UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A REVIEW OF EARTHQUAKE RESEARCH APPLICATIONS IN THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM: 1977-1987

PROCEEDINGS OF CONFERENCE XLI

SAN DIEGO, CALIFORNIA - JUNE 23-25, 1987
DENVER, COLORADO - SEPTEMBER 9-11, 1987
KNOXVILLE, TENNESSEE - OCTOBER 20-22, 1987

SPONSORED BY
THE U.S. GEOLOGICAL SURVEY, THE NATIONAL SCIENCE FOUNDATION,
THE FEDERAL EMERGENCY MANAGEMENT AGENCY, AND
THE NATIONAL BUREAU OF STANDARDS

March 3, 1849

OPEN-FILE REPORT 88-13-A

Reston, Virginia
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1988

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FOREWORD

When the National Earthquake Hazards Reduction Program (NEHRP) began in October 1977, two broad national goals were emphasized: 1) increasing fundamental knowledge on all aspects of earthquakes and their effects, and 2) applications of the earthquake-hazards-knowledge base to reduce the risk from future earthquakes. Primary responsibility for achieving these two goals is assigned to the Federal Emergency Management Agency (FEMA), the lead agency, the National Bureau of Standards (NBS), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS).

In 1987, the tenth year of the NEHRP, the four principal Federal agencies convened three regional workshops to bring together from all over the United States some of the "Champions" of research applications." One-hundred Champions--individuals who succeed in finding ways to use the earthquake-hazards-knowledge base to enact and implement loss-reduction measures in their communities--met for the first time ever under the auspices of the NEHRP and discussed their experiences during the past 10 years, identifying what had happened and why. These experiences are summarized in this volume as a permanent record for the four agencies (and others) to use in planning future programs and in the adoption and implementation of seismic safety policies.

This volume is dedicated to all "Champions" of research applications. Three recently deceased Champions are singled out for the many outstanding contributions they made in long productive careers. They are Professor Otto W. Nuttli, St. Louis University; E. Erie Jones, Executive Director, Central U.S. Earthquake Consortium; and Robert B. Rigney, until his retirement, the Administrative Officer, San Bernardino County, California. These individuals left a permanent legacy of ideas, accomplishments, and colleagues who have a strong committment to research applications.

We believe that many more Champions will emerge in the second decade of NEHRP.

Gary Johnson
Federal Emergency Management Agency

William Anderson
National Science Foundation

Richard Wright
National Bureau of Standards

Walter Hays
U.S. Geological Survey

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A REVIEW OF EARTHQUAKE RESEARCH APPLICATIONS IN THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM: 1977 - 1987

by

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and
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U.S. Geological Survey
Reston, Virginia 22092
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Menlo Park, California 94025

INTRODUCTION

This report is the first of two reports documenting the results of three regional workshops involving 100 participants from throughout the Nation convened in June, September, and October 1987, under the auspices of the National Earthquake Hazards Reduction Program (NEHRP). The purpose of the workshop was to review some of the principal research applications that have been made throughout the Nation since 1977--the year that the National Earthquake Hazards Reduction Act (hereafter referred to as the Act) was enacted into law. The Act called for an integrated research and research-applications program, where the individual components are described as follows:

1. Research

   - Basic causes of earthquakes
   - Control and modification
   - Earthquake prediction
   - Reservoir-induced earthquakes
   - Earthquake effects (hazards)
   - Preparation of risk assessments and land-use guidelines
   - Methods of designing and building man-made works to resist earthquakes
   - Social and economic adjustments that would lessen the harm done by earthquakes, and
   - Domestic and foreign experience with earthquakes

2. Applications

   - Enlightenment uses (public information and education on all aspects of earthquakes and their effects)
   - Decisionmaking uses (information about seismic hazards and risk that State and local governments can apply in building codes, land-use guidelines, and financial incentives)
   - Practice uses (information about seismic hazards and risk that can be applied to improve earthquake-resistant design, construction practices, and preparedness planning)

The three workshops were organized by the U.S. Geological Survey (USGS). All four principal agencies of the National Earthquake Hazards Reduction Program, the National Science Foundation (NSF), the Federal Emergency Management Agency

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(FEMA), the National Bureau of Standards (NBS), and the USGS sponsored the workshop. They were designed to bring together people from various parts of the United States who had provided leadership and attained explicit knowledge on the research applications process.

WORKSHOP PARTICIPANTS

San Diego Workshop - The first workshop was held in San Diego, California, on June 23-25, 1987. The scope was to review earthquake research applications in California. The participants were:

Dr. Mihran S. Agbabian	University of Southern California
Dr. Richard Andrews	Governor's Office of Emergency Services
Mr. Allen Asakura	City of Los Angeles
Mr. Bruce Baird	Safety Science, Inc.
Dr. Robert Brown	U.S. Geological Survey
Ms. Jane Bullock	Federal Emergency Management Agency
Dr. James F. Davis	State Geologist, California
Dr. A. J. Eggenberger	National Science Foundation
Mr. Richard Eisner	Bay Area Regional Earthquake Preparedness Project
Dr. John Filson	U.S. Geological Survey
Mr. Paul Flores	Southern California Earthquake Preparedness Project
Ms. Laurie R. Friedman	Federal Emergency Management Agency
Mr. James Goltz	Southern California Earthquake Preparedness Project
Ms. Paula L. Gori	U.S. Geological Survey
Dr. Walter W. Hays	U.S. Geological Survey
Dr. Paul C. Jennings	California Institute of Technology
Mr. Gary Johnson	Federal Emergency Management Agency
Dr. Boris Karapetian	Polytechnic Institute of Erevan, Armenia
Mr. John Kariotis	Kariotis & Associates
Mr. William J. Kockelman	U.S. Geological Survey
Dr. George Mader	William Spangler & Association, Inc.
Ms. Shirley Mattingly	City of Los Angeles
Mr. Frank McClure	Lawrence Berkeley Laboratory
Dr. Joanne Nigg	Arizona State University
Mr. Robert A. Olson	VSP Associates, Inc.
Dr. Risa Palm	University of Colorado at Boulder
Ms. Barbara Poland	General Telephone and Electricity
Dr. Badaoui M. Rouhban	UNESCO Division of Earth Sciences
Dr. Roger E. Scholl	Counter Quake Corporation
Mr. Stanley Scott	Institute of Governmental Studies
Mr. Roland L. Sharpe	Engineering Decision Analysis Company, Inc.
Dr. Jogeshwar P. Singh	Geospectra Inc.
Mr. Karl V. Steinbrugge	Consultant
Dr. Charles C. Thiel	Telesis Consultants
Dr. Herbert Thier	California Earthquake Education Project
Dr. Kathleen Tierney	University of Southern California
Mr. L. Thomas Tobin	California Seismic Safety Commission
Mr. Kenneth C. Topping	Los Angeles City Planning Department
Dr. John H. Wiggins	Crisis Management Corporation

<u>Denver Workshop</u> - The second workshop was held in Denver, Colorado, on September 9-11, 1987. The scope was to review earthquake research applications in the Western United States (excluding California). The participants were:

Dr. John Aho	CH2M
Dr. William Anderson	National Science Foundation
Mr. Christopher Arnold	Building Systems Development, Inc.
Ms. Genevieve Atwood	Utah Geological and Mineral Survey
Mr. Jerold Barnes	Salt Lake City Planning Commission
Dr. Marvin J. Bartholomew	Montana Bureau of Mines and Geology
Dr. Patricia Bolton	Battelle Seattle Research Center
Mr. Richard Buck	Federal Emergency Management Agency
Ms. Jane Bullock	Federal Emergency Management Agency
Mr. John P. Byrne	Colorado Division of Disaster Emergency Services
Mr. Brian Cowan	Federal Emergency Management Agency
Mr. Hugh Fowler	Washington State Department of Community Development
Ms. Laurie R. Friedman	Federal Emergency Management Agency
Ms. Paula L. Gori	U.S. Geological Survey
Mr. Donald Gransback	Hawaii Office of Civil Defense
Dr. James R. Harris	J.R. Harris & Co.
Dr. Walter Hays	U.S. Geological Survey
Mr. Gary Johnson	Federal Emergency Management Agency
Mr. William J. Kockelman	U.S. Geological Survey
Mr. Ray Lasmanis	Washington State Department of Natural Resources
Ms. Carole Martens	University of Washington
Mr. Clark Meek	Idaho Bureau of Disaster Services
Dr. Dennis Mileti	Colorado State University
Mr. Monte C. Mingus	Federal Emergency Management Agency
Dr. Joanne Nigg	Arizona State University
Mr. Nicholas B. Nikas	Federal Emergency Management
Dr. Linda Noson	University of Washington
Dr. Risa Palm	University of Colorado
Ms. Jane Preuss	Urban Regional Research
Dr. Lawrence Reaveley	Reaveley Engineers Associates, Inc.
Dr. Lidia L. Selkregg	University of Alaska
Mr. Chuck Steele	Federal Emergency Management Agency, Region X
Mr. Jim Tingey	Utah Division of Comprehensive Emergency Management
Mr. Jack Truby	Colorado Division of Disaster Emergency Services
Ms. Susan Tubbesing	University of Colorado
Mr. Mike Webb	Alaska Division of Emergency Services
Mr. Doug Sprinkel	Utah Geological and Mineral Survey

Knoxville Workshop - The third workshop was held in Knoxville, Tennessee, on October 20-22, 1987. The scope was to review earthquake research applications in the Eastern United States (including Puerto Rico and the U.S. Virgin Islands). The participants were:

Mr. Robert L. Acerno	Federal Emergency Management Agency
Dr. William Anderson	National Science Foundation
Professor Joyce Bagwell	Baptist College at Charleston
Dr. James Beavers	Martin Marietta Energy System, Inc.
Mr. Brian Cowan	Federal Emergency Management Agency
Dr. David Elton	Auburn University
Ms. Julia I. Escalona	Federal Emergency Management Agency
Dr. John Filson	Office of Earthquakes, Volcanoes and Engineering
Ms. Pamela Johnston Fischer	Geoscience Services
Mr. Ed Fratto	Earthquake Program Manager for the Commonwealth of Massachusetts
Mr. Jon Furst	Federal Emergency Management Agency
Mr. Donald Geis	American Institute of Architects
Dr. David Gillespie	Washington University
Ms. Paula L. Gori	U.S. Geological Survey
Professor Ajaya K. Gupta	North Carolina State University
Dr. Walter Hays	U.S. Geological Survey
Mr. Richard Holt	Weston Geophysical Corporation
Mr. William J. Kockelman	U.S. Geological Survey
Mr. Robert W. Johnson, Jr.	Tennessee Emergency Management Agency
Mr. Erie Jones	Central United States Earthquake Consortium
Dr. Charles Lindbergh	The Citadel
Ms. Ann G. Metzger	Memphis State University
Dr. Jose Molinelli	University of Puerto Rico
Mr. Craig Neil	Maine Geological Survey
Mr. Russell A. Newman	Tennessee Emergency Management Agency
Dr. Joanne Nigg	Arizona State University
Mr. Douglas Nyman	Nyman Associates
Mr. Norman Olson	South Carolina Geological Survey
Ms. Susan Olson	Kentucky Disaster and Emergency Services
Dr. Miguel Santiago	University of Puerto Rico
Mr. Jim Smith	Federal Emergency Management
Dr. Tsu L. Soong	Department of Civil Engineering
Ms. Susan Tubbesing	University of Colorado
Mr. Paul White	Federal Emergency Management Agency
Ms. Corinne Whitehead	League of Women Voters of Kentucky

WORKSHOP PROCEDURES

The three workshops were unique in that no prior workshops had ever been convened under the auspices of the NEHRP with the objectives of:

1. Determining what happened during the past ten years in a specific category of research applications in a particular part of the Nation.

2. Identifying the principal causative factors controlling the outcome. (Note: the elements of the research-applications process were the issue, not success or failure.)

Lacking a precedent, the following strategies were used to develop the workshop and programs and to provide non-threating forums for exchange of information on the research-applications process in each region. The principal strategies were:

1. The scope of each workshop was arbitrarily limited by the geographical boundaries (that is, California, the west excluding California, and the east including Puerto Rico and the U.S. Virgin Islands). This strategy focused the discussion and kept the number of workshop participants small that is, 35 to 40 people.

2. In order to utilize established leaders in each geographic region, six people in each region were invited to serve on a Regional Program Committee. Their charge was to assist in the formulation of the workshop program for their region. Also, they were asked to assist in the review of the final report that would distill, synthesize, and integrate the findings of the three individual workshops.

The Regional Program Committees were:

California

Mihran Agbabian
Robert Brown
Kathleen Tierney
Richard Andrews
Karl Steinbrugge
Thomas Tobin

West (excluding California)

Genevieve Atwood
James Harris
Dennis Mileti
Pat Byrne
Ray Lasmanis
Norman Olson

East (including Puerto Rico and the U.S. Virgin Islands

James Beavers
Erie Jones
Richard White
Edward Fratto
Miguel Santiago
Risa Palm

3. The same themes were developed in each workshop program. Because the rates of progress are different in each region, this strategy provided a means to compare the research-applications process now underway in each region.

4. One person, Dr. Joanne Nigg of Arizona State University, who has unique knowledge and experience on the research-applications process, was asked to give a key note presentation in all three workshops. This strategy gave all participants equal access to the same source of information and established a common framework of understanding.

   In addition, a report by Robert Yin and Gwendolyn Moore entitled, *The Utilization of Research*, was provided to all workshop participants to supplement the information provided by Dr. Nigg. The research by Yin and Moore was supported by the National Science Foundation.

5. Individuals having specific experience and knowledge were nominated and approved by the Regional Program Committees. These individuals were then invited to prepare a paper in advance of the workshop. The papers were disseminated and discussed at the workshop. Individuals were given 60 days after their regional workshop to finalize their manuscripts for the proceedings.

6. Each person invited to prepare a paper was asked to answer specific questions in their paper and in their oral presentation. These questions were:

   a) What were the planned and actual outcomes of the specific applications.

      - What length of time and level of effort were involved?
      - What were the scope and scale of the applications?
      - Who were the key players? Why?
      - What was the funding history?
      - What were the internal and external motivating events (if any) that stimulated process.

   b) What specific research studies contributed to the knowledge base required for the applications?

      - Who funded them?
      - What drove the applications--the research or the needs?

   c) What specific translation activities helped to facilitate the applications? Who performed them?

   d) What specific dissemination events contributed to the eventual success of the applications?

      - Which of these events were most significant to the eventual successful applications?
      - Which events were not significant?

   e. If the specific process for a given application could start over, what factors, (people, programs, procedures, plans, etc.) would you change.

      - What would you do differently now because of your "perfect" hindsight to ensure success?
      - Why?

   This strategy ensured that all of the important factors would be identified and evaluated.

7. In each workshop, three small discussion groups consisting of 10 to 15 people were formed. This strategy gave everyone an opportunity to share information and insights on the research-applications process.

   Each discussion group had co-moderators (usually members of the Regional Program Committee) and a recorder. The recorders were provided with the checklist shown in Table 1 to facilitate identification of the principal causative factors controlling the outcome of a particular research application.

Table 1

Parameters

- Perceived need
- Internal advocates (advisors)
- External champions
- Research products and findings well accepted by research community (i.e., credibility of researcher to peers)
- Interaction between researchers and users
- User-friendly products
- Information transfer mechanisms
- Adequate dissemination of research results
- Adequate funds for application
- Incentives for applications
- Lack of disincentives for application
- Windows of opportunity
- Perceived or actual legal liability

WORKSHOP PROGRAMS

The programs of all three regional workshop were organized in the same way in order to provide a common framework for comparing the same types of research applications in various parts of the Nation. The sessions, objectives, and speakers integrated for all three workshops are described below.

SESSION I: THE PROCESS LINKING RESEARCH AND RESEARCH APPLICATIONS IN THE NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM

Objective: To establish a basic framework of understanding of the four elements of the research-applications process (i.e., the dynamic process that links producers and users of information and leads to its utilization) and to give an overview of the current understanding of why some applications have experienced problems and lagged behind the increase in knowledge base.

Review of the current knowledge base on the overall research-applications process.

-- Joanne Nigg, Arizona State University

SESSION II: EVALUATION OF APPLICATIONS FOR ENLIGHTENMENT USES

Objective: To start with specific applications and to look introspectively at the research-applications process to determine what happened, why it happened, how long it took, and the problems that were or were not overcome.

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APPLICATIONS: PUBLIC INFORMATION, AWARENESS, EDUCATIONAL, AND TECHNOLOGY TRANSFER PROGRAMS

Southern California Earthquake Preparedness Project
-- Paul Flores, Southern California Earthquake Preparedness Project

Bay Area Regional Earthquake Preparedness Project
-- Rich Eisner, Bay Area Regional Earthquake Preparedness Project

California Earthquake Education Project
-- Herbert Thier, California Earthquake Education Project, University of California

Perspectives on Public Information and Awareness Programs in the Puget Sound, Washington Area
-- Carol Martens, Seattle Earthquake and Education Project, University of Washington

Perspectives on the State-Federal Partnership to Conduct a 5-year Program on Regional Assessment of Earthquake Hazards in the Wasatch Front Area, Utah
-- Doug Sprinkel, Utah Geological and Mineral Survey
-- Jim Tingey, Utah Division of Comprehensive Emergency Management

Earthquake Education Center, Charleston, South Carolina area
-- Joyce Bagwell, Baptist College at Charleston, South Carolina

Technology Transfer Development Council, Southeastern United States
-- Charles Lindbergh, The Citadel

A Regional Earthquake Information Center
-- Ann Metzger, Center for Earthquake Research and Information

Perspectives on Developing the Materials and Knowledge Base for Design Professionals and Fostering their Applications
-- Don Geis, America Institute of Architects

APPLICATIONS: LEARNING FROM PAST EARTHQUAKES

Objective: To discern the impacts, if any, that important earthquakes have had on:

1. Public awareness and concern,
2. Educational programs,
3. Policies of State, local, and Federal government with respect to siting and regulation of construction and land use.
4. Federal, State, and local earthquake preparedness, and
5. Legislation with a goal of saving lives and reducing potential losses from earthquake hazards.

Sixteen Years After the 1971 San Fernando Earthquake
-- Paul Jennings, California Institute of Technology

Eight Years After the 1979 Imperial Valley Earthquake
-- J. P. Singh, Geospectra Inc., Associates

Four Years After the 1983 Coalinga Earthquake
-- Kathleen Tierney, University of Southern California

Perspectives 28 Years After the August 18, 1959, Hebgen Lake, Montana Earthquake
-- Mervin J. Bartholomew, Montana Bureau of Mines and Geology

Perspectives 23 Years After the March 27, 1964, Prince William Sound, Alaska Earthquake
-- John Aho, CH2M Hill

Perspectives 22 Years After the April 29, 1965, Puget Sound, Washington Earthquake
-- Linda Noson, University of Washington

Perspectives 222 Years After the November 18, 1755, Cape Ann, Massachusetts Earthquake
-- Richard Holt, Weston Geophysical Corporation
-- Ed Fratto, Massachusetts Civil Defense Agency and Office of Emergency Services

Perspectives 175 Years After the 1811-1812 New Madrid Earthquakes
-- James Beavers, Martin Marietta Energy Systems, Inc.
-- Erie Jones, Central United States Earthquake Consortium
-- Corinne Whitehead, League of Women Voters of Kentucky

Perspectives 101 Years After the August 31, 1886, Charleston, South Carolina Earthquake
-- Joyce Bagwell, Baptist College at Charleston
-- Norman Olson, South Carolina Geological Survey
-- Charles Lindbergh, The Citadel
-- Paula, Gori, U.S. Geological Survey

Perspectives 69 years after the October 11, 1918, Mayaguez, Puerto Rico Earthquake
-- Miguel Santiago, University of Puerto Rico at Mayaguez

APPLICATIONS: STIMULUS FOR ACTION

Perspectives and discussion of the factors that stimulate action
-- Charles Thiel, Telesis Consultants

SESSION III: EVALUATION OF APPLICATIONS FOR DECISIONMAKING USES

Wasatch Front, Utah
-- Genevieve Atwood, Utah Geological and Mineral Survey
-- Jerold Barnes, Salt Lake City Planning Commission
-- Larry Reaveley, Reaveley Engineers and Associates

Massachusetts
-- Ed Fratto, Massachusetts Civil Defense Agency and Office of Emergency Services

Charleston, South Carolina
-- Dave Elton, Auburn University

San Juan, Puerto Rico
-- Jose Molinelli, University of Puerto Rico at Rio Piedras

Virgin Islands
-- Pamela Johnston-Fischer, Formerly Coordinator of Virgin Islands Disaster Programs

Six Cities in the Central United States
-- Brian Cowan, Federal Emergency Management Agency
-- Corinne Whitehead, Federal Emergency Management Agency

SESSION IV: EVALUATION OF APPLICATIONS FOR PRACTICE USES

To identify the changes in practice that have occurred in the past decade in the United States and discern the likely trends of change for the next decade.

