for preparation of the implementation plan, which, by the way, must be submitted by the President to the Congress by May 1978. While the legislation has only been recently enacted and signed, I am happy to report that the Executive Branch--the White House offices and the agencies--has been working steadily since last spring on the implementation plan. We were fortunate in that we persuaded one of the best experts in the country, Karl Steinbrugge, former chairman of the California Seismic Safety Commission, to join us on a nearly full-time basis for this planning effort. A working group of agency experts and an external advisory and review group are now refining the first draft of the implementation plan. Consideration is being given to issues in the areas of:

- Preparedness and response planning;
- Earthquake prediction and warning;
- Land use planning;
- Building standards, design criteria, and construction practices;
- Lifeline facilities;
- Design construction and rehabilitation of federal facilities;
- Finance;
- Knowledge transfer.

Shared governmental responsibility has long been accepted in disaster preparation. We hope that the implementation plan will provide for federal leadership in the development of those aspects of an earthquake hazards reduction program which are national in nature, for example, prediction, research and information sharing.

High priority has been given to involving state and local governments in a continuing, systematic way in the development of a comprehensive implementation plan. This involvement is being achieved in a number of ways. State and local representatives are included on our advisory group.

In September, our working group met with western states representatives, the Earthquake Engineering Research Institute, and with voluntary agencies in a meeting arranged by the American National Red Cross.

In October, two special all-day meetings were conducted. 37 public interest groups representing officials at the state and local levels of government were invited. These organizations were being given the opportunity to comment on and participate in the design and evolution of the plan. Still further contact has been possible through an inquiry sent to 48 private sector organizations, some of them having a state or local government orientation.

Many of the members of our federal working group are participating in this conference--a chance to rub shoulders with those having the viewpoint of state and local government.

And, as we continue our drafting and development of the implementation plan over the next several months, there will be further opportunity both formally and informally for state and local comment.

Those of us who have been working on this earthquake hazards reduction plan at the federal level are optimistic that a sensible, realistic plan can be formulated. Nonetheless, it is a tremendous challenge, and in a real sense a shared responsibility with the greater part of the necessary action for preparedness resting in state and local governmental jurisdictions and in the private sector.

To further describe the challenge, let me just list some of the questions that must be addressed in the formulation of this implementation plan. You will see that each considers issues that must be dealt with at the state as well as at the federal level.

> Can the policies of federal agencies be brought into a common framework, so states and communities have a consistent set of federal constraints and incentives?
>
> What level of government should prepare contingency plans to respond to, and recover from, a large-magnitude earthquake?
>
> Who bears the responsibility to evaluate and announce to the public earthquake predictions? Especially during the coming years when earthquake prediction is still principally in the research, not operational phase?
>
> Should the federal government require earthquake hazards reduction considerations in its grants programs to states and communities?
>
> At what point do the costs of providing stronger buildings exceed the reduction in risk of future losses in earthquakes?
>
> Are there realistic approaches to mitigating the hazards of existing substandard structures short of large scale reinforcement programs?
>
> Are there practical economic limits to disaster preparedness that suggest concentration on prediction, warning, and evacuation?
>
> How can we best place in the hands of citizens, business and industry the information that will allow them to make their own decisions on how much risk they are willing to bear?

Most American state and local governments have not yet considered, or given high priority to, earthquake hazards reduction either because their distance from earthquake-caused catastrophes has given them a sense of relative security from quakes, or because quakes are infrequent in their parts of the country. Earthquake hazards reduction planning and implementation will of course vary in priority ranking from community to community, depending upon the degree to which earthquake hazards are perceived and upon the extent to which other more apparent and imminent natural and man-made hazards peculiar to the area are likely to occur. To one degree or another, all 50 of our states are vulnerable to earthquake activity and at least 39 of them are earthquake-prone. All state and local governments in the earthquake-prone states would be prudent to take reasonable earthquake hazards reduction precautions.

State and local government planning and action for earthquake hazards reduction cannot be separated entirely from planning for other disasters and hazards. Some states and cities have known hazards which are more realistically threatening than earthquakes. This too must be assessed, and the states have a major role in making the determination.

In the implementation plan, we want to meet the objectives set forth by the Congress by developing an approach which will take advantage of, and catalyze, the strengths of each of the several levels of government. The development and implementation of continuing, coherent mechanisms for keeping federal officials and the research community informed of the needs and capabilities of state and local organizational units in earthquake hazards reduction is our fundamental goal.

This meeting is important to us. We need and want your help. The Council of State Governments, in grappling with the problems afforded to the states in formulating sound, well-reasoned disaster mitigation programs, is acting most responsibly, especially in examining how the states can deal with earthquake predictions in anticipation of the ability to predict earthquakes, as well as with disaster response. But a caution: in 1549 the *cadi* (the local judge or top regional governmental official) of an eastern area in Iran tried unsuccessfully to convince his people that a quake was imminent and that they should stay out in the open that particular night. They refused and the judge stayed out alone; but finding the night very cold, returned to his house. The quake did occur and the cadi perished with 3,000 others. Apparently the people's inaction caused him to doubt his skills.

As we examine these problems, let us remember Dr. McGree's admonition to "be calm," and at the same time prepare ourselves to communicate more effectively with the public than did the *cadi*.

V. CONFERENCE PARTICIPANTS

A. About the Participants

The conference was attended by 100 persons. It comprised representatives of many disciplines, agencies, and levels of government. Seismologists, geologists, geographers, engineers, sociologists, attorneys, economists, and political scientists attended.

The group included 31 state officials representing 17 states (15 of which were from the 22 states listed by the U.S. Geological Survey in the *Federal Register* of April 12, 1977 as among those subject to some degree of earthquake hazard). Ten participants came from organizations serving state governments; eight were representatives of regional and local jurisdictions; and six were from public interest organizations serving local jurisdictions and officials. 20 were officials of federal agencies.

The academic and consulting communities were represented by 23 persons, coming from ten universities and three consulting-research organizations. Two from the private sector were from insurance and utility interests.

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APPENDICES

A. Project Objectives and Work Plan

B. Robert Locke, "Scientists Recheck Calif. 'Bulge' for Earthquake Signs," Washington Star, April 23, 1978

C. Hazard Loss Maps for the Nine Most Destructive Natural Hazards

D. Otto W. Nuttli, "The Mississippi Valley Earthquakes of 1811 and 1812," from U.S. Geological Survey Earthquake Information Bulletin, Volume 6, Number 2, (March-April 1974), pp.8-13

APPENDIX A

Project Objectives and Work Plan

NSF/RANN Funded Project: "State Government Policy Options for the Utilization of Earthquake Prediction Technology" (Grant Number ENV 76-81112)

The National Conference on Earthquakes and Related Hazards held in Boulder in November is only one part of a project being undertaken by the Council of State Governments on earthquake prediction and public policy.

Project Objectives

The project's basic purpose has to do with the translation of earthquake prediction technology into appropriate state government policy and programs, including those of concern to local jurisdictions and the private sector under authority of state law. The Council's project identifies seven objectives:

1) To determine the general nature of the responsibility of state and local government bodies, officials, and agencies for validating earthquake predictions.