APPLICATIONS: REGULATION OF LAND USE

Utilization of Seismic Microzonation Principles
-- Charles Thiel, Telesis Consultants

Land-Use Plans Generated by Seismic Safety Elements
-- George Mader, William Spangle & Associates

Implementation of Land-Use Practices For Earthquake Hazard Mitigation in Provo, Utah and Bellingham, Washington
-- Patricia Bolton, Battelle Human Affairs Resource Center

Utilization of Ground-Shaking and Ground-Failure Hazard Maps in Utah
-- Larry Reaveley, Reaveley Engineers and Associates
-- Jerold Barnes, Salt Lake City Planning Commission

Utilization of Tsunami Hazards Maps in Alaska
-- Jane Preuss, Urban Regional Research

APPLICATIONS: THE BUILDING CODE PROCESS

The Process of Introducing New or Improved Seismic Design Provisions in the Western United States
-- Chris Arnold, Building Systems Development, Inc.

Utilization of Seismic Risk Maps (zone maps) and the Building Code Process: 1) Utah, 2), Washington, 3) Alaska, 4) Nevada, 5) Montana, 6) other Western States
-- Jim Harris, J. R. Harris & Co.

Perspectives on Seismic Risk Maps (Zoning maps) and The Building Code Process in the Eastern United States
-- James Beavers, Martin Marietta Energy Systems, Inc.

The Process of Designing, Low-rise Buildings
-- Ajaya Gupta, North Carolina State University

APPLICATIONS: DESIGN OF LIFELINE SYSTEMS

Perspectives on Improving Earthquake Resistant Design of Lifeline Systems
-- Douglas Nyman, Nyman Associates

Hazardous Building Ordinance in Los Angeles
-- John Kariotis, Kariotis and Associates

Guidelines for Evaluating the Needs for Strengthening and Repair of Existing Buildings in the University of California System
-- Frank McClure, Lawrence Berkeley Laboratory

APPLICATIONS: RETROFIT OF EXISTING BUILDINGS AND DESIGN OF NEW BUILDINGS

Experiences with Strengthening and Repair of Existing Buildings and Considerations for Damage and Loss control

1. Los Angeles Area
   -- Al Asakura, City of Los Angeles Department of Building & Safety

2. Northern California
   -- Roland Sharpe, Engineering Decision Analysis Co., Inc.

3. Long Beach, California
   -- John Wiggins, J. H. Wiggins Company

The Process of Dealing with Existing Hazardous Buildings In Utah: Stengthening, Retrofit, and Base Isolation Options
-- Larry Reaveley, Reaveley Engineers and Associates

The Process of Existing Hazardous Buildings in the Eastern United States: Strengthening Retrofit, and Base Isolation Options
-- Tsu L. Soong, State University of New York at Buffalo
-- Richard White, Cornell University

A Base Isolation System in the New San Bernardino County Services Building --
-- Ken Topping, City of Los Angeles Planning Department

Private Sector
-- Barbara Poland, Business and Industry Council for Emergency Planning and Preparedness
-- Roger Scholl, URS Engineers

APPLICATIONS: THE LEGISLATIVE PROCESS FOR ACHIEVING EARTHQUAKE HAZARD REDUCTION

Utah
-- Genevieve Atwood, Utah Geological and Mineral Survey
-- Lorayne Tempest-Frank, Utah Division of Comprehensive Emergency Management

Washington
-- Ray Lasmanis, Washington Department of Natural Resources
-- Hugh Fowler, Washington Department of Community Development

Hawaii
-- Don Gransback, Hawaii Civil Defense

Alaska
-- Lidia Selkregg, University of Alaska

California
-- L. Thomas Tobin, California Seismic Safety Commission

APPLICATIONS: MITIGATION, RESPONSE, AND RECOVERY PLANNING

Response and Recovery Planning with Consideration of the Scenario Earthquakes Developed by California Division of Mines and Geology
-- Shirley Mattingly, City of Los Angeles
-- Richard Andrews, California Office of Emergency Services

The Southern California Earthquake Forecast and the Parkfield, California Earthquake Prediction
-- Jim Goltz, Southern California Earthquake Preparedness Project

Response and Recovery Planning in St. Louis
-- David Gillespie, Washington University

Response Planning in Tennessee
-- Russell Newman, Tennessee Emergency Management Agency

The papers prepared for the three regional workshops follow in the next section of this report. Interpretation of the papers and recommendations of workshop participants will be contined in a separate publication.

ACKNOWLEDGMENTS

A special note of gratitude is extended to Joanne Nigg and Susan Tubbesing who served as facilitators, respectively, for the Denver and Knoxville meetings. The contributions of Mihran Agbabian, Richard Andrews, Robert Brown, Karl Steinbrugge, Kathleen Tierney, Thomas Tobin, Genevieve Atwood, Pat Byrne, James Harris, Ray Lasmanis, Dennis Mileti, Norman Olson, James Beavers, Edward Fratto, Erie Jones, Miguel Santiago, Richard White, and Risa Palm are gratefully acknowledged. The National Science Foundation and the Federal Emergency Management Agency provided funding for the three workshops.

Carla Kitzmiller and Shirley Carrico, USGS, provided administrative support.

REFERENCE

Yin, Robert and Moore, Gwendolyn, B., The Utilization of Research: Lessons from the Natural Hazards Field, COSMOS Corporation, January 1985.

FRAMEWORKS FOR UNDERSTANDING KNOWLEDGE DISSEMINATION AND UTILIZATION: APPLICATIONS FOR THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

Joanne M. Nigg
Arizona State University
Tempe, Arizona

The question of how to successfully apply research findings to reduce earthquake hazards is indeed a complex problem. There are several issues that must be considered when answering this question: Which research results are to be applied? When there are competing or conflicting research findings, as there almost assuredly will be, who will determine which are valid? Who, if anyone, will be responsible for prioritizing the problems which these findings address? By whom are they to be applied? To what purposes are they to be addressed--for enlightenment, practice, or decision making uses? What characteristics are associated with these different types of utilization? Is utilization always the same, or does it change? To what extent is utilization situation-specific and to what extent is it generalizable? Who will benefit and who will be disadvantaged, or should these questions of vested interest be of concern when the "public interest" is being served by the application of research results? To what extent can knowledge actually affect either practice or policy? Do we, in fact, have an adequate amount of information to answer these questions about research utilization?

Before we can begin to address these questions, it is important to start with a set of common definitions of what is meant by "utilization." Larsen (1980) reminds us that without a standard terminology (which has been lacking in the field of

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knowledge utilization research), the comparison of research findings is almost impossible. For example, research in this area has frequently used the terms "research application," "technology transfer," "innovation diffusion," and "information dissemination" (or any mixture of these terms) interchangeably. _What_ was being transmitted, however, and _how_ it was being transmitted were often quite different, which yielded different conclusions about the factors and processes that affected the successful adoption or utilization of knowledge.

DEFINITIONS AND COMPONENTS OF UTILIZATION

For this reason, the following definitions (abstracted from Glaser _et al._, 1983) are being offered to provide some structure for the remainder of this paper:

> _Knowledge_--an idea, product, process, procedure, or program of action.
>
> _Dissemination_--the transmission of knowledge toward potential users.
>
> _Utilization_--the application of available knowledge by a new user.

Whenever these terms are used, however, it will be important to specify what form of knowledge is being discussed, how that knowledge is being transmitted, to whom it is being transmitted, by whom it is being transmitted, and what form the application is expected to take. To better understand the need for this specificity, let us look at each of these components of utilization as they are related to the issue of earthquake hazard reduction.

Description of the Knowledge Being Transmitted

The "form" that knowledge takes will depend upon the use it is expected to have. Research results, as reported in final reports or technical papers, are usually not appropriate for direct application by some user group. This basic knowledge must be transformed in some way to make it more usable by an intended user group. For example, Davis and Salasin (1979), in their discussion of factors which are necessary and sufficient to account for utilization within an organization, highlight the importance of communicating about the proposed innovation (here referring to a new technique) in a clear manner that provides evidence for the workability of the proposed change (in language and concepts understandable to those making the adoption decision) as well as how it can be implemented.

Glaser and his colleagues (1983) discuss several factors related to the "innovative element" (that is, the form into which the knowledge is "packaged") that have been found to affect the willingness to adopt by a user group.

Perceived Advantage. Adoption of an innovation or idea (i.e., knowledge) by a user group is more likely if some advantage--either personal or organizational--is perceived to accompany it. For example, decision makers may be more likely to adopt an innovation if they believe it could assist them to resolve a persistent problem.

The adoption of an innovation may also have unanticipated consequences (referred to by Rogers and Shoemaker [1971] as "latent consequences") that could become defined by those affected as disadvantages. For example, the adoption of a new technique or procedure may be perceived by practicing professionals as disadvantageous if their prestige or status within the organization is changed because of the proposed adoption, thereby resulting in their resistance toward the innovation.

Another factor related to innovation resistance is the professional's perceived devaluation of current knowledge or skills. If, for example, new seismic design criteria are recommended for inclusion in a community's building code, some members of the engineering profession practicing in that community may oppose the adoption of such criteria because their experience with seismic design has been minimal, thus potentially limiting their ability to compete for some projects. This possibility could result in not just economic disadvantage but professional embarrassment that one's engineering skills and knowledge are somewhat deficient.

Kotter and Schlesinger (1979) have suggested four pertinent approaches to overcoming this resistance, each of which is related to the type of resistance encountered:

1. Education + communication--when resistance is due to the diffusion of misinformation within the user group.
2. Participation + involvement--when those other than the adopter have the power to resist.
3. Facilitation + support--when organizational role responsibilities change or skill enhancement is needed.
4. Negotiation + agreement--when some group with considerable power to resist "loses out" if change takes place.

<u>Compatibility</u>. The greater the compatibility between the new knowledge form and the users' values, norms, procedures, and facilities, the greater their willingness to adopt the innova-

tion. This seems to be especially true when the innovation can be assimilated within the "professional ideology" of the adopter. For example, the usefulness of earthquake loss estimation studies may be widely supported by emergency managers because the results of such research could improve their capability to respond to a destructive seismic event, an activity which fulfills one of their professionally-recognized responsibilities. It should be recognized, however, that such support is often contingent on the <u>setting</u> in which the professional lives and works. The emergency manager in a community in a seismically active area is more likely to see the need for such loss studies than is the manager in a less active area.

<u>Comprehensibility</u>. A change or technique that is easily understood by the potential user is more likely to be adopted. Again, this points to the need to translate basic research findings into forms that can be understood within the cognitive and linguistic frameworks routinely used by the targeted receivers of the information. For this reason, Sundquist (1978) talks about the need for both "academic intermediaries" and "research brokers" who could stand between the researcher and the policy maker (or other user) to translate the disciplinary jargon in which most research results are couched into recommendations, techniques, or information items that would be of more direct applicability by a user group.

<u>Practicality</u>. Recommendations or techniques derived from research findings are more likely to be adopted by users if those users have the resources (funding, facilities, staff, and expertise) available to put those suggestions into effect. Even

if the new knowledge is understood by the potential user and is expected to assist the user in fulfilling his/her professional responsibilities, the suggestion is unlikely to be implemented if the organization or the community lacks sufficient resources to do so. For example, planning professionals in smaller, more rural communities may see the value of microzonation as a non-structural mitigation measure that could reduce direct exposure of people and structures to liquefaction-induced dangers but be unable to utilize such techniques due to a lack of personnel to perform such assessments or the lack of a financial base which would allow the community to hire someone with adequate skills to perform the assessment.

Knowledge Transmitters

One of the most frequently cited reasons for the failure of attempts to utilize research knowledge is the unsatisfactory transmission of that knowledge by knowledge producers (usually identified as academics or scientists). Szanton (1981), in an extensive review of attempts by knowledge producers (in this case academics) to advise local public officials on various policy problems, concluded that overwhelmingly both knowledge producers and utilizers considered the outcome of the advisement attempts to be failures. Unusable advice, he stated, was not good advice. From the perspective of the users, what frequently made advice unusable was overly complicated analysis of data (frequently referred to by academics as "elegant" analysis) and highly technical recommendations that were impractical (seen by the researchers as examples of ingenuity, scholarly innovation, "breakthroughs," and being on the "cutting edge" of their discipline).

To overcome these problems, Szanton identified several guidelines for advisors of local government officials to follow. Three of these are pertinent for this discussion of knowledge transmitters.

1. Identify a client. Although this may seem a simplistic suggestion, the identification of a targeted user who has the capability to utilize the advice (or knowledge) presented may be much more difficult than it appears. As mentioned above, the information being transmitted must fit the perceptions, values, and professional ideologies of the user, who also has to have the ability and resources to adopt and implement the suggestions.

2. Learn from the client. In order to enhance the likelihood of adoption, the knowledge producer must understand the constraints within which the user organization makes decisions. Weiss (1978) stresses the importance of understanding the political climate of a community because of the limitations it can place on the kinds of changes that are feasible, on how quickly adoption of changes can take place, and what the costs (social and political as well as economic) of the suggested change entail. To gain this insight, Szanton points out the necessity of developing a set of "working colleagues" within the targeted user group.

3. Find internal champions. A "champion" is someone who has credibility within the user group and who is willing to promote the adoption of new techniques or practices. Champions, Szanton observes, are more likely to actively promote the innovation or change if they have been involved in or consulted

with during the initial stages of the research development or translation process.

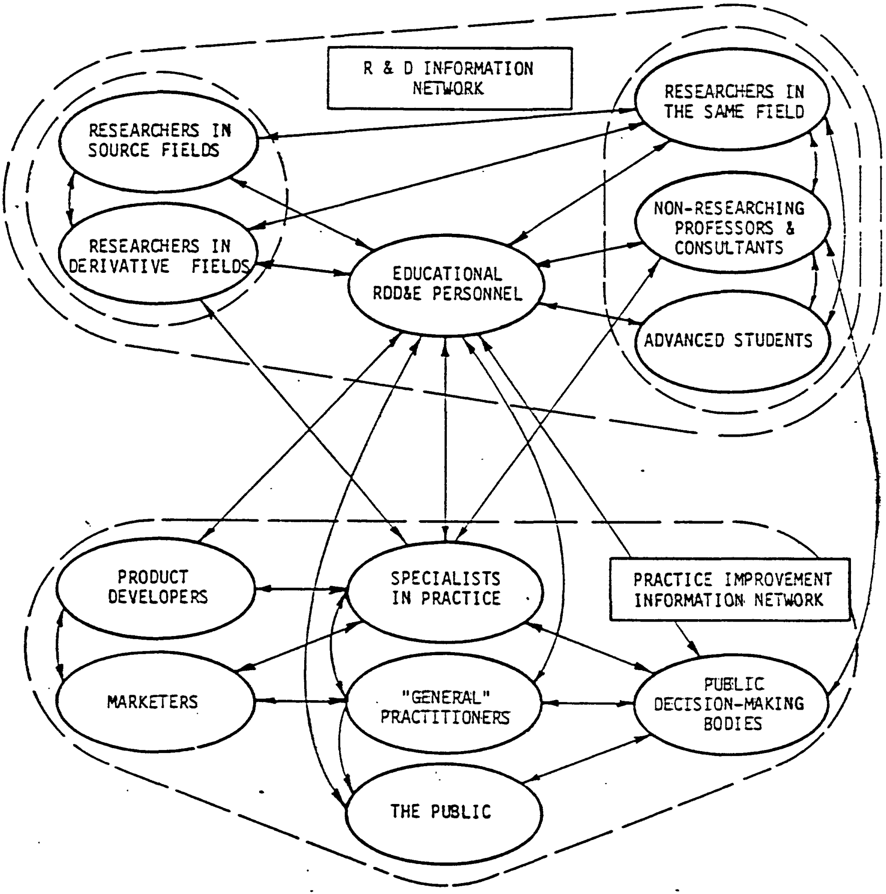
Two characteristics of potential champions may be especially desirable. Much of the innovation diffusion literature points out that successful, well-respected professionals and practitioners are seen as _opinion leaders_ who can become influential in promoting the adoption of new ideas and new products (cf. Rogers, 1962). Also, _role accumulators_--those persons who are active in many non-overlapping social networks--are more likely to adopt innovations earlier and more frequently (Glaser _et al._, 1983).

Knowledge Transmission

Throughout the knowledge utilization literature, direct interpersonal communication between knowledge producers and users is required for utilization to occur. In their studies of knowledge utilization, Yin and his colleagues (Yin and Moore, 1985; Yin and Gwaltney, 1981) have stressed repeatedly the importance of developing a network of _two-way_ communication between the knowledge producer and knowledge user. Upon completing their analysis of the utilization of findings from nine research projects, Yin and Moore (1985:70) state "the most consistent pattern leading to utilization was the prevalence of rich and direct communication between knowledge producers and users throughout the design and conduct of the research project." Figure 1 illustrates the complexity of a mutually influencing network of researchers and potential users during the knowledge creation-dissemination process.

FIGURE 1.

AN ILLUSTRATION OF A MUTUALLY-INFLUENCING NETWORK OF RESEARCH PRODUCERS AND USERS.



SOURCE: YIN AND MOORE, 1985

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Havelock (1969), in discussing the importance of <u>linkages</u> between producers and users, states the greater the overlap (in terms of both the number and variety of types of contacts) between the resource (or knowledge producer) system and the user system, the more effective the diffusion of new ideas and techniques will be. The <u>redundancy</u> of similar messages transmitted through different channels should improve the likelihood of acceptance of the message. Havelock also maintains that the medium of linkage--that is, the channel or channels through which information is disseminated--should be compatible with the experience and style of the receiver to increase the likelihood of positive acceptance.

Glaser and his colleagues (1983) reviewed an impressive body of literature on the influence of informal communication processes and concluded that the likelihood of utilization can be enhanced when messages are transmitted from (1) professional influentials, (2) those with enthusiasm about the benefits of the outcomes of the utilization, and (3) liked or compatible others in one's personal social networks.

To enhance the two-way flow of communication, however, requires special investment and commitment on the part of the research community to incorporate and respond to the concerns of potential users throughout the research process. Szanton (1981: 60-61) discusses the reasons why this collaboration generally does not occur.

> Most faculty members are trained and accustomed to work alone or, at most, in small groups of scholars in their own discipline. But the analysis of a significant policy problem almost always requires several perspectives and a number of disciplines. An academic working alone, or with only

> familiar colleagues, will therefore tend to respond merely to a piece of a problem, and perhaps only a quite small piece. As many have pointed out, moreover, most faculty members are rewarded only as scholars and teachers, especially the former. The approval they seek is that of their peers, and that depends on the quality and number of their scholarly publications; the informal, nondisciplinary, and often verbal communications most useful to a governmental client do not qualify.

Some suggestions have been made to encourage the interaction among researchers and users. Swanson (1966) suggests that these informal, face-to-face interactions can be enhanced by first identifying groups that already engage in information-exchange and then by expanding the selective communication networks within these groups. Yin and Moore (1985) propose four steps that research investigators can take to increase utilization of their results: (1) become active in associations to which both knowledge producers and users belong; (2) when designing a project, identify the specific groups that may use the research results; (3) during the project, be sensitive to ways that the research might be modified to meet emerging user needs or changed problem definitions; and (4) plan to produce at least one product that is aimed directly at a user group.

Besides these interpersonal exchanges during the research process, Glaser and his colleagues (1983) have identified two other situations in which two-way communication can take place to enhance utilization. <u>Conferences</u> provide an opportunity for researchers to present research findings or instances of exemplary practice in depth to potential users. With the possibility to question researchers and clarify practices, practitioners are much more likely to consider using the information presented than they would be if exposed to a one-way flow of information (e.g., a video tape, a movie, or a publication). Site visits allow practitioners to participate in the demonstration of a new procedure or technique to gain some direct experience. Such demonstrations have been found to result in adoption especially when explicit plans have been formulated to provide follow-up services to participating practitioners.

KNOWLEDGE UTILIZATION AS A PROCESS

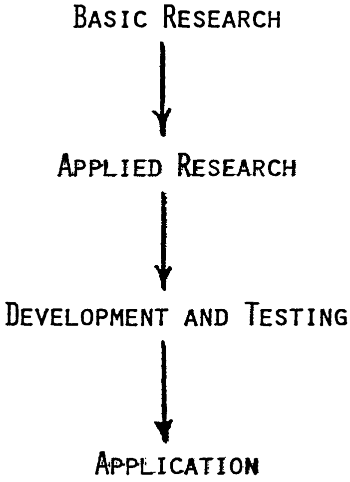
From the preceding discussion, it should be clear that the perspective taken in this paper is that the application of knowledge is not an event or outcome; rather, utilization is being conceptualized as a process. The successful utilization of research knowledge--whether from the physical, social, or engineering sciences--depends on inputs, decisions, influences, and interactions at crucial stages between the conduct of basic or problem-focused research and the application of that knowledge to reduce earthquake threats to the social and built environments.

Weiss (1979) discusses several different models of knowledge utilization, four of which have some relevance for the purpose of this workshop--the knowledge-driven model, the problem-solving model, the interactive model, and the enlightenment model.

The Knowledge-Driven Model

This model, also referred to as the "research, development, and diffusion (RD&D) theory" (cf. Guba, 1968), is the most widely used in the field of utilization (Figure 2). It derives from the natural sciences, and few examples of its applicability for the social sciences can be found. This linear model assumes

FIGURE 2. KNOWLEDGE-DRIVEN MODEL



that if basic knowledge exists, its development and utilization will naturally follow. From this perspective, the ultimate user (who is generally not even identified or considered by the researcher) is assumed to be passive during the research process but will actively adopt the resulting innovation or use the information once it is made available.

Yin and Moore (1985) have identified four conditions of this "technology-push" process.

1. Applied research is conducted because of the prior existence of basic research.
2. The need for the research is defined entirely by the research investigator.
3. The research results are further contributions to knowledge, with the major publications being academic (or scholarly) ones.
4. When utilization occurs, the research often leads to the development of a commercializable product.

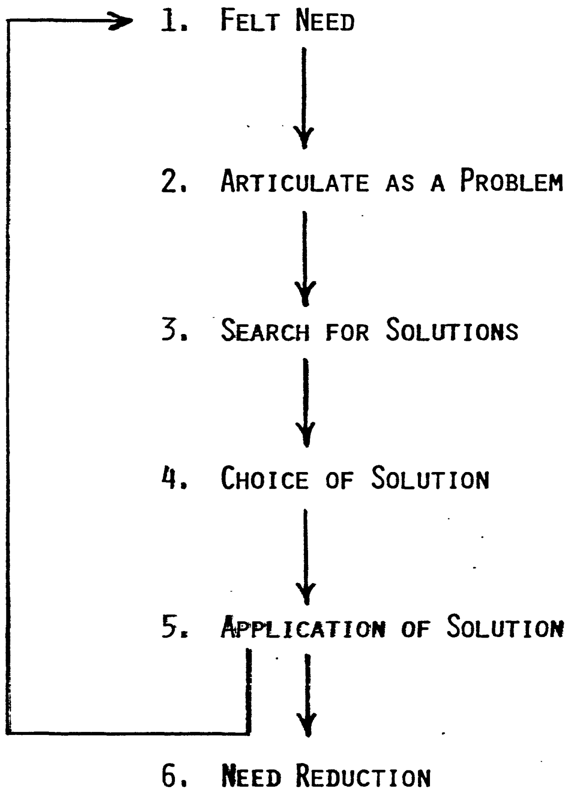
Surely, much of the scholarly research conducted in the areas of seismology, geophysics, geology, and engineering fall within the domain of this model.

The Problem-Solving Model

This model is driven by the need to directly apply the results of a specific study to a user's pending decision. The expectation is that the research will provide empirical evidence and conclusions that will aid in the solution of a policy or technical problem. This linear sequence model (Figure 3) has been characterized by Yin and Moore (1985) as a "demand-pull" model.

In these instances, the user creates the need for the research by proposing the problem that the researcher should be

FIGURE 3. PROBLEM-SOLVER MODEL



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addressing and purposefully commissioning research to fill the knowledge gap. The assumption is that because the user is the primary motivator behind the research activity, implementation would naturally occur once the research findings were made available.

The Interactive Model

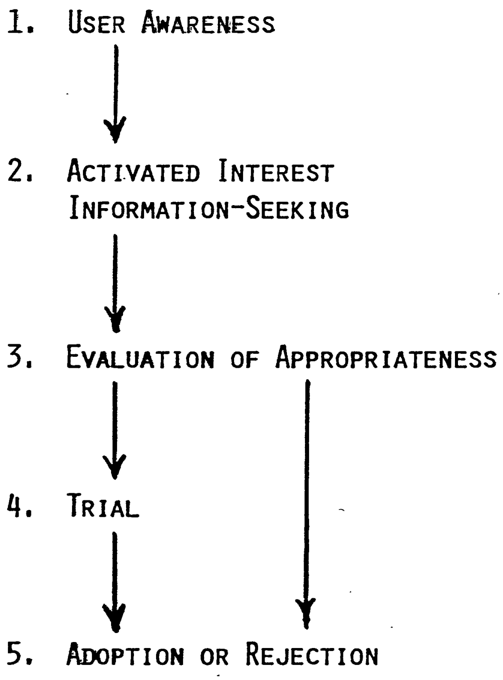
The emphasis of this model is on diffusion--the movement of messages from person to person and system to system. The importance of informal communication within and across networks is at the heart of this model. Unlike the first two models, this process is not one of linear order, moving from research to an adoption decision. Rather, it is a disorderly set of interconnections and two-way flows of communications and influences that defies a neat, sequential diagram. Figure 1 presents a modified version of this model.

Havelock (1969) developed a model (Figure 4) based on Rogers' (1962) diffusion study findings to explain how various information sources influence the decisions and behaviors of individuals embedded in this complex matrix of relationships. Of these communication influences, Havelock writes:

> In terms of phases of adoption, the following generalizations seem to hold: impersonal sources are most important during the "awareness" phase; during the "interest-information seeking" phase the receiver may turn to an expert, to the mass media, or to personal contacts as sources of information. Personal sources, however, assume greater importance at the evaluation, or "mental trial" stage. Following an actual trial, the individual tends to rely on his own judgment regarding the value of the innovation (10-37).

Two of the seven factors which Havelock (1969) identifies as significantly important in the dissemination/utilization process

FIGURE 4. AWARENESS-ACTIVATED MODEL



directly relate to the interactive model and its related communication influences. First, the <u>structure</u> of the relationships is important. The greater the degree of systematic organization and coordination between the resource and user systems, the more likely it is that research knowledge will be utilized. Second, the <u>openness</u> of components of the two systems is also important. If there is a readiness to exchange information between and among members of the research and user systems, utilization becomes more likely. Havelock sees openness as both a prerequisite to the establishment of linkages (discussed above) and a component of a structure that makes utilization more feasible. The concept of openness implies that users are not merely passive receptors of information to which they are exposed (as is their characterization in the knowledge-driven model), but they actively engage in information-seeking and information-exchange activities.

<u>The Enlightenment Model</u>

Enlightenment refers to the unconscious diffusion of general research conclusions that ultimately change the ways the public, decision makers, and practitioners come to define a problem and its alternative solutions. This is the way that most research, especially social science research, enters into the policy arena. Neither information seekers nor decision makers are seen as necessarily active participants in the dissemination/utilization process. Weiss (1979) summarizes the model nicely:

> There is no assumption in this model that decision makers seek out social science research when faced with a policy issue or even that they are receptive to, or aware of, specific research conclusions. The imagery is that of social science generalizations and orientations percolating through informed publics and coming to shape the way in

> which people think about social issues. Social science research diffuses circuitously through manifold channels--professional journals, the mass media, conversations with colleagues--and over time the variables it deals with and the generalizations it offers provide decision makers with ways of making sense out of a complex world (429).

From this perspective, then, research doesn't solve problems. Instead, it provides an intellectual setting of concepts, propositions, orientations, and generalizations that can be used by decision makers, who are likely to be quite distant from the research process and the knowledge producers, to define their problems and evaluate the options for coping with them (Weiss, 1978).

SUMMARY

Throughout the next few days of this workshop, the appropriateness and applicability of these models will be determined by the specification of the utilization components each speaker has chosen. Who is the research producer, and how does that investigator define her/his role with respect to the dissemination or utilization of research findings? Who is the expected user of research knowledge, and what factors will influence whether that user is a passive or active receptor of this new information? What structures or systems exist to enhance knowledge transmission? What are the characteristics of individuals, organizations, systems, and communities which promote or inhibit the transmission and application of information? What is the expected purpose to which the information is to be applied--to change practice, to influence policy making, or to enlighten people's ways of thinking about earthquake threat and how to cope with it?

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INNOVATIVE PLANNING AND KNOWLEDGE TRANSFER: THE HISTORY OF THE SOUTHERN CALIFORNIA EARTHQUAKE PREPAREDNESS PROJECT (SCEPP)

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With passage of Assembly Bill 2202 (Vicencia) in September, 1980, the Seismic Safety Commission was authorized to "initiate with the assistance of other state, federal and local government agencies, a comprehensive program to prepare the state for a major earthquake prediction." While September, 1980, was significant for the SCEPP project witnessing as it did the passage of legislation and the first Policy Advisory Board meeting, the impetus for the program SCEPP was to pursue must be traced back at least five years. Beginning about 1975, a series of events occurred which significantly shaped the form the project would take as well as its mission and program.

An event which generated greatly enhanced awareness of the earthquake threat to southern California was the discovery and subsequent public announcement of the "Palmdale Bulge" in early 1976. This large area of uplifted land centered near the City of Palmdale was considered by scientists to be a potential precursor to a major southern California earthquake. The implications of the Bulge were subjects of intense news coverage and stimulated official concern over the adequacy of preparedness and response procedures at the state and local levels of government.

Shortly after announcement of the Palmdale Bulge, Dr. James Whitcomb, an earth scientist at Caltech announced his prediction that a moderate sized magnitude 5.5 to 6.5 earthquake could occur in the San Fernando Valley area of Los Angeles within a year of April, 1976. Whitcomb's prediction, which was based on data unrelated to the uplift, served to intensify public discussion and official concern. The work of another Caltech scientist, Dr. Kerry Sieh further focused public attention on the earthquake threat to southern California with his discovery that at least eight major earthquakes had occurred along the south-central San Andreas fault in the last 1,200 years. With an average recurrence interval of 145 years and the last of these major earthquakes having occurred in 1857, it was estimated that the yearly probability of the next major earthquake was 2 to 5 percent per year and greater than 50 percent in the next thirty years.

Although the earthquake predicted by Whitcomb had not occurred within the time period predicted and the Palmdale Bulge had lost some of its earlier salience, sufficient national level attention had been drawn to the earthquake threat that it became a significant policy priority with passage of the National Earthquake Hazards Reduction Act of 1977. The Act established several objectives including development of earthquake resistant design methods and procedures; the capability to predict earthquakes and characterize seismic hazards; model codes in cooperation with state and local officials and practicing professionals; and plans to prepare for, respond to and recover from earthquake events. The agency designated to administer the program was the Federal Emergency Management Agency (FEMA). Within FEMA there was an initiative to develop a lead project in the earthquake field in line with the mandate of the 1977 Act.

It was clear to FEMA officials that such a project should be established in California. The events and discoveries of 1976 had identified California as the state with the greatest seismic risk. California also had, to a greater extent than other states, developed policies toward earthquake hazard mitigation and response. With a commitment to "cooperative federalism," FEMA sought a state level ally with which to launch a federal-state earthquake preparedness venture.

FEMA established, as its point of contact in California, Assemblyman Frank Vicencia's Assembly Subcommittee on Emergency Planning and Disaster Relief. The Subcommittee had in 1979 conducted a review of California's ability to handle a major earthquake. The conclusion was that the state was unprepared to cope with such an event and particularly lacking in its ability to cope with an earthquake prediction. In discussions between FEMA and representatives of Vicencia's committee a basic outline of the federal-state project evolved. Initially, the project has conceptualized as a prototype prediction response program which would be developed by FEMA and the state in cooperation with local governments in California.

President Jimmy Carter's concern about the effects of a catastrophic earthquake, stimulated by the May, 1980, eruption of Mount St. Helen's, led to a directive that the National Security Council examine the possibility of a great California earthquake, existing preparations for such an event and requirements for additional federal actions. In September, state officials were briefed on the findings of the NSC study which concluded that a great earthquake was increasingly probable, would cause extraordinary damage and that no level of government was adequately prepared. One recommendation of the study called for FEMA to establish "a small dedicated staff in California to concentrate on earthquake preparedness . . . ."

In June, 1980, monthly meetings began in Los Angeles under the auspices of the "Earthquake Prediction Planning Project." Those in attendance included representatives of the City of Los Angeles, the State Office of Emergency Services, the California Division of Mines and Geology, the Seismic Safety Commission, the State Legislature and both regional and national offices of FEMA. Out of these discussions emerged agreement that the geographical area to be the focus of the federal-state project would be that subject to the strongest shaking: a five county region which included Los Angeles, Orange, Ventura, Riverside and San Bernardino. In July, agreement was reached between state and FEMA officials on a funding level of approximately $1.5 million for a three year period. In the course of the summer other details of what would become the SCEPP project were finalized: the administrative agency would be the Seismic Safety Commission, a permanent policy board would act as a board of directors for the project, the board would appoint a manager for the project who would develop a work program and oversee administration. With other important elements of the project yet to be debated and decided, the legislature passed AB 2202 which was signed by Governor Brown on September 11, 1980.

EVOLUTION OF THE SCEPP PROGRAM

Work Plan 1981-84: research and program development under the seismic safety commission.

AB 2202 called for the initiation of an earthquake prediction response program to be administered by the Seismic Safety Commission. The legislation stipulated that participation in the program include federal, state and local levels of government and that the products of the program be prototypes, transferable to other high risk areas of the state. At the federal level, the National Earthquake Hazards Reduction Act was amended to require FEMA to develop a prediction response plan which was to include a prototype plan for one high-risk metropolitan area.

Within these broad parameters the SCEPP project continued to evolve. The initial focus of planning was earthquake prediction, however, there were consistent pressures to broaden the scope of the program to include preparedness for unpredicted earthquakes as well. A second shift was in response to federal legislation requiring a metropolitan planning emphasis. Scientists had suggested that a five county region in southern California which included the City of Los Angeles was the most vulnerable to a catastrophic earthquake. Thus, SCEPP's goal, as stated in the Projects' first work plan was "to stimulate preparedness for predicted or unpredicted catastrophic earthquakes in the most heavily populated portions of a five-county region in southern California."

The Project's objectives were to develop a prototypical planning process and plans with selected local jurisdictions and private sector organizations ("planning partners") for responding to predicted or unpredicted major earthquakes. SCEPP would also develop prototypical and transferable earthquake education and information approaches and materials. Finally, the Project was to develop a model comprehensive regional management system for response to predicted or unpredicted catastrophic earthquakes. The mechanisms for plan development, locally-based partnerships, were to include a county, a large city government, a smaller city, private sector entities and selected social groups or units.

Earthquake Prediction: Japan and the Asilomar Workshops

One of SCEPP's first tasks in pursuit of prediction response planning was a research trip to Japan to study the Japanese prediction system and transfer relevant institutional models to the southern California planning region and the United States in general. Upon their return, SCEPP staff planned and carried out the Earthquake Prediction Warning/Communications Workshop. The workshop, held December 1-4, 1981, was attended by 43 federal, state and local officials as well as scientists and news media representatives. The workshop provided a forum for presenting the findings and recommendations of the Japan research team and for discussion of four topic areas in earthquake prediction. These areas included structure and organization for a prediction warning and communications system, prediction warning terminology, public warning, and prediction education and information. The Japan trip and workshop resulted in SCEPP's first reports or products: The

"Japanese Earthquake Prediction/Preparedness Program" and "The Earthquake Prediction Warning/Communications Workshop Proceedings."

The recommendations of these early reports on prediction mainly called for broad national policy changes. The report on the Japanese prediction system called for a higher priority for prediction efforts and preparedness in the United States, greater coordination of federal and state hazard reduction programs, identification of long and short-term prediction for planning purposes and greater efforts to communicate prediction information to the media and public. The Asilomar workshop recommendations were somewhat more specific in suggesting that a terminology for expressing earthquake potential be adopted by local, state, and federal agencies; that CEPEC and NEPEC be asked to review the scenario outlined in the FEMA/NSC report and validate that a long-term prediction was in effect for southern California; that research into prediction related legal liabilities be conducted and that an operational prediction monitoring system be outlined for federal consideration. As a follow-up, SCEPP established the Earthquake Prediction Warning/Communications Task Force in January, 1982, to promote implementation of the recommended actions. CEPEC and NEPEC were asked to evaluate the NSC report and a letter was sent to USGS urging adoption of the proposed terminology as a national standard.

Success in implementing these recommendations was limited. Initial deliberations by CEPEC and NEPEC on the terminology resulted a decision by CEPEC that endorsement of the terminology was a national issue and NEPEC deferring the matter to the USGS. A SCEPP request that the prediction review panels validate the long-term prediction for the southern San Andreas met a similar fate. NEPEC did not give the FEMA/NSC scenario a full evaluation and no official endorsement or validation was issued. CEPEC regarded it as inappropriate for the state council to evaluate a federal report. A somewhat more favorable outcome occurred on the development of an operational earthquake prediction network as the USGS in April, 1982, outlined a plan to design such a network.

Under a one year extension of the SCEPP project approved by the Governor in July, 1983, prediction was to receive continued emphasis. A second Asilomar Prediction Workshop was planned which had as its goal development of a course of action which would lead to an Earthquake Prediction Evaluation, Warning and Response System. The sixty-five participants representing the scientific community, state and local government and the private sector assigned recommended actions priority ratings of high, medium and low, a time frame to report progress and a lead agency. The recommendations assigned high priority included development of common criteria for making prediction decisions; adoption of the Wallace/Davis/McNally terminology by NEPEC, CEPEC, USGS, FEMA, OES and other agencies; legislative changes to assure immunities for public entities in responding to a valid earthquake prediction; a procedure for rescinding or extending a prediction once issued and prediction response plans to be developed by all governmental jurisdictions in seismically hazardous areas. In September, 1984, the Governor signed AB 3321 which amended several sections of the Government Code to provide that the Governor may issue a warning as to the existence of an earthquake or volcanic prediction and, upon such issuance, public entities and employees would have immunity from liability for actions taken or not taken in response to the prediction.