2) To determine the responsibility of governmental bodies, officials, and agencies for issuing public earthquake warnings, including appropriate terminology and procedures.

3) To identify and examine legal, political, administrative, social, and economic issues related to the utilization of earthquake predictions.

4) To analyze and evaluate the opportunities and need for policies and programs for assessment and reduction of hazards and for increased response readiness.

5) To formulate alternative policies, programs, and planning guidelines, also approaches to developing possible state legislation related to the utilization of earthquake prediction.

6) To prepare documentation that will aid consideration of suggested policies and actions by state and local executive and legislative officials.

7) To determine the need for follow-up technical assistance to state and local governments, including further research on policy and administrative issues as well as provision of continuing means for exchange of knowledge among the scientific community, public officials, and other interested parties.

The project is concerned not just with earthquakes but also with earthquake-related hazards, such as tsunamis, floods, fires, and ground failures. Many of the latter hazards are more likely to result from causes other than earthquakes; they also occur more frequently and in more states, thus giving emphasis to the significance of an all-hazard approach in the conduct of the project, preferably in the context of comprehensive emergency preparedness.

Project Work Plan

The Boulder conference provided a forum for the exchange of views among state and other public officials, scientists and other invited participants. The conference agenda and participation were designed to be interdisciplinary, with consideration given to the status and significance of earthquake prediction technology and resultant policy, legal and administrative issues, including those applicable to earthquake-related hazards.

Other aspects of the work plan include the following steps, only the first of which has been initiated prior to the Boulder conference:

1) To assist the Council's project in the examination of public policy and administrative issues, three select committees of state officials have been created by the National Association of Attorneys General, the Council of State Planning Agencies, and the National Association of State Directors for Disaster Preparedness.

2) Policy position papers will be drafted for consideration by national and regional conferences of the Council of State Governments, the National Governors' Association, the National Conference of State Legislatures, the National Association of Attorneys General, the Council of State Planning Agencies, and the National Association of State Directors for Disaster Preparedness.

3) Federal Agency representatives and Congressional committee staffs will be consulted on aspects of the project concerned with federal responsibilities and programs and intergovernmental relations.

4) A final project report will be prepared summarizing general findings, conclusions and recommendations applicable to state government actions and programs.

The Council's project staff will be supplemented by resource persons expert in various fields and will seek to utilize the product of the Working Group on Earthquake Hazard Reduction created by the Office of Science and Technology Polity of the Executive Office of the President. It will also consult with representatives of federal, state, and local governments, some of whom have been organized into two advisory committees of representatives chosen, respectively, from a) federal agencies and b) associations of local government jurisdictions and officials.

Appendix B

Page 70 has been removed.

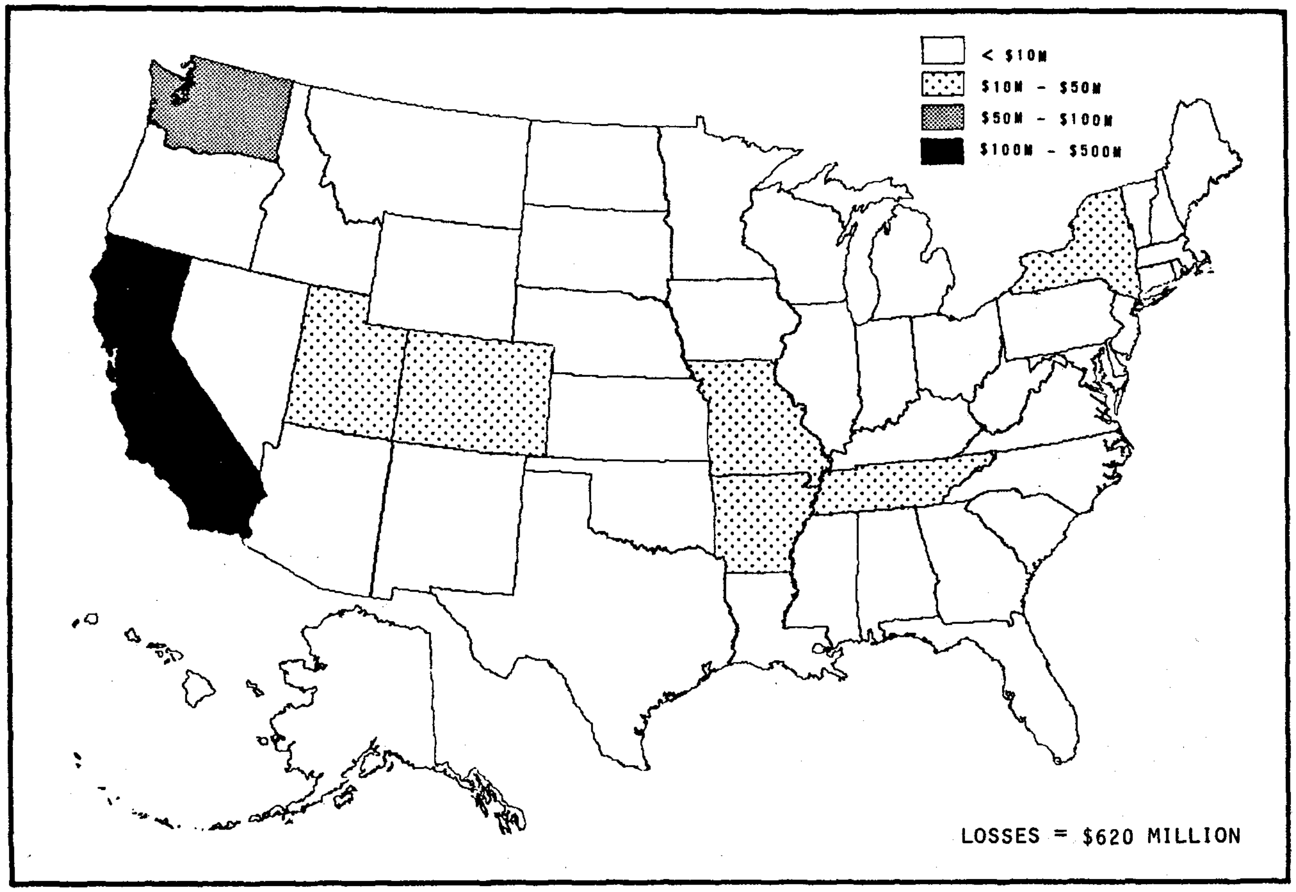
Because of copyright restrictions, the following newspaper article has been omitted: "Scientists Recheck Calif. 'Bulge' for Earthquake Signs," by Robert Locke, The Washington Star,* Sunday, April 23, 1978.