Preparedness: The Planning Partners and Strategy for Transfer

The key objective of the SCEPP project was the development, in cooperation with selected public and private sector planning partners, of prototypical plans for responding to predicted or unpredicted catastrophic earthquakes. The Work Plan called for completion of such plans for a county, a large city government, a small to mid-sized city government, selected entities of the private sector and social groups or units by the fall of 1983. The planning partner concept was based on a reciprocal and beneficial relationship between SCEPP and the partner. SCEPP would provide guidance in development of a jurisdiction or organization wide plan. The partner would provide commitment and resources mainly in-kind services including the formation of working committees to discuss common problems, share information and coordinate plans.

San Bernardino County was an early choice to be the partner with which SCEPP would develop a prototype county earthquake preparedness plan. San Bernardino was the county with the greatest vulnerability to a great earthquake along the southern San Andreas and had provided considerable support for development and implementation of the SCEPP project. Some steps toward preparedness had been undertaken by the county but much remained to be done. In March, 1981, a Memorandum of Understanding between SCEPP and San Bernardino County was signed followed on April 6 by approval by the Board of Supervisors. The planning effort got underway with SCEPP staff and members of several county committees addressing long-term prediction, short-term prediction, immediate post-impact response and short-term recovery.

Similarly, the City of Los Angeles was, from very early on the designated large city partner. In July , 1982, an MOU was signed by SCEPP and the City. It required the SCEPP-City effort to: complete the city's draft earthquake prediction response plan; coordinate with the Pre-Earthquake Planning for Post-Earthquake Recovery (PEPPER) project; research and propose action on federal disaster assistance, prediction related legal authorities and liabilities associated with local government response and earthquake insurance; stimulate small business and industry planning for an earthquake; and develop emergency information and response information for the handicapped. In September, the City Council approved and the Mayor signed the agreement.

Security Pacific Bank became aware of SCEPP in the Summer of 1981 and approached the Project for help in preparing the bank for a catastrophic earthquake. While there was top management support for the partnership with SCEPP, the subject of earthquake prediction was anathema to bank executives. Nevertheless, a partnership with a major corporation with headquarters in a high rise building in downtown Los Angeles was welcomed by SCEPP. In the MOU signed by SCEPP and the bank in March, 1982, there were two areas of planning emphasis. One was to develop a program of earthquake preparedness, response and recovery for a catastrophic earthquake. The other was to prepare plans for minimizing structural and non-structural damage in Security Pacific's high-rise corporate headquarters and guidelines for employee safety.

With the San Bernardino, Los Angeles and Security Pacific partnerships underway, SCEPP approached the City of Westminster in Orange County about being the prototype small city. The city was represented on the PAB so an arrangement was rapidly finalized in September, 1982. The agreement centered on five areas. SCEPP was to assist the city in assessing the threat posed by a magnitude 8.3 earthquake on the San Andreas; prepare a draft, four-phase earthquake and earthquake prediction plan; review and expand upon mitigation programs; explore strategies for involving citizens and neighboring jurisdictions in preparedness programs and make available to the city all information from parallel research done by SCEPP for other planning partners.

These partnerships resulted in development of SCEPP's core planning products as well as a number of other "transferable" materials. San Bernardino's extensive network of earthquake planning subcommittees produced documents which, after peer review and revision, became the "Comprehensive Earthquake Preparedness Planning Guidelines -- County," the "Neighborhood Self-Help Program Planning Guide" and "Guidelines for School Earthquake Safety Planning." The Los Angeles partnership yielded the large city prototype plan "Comprehensive Earthquake Preparedness Planning Guidelines -- Large City." Work with the City of Los Angeles also stimulated research carried out by SCEPP staff which resulted in publication of "Earthquake Insurance: A Public Policy Dilemma" and "Earthquake Prediction Response: Legal Authorities and Liabilities." In response to provision in the SCEPP-City MOU that the effort "stimulate private small business and industry planning for an earthquake," SCEPP developed the "Guidelines for Local Small Businesses in Meeting the Earthquake Threat" and an audio-visual module and brochure which addressed business and industry preparedness. Finally, the Los Angeles partnership produced a report entitled "Earthquake Preparedness Information for People With Disabilities." The partnership arrangement with Security Pacific Bank resulted in the "Comprehensive Earthquake Preparedness Planning Guidelines -- Corporate" and material which was incorporated into a slide-tape module and brochure entitled "Earthquake Preparedness in High Rise Office Buildings." Finally, the Westminster partnership yielded the small city prototype plan "Comprehensive Earthquake Preparedness Planning Guidelines -- City."

As a result of the work performed within the four partnerships and the requirement that SCEPP products be transferable, a model planning process was developed by SCEPP with the assistance of TEMJAM Industries. The model planning process included a ten-step approach to initiating an earthquake preparedness program. It also called for the preparation of recommendations by planning committees and, upon adoption of those recommended actions by the appropriate organizational authority, implementation. The process includes education, training and an ongoing program of tests and exercises to ensure the continued viability of the plan. The SCEPP planning process recognized four phases or elements under which specific actions were recommended. The first was long-term prediction response incorporating actions to be taken a few years to a few decades before the earthquake occurrence. A second element was short-term prediction response involving actions recommended for a greatly accelerated effort under the time constraints of a few days to a few weeks before the earthquake. The emergency response element included actions to be taken during the first seventy-two hours to a few weeks after the earthquake. The fourth element was short-term recovery with recommended actions for the first one to two months following the earthquake. The planning process was incorporated into a "Users Guide" which appeared as the first section of SCEPP's "Comprehensive Earthquake Preparedness Planning Guidelines."[1] The planning process was also offered to SCEPP target audiences by way of a slide/tape program entitled "The Planning Process: Preparedness in Earthquake Country."

With SCEPP's one-year extension approved by the Governor in July, 1983, the Project, its PAB and the Seismic Safety Commission oriented themselves to concluding planning efforts through a transfer of SCEPP products and planning strategy to appropriate users in the five county region. A committee of the Policy Advisory Board called the Ad Hoc Committee on Transferability Strategy began meeting in October, 1983. It was decided that SCEPP would transfer its planning products and other materials to appropriate users through a series of county-based earthquake conferences one of which was to be held in each of the five counties in SCEPP's planning region. At these conferences SCEPP and its planning partners would discuss their experiences, provide a fairly detailed introduction to the SCEPP planning process and provide conference participants with the appropriate guides and materials.

On March 15, 1984, the first of the transfer conferences was held, co-sponsored by SCEPP and Orange County. The Orange County Board of Supervisors had earlier passed a resolution which committed the county to earthquake preparedness planning and endorsed the county-wide conference. On April 4, a similar conference was held in Los Angeles County co-sponsored by SCEPP and the Emergency Preparedness Commission for the County and Cities of Los Angeles. Over one thousand people attended the two conferences which included the entire spectrum of potential SCEPP product users. In the sessions which targeted local government, business and industry, neighborhoods and community, and schools, participants were provided with an orientation to the SCEPP planning process and the products developed under the partnerships.

Earthquake Education and Information

One of SCEPP's four basic objectives was to develop prototypical and transferable earthquake education and information approaches and materials. The Earthquake Hazards Reduction Act of 1977 had identified "public education and involvement programs" as a basic element of earthquake preparedness. The need for effective communication of hazard awareness and preparedness

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[1] The guideline for corporations and large cities contained three elements: earthquake preparedness, emergency response and recovery.

information was echoed in a number of studies and investigations including a 1978 report by the Working Group on Earthquake Hazards Reduction of the Office of Science and Technology Policy (Executive Office of the President) and studies sponsored by the California Assembly, the National Security Council and FEMA.

SCEPP's role in the area of earthquake education and information was to develop a long-term earthquake information program design and strategy. Taking a systematic approach to the task, the Project first inventoried available public information and educational material. An assessment was then undertaken to determine the quality of this material. These steps were followed by a needs assessment to identify appropriate target audiences and an evaluation of alternative dissemination methods. The final step was to develop a program design.

From June to November, 1981, SCEPP gathered preparedness related material from a wide array of public an private sector agencies. The material received was catalogued and included in the SCEPP library. The solicitation of earthquake preparedness information and education resources also resulted in publication of "Earthquake Public Information Materials: An Annotated Bibliography." Review of the information acquired facilitated the identification of information gaps and audiences not addressed by existing materials. The information gathering exercise was also regarded as a first step in the process of networking or establishing links with information providing groups in the region.

The acquisition and review of available preparedness information and education materials afforded an opportunity for evaluation and further needs assessment. The SCEPP research team which visited Japan found that the Japanese had a comprehensive, integrated program involving the schools, media, government and industry. The education and public information materials examined were found to be graphically interesting, simple to follow and well integrated into earthquake planning efforts. In the United States, as in Japan, there was a great deal of inexpensive or free material available, however, this material was duplicative, poorly illustrated and narrowly focused on the middle class homeowner. The SCEPP assessment also revealed that California schools did not have an adequate earthquake education curriculum. Drawing on various studies, it was found that greater efforts were needed to raise public awareness of the earthquake threat and that this awareness be combined with information featuring manageable "how to" preparedness steps for individuals and groups. Several recommendations came out of this assessment: SCEPP should advertise and disseminate existing materials which were clear, interesting and easy to follow; develop an integrated awareness campaign which combines information and preparedness; address information gaps; identify and establish links with earthquake information providers; identify accessible informed sources for the media and to maintain awareness of scientific advances and promote the credibility of scientists in the public mind.

In determining appropriate means of dissemination and outreach, research was cited which emphasized the importance of repeated exposures in varied formats communicated through multiple channels. Studies also indicated that many groups which were highly vulnerable: the elderly, disabled, non-English speaking and socio-economically depressed were not being reached with earthquake hazard information. SCEPP's close examination of existing research literature on education and information dissemination resulted in several key recommendations. One called for establishment of an earthquake information and planning center which would house active outreach programs and link public education, preparedness and regional computer-assisted management systems. It was also recommended that materials be prepared in other languages and disseminated through indigenous networks. A set of recommendations called for development of a marketing approach to earthquake preparedness and awareness and their dissemination. Finally, a series of target audiences was identified which included: the news media (radio, television and print), public officials, homeowners, apartment dwellers, residents of mobile homes, employees, persons with disabilities, schools, southern California visitors, hospitals, institutions of incarceration and the general public.

Several SCEPP products were developed to address the identified dissemination needs and some of the target groups. The public relations firm of Nelson and Visel, Inc. was retained by SCEPP to develop a strategy for motivating the public to prepare for earthquakes and make recommendations on how a marketing approach could be applied to earthquake preparedness. In May, 1983, SCEPP published "Earthquake Preparedness in Southern California: A Marketing Approach." A number of slide-tape modules were produced including "Earthquake Preparedness in Mobile Home Communities," "The Earthquake Threat: Living in Apartments," and "Earthquake Preparedness in High-Rise Office Buildings." Brochures addressing apartment and mobile home dwellers and employees who work in high-rise office buildings were also developed. In addition, brochures were designed which addressed two additional target groups: the disabled and southern California visitors. Slide-tapes and brochures directed to the preparedness needs of apartment and mobile home residents, the disabled and southern California visitors were translated into Spanish.

As the final step in development of a long-term strategy, SCEPP published in March, 1983, the document "Earthquake Public Information and Education Program Design." It incorporated the results of SCEPP's education and public information literature review, the evaluation of this literature, the assessment of dissemination methods and called for a five-year phased program to increase earthquake preparedness in all sectors of the population.

Regional Management System: The San Bernardino Pilot Project

One of SCEPP's four basic objectives under the first Work Plan was to "develop a model comprehensive regional management system for response to predicted or unpredicted catastrophic earthquakes." A project to address this objective was initiated in February, 1982, with the Policy Advisory Board directing SCEPP to move ahead by convening a technical committee to discuss a system, conduct a one-day workshop to evaluate needs and then assemble a contract with the Southern California Association of Governments for study design.

By December, 1982, the technical committee had met, conducted the workshop and recommended that SCEPP carry out a data base design study. The study would be conducted by the Southern California Association of Governments and TEMJAM Industries, Inc. The initial approach to the study was to inventory and assess existing data, computer hardware and models. The basic finding of the inventory was that there were sufficient data in the region to develop and test a data base design that would improve planning and response and be transferable. Following the research and analysis by SCAG and TEMJAM Industries, the design was developed and presented to the PAB. The SCAG report estimated that the cost of a fully operational database would cost nearly $1 million.

As a next step, a pilot project was initiated in February, 1983, with the County of San Bernardino. SCEPP received supplemental funding from FEMA for this effort with SCAG and TEMJAM continuing to work as consultants on the project. The Environmental Systems Research Institute which provided necessary data and software was also retained by SCEPP to work on the pilot project. The project was conducted over a seven month period with SCEPP providing overall management and coordination. The project study area covered a twenty square mile area, incorporated four political jurisdictions and included a diverse blend of land use and hazards.

The primary goal of the pilot project was "to test the feasibility and practicality of using automated processing techniques for performing socio-economic analyses of potential earthquake losses." Within this goal three objectives were pursued: to develop a geographic database of sufficient size, quality and resolution to allow for computer modeling of earthquake impacts and damage estimation; to utilize geophysical and socio-economic models in the earthquake event simulation and damage estimations; and to produce maps and printed reports at a level of detail useful to local planning efforts.

The results of the pilot project included: a Basic Map Atlas which includes various geophysical and socio-economic data; shaking intensity (Modified Mercalli) maps for three scenario events including an 8+ event on the southern San Andreas fault; "at risk" maps with tabular data for multiple family dwellings, commercial and industrial establishments and critical facilities; and damage and population vulnerability maps with tabular data showing total structures damaged, total dollar loss, deaths and injuries and homeless caseload.

In November, 1983, the pilot project, its data, findings and conclusions, were published in the SCEPP document "Pilot Project for Earthquake Hazard Assessment." The basic conclusion of the report was that the technology is available to perform automated modeling for the purpose of earthquake preparedness planning. Several issues were identified as requiring resolution prior to development of an operational Regional Information Management System (RIMS). The total area to be served by the system had to be identified. Leadership and participation would be required from all levels of government and the private sector. The cost of developing and maintaining the RIMS had to be evaluate in light of potential long-term benefits. Logistical and administrative aspects required careful consideration prior to implementation. The consultant group responsible for the report recommended creation of a policy group to deal with these regional and intergovernmental issues and pursue the goal of developing and implementing the RIMS over a five year period.

Work Plan 1984 to 1987: Earthquake Preparedness, Regional Planning and Hazard Mitigation Under the Office of Emergency Services

In the fall of 1983, SCEPP was still in operation thanks to an extension of the Project through July, 1984. Nevertheless, the assumption on the part of SCEPP staff, the PAB and the Seismic Safety Commission was that the Project would end the following summer. The Project's activities centered on transfer of products within the region and identification of a suitable entity to continue dissemination of SCEPP materials after the Project had ceased to exist. The initiative to continue the SCEPP project was twofold.

The Coalinga earthquake of May 2, 1983, generated renewed activity by the California Assembly's Government Operations Committee. This committee had been instrumental in helping establish SCEPP and despite personnel changes, maintained a continuing interest in the Project and earthquake issues in general. Hearings were held in November which focused on earthquake prediction, preparedness, recovery and the role of SCEPP. The general view presented in testimony before the Committee was that there had been progress in preparedness activity in the state and that SCEPP had played a significant role. The consensus among those who came before the committee, however, was that there remained considerable work to be done, particularly in transferring the SCEPP planning process and products to potential users. On a second front, discussions were initiated within FEMA regarding the wisdom of allowing the SCEPP project to lapse. SCEPP was considered one of FEMA's most successful programs and clearly the need for preparedness planning remained. The position eventually reached by FEMA was that SCEPP should continue the work begun in 1980 and that the Project should be incorporated into a permanent organizational setting, more specifically, the Office of Emergency Services.

The outcome of the assembly committee hearings was a decision to draft legislation extending SCEPP beyond July 1, 1984. Assembly Bill 2662 (Alatorre and Campbell) was introduced in February, 1984. The bill proposed continuation of SCEPP for three years; an appropriation of $750,000 for fiscal year 1984-85 would be allocated to the SSC and OES in equal shares (with encumbrance of funds contingent upon receipt of matching federal assistance funds). The appropriation was for "further comprehensive earthquake preparedness in southern and northern California." The northern California reference was to the Bay Area Regional Earthquake Preparedness Project which had been initiated in July, 1983 (as the Bay Area Earthquake Study) to stimulate preparedness in the Bay Area. SCEPP would operate under the executive authority of the Office of Emergency Services and BAREPP would be administered by the Seismic Safety Commission.

The legislation identified four broad objectives to be pursued by the two projects. The first of these was to promote comprehensive earthquake preparedness actions by local jurisdictions and the private sector. The projects were also required to provide planning assistance and coordination in the development of improved regional response capabilities for predicted or unpredicted major earthquakes. A third objective was to provide technical and planning assistance to local jurisdictions in development and implementation of programs of hazard mitigation and prevention. Finally, the legislation called for a local incentive grant program to promote demonstration projects in comprehensive earthquake preparedness. The bill was passed and signed by the Governor on July 6, 1984.

Transfer, Planning Assistance and Evaluation

Each of the objectives as outlined in AB 2662 was translated into a Work Program "element." The element which corresponded to promoting comprehensive earthquake preparedness was broadly defined as "planning guidance development, transfer, planning assistance and evaluation." Under this element SCEPP continued to develop new planning products, transfer these products to appropriate users, provide assistance in their application and evaluate the effectiveness of transfer and assistance.

A major task under this element was to continue the process of transferring SCEPP products to appropriate users in the remaining three counties in the planning region: Ventura, San Bernardino and Riverside. These conferences were held during the first year of the three year extension period: the Ventura conference in September, 1984, with San Bernardino and Riverside in April of 1985. Although the content of the sessions varied somewhat, each conference was co-sponsored by SCEPP and the host county and preceded by a board of supervisors endorsement of the conference. As in Orange and Los Angeles Counties, the three conferences held during this period attracted a broad spectrum of participants representing local government, business and industry, schools, and volunteer and community service organizations. SCEPP's visibility, in no small part a result of the county conferences, greatly increased during this first year of the three year extension. With this greater visibility, the Project experienced a tremendous increase in the demand for products. Satisfaction of this demand was expensive for SCEPP both monetarily and in terms of staff time. A plan was developed to distribute SCEPP products through the Los Angeles Chapter of the American Red Cross on a cost recovery basis. A Memorandum of Understanding was signed in the Fall of 1985 with distribution getting underway in December.

During the second and third years of the Work Program, SCEPP was to identify local jurisdictions in southern California which had not received the Project's planning guidelines and transfer these materials to them. Cities became the focus of this task in that all five county governments in SCEPP's planning region had been co-sponsors with the Project in holding one of the county-based earthquake conferences. Thus, county officials would have received the planning materials prior to or during the conference held in their respective jurisdictions. It was determined that forty-two cities in the region, most of them in Los Angeles County, had not received the Comprehensive Earthquake Preparedness Planning Guidelines for cities. Although several transfer options which included an orientation to the guidelines and SCEPP planning process were considered, time and funding constraints rendered workshops or one-on-one instruction impossible. In January, 1986, the guidelines were mailed to the forty-two non-recipient jurisdictions.

SCEPP was also required to provide planning assistance to local jurisdictions in Orange and one other county during FY 1984-85. In June, 1984, the Orange County Board of Supervisors adopted a resolution which committed the county to an earthquake preparedness planning program to be pursued with the support and assistance of SCEPP. The SCEPP/Orange County planning effort spanned the entire three years of the Work Program and resulted in development of a long-term earthquake preparedness plan. The plan included mitigation of structural, non-structural and secondary hazards such as fire and hazardous materials release, revenue loss and fiscal recovery, land use and zoning regulation, employee training, protection of records, and development of a multi-year earthquake public education program. The plan was approved by the Orange County Board of Supervisors in December, 1986. Currently, SCEPP is involved in ongoing assistance to the County in the plan implementation process.

Riverside County was to be the second of the jurisdictions in the planning region to receive planning assistance from SCEPP. Preliminary meetings were held in May and June 1985 to develop a workplan. However, internal organizational changes in Riverside County resulted in a waning of original interest and no planning assistance was undertaken. SCEPP's provision of planning assistance to a second county did not occur until September, 1986, when initial meetings were held with Los Angeles County officials. Subsequently, work plans were developed to pursue a five year earthquake preparedness plan for the county. Four major elements were identified in the plan which included: emergency preparedness and response; earthquake hazard reduction; earthquake education and self-help preparedness and post-earthquake recovery and reconstruction. In mid-March, 1987, a workshop co-sponsored by SCEPP and the County of Los Angeles was held to finalize the five-year plan. Workshop participants representing all County departments with a significant role in earthquake preparedness and response were asked to review, modify, prioritize and approve plan objectives under the four major elements. The plan will soon be submitted to the Board of Supervisors for approval.

A third recipient of planning assistance from SCEPP was the City of Los Angeles which approached SCEPP in June, 1986, for assistance in developing a draft earthquake prediction response policy for the City's Emergency Operations Organization. SCEPP assembled a workshop design, recruited subject area speakers, provided facilitator and recorder training and provided staff assistance for the workshop which was held in mid-October, 1986. The outcome of the workshop was a draft prediction policy statement which is currently being finalized for presentation to City Council. SCEPP has also provided assistance to the City of Los Angeles in preparing for the second International Earthquake Conference to be held in April, 1987.

In addition to local jurisdictions, SCEPP has promoted preparedness for, and provided planning assistance to, business and industry, schools, community organizations, and voluntary associations in its five-county planning region. During 1984 and 1985 SCEPP, with the assistance of Durkin and Associates, developed a number of products directed at small businesses including a brochure and audio-visual presentation ("Earthquake Preparedness: A Key to Small Business Survival") and a workshop to introduce methods of outreach to minority small business owners. The most tangible outcome of this outreach was translation of the small business brochure (in abbreviated form) into Spanish, and more recently, into Vietnamese and Chinese. Also prepared were sections on the role of small business in a community preparedness effort for the recently published (October, 1986) "Model Community Self-Help Campaign for Earthquake Preparedness."

SCEPP outreach to schools under the new Work Program began informally with a small workshop attended by school district and county superintendent office representatives to exchange ideas and information. The major outcome of the workshop was a clear indication that school districts were concerned about legislation (AB 2786) requiring schools to have earthquake emergency plans. In response to this concern and to provide assistance to SCEPP in addressing the preparedness needs of schools, the Project organized the School Safety Planning and Education Task Force. Task force membership included representatives from each of the five county offices of the superintendent of schools, the Los Angeles Unified School District, the Seismic Safety Commission's Education Subcommittee and private schools. The Task Force developed, printed and disseminated an "Earthquake Preparedness Checklist for Schools." This checklist highlights key information pertaining to AB 2786 and includes school planning considerations which address preparedness, response and recovery. The Task Force also prepared a working paper on school earthquake resource centers and assisted SCEPP staff in assessing the role of schools in neighborhood self-help campaigns and in development of the community wide preparedness model.

Planning and technical assistance have been provided by SCEPP to community organizations in the region from the initiation of the new Work Program. Conducting neighborhood and community self-help campaigns has enabled SCEPP to test new approaches to stimulating preparedness among this important constituency. Workshops, training seminars and ongoing planning assistance have been provided to church groups, homeowner associations, Neighborhood Watch programs, Chambers of Commerce, and local business and jurisdiction initiated programs. SCEPP's experience in providing this assistance was documented in the publication "Model Neighborhood Self-Help Campaign" which became available in October, 1985. This product was designed to promote self-help earthquake preparedness at the neighborhood level and identify necessary steps in conducting an effective neighborhood preparedness campaign. A brochure entitled "Guide to Initiating a Neighborhood Self-Help Campaign" which highlights the key steps identified in the Neighborhood Model was developed for use by neighborhood leaders and organizers.

Designed to integrate the preparedness and mitigation efforts of the various elements of the community, mainly schools, local businesses and neighborhood based organizations, SCEPP first developed a model community self-help campaign then introduced this product at a well attended conference in October, 1986. The "Model Community Self-Help Campaign for Earthquake Preparedness" was developed by SCEPP staff to provide community organizers a guide in initiating a campaign to ensure community self-sufficiency by promoting the concept of self-help in preparing for, and responding to, an earthquake disaster. The model incorporates the imperative that all three segments of the community--schools, businesses and neighborhood organizations--be involved in the campaign. The Community model and other preparedness literature were provided to participants of the Earthquake Preparedness Conference for Community Self-Help held on the Queen Mary on October 30, 1986.

SCEPP, as part of its ongoing provision of planning assistance to local jurisdictions, was actively involved in the Statewide Earthquake Preparedness Campaigns in 1985, 1986 and 1987. In 1985 and 1986, the campaigns were carried out over a one week period in April and were initiated by a gubernatorial proclamation. The proclamation was followed by a multi-media earthquake preparedness and awareness effort with special programs and exercises performed by local government, schools and other community groups. SCEPP's role in these two campaigns was to assist in the planning and organization of locally-initiated activities in southern California. The support to local governments provided by SCEPP included development and distribution of an Earthquake Week Poster, a local government information packet and a media information kit. SCEPP also participated in OES organized response exercises at Los Alamitos Armed Forces Base. In 1987, the campaign was designated for the entire month of April. SCEPP's role also expanded. In addition to providing assistance to locally generated campaigns in southern California, SCEPP will manage a consultant contract under which all statewide campaign activities are to be developed.

A final task under this broadly defined element was to conduct an evaluation of the SCEPP transfer strategy. The goals of this research effort were to: assess the county conference as a planning product delivery mechanism; determine the actual level of application of SCEPP's developed products; and determine the level of planning assistance required for effective use of the products. The study design included a survey of persons who attended the five county-based earthquake conferences as well as a "control" group made up of persons who had received SCEPP products but had not attended a conference. The Institute for Social Science Research at UCLA was retained for questionnaire development, data reduction and assistance in data analysis. Based on an analysis of 684 returned questionnaires, a number of conclusions and recommendations were offered. In transfer of SCEPP products, the conferences were highly effective in orienting participants to the earthquake threat and to practical preparedness measures at the individual and organizational level. In comparison with those who had not attended a conference, conference participants were more likely to have read and discussed the SCEPP materials and initiated preparedness actions. The evaluation indicated that orientation and instruction in use of SCEPP's planning products are crucial to implementation of planning actions. For future transfer, respondents preferred a more focused setting, one in which orientation to a specific product or "product set" was provided to the principal users in a workshop setting.

Levels of application of specific SCEPP products varied considerably. The evaluation revealed that city and county governments in the five county region had already addressed the earthquake threat in their emergency plans upon first contact with SCEPP. Most, however, had placed heavy emphasis upon response rather than pursue a more balanced effort to address preparedness, response and recovery on an equal footing. Exposure to SCEPP's Comprehensive Earthquake Preparedness Planning Guidelines for local jurisdictions motivated emergency management officials to reevaluate the adequacy of their existing plans but most stopped short of launching coordinated efforts to implement SCEPP's planning process. Schools and corporations were the most likely to initiate and follow through with planning steps identified by SCEPP. Small businesses and neighborhood based organizations were least likely to have used the SCEPP materials targeted for these potential users. Overall, a pattern emerged of organizations achieving various levels of preparedness consistent with SCEPP's recommended process, but few having carried the process to conclusion.

The evaluation revealed that a number of barriers were encountered in pursuit of adequate levels of earthquake preparedness including financial constraints and a lack of commitment by top management among organizational users of SCEPP products. A lack of adequate financial backing, weak organization and low levels of awareness among neighborhood residents were cited as barriers on the individual and group levels of preparedness. While some of these problems cannot be directly remedied through planning and technical assistance, SCEPP could develop strategies for overcoming these barriers and provide available resources and referrals to promote more thorough use of the products. The evaluation report was completed in September, 1986, and will be published under the title "The Transferability of SCEPP's Products: A Report of Evaluation Findings 1983-1985."

Regional Earthquake Preparedness Planning

Under SCEPP's first work program, the regional planning element consisted of a focused attempt to determine the feasibility of developing a Regional Information Management System (RIMS). SCEPP, under the new Work Program, was to expand the scope of regional earthquake planning by "providing planning assistance and coordination in the development of improved regional response capabilities for predicted or unpredicted major earthquakes, including programs of tests and exercises." This overall goal generated three interrelated tasks. The first was to establish and provide staff support to a multi-county planning task force assembled to identify regional response and recovery problems and develop a regional planning scenario. A second task involved planning assistance for, and participation in, regional earthquake response exercises in 1985, 1986 and 1987. Finally, earthquake prediction, which had been a major focal point of early SCEPP activity, was now subsumed under the regional planning element. SCEPP was to support efforts in the design of an earthquake prediction evaluation, warning and response system and promote its testing, on a regionwide basis, in California.

In late 1984 and early 1985, the task force to address regional issues began to take shape under a contract with TEMJAM Industries, Inc. During this period, the Biregional Earthquake Planning Advisory Committee, a short-term task force appointed by the Seismic Safety Commission and the Office of Emergency Services, reviewed a number of working papers submitted by SCEPP and BAREPP. The outcome of this preliminary examination of regional issues was a report entitled "Multijurisdictional Earthquake Planning for the Southern California Region." This report identified several areas in which regional emergency planning and management could be improved: in threat assessment, in identification and analysis of multi-jurisdictional planning issues, in developing a program to address regional planning, in emphasizing the compatibility between the Integrated Emergency Management System and SCEPP's planning guidance, and in developing a model program of tests, drills and exercises related to emergency regional management.

Upon completion of the work of BEPAC, TEMJAM recommended that two regional advisory panels be created, one to address regional issues in northern California, the other to address regional planning in southern California. It was proposed that a Regional Earthquake Planning Advisory Committee be established for southern California to provide necessary guidance, direction and coordination to ensure accomplishment of subsequent steps in multijurisdictional planning. After considerable debate over the scope of the regional planning effort and the role of REPAC, SCEPP's Policy Advisory Board directed the Project to pursue three tasks. SCEPP was to establish Specialist Groups to work with the Project in outlining the scope of the regional planning effort, prepare a comprehensive report on regional response and recovery problems, develop a regional concept of emergency management for southern California, and finally, develop a multi-year program for regional earthquake preparedness planning. SCEPP, through a contract with the Terence Haney Company (formerly TEMJAM, Industries), is currently preparing a report which contains scenario information needed to drive the entire planning process.

SCEPP's first of several efforts to promote the development of a functional earthquake prediction system took the form of a third Asilomar prediction workshop. The workshop, held in the Summer of 1985, sought to review developments and discuss future directions toward the goal of promoting a functional prediction system. Two prediction situations were closely examined early in the proceedings: The long-term prediction by the U.S. Geological Survey for an earthquake on the Parkfield segment of the San Andreas fault and a prediction "advisory," also issued by the USGS in June, 1985, for the San Diego metropolitan area. Workshop participants were divided into four task groups which were composed of scientists, emergency management officials of all levels of government and the private sector, academicians and the news media. The outcome of the workshop was a set of recommendations, grounded in the experience of recent predictions, which addressed evaluation and validation, warning and communications (from the standpoints of issuing a warning and public awareness and education to facilitate effective public use of a prediction) and prediction response planning. As in earlier Asilomar workshops, SCEPP staff followed-up on these recommendations and, where possible, attempted to promote their implementation. Two follow-up tasks to the workshop were the assembly of workshop proceedings published as "Earthquake Prediction Evaluation, Warning and Response System Workshop: Proceedings" and documentation of the Parkfield and San Diego earthquake predictions which was entitled "The Parkfield and San Diego Earthquake Predictions: A Chronology." Both were published in October, 1985.

Planning and technical assistance to promote a functional earthquake prediction system was provided to OES in developing a short-term prediction response plan for California (under AB 938) and in proposing prediction communication and response measures for a possible short-term Parkfield prediction. Assembly Bill 938 (Alatorre) appropriated one million dollars to the Department of Conservation to upgrade seismic and crustal deformation instrumentation near Parkfield. It also provided OES $75,000 to develop a comprehensive emergency response plan for short-term earthquake predictions. Currently, this plan is being prepared under contract with the Center for Planning and Research. The SCEPP director is serving as Contract Manager with support from staff. The work plan calls for revised administrative and operating procedures for CEPEC and a short-term prediction response plan which includes an overall concept of operations for OES and state agencies and response procedures geared to factors of probability, magnitude, timeframe and risk.

Although the planning work associated with the mandate of AB 938 was to cover any statewide short-term prediction, the Parkfield situation posed a dilemma for OES. The USGS had developed threshold criteria and procedures to issue a short-term prediction for Parkfield and published details of these plans in January, 1986. The USGS plan called for notification of OES at the highest level of alert under which there was a significant probability that an earthquake would occur at Parkfield within three days of issuance. OES did not have a plan to deal with such an advisory and could not wait for completion of the Statewide prediction plan due to be operational in mid-1987. At SCEPP's suggestion, a working committee was appointed by OES which included representatives from OES, USGS, CDMG and the six counties which would be affected by a damaging level earthquake at Parkfield. SCEPP's director was appointed chair of the group, eventually named The Parkfield Response Working Group. The group met several times between May and August, 1986. In October, the OES director was provided with a report containing several recommended response actions. It was suggested that OES adopt procedures for the Sacramento Warning Center to receive notification from USGS and warn affected jurisdictions. Roles in evaluation of a Parkfield prediction were recommended for CEPEC and CDMG. A proposed Memorandum of Understanding would provide for notification of OES at lower levels of alert to assure adequate mobilization should the highest alert level ultimately be reached. Also recommended was an OES request to the Attorney General for an opinion to clarify legal authorities and liabilities associated with local government prediction response actions. The Working Group also sought the OES director's approval to continue working with local jurisdictions to promote prediction response planning, to develop a public education and awareness campaign for Parkfield and hold an exercise to test communication and response procedures. All of these recommendations were either implemented or have been initiated. A successful table-top exercise to test Parkfield communication and response procedures was held in February, 1987.

SCEPP has participated in two regional response exercises sponsored by OES in 1985 and 1986 and will assist in the planning and execution of a similar test in 1987. SCEPP staff served as observers in the 1985 exercise held at the Los Alamitos Armed Forces Reserve Center. The purpose of the exercise was to test the state emergency response plan following a major earthquake along the southern San Andreas fault. In a similar exercise held in April, 1986, entitled "Validation '86," SCEPP took a more active role in the simulation with staff assigned duties in disaster intelligence and situation assessment. For the 1987 exercise, SCAG will prepare a work plan for the exercise and provide staff support to the exercise planning team. SCEPP's director will chair the situation assessment committee.

Technical Assistance for Earthquake Hazard Mitigation

Under this program element, SCEPP set as its goal the provision of technical and planning assistance to local jurisdictions in the development and implementation of hazard mitigation and prevention programs. The reduction of earthquake vulnerability was to be pursued through provision of technical information, training and dissemination of research results and promotion of their application.

Based on an early recommendation that SCEPP "establish necessary links" among organizations which provide earthquake related services or information, the Project began work in September, 1983, to develop an automated information network and referral system. SCEPP staff assembled a questionnaire which was sent to two-hundred organizations identified as providers of scientific, technical, planning and earthquake preparedness information and services. The purpose of the questionnaire was to generate basic data to be stored on computer software and made available to fill requests for information, services or referrals. After preliminary work had been completed, BAREPP joined SCEPP in a cooperative effort to finalize a functional system. SCEPP's Bay Area counterpart provided additional information and finalized the computer software package. Both projects automated their libraries and these too became part of the Information Network and Referral System. This system went "on line" in June, 1985, and the projects have continued to maintain and update the system as additional informational became available.

In addition to the INRS, SCEPP attempted to promote awareness and implementation of earthquake hazards and mitigation measures through presentations at conferences, workshops and newsletter items. In October, 1984, SCEPP co-sponsored, with the Los Angeles County Regional Planning Commission, a symposium entitled "The Seismic Safety Fix: Retrofit Requirements for pre-1933 Buildings -- What Should They Be?" Working in conjunction with the City of Los Angeles and William Spangle and Associates, SCEPP co-sponsored a March, 1985, workshop on pre-earthquake planning for post-earthquake recovery (PEPPER). In April, 1985, SCEPP designed and presented a panel discussion on the state mandated Seismic Safety Element at the General Assembly of the Southern California

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Association of Governments. SCEPP added a number of technical seminars to the San Bernardino and Riverside conferences also held in April, 1985. As part of the ongoing planning and technical assistance to Orange County, SCEPP contracted with TEMJAM Industries to provide an earthquake vulnerability analysis for the county and later retained the Reitherman Company to train county building officials to perform structural vulnerability assessments on county-owned facilities. In November, 1985, SCEPP was one of several co-sponsors of a regional workshop designed to promote effective use of geo-technical information by local jurisdictions.

More recently, SCEPP initiated a review of research materials on structural earthquake hazard reduction and, in consultation with the Seismic Safety Commission, developed a seminar program on the hazardous building problem. The seminar was held in May, 1986, and attracted one-hundred and sixty participants. A model hazardous buildings ordinance was presented at the seminar which also offered presentations on local hazards reduction programs, building ordinance administration and compliance and the costs and benefits of earthquake hazards reduction. As a follow-up to this seminar and to more fully assess the hazardous buildings problems in southern California jurisdictions, SCEPP developed a survey questionnaire which was mailed to the chief building official in each of the jurisdictions in SCEPP's planning region. Analysis of returned questionnaires has not yet been initiated.

"Hazardous Materials and the Earthquake Threat" was the theme of a seminar co-sponsored by SCEPP and the University of California, Riverside Extension in November, 1986. The program included the topics of government and industry response planning, the regulatory framework, legal liability questions and technical aspects of hazard identification and mitigation. The seminar utilized materials developed by BAREPP and assistance from the Association of Bay Area Governments.

SCEPP's program element on technical assistance for earthquake hazard mitigation has also accommodated the production of SCEPP's quarterly newsletter "Update." The newsletter has a circulation of approximately 4,000 and provides an important link between SCEPP and its planning region as well as the wider emergency management community. The articles which appear are written by SCEPP staff and reflect the ongoing Project activities as well as information on upcoming events, new legislation, policy changes and research endeavors. SCEPP has produced a newsletter since May, 1981.

The Local Incentive Program: Demonstration Projects in Earthquake Preparedness

SCEPP's overall goal under this element was to establish a Local Incentive Program to promote demonstration projects in comprehensive earthquake preparedness. The program called for funding of innovative approaches to earthquake preparedness in the areas of neighborhood self-help, hazardous building identification, emergency information management systems, cooperative efforts between the public and private sectors and special community needs. Two additional program criteria were that the proposed projects not be funded under existing local, state or federal programs and that the outcome or products of the LIP program be transferable to other local jurisdictions.

In December, 1984, notices were mailed to all local jurisdictions in SCEPP's and BAREPP's planning regions indicating the intent to issue a Request for Proposal. Nearly 250 jurisdictions expressed an interest in submitting proposals. The RFP was mailed in February, 1985, with a 45 day deadline. Projected start-up dates for funded projects was June, 1985, with all work to be completed by June 30, 1986. Twelve proposals were received and evaluated by SCEPP staff and a PAB appointed ad hoc committee. A final list of seven projects was approved by the full PAB and forwarded to the directors of the Office of Emergency Services and Seismic Safety Commission for final funding decisions. The total amount of funds available for the LIP program was $250,000.