*The Washington Star, 225 Virginia Avenue, S.E., Washington, D.C. 20003

APPENDIX C

Hazard Loss Maps for the Nine Most Destructive Natural Hazards

Source: J. H. Wiggins Company, 165 South Pacific Coast Highway, Redondo Beach, California 90277



ANNUAL EARTHQUAKE LOSSES BY STATE FOR 1970 CONDITIONS

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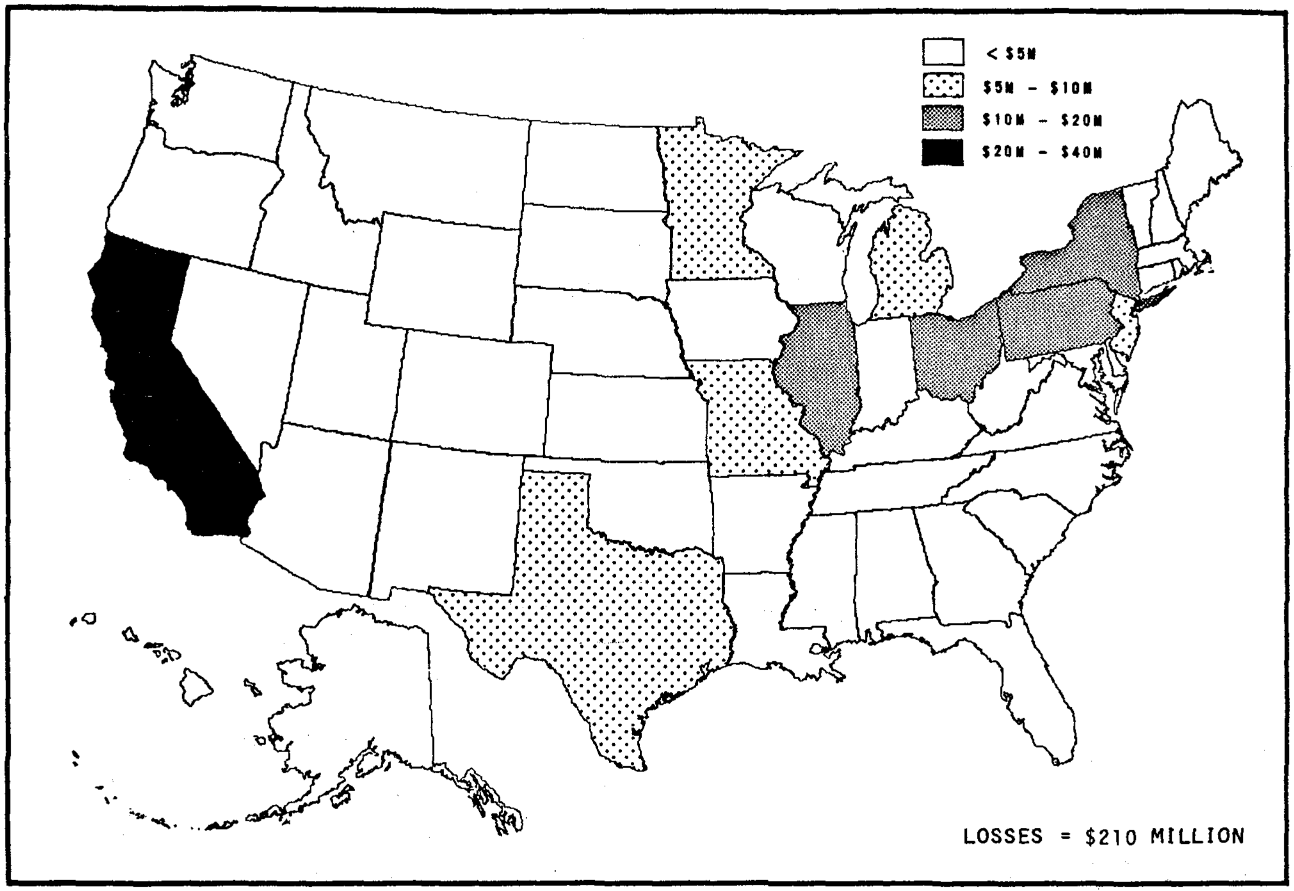
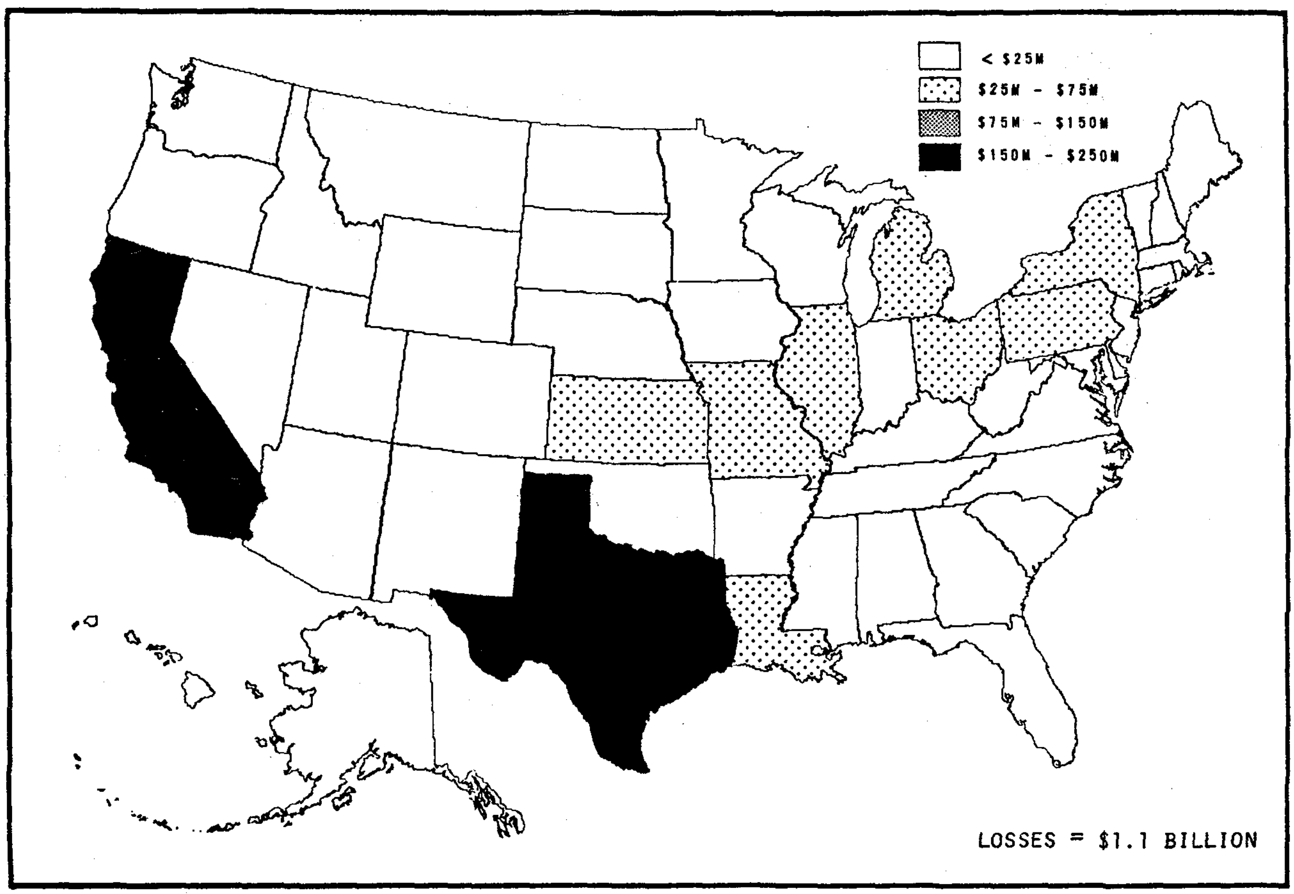
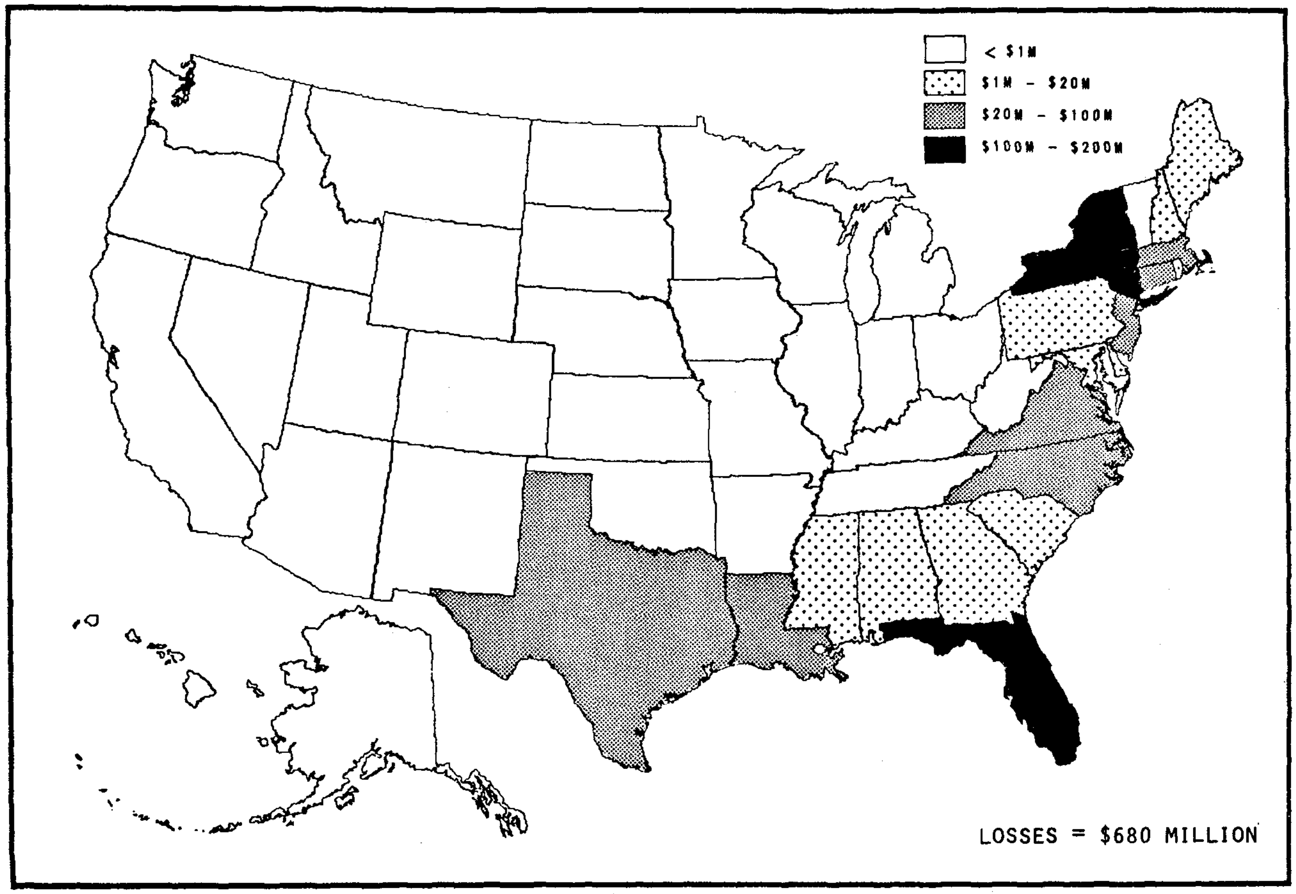


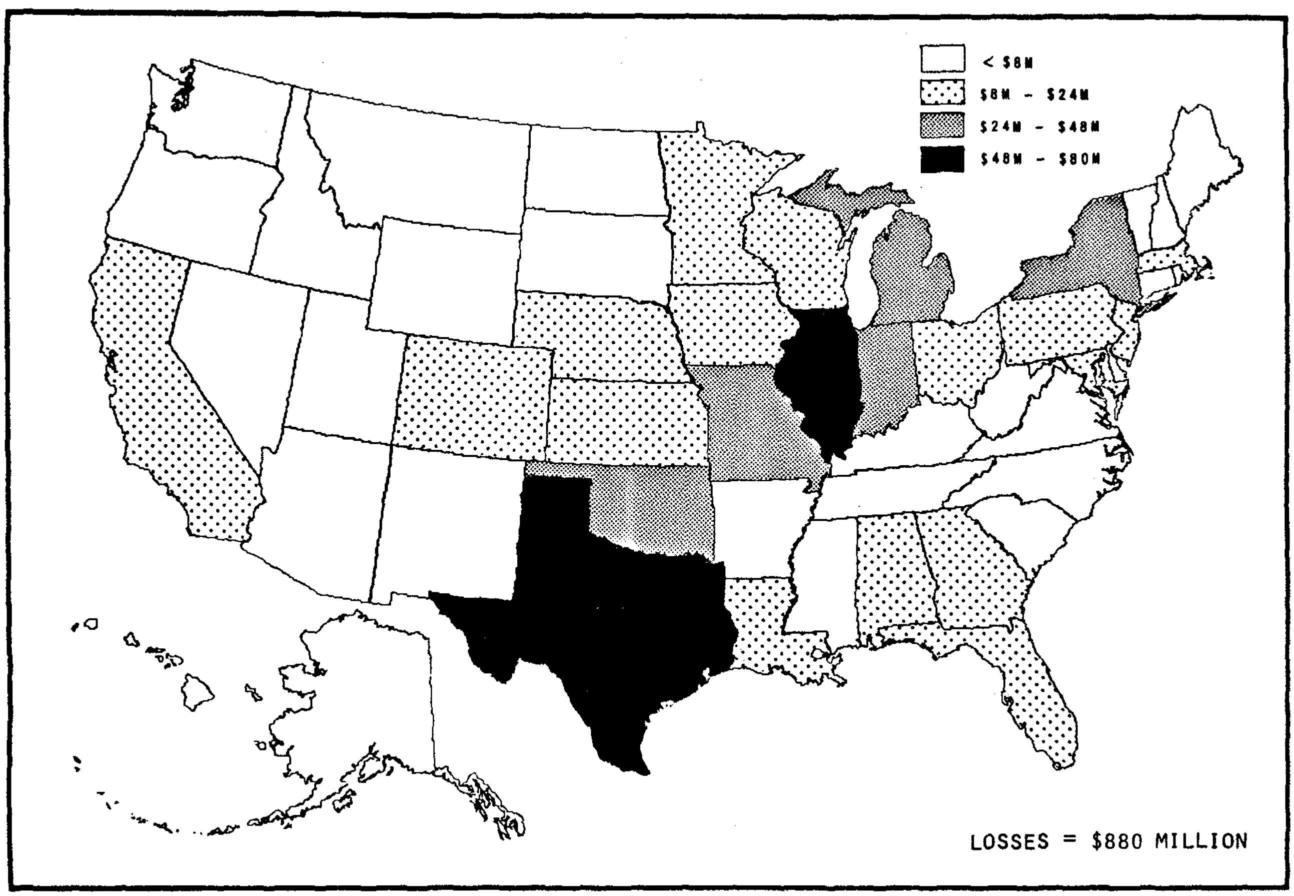
ANNUAL LOSSES FROM LANDSLIDE BY STATE FOR 1970 CONDITIONS



ANNUAL LOSSES FROM EXPANSIVE SOILS BY STATE FOR 1970 CONDITIONS



ANNUAL LOSSES FROM HURRICANE BY STATE FOR 1970 CONDITIONS



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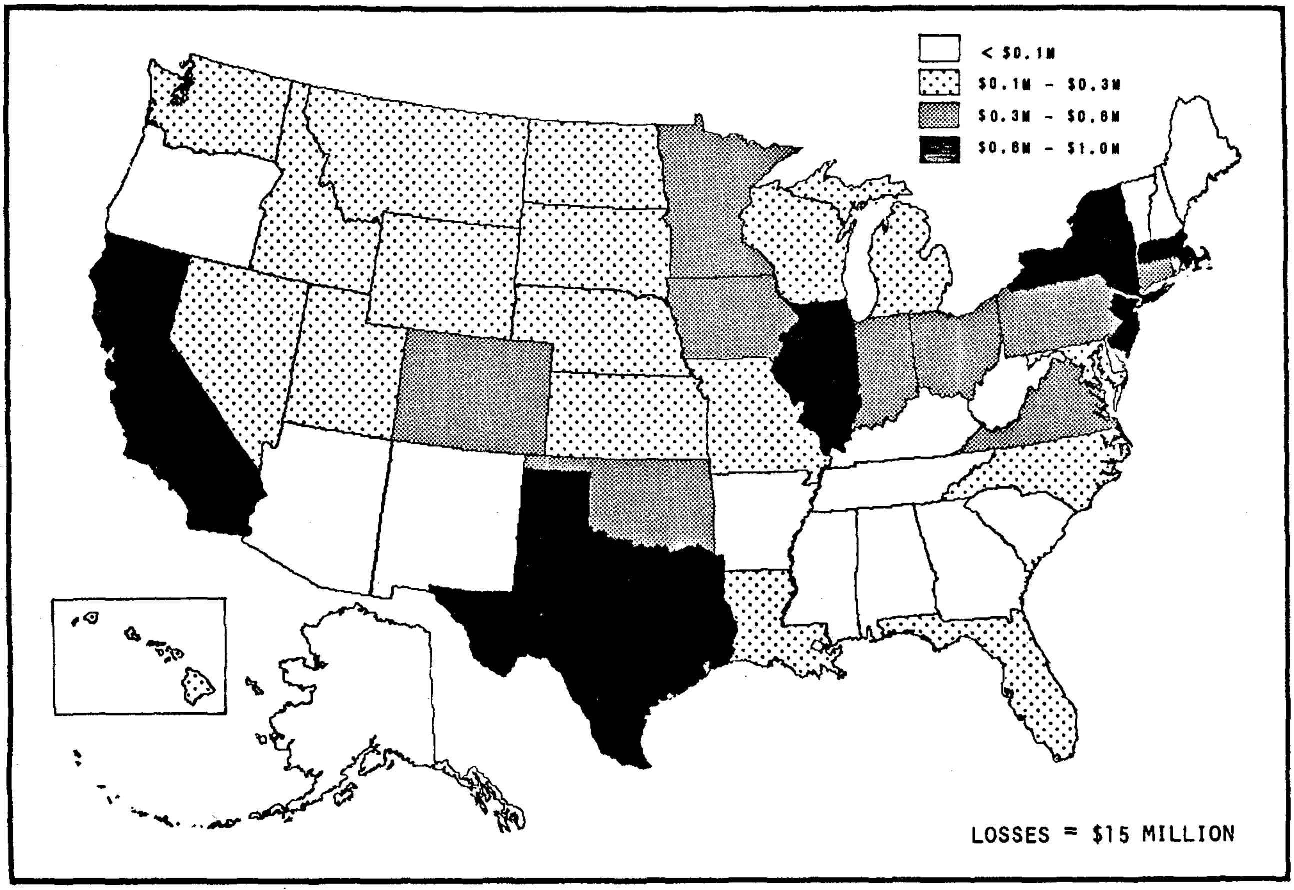