All seven of the proposals recommended were approved and work began in mid-June with SCEPP staff assigned to monitor the projects. The seven approved LIP projects included: development and demonstration of an automated emergency management system ("Emergency Preparedness Planning and Operations System") by the City of Los Angeles, Planning Department; a comprehensive neighborhood self-help program (Project QUAKE S.A.F.E.) to be implemented in four demographically and geographically different areas of Riverside County by the Riverside County Fire Department; development and dissemination of a comprehensive file identifying the locations of disabled persons who may require special resources and services in the event of a disaster by the Los Angeles Mayor's Office for the Handicapped; a working handbook for communicating to Spanish-speaking, Vietnamese-speaking and the deaf, designed as a ready reference for use of paramedics and others in emergency situations to be assembled by the City of Santa Ana Fire Department; a comprehensive community outreach program involving translated preparedness materials for Westminster's Vietnamese population conducted by the City of Westminster's Emergency Services Division; create a cadre of trained school staff to further train school personnel in use of the Hands-On Earthquake Learning Package, a project of the Los Angeles Unified School District; development of a home and commercial business guide to preparedness in English and Chinese, supplemented by a multi-cultural videotape by the Neighborhood Improvement Division of the City of Monterey Park. Local jurisdictions were to submit quarterly reports and complete funded work by June 30, 1986.

In December, 1985, the City of Santa Ana indicated that difficulties had been encountered in complying with the work originally proposed. Ultimately, the contract was canceled and funds were redirected to the LIP project undertaken by the Los Angeles Unified School District. In the last quarter of the funded projects, it became clear to SCEPP that final products would not be received from most of the local jurisdictions in time. SCEPP provided assistance to these jurisdictions to promote completion of the projects in a timely fashion.

SCEPP initiated a second cycle of the LIP program in March, 1986, with the issuance of a Request for Proposal. Eighteen proposals were received by the May 21, 1986, deadline. Three proposals were approved for funding.

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The County of Ventura, Sheriff's Department received LIP funds to pursue a program entitled "Silent Quake: Preparedness for Persons Who are Deaf". Also funded was a project by the County of San Bernardino, Department of Housing and Community Development entitled "A Cooperative Approach for Identifying and Financing Seismic Retrofit in California." A third award to the City of Los Angeles Fire Department for "Volunteer Response Team Training" was declined after consideration of available resources and scheduling. Products of the two remaining projects were to be completed by April, 1987.

Discussions of a strategy to transfer LIP-generated projects to other jurisdictions have taken place within SCEPP and between SCEPP and BAREPP. These discussions resulted in plans to develop a consistent format for the "how to" documents provided by the contractor and to "package" these products for more effective transferability. Rather than promote the use of these products through a conference designed specifically around LIP, SCEPP will make them available within the context of other SCEPP tasks over the next three years.

SCEPP'S FUTURE

Late in 1986 as SCEPP's second legislated extension drew to a close, the basic question regarding continuation of the Project was once again raised. Among those involved with SCEPP, the general consensus was that promotion of earthquake preparedness in southern California should continue and that SCEPP was the most appropriate vehicle for this mission. SCEPP was credited with having successfully encouraged and supported local preparedness and hazard mitigation efforts and, in recognition of this accomplishment, should be continued for an additional three years. On the basis of this assessment, the Seismic Safety Commission sponsored legislation, introduced by Senator Alquist, which continued SCEPP until June 30, 1990. Senate Bill 1973 passed the legislature and was signed by the Governor in September of last year.

SB 1973 authorized the continuation of SCEPP and BAREPP activities by mandating that:

> "The projects authorized by this chapter shall promote voluntary actions by local jurisdictions, volunteer agencies and associations, and private organizations which address all aspects of seismic safety, including, but not limited to, mitigation, public information and education, response, and recovery planning."

In identification of activities which the projects might pursue the legislation is flexible.

> "The projects may do all of the following:
>
> (1) Provide planning and technical assistance for developing and implementing earthquake hazard mitigation and loss prevention programs that reduce earthquake vulnerability.

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(2) Provide planning and technical assistance to improve regional, local, community, corporate, and public and private school preparedness.

(3) Provide planning and technical assistance to local jurisdictions to improve regional and local agencies' response capabilities for predicted and unpredicted earthquakes.

(4) Participate with local, regional, state, and federal agencies, councils of government, and private organizations in providing education and training workshops and conferences on comprehensive earthquake preparedness.

(5) Promote innovative approaches by local jurisdictions in the areas of public education and individual, community, and private-sector preparedness."

The flexibility provided in this language allows the projects ample opportunity to continue many successful programs now underway and the equally important opportunity to address new planning needs.

SUMMARY AND CONCLUSIONS

The overall goal of SCEPP has been "to stimulate preparedness for predicted or unpredicted catastrophic earthquakes in the most heavily populated portions of a five-county region in southern California." This goal has provided a framework for a more functional set of operating objectives which have defined the project's many individual tasks. These objectives included: the development and transfer of a prototypical planning process and plans through which preparedness in southern California would be greatly enhanced; to promote interdisciplinary and intergovernmental discussion of earthquake prediction and promote development of an operational prediction evaluation warning and response system; to generate enhanced awareness of the earthquake threat and understanding of earthquake hazards; and to place regional level earthquake planning on the public policy agenda.

While SCEPP's goals have remained constant, strategies and activities have shifted to reflect changes in the planning environment. Despite an ambitious "task" oriented Work Program for SCEPP's first three years of operation (1980-1983), much groundwork remained to be accomplished. A new and largely "generalist" staff worked to gain an understanding of problems, issues and planning needs. Planning partnerships were established; in some cases, painstakingly cultivated and maintained. Target audiences were identified and products to address the needs of these groups were developed. By the time implementation of the second Work Plan began, SCEPP had consolidated its program into four functional areas which more closely focused the Project's efforts. Specialization occurred among staff although the team concept was maintained and strengthened. It became clear that the gaps in preparedness were significant and that despite SCEPP's best efforts some needs would not be met.

Based on the retrospective account of SCEPP's first years of operation, a number of conclusions or summary statements seem in order. These conclusions, framed as lessons learned, will touch on various aspects of the

Project, its structure, and methods of operation.

- Planning Partnerships: Close working relationships with the public and private sector were of critical importance in gaining insight into the workings of local government, business and community-based organizations. Perhaps the most beneficial outcomes of these partnerships were mutual respect, trust and empathy which facilitated development of a "bottom up" or "user driven" planning process. In assembling prototype materials with planning partners, SCEPP and the PAB were able to identify the most critical planning needs early in the life of the Project thus avoiding unproductive ventures beyond the resources of the Project.

- Transfer and Application: The transfer of products developed through the planning partnerships proceeded in a systematic manner. By all measures employed to evaluate the transfer strategy, the county-based conferences were highly successful in raising earthquake awareness, promoting an understanding of SCEPP's planning process and motivating SCEPP's target audiences to evaluate their preparedness needs. SCEPP's expectation that transfer and orientation to the planning guides received at the conferences would lead to the immediate initiation and implementation of comprehensive preparedness programs, however, was overly optimistic. SCEPP discovered that there were barriers and constraints in the planning environment, some serious enough to preclude comprehensive planning. Planning and technical assistance requirements of SCEPP product users were greater than anticipated.

- Peer Review and Evaluation: Early in the design and evolution of the Project, a system checks were instituted to assure that products and materials developed by SCEPP met the needs of users. The most common "quality assurance" check was peer review in which a group of knowledgeable and experienced professionals were asked to review a product prior to publication. The goal of this process was to assure current, accurate and relevant information and instruction. Two evaluation studies were conducted to assess progress in meeting SCEPP's goals. One of those was a lengthy narrative history and analysis of the Project by an outside reviewer. The other was an internal review of transfer, application and planning assistance. The significance of these procedures beyond the obvious program benefits is the fact that Project leadership was willing to undergo close scrutiny.

- Comprehensive Planning: SCEPP developed and transferred a comprehensive planning process which places appropriate emphasis on long-term preparedness and hazard mitigation, prediction, emergency response and recovery. While full implementation of the SCEPP process has not been widespread in the region, evaluation research has demonstrated that SCEPP has stimulated discussion and review of existing plans in light of the recommended process and planning elements. It appears that there is, among all SCEPP target groups, an emerging consensus that emergency response planning alone is insufficient and that other planning elements, especially preparedness and hazard mitigation, must be addressed.

- Research Application and Knowledge Transfer: SCEPP has a record of innovation both in its own program and in the information and knowledge the Project has made available to organizations in the planning region. SCEPP's planning and public information materials have been based on state-of-the-art knowledge in the fields of seismology, engineering, social sciences, public administration and planning. SCEPP as served as a key link between knowledge producers and knowledge users by interpreting and packaging important new ideas as well as developing innovative approaches to knowledge transfer. The three Asilomar prediction workshops are examples of this process wherein policy level representatives of the scientific community, local, state and federal emergency management, social sciences, business and industry and the news media met to discuss the complex issues associated with the emerging technology to predict earthquakes.

- Regional Planning: It was clear to SCEPP and the PAB very early that a catastrophic southern California earthquake would have a regional impact. Nevertheless, it was reasoned that public and private sector entities must prepare at the organizational and jurisdictional level before regional approaches could be considered. SCEPP has taken basic steps toward a regional planning focus through completion of the RIMS pilot project and initiation of basic studies to identify regional needs and planning issues. Despite these important steps, regional planning remains a concept, though one which SCEPP has pursued as a basic objective.

- Neighborhood and Community Preparedness: Perhaps the most critical need for individual and group preparedness lies at the neighborhood and community level. Yet sustained and effective preparedness programs have been difficult to establish due to a lack of organization at the local level, inadequate resources and low salience of the earthquake threat among residents, business owners and other neighborhood-based groups. SCEPP has, however, provided assistance to numerous individual community groups in the planning region with positive results. SCEPP's Model Community Self-Help Campaign, recently introduced at a well attended conference provides strategies for overcoming barriers and has generated considerable interest among community organizers.

ADVOCACY OF EARTHQUAKE PREPAREDNESS: THE BAY AREA REGIONAL EARTHQUAKE PREPAREDNESS PROJECT (BAREPP)

By
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I. THE BAY AREA REGIONAL EARTHQUAKE PREPAREDNESS PROJECT

The Bay Area Regional Earthquake Preparedness Project (BAREPP) is the second of two regional earthquake preparedness programs initiated and supported by the Federal Emergency Management Agency (FEMA) and the State of California.*

The first earthquake preparedness program initiated by FEMA and the State was the Southern California Earthquake Preparedness Project (SCEPP). Its role was to develop innovative approaches to local earthquake preparedness. Earthquake preparedness planning was initiated by the Bay Area Earthquake Study (BAES) in 1983 which laid the groundwork for the development BAREPP. Funding for BAES was provided by FEMA to the California Seismic Safety Commission to undertake a needs assessment and develop a constituency for an earthquake preparedness project in the San Francisco Bay Region. BAES' purpose was to determine what incentives and support would induce local government officials and the business community to initiate earthquake preparedness activities. BAES research identified technical assistance and resource materials as key ingredients to local action and defined the target audience as elected officials and senior management in both government and business. BAES laid the groundwork for the creation of BAREPP by the Commission in 1984.

By 1984 SCEPP had developed a variety of instructional planning guidelines for local government and business preparedness, based on the concept of *Comprehensive Earthquake Preparedness*, derived from the comprehensive planning theories of city and regional planning. With SCEPP's materials available, the Bay Area Regional Earthquake Preparedness Project (BAREPP) began an implementation program to disseminate guidelines and support local preparedness programs . This second phase of BAREPP's work focused on the following areas:

- Public advocacy of earthquake preparedness
- Promoting and facilitating local government and corporate preparedness through the provision of planning and technical assistance

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*Federal funding for both SCEPP and BAREPP is provided by the National Earthquake Hazards Reduction Program (NEHRP)

- Dissemination of a project newsletter, *NETWORKS*, as a vehicle for intra-regional communication
- Developing a Regional Resource and Information Center containing a library of publications and training materials
- Developing alternative methods of advocacy and information dissemination
- Conducting earthquake preparedness campaigns
- Convening conferences and training workshops

BAREPP and SCEPP are not viewed merely as public information and educational programs. While a significant portion of staff time and budget focus on public information, particularly during the annual Statewide Earthquake Preparedness Campaign held each April, on a daily basis, the project operates as a conventional consulting firm. Project staff work with senior staff of jurisdictions to help generate political support for preparedness; organize staff and establish a planning process and work program; provide planning and technical support to the jurisdiction's program; and serve as facilitators to assist local government staffs. BAREPP's Regional Resource Center, which houses technical publications, training materials, and an extensive library of slides of earthquake damage is both a staff resource and a regional depository of technical information. Using project resources and their professional experience in earthquake preparedness, BAREPP staff act as both translators of technical information for a public audience and advocates of earthquake preparedness.

The central theme of BAREPP's work is advocacy, and the resources SCEPP and BAREPP produce provide the technical and information base for that advocacy. BAREPP's charge is to change how people think about the earthquake threat and how they behave in response to that knowledge. BAREPP is in the business of application and therefore takes a very pragmatic view of research.

BAREPP is currently completing its third year of work in the San Francisco Bay Region as part of the California Seismic Safety Commission. On July 1 the project will be transferred to the Governor's Office of Emergency Services to join SCEPP in a combined northern and southern California earthquake preparedness effort. While there will be joint administration of the two projects, the focus of BAREPP will remain on the 10 counties of the San Francisco Bay Region. This focus reflects a traditional affinity between the region's counties and a project area containing the majority of the population at risk to earthquakes in the north-central portion of the state.

In passing Senate Bill 1973 which extends BAREPP and SCEPP until 1990, the State of California made a significant commitment to comprehensive earthquake preparedness programs that emphasize mitigation. In fact, while federal resources available to the State through NEHRP have declined by 50% in the past year, State resources have increased to ensure the continuation of the program effort.

II. RESEARCH APPLICATION BY BAREPP

In describing the application of research by BAREPP it is necessary to distinguish between the direct application of the research findings and what might best be described as the anecdotal application of research. The first category, direct application, describes a structural engineer incorporating data and research findings derived from an assessment of post earthquake damage to structures into a professional engineering practice. The second category, anecdotal application, involves narrative descriptions of cause and effect that are general in nature and refer to the general conclusions drawn from specific research findings. BAREPP's use of research falls into this second category of application. The target audience of BAREPP's programs are public officials, business leaders, and members of community organizations who need to know the effects of earthquakes, but are not necessarily interested in knowing the mechanics of structures and materials. The objective of BAREPP's transfer of information is *awareness* and *familiarity* rather than *knowledge* and *competence*. This distinction describes both the role of BAREPP as a translator of technical research findings and BAREPP's method of information dissemination which involves narrative rather than data and focuses on general causal relationships rather than technical detail.

This orientation is evident in the following descriptions of research that supports the efforts of BAREPP. To the five questions of the journalist "Who? What? Where? When? and Why? we have added "How?" so that we can draw on research findings which address not only the message, but the content and delivery of information.

▩ **What will happen?**

- Research on building damage and damage mechanisms
    What types of structures are vulnerable to damage?
    What are the "weak links" in these structures?
    What is the "mode of failure?"
    (Note: Recently completed research developing building vulnerability data that presents expected damage as a percentage of "Cumulative Damage Potential Expressed as Expected Damage Discounted to Present Value" is difficult to translate for local businesses or city officials).

- Research on geologic manifestations of earthquakes
    Fault mapping
    Mapping of liquefaction potential
    Mapping of areas of potential ground failure
    Mapping ground shaking intensities and potential
    Microzonation studies

- Development of regional scenarios depicting regional inter relationships and potential damage to lifelines

- Research on human behavior before, during and after earthquakes
    - Occupant behavior in various building types and environments
    - Community group response and organization

- **Where and when will it happen?**
    - Probabilistic studies of earthquake potential

- **Who can change what will happen?**
    - Studies to determine level of official awareness
    - Studies to determine who effects change in government and business
    - Studies of organizational behavior
    - Identification of key decision makers
    - Studies to determine what will motivate these key actors

- **How do professionals communicate effectively?**
    - Marketing studies of target groups
    - Program and project evaluations to determine cost effectiveness

III. BAREPP'S ACTIVITIES THAT FACILITATE APPLICATION AND DISSEMINATION OF RESEARCH

BAREPP's dissemination activities fall into the following categories:

Planning Partnerships/Planning and Technical Assistance

As planning consultants to officials of local governments and businesses BAREPP staff draw on research findings to assist these officials with specific applications. Such applications include geologic and seismic data and data on building stock and earthquake performance used in a local vulnerability analyses; data on building performance and its relationship to injury and occupant behavior for presentations to employee training; and marketing data used to develop community campaigns.

Regional Conference

More than 750 business and government managers participated in BAREPP's first Regional Conference in April, 1986. Information of a general nature about the earthquake threat and the comprehensive earthquake preparedness approach were presented to an audience of local government officials and business leaders. The information was packaged for distribution and presented with graphic materials. Small group breakout sessions on specific topics followed the plenary sessions. In the breakout sessions business and government leaders who had initiated preparedness programs in their agencies, rather than by consultant "experts", made the presentations "Experts" on the success of these programs were found among the members of the audience.

Training Workshops

Three sets of training workshops on specific topics were convened at locations throughout the Bay Region to provide specific information about earthquake preparedness to government and industry staff with operational responsibilities. These workshops presented research findings from the recent Mexico City, Coalinga, and El Centro earthquakes that addressed specific interests of workshop participants. For example, presentations for managers of high-rise buildings included data on building performance, earthquake effects on building contents, occupant behavior, and preparedness needs.

Earthquake Preparedness Campaigns

BAREPP participates with SCEPP and the Governor's Office of Emergency Services in organizing and coordinating the annual Statewide Earthquake Preparedness Campaign. General information on individual preparedness is provided to local governments for dissemination to the general population. In addition, BAREPP supports local government community awareness programs of a number of jurisdictions in the Bay Region. For the past two years, BAREPP has experimented with a "marketing approach" to promote earthquake preparedness. Using methods derived from marketing research and employing the assistance of a public relations consultant, BAREPP staff helped organize earthquake preparedness campaigns in a Daly City shopping center and in a group of retail shops in San Jose. The campaigns were timed to coincide with the Statewide campaign.

Press Briefings

BAREPP has developed working relationships with the region's major media outlets. After two years the project has successfully become a contact point for reporters seeking interpretation of seismic information provided to the media by other organizations. In this role BAREPP translates technical information for reporters and provides additional sources for interpretation of events. After the Mexico City Earthquake this relationship gave BAREPP the opportunity to feed information and research findings to reporters who wanted to relate the events in Mexico with potential earthquake problems in the Bay Region. Stories citing previously published research on the geology of the region, building performance, and the potential impact of a major earthquake on this region were printed in Bay Region newspapers.

More recently BAREPP organized a press conference to announce the release of a scenario for an 1868 type earthquake on the Hayward Fault. The press briefing resulted in coverage on the evening news segments of the CBS, ABC, and NBC television and radio network affiliates and in feature articles in the region's daily press.

IV. IMPROVING THE IMPLEMENTATION PROCESS

There are significant voids in research data that if filled would allow more effective use of existing information and technical data. While additional research is clearly needed in the fields of seismology, geology, and building performance, there is an even greater need to develop more effective ways to use the data we now have. The research community has known since 1933 that unreinforced masonry structures in seismically active regions pose a threat to life. The Caracas and San Fernando earthquakes taught us that non-ductile concrete frame structures are a collapse hazard. The impact of building configuration on structural performance is now well known, as is the relationship between site geology and ground shaking intensity and duration. There will be few surprises in the next moderate or larger earthquake that strikes California. The question that begs to be addressed by researchers is how we can more effectively use existing information. This question can be divided into the following areas for research:

- Cost effectiveness of preparedness program activities
- Market research on motivating government and business preparedness
- Studies of the social and economic impacts of hazard abatement programs
- Development of financing methods for strengthening existing structures

Nearly 83% of the federal funding provided by the National Earthquake Hazards Reduction Program (NEHRP) supports research activities of the National Science Foundation and the United States Geological Survey. In contrast support from NEHRP for state and local programs to reduce earthquake hazards through the application of existing data was recently reduced from $1.5 million to under $1 million a year.