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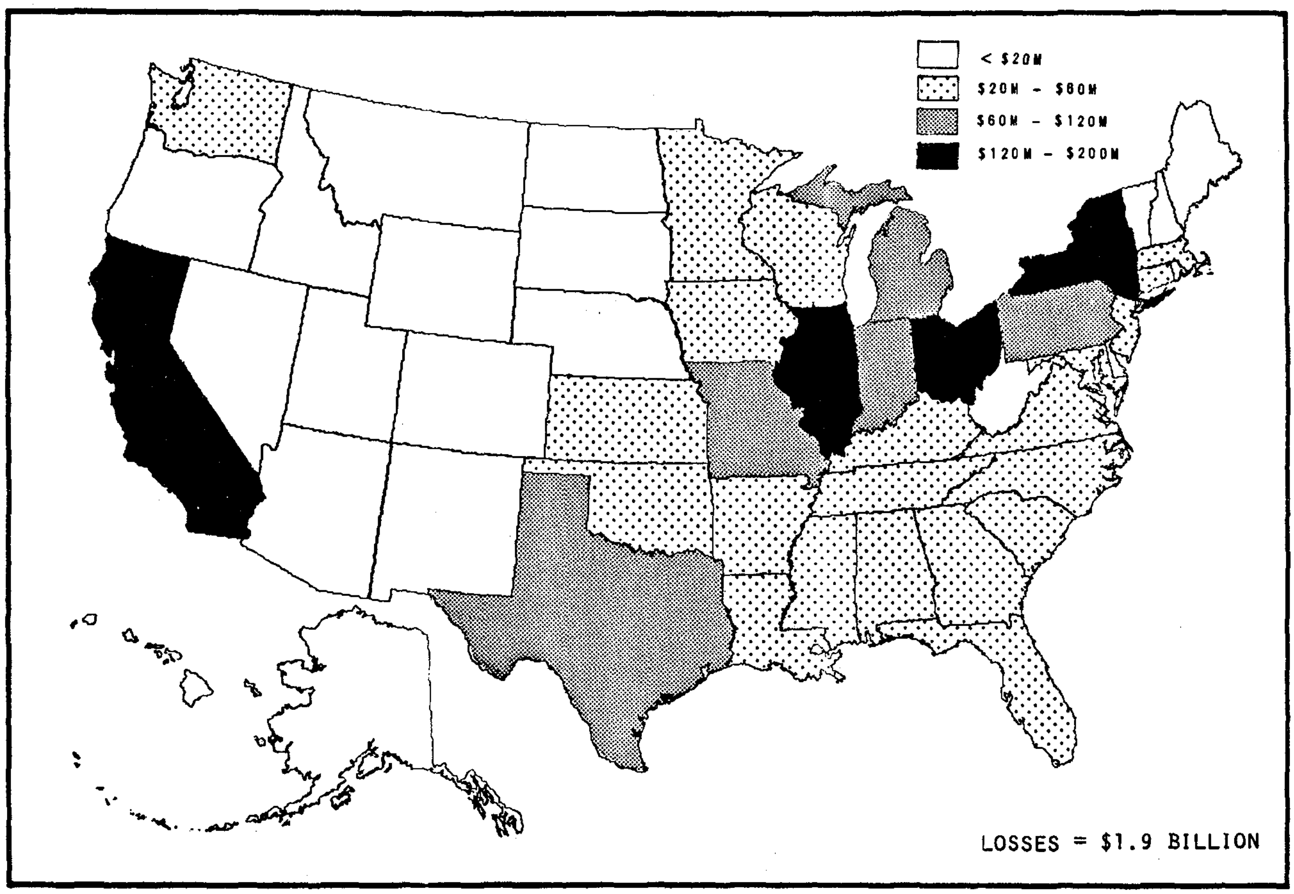
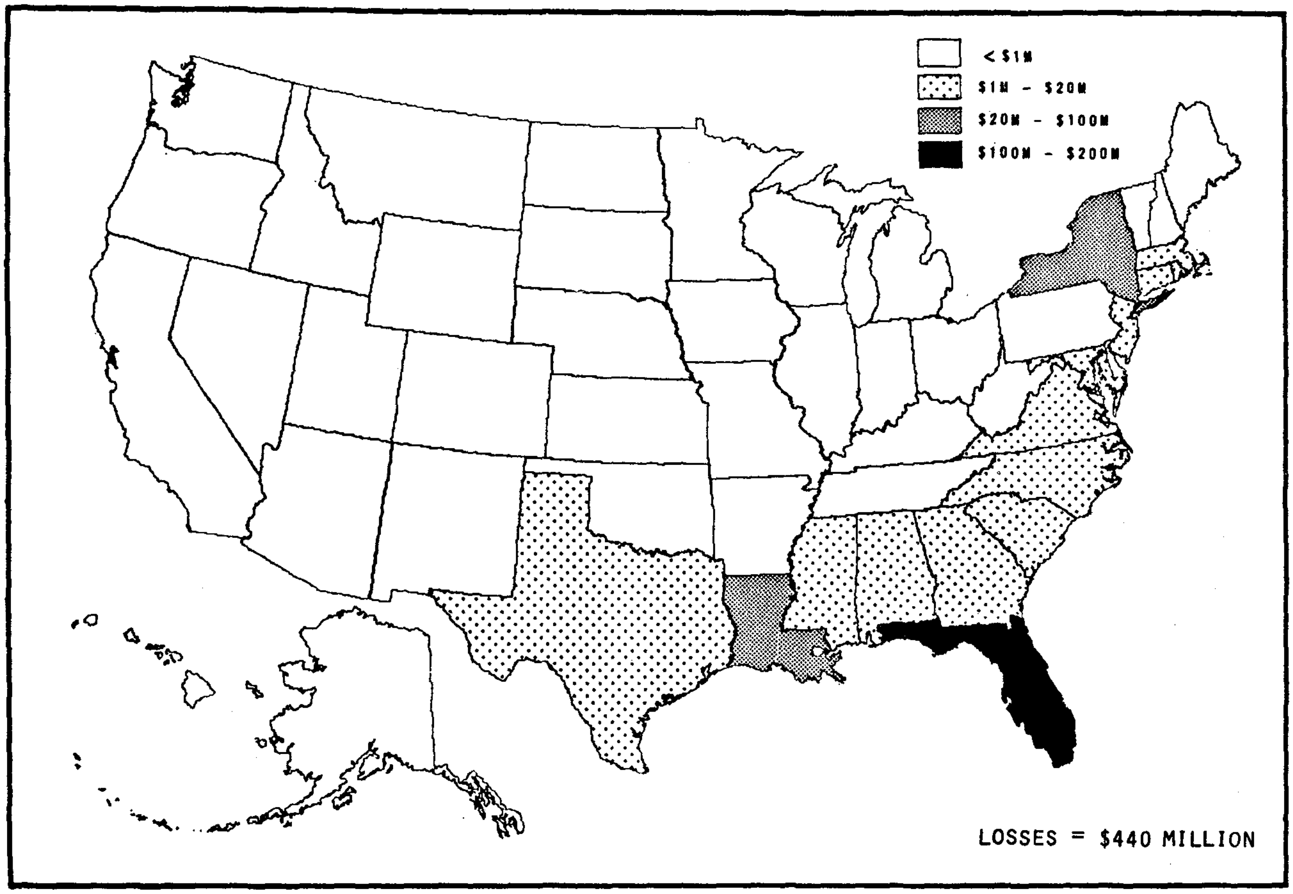
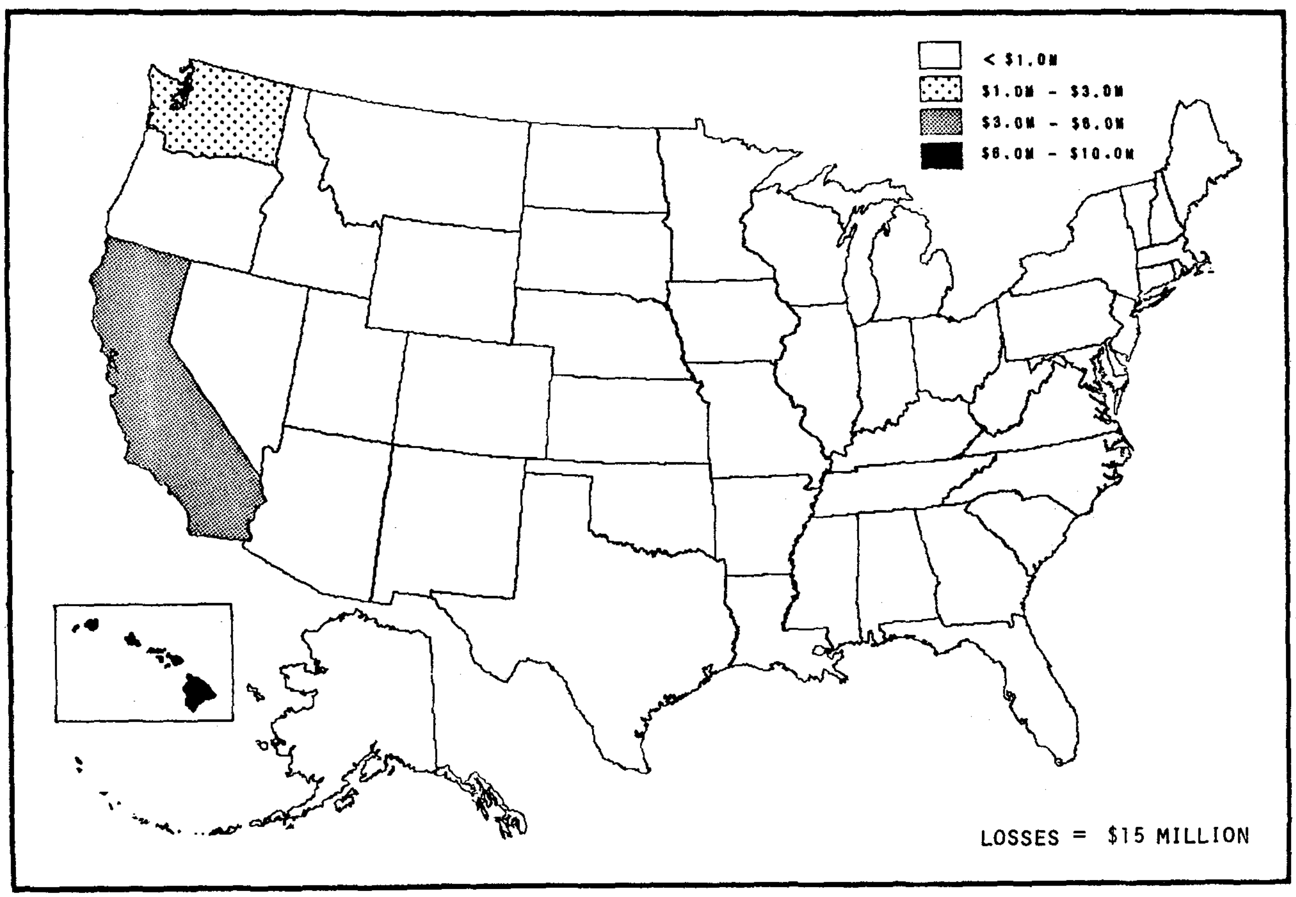


ANNUAL LOSSES FROM RIVERINE FLOOD BY STATE FOR 1970 CONDITIONS



ANNUAL LOSSES FROM STORM SURGE BY STATE FOR 1970 CONDITIONS



ANNUAL LOSSES FROM TSUNAMI BY STATE FOR 1970 CONDITIONS

APPENDIX D

The Mississippi Valley Earthquakes of 1811 and 1812

Otto W. Nuttli, from U.S. Geological Survey Earthquake Information Bulletin, Volume 6, Number 2, (March-April 1974), pp. 8-13

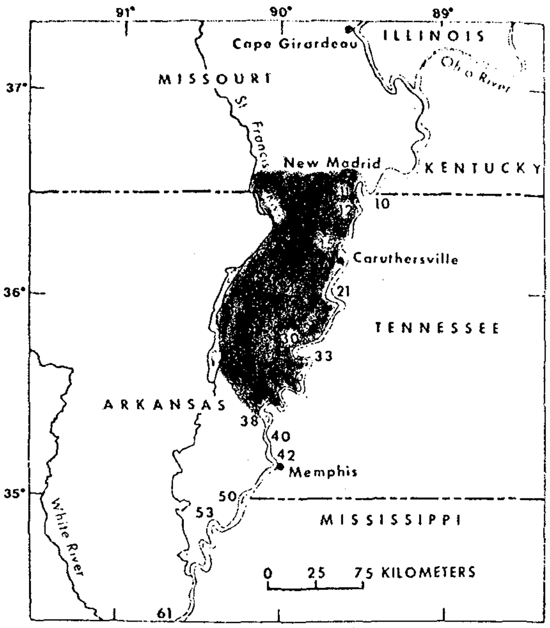
Shortly after 2 o'clock on the morning of December 16, 1811, the Mississippi River valley was convulsed by an earthquake so severe that it awakened people in cities as distant as Pittsburgh, Pennsylvania, and Norfolk, Virginia. This shock inaugurated what must have been the most frightening sequence of earthquakes ever to occur in the United States. Intermittent strong shaking continued through March 1812 and aftershocks strong enough to be felt occurred through the year 1817. The initial earthquake of December 16 was followed by two other principal shocks, one on January 23, 1812, and the other on February 7, 1812. Judging from newspaper accounts of damage to buildings, the February 7 earthquake was the biggest of the three.

In the Mississippi and Ohio River valleys the earthquakes did much more than merely awaken sleepers. The scene was one of devastation in an area which is now the southeast part of Missouri, the northeast part of Arkansas, the southwest part of Kentucky, and the northwest part of Tennessee. Reelfoot Lake, in the northwest corner of Tennessee, stands today as evidence of the might of these great earthquakes. Stumps of trees killed by the sudden submergence of the ground can still be seen in Reelfoot Lake.

Uplift of over 3 meters was reported at one locality several hundred kilometers to the southwest of the epicentral zone where a lake formed by the St. Francis River had its water replaced by sand. Numerous dead fish were found in the former lake bottom. Large fissures, so wide that they could not be crossed on horseback, were formed in the soft alluvial ground. The earthquake made previously rich prairie land unfit for farming because of deep fissures, land subsidence which converted good fields to swamps, and numerous sand blows which covered the ground with sand and mud. The heavy damage inflicted on the land by these earthquakes led Congress to pass in 1815 the first disaster relief act providing the landowners of ravaged ground with an equal amount of land in unaffected regions.

Some of the most dramatic effects of the earthquakes occurred along the rivers. Entire islands disappeared, banks caved into the rivers, and fissures opened and closed in the river beds. Water spouting from these fissures produced large waves in the river. New sections of river channel were formed and old channels were cut off. Many boats were capsized and an unknown number of people were drowned. There are some graphic eyewitness descriptions in contemporary news-papers made by boatmen caught on the Mississippi River near Little Prairie, not far from the present-day town of Caruthersville, Missouri. Navigators reported the greatest damage along the Mississippi River occurred between islands 30 and 40 (see map).

Although the total number of deaths resulting from the earthquakes is unknown, the toll probably was not large because the area was sparsely populated and because the log cabin type construction that was prevalent at that time throughout the epicentral region withstood the shaking very well. Masonry and stone structures did not fare so well, however, and damage to them was reported at distances of 250 kilometers and more. Chimneys were thrown down in Louisville, Kentucky, about 400 kilometers from the epicentral area, and were damaged at distances of over 600 kilometers.