The need to support earthquake research is well documented. However, the research priorities of NEHRP must also acknowledge the need to develop and support effective <u>application</u> and <u>implementation</u> programs through the provision of adequate and consistent funding.

The question that will be asked after the next damaging earthquake will not be "Why did it happen?" The question will be "After spending so many dollars on research, why were we not able to prevent the loss of life, injury, damage, and economic disruption?"

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THE CALIFORNIA EARTHQUAKE EDUCATION PROGRAM

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Introduction

The California Earthquake Education Project is a major activity of the Lawrence Hall of Science, University of California, Berkeley, Funded by legislative act of the State of California, CALEEP has developed extensive educational materials for schools and community groups on earthquake science and earthquake preparedness. The project, currently in its dissemination phase, is a cooperative effort between the Lawrence Hall of Science and the California State Seismic Safety Commision. Legislative funding for CALEEP over the last six years has totalled nearly $1,000,000.

Goals:

CALEEP activities are designed to:

- Increase participants' awareness of potential earthquake hazards.
- Teach participants preparatory measures that may reduce injury and financial loss from earthquakes.
- Encourage participants to take action to improve personal and community safety and well-being during and after earthquakes.
- Utilize public and student interest in earthquakes to teach basic concepts and processes of geology and other sciences.

The CALEEP program, which includes over twenty educational activities, is available to teachers, science coordinators, and community leaders. These activities, classroom-tested during a two-year pilot program, emphasize participatory, materials-based learning. Participants are encouraged to explore earthquake concepts through a variety of mediums including: "vicarious field trips" to places in the world where fault movement is occurring, a tape recording made by an Anchorage resident as he experienced the 1964 earthquake, neighborhood hazard inspection tours, and a wide variety of maps and charts. Plans are made and budgets drawn up for making a home quake-resistant; individuals attempt to "survive" a computer-generated 'quake, and groups act out their responses to various earthquake scenarios. The diversity of this set of activities allows leaders and teachers to design programs that best address the needs and abilities of their group or class. A description of each activity can be found in the CALEEP sampler[1]. All materials are provided at cost, and permission is granted to users to reproduce worksheet masters for participants.

Research Which Contributed to CALEEP

The CALEEP program is primarily needs driven. Two different kinds of needs have significantly shaped the effort. First, there is the nationally recognized need for more effective earthquake education to increase preparedness and contribute to the mitigation of the effects of serious earthquakes. The interest, effort, and cooperation of the California Seismic Safety Commission, the California State Department of Education, and the Lawrence Hall of Science of the University of California in conceptualizing and getting the CALEEP project started is clear evidence of the realization of the need in California. The significant funding, received to date from the California State Legislature to support the work of CALEEP, is clear evidence of the acceptance of the impoartance of the need by the leadership and the people of the State of California. The current importance of the need is clearly emphasized by the following statement from <u>California At Risk</u>: Reducing Earthquake Hazards 1987 to 1992[2], the official program of the state under the legislatively enacted California Earthquake Hazards Reduction Act of 1986.

> "Earthquake education and information are crucial to improving earthquake safety. The initiatives presented below rest on the beliefs that properly educated citizens can save lives and reduce property damage by informed action before, during, and after earthquakes, and that the students educated about earthquake safety today will be better able to cope with them now, and as the adults of tommorow. Moreover, providing earthquake education and information is a cost-effective approach to increasing earthquake safety, as money invested in teaching people how to make their own homes and workplaces safer can bring substantial dividends as they carry out these earthquake safety measures and encourage others to do the same."

The second kind of need that has significantly shaped CALEEP is the need nationally and statewide for more effective science-technology-society oriented science education in the schools. Documented in numerous national and statewide conferences and reports[3], the need and the difficulties involved in meeting it are well known. CALEEP uses both teacher and learner interest in a societal issue of importance (effects of earthquakes in this case) as the motivator for more effective basic science and technology education. This approach is proving highly effective in contributing to meeting the need for more effective science education for citizens in our society.

At least two kinds of research studies provided the knowledge base that made CALEEP possible. First, the studies by Nigg, Tierney, Turner[4] and others on what the public does and does not know about earthquakes; how they handle information when it is presented to them; and how they react at the time of a disaster or increased perceived risk of a disaster. The challenge, these studies and others presented for CALEEP was the fact that although it is posible to make the public <u>aware</u> of earthquakes and their effects, it is very hard to sustain the public's interest over an extended period of time. More important, it is very difficult to get the public to take <u>action</u> to prepare themselves and their communities to help mitigate the effects of an earthquake. This information and the results of the public survey carried out by CALEEP right at the start of the project indicated that it was important to build on awareness and develop understanding of the causes of earthquakes and their effects on people and property. This understanding, combined with practical suggestions for preparedness and mitigation efforts, is necessary to increase intentionality and bring about direct action by individuals to prepare themselves and contribute to their communities' efforts to mitigate the effects of earthquakes. This is why more than public information campaigns, to make people aware of the issue, are needed. Public education, with its emphasis on long-term efforts is needed to develop enough understanding and intentionality on the part of individuals to motivate actual preparedness action.

The second group of research studies contributing to the knowledge base for CALEEP, are the wide variety of efforts to understand science and how to teach it to learners of various ages[6]. A unique contribution of CALEEP has been the bringing together of individuals and groups concerned about earthquake preparedness and mitigation research with those concerned about how to more effectively teach science and technology to learners of various ages. This has led to the identification of challenging areas for increased future research, such as what can be the role of students in instructing and motivating their parents regarding earthquake preparedness and mitigation activities.

Activities That Facilitate the Development of CALEEP

Identifying the specific need for more earthquake science and preparedness education, as part of the general need for more effective science and technology education in California, was an important step that facilitated the research application process. By identifying how the specific CALEEP goal of earthquake education could be accomplished, as part of the school systems' desire for increased quantity and quality of science education, made CALEEP something that contributed to acomplishing the goals of the school. It did not become something "extra" recommended or mandated and, therefore, considered a burden by the schools. In order to accomplish this right from the beginning, CALEEP worked closely with the State Department of Education and leading school systems and science educators in the state in the formulation of the content and approach of the program. Knowing from the beginning that the success of the program would be determined by the desire of the teachers in the classroom to use it, practising teachers were involved as part of the project staff from the onset. In addition to the teachers who, on leave from their school systems, worked full time with the project, extensive use was made of the classroom as a laboratory for development. This emphasis on the classroom as the laboratory for designing and evaluating the activities of the program, was combined with the expertise and experience of the Lawrence Hall of Science in developing and disseminating educational programs. Project staff at Lawrence Hall, made up of teachers, earth scientists, and science educators, utilized the unique scientific and human resources of the University of California, Berkeley campus, in order to effectively design the educational materials of the project. The essential work of designing the program was carried out by the core staff of the project working at the Lawrence Hall of Science. Early, carefully monitored and analyzed trials of the project's activities by classroom teachers in Northern and Southern California provided the field-based input necessary to effectively translate the needs for earthquake education into material that teachers would want to use in <u>their</u> instructional programs. The support of the legislature and leadership of the California Seismic Safety Commission in establishing the program, were critical to the development of the program. The clear identification by the legislature and Seismic Safety Commission of the importance and need for the program, gave it status in the education community. Carrying out the program at the Lawrence Hall of Science, with the early and extensive involvement of teachers and other school leaders from the field, helped to prevent the schools from considering the program another demand put on them by an outside agency. Working closely with the State Department of Education, the activities developed were correlated to the expectations for science education in the state. In this way, it was possible to present teachers and schools with edeucational materials that helped meet a significant societal need (earthquake proeparedness and science education), while contributing to their own goals for the instructional program at science in their school[1].

Dissemination of the CALEEP materials

The finest educational innovations or research applications are worthless if they are not used. Dissemination of educational materials, so that they become a real part of the ongoing instructional program of the schools, is a complex task. From the very beginning of the project, dissemination has been a major concern in all activities undertaken by CALEEP. During the early design and development phases of the project, schools and school leaders in northern and southern California were made part of the process by acting as trial schools. Rather than just using these schools for CALEEP's purposes, significant efforts were made to develop local leaders in each situation. The materials were developed as individual activities, with many choices open to the local district or school in how they were to use them. This has encouraged a wide variety of formats for using CALEEP, ranging from schools that use selected activities to enrich their existing science and social science programs, to those school systems that have used the materials as a resource to design their own preparedness curriculum based on CALEEP. CALEEP has focused on the development of local leadership, using a variety of models to accomplish this goal. Major events used to initiate this process were awareness and training events put on by CALEEP staff for teachers and other local leaders. Awareness sessions are up to 3 hours in length, require little commitment on the part of the attendee beyond being there and are intended to introduce the program to an area. Training events are about 6 hours long, require the commitment by the individual or the school system to purchase the CALEEP kit and are intended as the beginning of extensive local use of materials. Staff costs for training and, in the early years, part of the cost of the materials were subsidized by the project out of its limited budget. This decision caused some problems, such as overspending when interest and participation increased rapidly but in retrospect, was necessary so that uptake would be widespread as intended by the legislature. Trained individuals were encouraged to become local leaders by being given incentives (special equipment, honoraria etc.) to organize and put on awareness and training sessions in their own area. Special leadership development events were held to build independence into identified local leaders and this process is continuing at present. As part of the leadership development phase of the project dissemination and implementation centers were established at six campuses of the California State University system. Established with the cooperation of the State University chancellor's office and as a result of competitive proposals these centers have proved to be highly effective in institutionalizing the program in various regions of the state. Equally important, each center has evolved approaches for involving pre-service teachers in the program ranging all the way from awareness sessions to building CALEEP training into the basic teacher preparation program of the campus. This emphasis on training of pre-service teachers is particularly effective, since as these individuals obtain positions they bring knowledge of the program to many schools. Their expertise reduces the need for continuous initial training events at the school level. Presentations at professional meetings and the publication and distribution of the CALEEP newsletter have made significant contributions to the dissemination process. Last, but certainly not least, the materials themselves have been designed with dissemination and implementation in mind. For example, the Earthquakes, Environments and Effects videotape was designed as a vehicle for getting groups interested and involved. It has been used very effectively to kick off programs and as a means of encouraging parental participation in the preparedness efforts. The <u>Living Safely In Your School Building</u> brochure and related activities were designed to focus on non-structural hazards (an area where one can easily make a difference), as a means of encouraging broad based support from school safety officers and similar individuals concerned about preparedness. This has contributed to the implementation of the overall CALEEP program.

Throughout the program, significant efforts have been made to make the program known to professional and parental leadership of the public and private schools in the state, by participating in their meetings and conventions and organizing various events at their request. The project has also coordinated its efforts with other groups such as the Bay Area Earthquake Preparedness Project (BAREPP), the Southern California Earthquake Preparedness Project (SCEPP) and various other groups, such as the American Red Cross, and Junior League, concerned about earthquake planning and preparedness. Special efforts were made to coordinate the work of the project with the public information interests and efforts of the State Office of Emergency Services and interested county OES offices. This proved highly effective in getting the program more widely known by cooperative efforts, such as CALEEP's preparation of the school oriented materials for use in the Governor's Earthquake Preparedness Week activities in 1985. This cooperative effort with OES provided effective, usable preparedness materials to schools for use during the week, while helping to make these schools more aware of the entire CALEEP program. In 1987, at the request of the California Science Supervisors Association, CALEEP made available a similar set of preparedness materials for use during Earthquake Month. This cooperative, low cost, somewhat informal, effort proved highly productive in further encouraging local leadership.

Each of the major dissemination activities described above and the many others too numerous to describe here, were significant in one way or another to the growth of the program. Considering the size and complexity of the State of California and its educational system and the relatively small size of the CALEEP budget, the decision was made to use a wide variety of approaches to encourage as much local leadership as possible. Therefore, it is very hard to identify which events or approaches were not significant. Rather, as described in the next section, the real issue is which events should have been given earlier and/or greater emphasis.

Improving the application process

The CALEEP dissemination process is still underway and significant future dissemination and implementation needs exist. Therefore, the "perfect hindsight", that allegedly becomes available at the end of an effort, is surely not now available. However, looking back, it is clear that a number of things would be done differently, if we knew then, what we know now. There are, however, two constraints that determine the comments that follow:

1. It is assumed that the size of the CALEEP budget (approximately $135,000 year in direct costs) would be the same and the expectations for the project to have impact statewide were maintained.

2. Despite the significant efforts made by CALEEP, the Seismic Safety Commission and others, the actual commitment of resources to the project by the State Department of Education would have remained the same.

CALEEP started up and has operated during a period of economic crisis for the California Public Schools. This has been a major factor in preventing the State Department of Education's financial involvement in the program.

Accepting these constraints, it is clear that first, if possible, the regional centers in cooperation with the California State University System should have been established earlier in the life of the project. They are effectively accomplishing the goal of providing regional resources, sensitive to the differences found in various regions of the state. Second, the teacher's mini-kit or $25.00 kit, designed this year, should have been offered earlier. Although it requires some limitations and compromises regarding the breadth and quality of the program's experiences, it appears to be a necessity, considering the increasing economic problems fared by the schools. It also makes available additional alternatives to schools wanting to adopt the program.

Knowing what we know now other changes would involve greater or lesser allocation of limited staff resources to various activites. A great deal of pragmatism and adaptability is necessary, if we are to really significantly affect formal education in the public and private schools of California.

This paper has concentrated on CALEEP's efforts to develop materials and disseminate them to the public and private schools of California. It has not focused on CALEEP's efforts in the community, which were an expectation of the program in the early years of the project. Work completed with the Girl Scouts of America, Senior Citizens Groups, Junior League and others has been highly effective, ranging from a girl scout badge in earthquake preparedness, to the evolvement of a cooperative program for young children involving Junior League (Oakland) and Audubon Nature Training Society (ANTS) leadership. CALEEP considers these efforts to have beeen extremely worthwhile and contributory to the quality of the school materials currently available. However, in recent years at the request of the education committee of the Seismic Safety Commission CALEEP has focused almost entirely on the schools. Had this been known from the beginning some different allocation of limited resources could have been made. The whole process has been evolutionary and probably was necessary, as the state, through the leadership of the Seismic Safety Commission and other agencies, has come to grips with developing effective long term statewide policies, practices and support for adequate earthquake information and education for all citizens of California.

The CALEEP effort has certainly been successful in raising the awareness of the public and private schools of the state to the need for earthquake science and preparedness education in California. Beyond awareness, the CALEEP effort has developed understanding in teachers and school leaders, regarding how they can effectively integrate earthquake science and preparedness materials into their ongoing instructional programs. Many are taking the action to make this a reality, but a great deal more needs to be done to accomplish the goal, which is a future adult population that:

1. Understands the nature, causes and potential destructive force of earthquakes.
2. Understands the value of, and takes the action to prepare themselves and their communities to mitigate the effects of earthquakes and
3. Understands the necessity, even in difficult economic times, to support necessary state and local expenditures for research, mitigation and preparedness efforts regarding earthquakes and the dangers they pose to life and property.

Summary

The accomplishments of the CALEEP program to date have been substantial. Outreach to schools providing information about the program and uptake and use of program materials by the schools has exceeded all expectations.

The project's efforts have clearly raised the awareness of the need for earthquake education in the state. The process of internalizing earthquake preparedness and earthquake science experiences into the instructional programs of the schools is well underway. Needed to continue growth and development of the program statewide are: further developmental efforts, especially in relation to secondary school materials; establishment of an earthquake education resource center in the state; continued availability of teacher and other educational leadership development activities; and ongoing leadership for earthquake education in the State Department of Education. Efforts are currently underway to obtain funding for these activities.

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PERSPECTIVES ON PUBLIC INFORMATION AND AWARENESS PROGRAMS IN THE PUGET SOUND, WASHINGTON AREA

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PAST PUBLIC INFORMATION AND AWARENESS PROGRAMS

Many efforts have been made to increase public information and awareness of the earthquake risk and the need for preparedness in the Puget Sound, Washington area at least as far back as the series of quakes between 1939 and 1949, and later, the April 29, 1965, Richter Magnitude 6.5 Puget Sound earthquake.

This has included the American Society of Civil Engineers, Puget Sound School Districts, the International Conference of Building Officials (ICBO) and the Seattle Building Department, Citizens and Scientists concerned about Dangers in Environment (CASCADE), Skagitonians Concerned About Nuclear Plants (SCANP), the Ad Hoc Committee on Geologic Hazards, the American Red Cross, the Seattle Council of Parents, Teachers and Students (PTSA), as well as agencies such as the United State Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), Offices of Emergency Services at the state, county and local level, the Puget Sound Council of Governments, and more recently, the Washington State Seismic Safety Council convened by Mr. Hugh Fowler, Director of the Division of Emergency Management, State of Washington, at the direction of Governor Booth Gardner. Numerous individuals have made contributions to public information and awareness as well.

Many of these efforts have resulted in significant gains, and certainly public and governmental awareness has increased, but none have resulted in a state level commitment to fund and embark on an on-going program of earthquake hazard reduction for the welfare of the citizens of the state of Washington.

SCHOOL EARTHQUAKE SAFETY AND EDUCATION PROJECT (SESEP) 1983-1986

The program to be looked at in more detail in this discussion is the School Earthquake Safety and Education Project (SESEP).

Defining the Needs: The Process and the Players

This section reviews the involvement and the steps taken to identify what needed to be done to improve the dissemination of public information and to increase awareness of state earthquake hazards among Washington residents.

In the early 1980's the Puget Sound Earthquake Preparedness Project was an entity organized and supported by Region X, Federal Emergency Management Agency (FEMA). It was a cooperative effort of local, state and federal government agencies, news media, educators, utilities, business and industry.

As part of the project, FEMA held an earthquake preparedness workshop on March 27, 1981. The workshop resulted in two task forces being established: one on Emergency Public Information and the other on Public Awareness and Education. Each was asked to complete the work by January 30, 1982.

In a cover letter accompanying the final report of the Public Awareness and Education Task Force, Mr. William Mayer, Regional Director of FEMA stated, "The public awareness of the earthquake hazard in this area must be raised through education and publicity programs." The Task Force recommendations dated January 25, 1982, included that programs should involve the entire community--schools, business, labor, volunteer agencies, etc.; and that they should be permanent and on-going.

Later that same year, 1982, the Washington State Department of Emergency Management conducted a survey of city and county emergency services officials within Puget Sound. The survey findings, sent to National FEMA, indicated that respondents felt their greatest needs were for public education programs and for school earthquake curriculum and preparedness programs.

Early in 1983 National FEMA was preparing to place earthquake education programs at three locations in the United States. Based on the information from the Washington State DEM survey, and the recurrence of Magnitude 6 and greater earthquakes in the Puget Sound, Washington area on an average of every 20 to 30 years, National FEMA selected Washington State as one of the three locations, and, the school population as the target population. Proposals were requested in the Spring of 1983.

To summarize, needs identified at the outset were that public awareness of the earthquake hazard had to be raised; the most effective method would be through permanent and on-going public education programs and especially programs targeted to the school community. These specific needs were identified between 1981 and 1983 through the coordinated efforts of federal agencies, state and local emergency services officials, the media, educators, business and industry.

Needs identified later are discussed in a section titled "Identification of Needs During Project," on page 4.