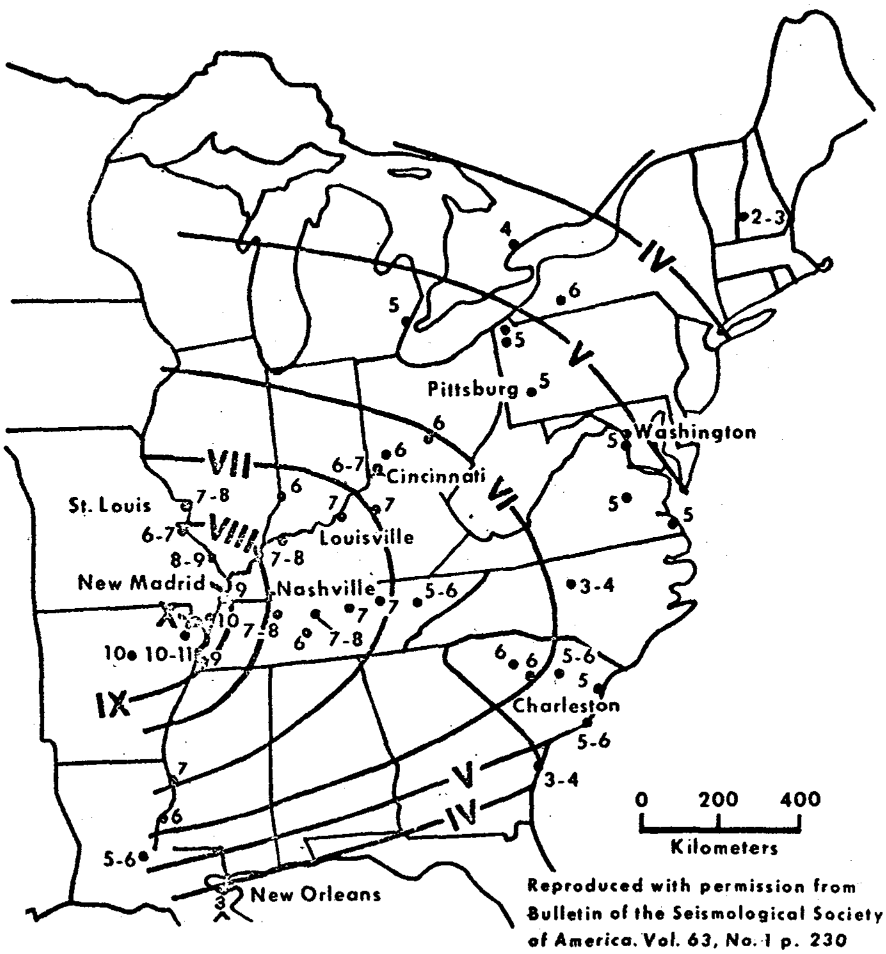


Epicentral region of the 1811 and 1812 Mississippi Valley earthquakes. Dark colored area is region of numerous sand blows. The numbers along the Mississippi River refer to islands as used by contemporary river navigators. The epicenter of the initial December 16, 1811, earthquake was near the southern end of the lake formed by the St. Francis River.

Although it is impossible to know the precise epicentral coordinates of the earthquakes, contemporary accounts of the events suggest that the epicenter of the December 16 shock was close to the southern limit of the area of sand blows. The epicenter of the February 7 shock was closer to the northern limit of the sand blows, near the town of New Madrid, Missouri. There is not sufficient information about the second main shock on January 23 to know its epicenter. Thus the common practice of calling the entire earthquake sequence the "New Madrid earthquakes" is somewhat misleading. From what is known about the present seismicity of the area, it can be inferred that their focal depths were probably between about 5 and 20 kilometers. The fault plane—or planes—on which the Earth rupture occurred are inferred to have had a NNE–SSW strike direction, more or less parallel to the Mississippi River.

The felt areas of the three largest earthquakes were extremely large. They extended south to the gulf coast, southeast to the Atlantic coast, and northeast to Quebec, Canada. The western boundary cannot be established owing to a lack of population. However, it can be estimated that the area of intensity V*or greater effects was approximately 2½ million square kilometers. This can be contrasted with the 1906 San Francisco earthquake, for which the area of intensity V or greater effects was about

* Modified Mercalli Intensity Scale.



Generalized isoseismal map for the earthquake of December 16, 1811. The solid lines delineate the outer limits for each region of intensity specified by Roman numerals.

150,000 square kilometers. The large difference in felt areas between the Mississippi Valley and San Francisco earthquakes, which had approximately the same magnitude and focal depth, can be explained by differences in attenuation of earthquake waves traveling through the Earth's outer crust. The crust in the Western United States tends to "soak up" earthquake energy, whereas in the central and eastern regions of the country the seismic energy experiences a much lower rate of absorption. Quantitative studies of recent earthquakes confirm this explanation.

Invariably the three questions that are asked when one describes the 1811–12 earthquakes are (1) could such earthquakes occur again, (2) if so, when will they happen, and (3) what would be the effect of such an earthquake if it were to occur now?

The answer to whether such earthquakes can happen again is yes. Field studies by M. L. Fuller of the U.S. Geological Survey published in 1912, provided topographic and geological evidence of large magnitude earthquakes predating the 1811–12 sequence. This evidence included ground cracks as large as any caused by the 1811–12 earthquakes in which trees fully 200 years old grew from the bottoms and slopes. Indications of more recent faults and of sandstone dikes filling old earthquake cracks were also found by Fuller. Furthermore, studies of the seismicity since 1812 show that the region is behaving in a manner more or less typical of active seismic zones.

The second question—when will another great earthquake happen—is much more difficult to answer. Extrapolation of magnitude and intensity recurrence curves is presently the only method of prediction available, but this is full of difficulties because the earthquake record covers far too brief a period of time and because earthquakes do not follow an exact cyclical pattern. Although extrapolations of recurrence curves for the region indicate return periods—depending on the investigator—of anywhere between about 400 to 1,000 years for an earthquake the size of the December 16, 1811 event, there is a possibility that such an earthquake might occur as soon as next year or as late as several thousand years hence.

It is easier to speculate on the effects that an earthquake the size of the 1811–12 series would have if it were to occur today than it is to predict when it will happen. In the epicentral area, a repeat of the kind of surficial damage experienced in 1811–12 can be expected. However, this would result in a much greater loss of life and property today because of the much larger number of people and man-made structures in the region than were there 162 years ago. Even more awesome is the size of the area that would be affected. The dispersion of the surface waves, combined with their low attenuation, would result in a large amplitude, long duration sinusoidal type of motion with periods in the same range as the natural periods of tall buildings. Although damage to buildings located outside of the immediate earthquake zone would be mostly nonstructural in character, the monetary amount could be expected to be very large. The emotional and psychological effects of a large earthquake in the central part of the country would probably also be considerable, particularly if the earthquake had a long aftershock pattern as the 1811-12 sequence did.

Perhaps the greatest danger of all arises from the sense of complacency, or perhaps total ignorance, about the potential threat of a large earthquake. The frequency of occurrence of earthquakes the size of those that took place in 1811-12 is very low; however, continuing minor to moderate seismic activity in the central Mississippi Valley area is an indication that a large magnitude tremor can someday be expected there again.