Description of the Project

Linda Noson, University of Washington seismologist, responded to FEMA's Request for Proposals in the Spring of 1983, and was awarded the grant to establish a school earthquake education program. The resulting program, the School Earthquake Safety and Education Project (SESEP) startup date was September 1, 1983. The funding was renewable yearly, for a maximum of three years. First-year funding was from FEMA through the Washington State Department of Emergency Management (WSDEM) to the Geophysics Program at the University of Washington in Seattle. Subsequent years were funded by the

Washington State Department of Emergency Management with money allocated by FEMA for state earthquake hazard reduction efforts. SESEP received two successive years of funding at the originally designated level; the third year, the project was continued, but at a reduced level. Total funding, FFY 1983 - FFY 1986, amounted to $138,000.

The year following the end of the original three-year project, a 1986-87 proposal for FEMA funds, with one-third local in-kind match, was developed by SESEP's staff and was approved and funded. This one-year project ends September 30, 1987.

The level of effort maintained consistently throughout the four years has been a part-time director and a part-time program assistant. From time to time specialists have been added to the staff who have been given specific tasks: FY1--a research consultant was retained to evaluate the effectiveness of using geology education materials designed by the Environmental Volunteers of California in condensed presentations focused on earthquake safety and education, also a graduate student with a seismology background worked as staff part time; FY2, a part-time volunteer coordinator was added to recruit, train and schedule a volunteer corps; and the final year, a graduate student in curriculum and instruction worked part-time on curriculum development.

Key players over all four years of the project were Linda Noson and Carole Martens. Linda Noson, a University of Washington seismologist, was a member of FEMA's Public Awareness & Education Task Force, and co-chaired, with Peter May, the Washington State Seismic Safety Council. Carole Martens is a teacher, active in school affairs, a registered citizen lobbyist--seismic safety issues; and was a member of the Washington State Seismic Safety Council.

The FY1 scope of work was ambitious. The task timeline required that several demanding and time-consuming tasks be accomplished during the first three months after startup. Some of the tasks were:

1. Make suggestions for modification of FEMA's <u>Guidebook for Developing A School Earthquake Safety Program</u> by September 19; and modifications and adaptation of the Environmental Volunteers' earthquake education materials for local use by October 14.

2. Introduce materials in Task No. 1 to the selected school populations.

3. Conduct a project planning workshop--report due November.

4. Establish an advisory board--report due November.

5. Produce a monthly newsletter.

6. Design and implement a tracking mechanism for the dissemination and use of products and services--due November.

7. Develop a method for measuring effectiveness of our products and services --due November.

8. Recruit and train volunteers: strategies due December; Actual due January.

9. Work with principals/earthquake safety committees in at least two K-6 schools to develop earthquake safety program action plans, and initiate their implementation.

Time and budget limitations resulted in focusing efforts on listed tasks 1, 2, 3, 4, 5, 7, and 9 and on two additional tasks: designing and implementing an "earthquake safety" day or week, one of the listed tasks; and seeking required approvals from the School District and the University of Washington Human Subjects division to pilot the SESEP project and work with students in the Seattle Public Schools, which was <u>not</u> one of the tasks. Permission to work within the Seattle School District was received November 15, 1983, considerably after the project startup date.

Internal/External Motivating Events

Some internal motivating events were: the Advisory Board which provided SESEP with a active sounding board for ideas, were willing to review documents and to act as expert resources;--Development/Director's Meetings in Washington D.C., during which staff gathered information, brainstormed, and shared ideas;--Volunteer program, the intent of which was to free staff from making all presentations, plus help "spread the word";--Education Research Consultant who provided professionalism in SESEP's testing method and success of presentations;--Workshops which informed, motivated and empowered others to become involved in earthquake preparedness.

External events also provided motivation: the Governor's annual proclamation of Earthquake Awareness Week; Media attention to SESEP and to the need for earthquake preparedness, both general and in the schools; the occurrence of major earthquakes and volcanoes: Mount St. Helens, Coalinga, Borah Peak, Mexico City, Chile and Nevado del Ruiz.

Identification of Needs During Project

Some project findings were: 1) motivation to develop earthquake safety plans existed because of the eruption of Mt. St. Helens in May of 1980, but no clear information on what to include and how to proceed was available; and 2) schools generally were unprepared for earthquake emergencies: drills were not required in all school districts; when required, they were frequently not carried out (Though earthquake drills were required in the Seattle School District in 1983-84, only 49 of the 67 elementary schools held drills); and parents were not informed about school emergency plans, if a plan existed.

Needs identified by the project clearly point out that past intermittent efforts to involve schools in earthquake preparedness activities had not achieved the level of preparedness desired. SESEP determined that schools were not prepared to handle earthquake emergencies, although some were motivated to begin earthquake emergency planning, and schools needed education and information to assist them in the process.
This lack of preparedness prevailed in spite of a statutory requirement, with mandatory language, that schools shall be prepared to meet sudden emergencies. RCW 28A.04.120 (10), Duties and Powers of the State Board of Education, written into the Washington Administrative Code (WACs), Chapter

180-41, Pupil Safety, in October, 1970, mandates that school district boards of directors shall be responsible for providing instruction of pupils and shall develop specific plans and procedures consistent with WAC 180-41...and in accordance with guidelines to be provided by the superintendent of public instruction.... Since its adoption, this statute has been narrowly interpreted to mean sudden "fire" emergency only. No other emergency planning has taken place on an institutionalized scale.

Contributing Research and its Funding Source
Initially, there were two important earthquake education tools used by SESEP. They were the draft version of the Guidebook for the Development of A School Earthquake Safety Program, developed with FEMA funding, and the Hands-on Earthquake Learning Package (H.E.L.P.) handbook and companion earthquake education models, developed by a non-profit group, the Environmental Volunteers of Palo Alto, California.

SESEP's field test of the Guidebook was a driver; the needs identified in the pilot schools testing the Guidebook drove the development of products. Some products developed to meet those needs were the User's Guide, (a brief manual to accompany the Guidebook), assemblies, lists of supplies and equipment needed, resource lists, etc.

Translation Activities that Helped Facilitate SESEP
Linda Noson's knowledge of earthquake risk information, and her ability to translate scientific terms and technical concepts, unfamiliar to the non-scientific community, into layman's language has helped school users at all levels, from Kindergarten through the State Board of Education, understand the risk and how it applies to them.

Carole Martens' knowledge of the school system structure, key individuals and the internal dynamics at various levels of the state's schools facilitated the introduction of new information into the public school system. She has been actively working as a volunteer in school affairs since 1973 and is well-known at both the local and state levels.

The User's Guide to the Guidebook for the Development of a School Earthquake Safety Program was developed to make the FEMA Guidebook more accessible to busy school administrators. The Guide contains page numbers and specific references to key sections of the larger document. It helps the user break down barriers set up by the size of the Guidebook. Another purpose was to supplement the Guidebook with information on regional seismicity. The User's Guide was developed by SESEP Staff.

Dr. Karen Brattasani, Educational Research Consultant, developed the pre-test/post-test design, the method for administering the test, and performed the assessment of test results. Her expertise and experience assured an unbiased test, both in design and administration and a valid translation of the results.

Because of the broad spectrum of expertise represented on the SESEP Advisory Board, all materials were given to the Board to review and revise. This process led to greater content accuracy and improvements in the final language.

Significance of Various Dissemination Events

A number of dissemination techniques were used during the life of the SESEP program: pilot schools, workshops, presentations, publicity through the media, volunteer corps and committees. Most were successful to some degree, but several could be rated extremely significant. These include the pilot schools, the workshops and the presentations.

Pilot Schools: Pilot schools were used as an initial strategy of the project. SESEP staff worked intensively with two pilot elementary schools the first year and three additional pilot schools the following two years. School staff and parents were given presentations. The Guidebook was field tested by the 5 schools, student assemblies were given, and hands-on learning center presentations on causes and effects of earthquakes and preparedness measures using the E.V. models were given to the studentbodies at least one time. This required two or three days at each school. The learning center lessons lasted 15 to 20 minutes. One class of 25 to 30 students, divided in two groups, rotated through the two learning centers every 45 minutes. Two pilot schools were selected for the pre-test /post-test. Also, SESEP staff worked with the earthquake safety committees of the pilot schools to assist in the development of their school earthquake preparedness plans. This level of contact resulted in a high degree of commitment at several of the pilot schools and led to information gained at school being used at home, shared at work, and in organizations.

Workshops: The workshops required tremendous energy in planning and preparation, however, both expected and unexpected results occurred as benefits of these events. School earthquake planning and preparedness at several schools, a special education program, and a school bus safety program all came about as the results of unexpected individual efforts following workshops.

Presentations: Presentations to targeted audiences also proved effective. This was made possible by the development of slide sets that could be grouped according to the needs of those who were scheduled to be in attendance at the presentations: principals, custodians, school nurses, teachers, parents, or students. These presentations were valuable in raising awareness of the earthquake risk in the Puget Sound region, and in particular how it impacts the school population.

Media coverage: Publicity was important to the SESEP program and the media was diligent in focusing attention on SESEP and the SESEP staff during times of worldwide natural disasters, or during the Governor's proclaimed annual Earthquake Awareness Week, and at other times such as during the legislative sessions when seismic safety bills were under consideration.

Committees: Establishing committees with broad membership to accomplish a specific goal:--Institutionalization of some elements of the program:
1. Safer schools manual supplement on science laboratory/classroom hazard identification and mitigation procedures. It is being developed cooperatively with the facilities divisions of the Washington State Office of

the Superintendent of Public Instruction (OSPI) and the Seattle School District (SSD), and two private consultants--a structural engineer and an urban designer. The manual is for publication and distribution by OSPI to school districts statewide.

2. Videotaping and distribution of earthquake education films:

a. School Earthquake Planning. Produced by Educational Service District #113, Tumwater, Washington, for general distribution upon request. The film covers information on Washington State seismicity, the importance of school district preparedness for earthquake emergencies, and the elements of a school plan.

b. Bus Driver Training Film. Produced by Seattle School District, Seattle, Washington, for distribution throughout Washington State, Canada, and the U.S., upon request. Covers historical earthquake occurrences and damages caused. Shows typical damage pictures and relates it to the situation bus drivers might find themselves in should a quake occur during bus route hours. Discusses importance of home preparedness for drivers and their families. (Scheduled to be filmed week of September 14, 1987.)

3. Bringing the concept of the environment's effect on man to the attention of the Basic Education Division of the Washington State Office of the Superintendent of Public Instruction (OSPI). This resulted in the inclusion of the concept within OSPI's environmental education curriculum framework. (See matrix below with comments by David Kennedy, Director of Curriculum, OSPI Basic Education Division.)

AIR	WATER	LAND	Row 1: Basic concepts. Everyone learns about air, water, and land.
PLANTS	PEOPLE	ANIMALS	Row 2: Everyone learns about how these three fit with air, water and land and lots of combinations.
ENERGY	BUILT ENVIRONMENT	HAZARDS	Row 3: Includes energy that drives the systems; the built environment because its something people do and its really central to our way of life and last is natural as well as human-made hazards--chemical hazards, earthquakes, lightening, landslides. Hazards relate back to all other areas and vice versa.

There is no other framework in the Office of the Superintendent of Public Instruction that contains anything at all to do with hazards. (End of Mr. Kennedy's comments.)

Previous developers of environmental education curricula (such as Project

Learning Tree and Project Wild) have limited the concepts included to man's effect on the environment and various ways to change behavior harmful to the natural environment. This matrix, when developed, will include the environments effects on man and man's ability to alter the harmful impact by selective actions.

Volunteer program: Volunteer workshops were conducted to train volunteers to give the hands-on learning center presentations.

The volunteer program proved to be unsatisfactory (not significant). The hope was that a corps of volunteers could be trained and available to respond to requests for presentations and to work with pilot schools and this would free up the staff to carry out other responsibilities. However, the time required to recruit, train, assign, and maintain the volunteer corps proved to be greater than the return warranted.

WHAT BARRIERS HAD TO BE OVERCOME?

BARRIER: An initial scope of work that was overly ambitious.
The task time line required that several demanding and time-consuming tasks be accomplished during the first three months after start up.

Seeking approval to carry out the project in the Seattle Public Schools was not included in the statement of work, but was a focus of staff efforts during the early months and the process took nearly three months to accomplish.

BARRIER: Administrative Turn-over--Lack of Continuity.
At the inception of SESEP, September, 1983, an internal conflict within the Seattle School District administration diverted attention. The superintendent resigned in January, 1984. His replacement retired two years later and a third superintendent was in place by the end of the first three years of SESEP.

The director of Facilities changed three times; the entire Professional Development staff was either RIFfed (reduction in forces) or retired during SESEP's timeframe; the budget director was released and a new one hired; the curriculum and instruction division was divided and re-staffed. Had this level of change been foreseen, it might have been decided to offer the program to a less complex, nearby school district.

BARRIER: Lack of Understanding of the Significance of the Earthquake Risk by School District Decision Makers.
For example, during a presentation to the Seattle School Board using slides and demonstrating the E.V. models, a member of the board of directors asked "Didn't the eruption of Mount St. Helens release all the pressure and we don't have to worry about earthquakes here anymore?" This common misconception points out the need for education programs at all levels.

BARRIER: Lack of Commitment to school earthquake preparedness.
A request for funding for earthquake emergency supplies and equipment for each school location within Seattle was made by the District Risk Manager as

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the result of a district earthquake preparedness advisory committee. It was initiated by the superintendent following a threatened boycott of the opening of school by parents and teachers at one of the pilot schools--housed in an unreinforced masonry structure. They wanted, among other things, earthquake preparedness measures taken at their school. The committee reviewing budget requests had received 72 requests. They ranked the earthquake supplies last--least important of all 72 requests.

Among the top ranked requests: Copy machines for the school offices. This was considered an immediate need, well understood by members of the ranking committee--many of whom were principals or past principals now administrators.

BARRIERS: School Earthquake Preparedness Funding is always in competition with highly visible and important causes: drug abuse prevention; AIDS curriculum development. This is consistently used as an excuse not to fund school earthquake preparedness. In districts where it is a priority, as it became in a neighboring school district, ways have been found to accomplish both.

STRATEGIES TO IMPROVE FUTURE PROGRAMS

1. Hold a Development Meeting prior to the initiation of future earthquake education programs.

A Development Meeting was held in Washington D. C. in November, 1983. In attendance were the project directors and some staff members from the three earthquake education programs, National FEMA staff, the National project supervisor, and developers of the Environmental Volunteers (E.V.) school program. The meeting covered familiarization with the E.V. program, discussions on networking, district level participation, recruiting volunteers, and program evaluation. The Development Meeting discussions and information, while valuable in November, would have been of even more value prior to the initiation of the project.

2. Reverse the task timeline. Begin with program development, have a program plan in hand when approaching a school district. Aim to introduce the project within the school district four to six months after the start of the school year.

This would allow time for the program staff to develop a preliminary program and establish networks within the school community, emergency response organizations, the media, and other important groups.

Already-developed materials could be identified, reviewed and adapted. An advisory board could be established. Strategies for publicity could be developed and ready. In other words, all preliminary planning and preparation could be completed before introduction of the program to the school district occurs. In that way, a package could be presented to a district that would include what you plan to do, how you plan to accomplish it, what you need from the district, and how the program will benefit the district.

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Timing the initial contact with the school district to avoid the opening of school could only improve the chances of success. Programs for the current year have already been established by the start of school. Optimum timing for school district consideration of new program options in Seattle is January-April. In Seattle, this is the budget setting period. Any program that has a budgetary impact that is to be implemented during the following year, must be entered into the budget process for consideration and adoption at this time.

3. Implement a quarterly written review of the program progress by the supervising officer.

This would give important feedback to the staff as to whether the expectations were being met. If expectations are not being met, direction could be given to help improve performance; if expectations are being met, encouragement can be given to continue on the present course.

CONCLUSIONS

SESEP's goals were to: 1) reduce the vulnerability of the school population to the life-threatening consequences of future earthquakes; and 2) improve students' knowledge and understanding of earthquake causes, effects and hazards. An undeclared goal was to transfer the learning from school to home and to the community at large through the students and the staff.

Successes that can be claimed by the program are, SESEP did raise awareness of the earthquake risk and of methods to reduce earthquake hazards among the school community; and it can be said with assurance that the students in the five pilot schools who had the benefit of the hands on learning center presentations know the causes and effects of earthquakes and self-protective measures to take. SESEP reached over 50 percent of all Seattle School District schools, 30 percent of the permanent staff members, and 11 percent of the 42,046 students. Beyond the Seattle Public Schools, SESEP reached over 50 public schools and school districts and numerous private schools and preschools in the Western United States and British Columbia, Canada. (See Appendix A, Summary of SESEP Activities.)

Also, a mailing of 250 survey questionnaires sent out during the current project year, resulted in a 17 percent return and the information that efforts made during the first three years of SESEP's existence, plus current efforts, are producing school planning and preparedness programs today--which reduces the vulnerability of the school population to the life-threatening effects of future earthquakes.

This leads to the conclusion that a limited, narrow-focused, short-term program, such as the School Earthquake Safety and Education Project, can accomplish a good deal, but does not have sufficient time to build the level of earthquake awareness and preparedness that a permanent and on-going program can foster. That desired level of success can only occur when the State of Washington recognizes the need for state level programs to educate the public and reduce earthquake hazards, and makes a commitment to provide leadership and the required funding. Until then, Washington State will remain at risk.

APPENDIX A

SCHOOL EARTHQUAKE SAFETY AND EDUCATION PROJECT (SESEP)
1983-September to 1986-July

SUMMARY

ACTIVITY WITH SEATTLE PUBLIC SCHOOLS

SCHOOLS

Over 50% (49 of 95) of the schools in the Seattle School District had contact with SESEP in one of the following ways:

1. Served as pilot schools
2. Requested information, consultation and/or presentations
3. Initiated a school program based on SESEP material
4. Registered for and attended a SESEP workshop

PERMANENT STAFF

Over 30% (1542 of 4795/June, 1986 count) permanent staff had contact with SESEP in one of the following ways:

1. Targeted Audience Presentations 430

Custodians	August,	1984	270
Nurses	Septem	1984	45
Principals	April	1986	90
Principals	March	1984	25

2. Two-8 hour Workshops 225

Jan.	1984	Pilot Sch (2)	15
Aug.	1984	Inservice	30
Oct.	1984	pilot sch (6)	25
Nov.	1985*	Planning	32
Feb.	1986*	Planning	90
April	1986*	Planning	33

*A small number of attendees were from outside SSD

3. Staff Presentations at Schools 887

High Schools		Middle Schools	
Franklin	104	Denny	52
Roosevelt	130	**Special Category**	
West Seattle	100	Wilson Pacific	54
		Marshall	37
		Sparples	65

Elementary Schools

Adams	40	Hughs	21
Brighton	28	Latona	29
Coe	36	Montlake	20
Decatur	22	Rainier View	22
Green Lake	44	Whitworth	47
Highland Park	36		

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1542

STUDENTS

Nearly 11% (4499 of 42,046/June, 1986 count) of Seattle School District students had direct contact with SESEP staff through school assemblies or small group hands-on learning center presentations. (Some learning center presentations were done by SESEP-trained volunteers.)

Middle Schools			859
Eckstein	1985	150	
	1986	150	
Hamilton		559	
Elementary Schools			3640
Adams		464	
Brighton	1984	324	
	1985	108	
Bryant		262	
Coe		426	
Highland Park	1985	486	
	1986	100	
Latona		172	
		153	
Montlake		212	
Sanislo		320	
Whitworth		613	
			4499

HANDICAPPED/ SPECIAL NEEDS STUDENTS

Three schools with handicapped and special needs students requested help in emergency preparedness planning:

Wilson Pacific
Green Lake
Meany Middle School

ACIVITY WITH OTHER SCHOOL DISTRICTS AND SCHOOL SYSTEMS

Requests for information, presentations and consultation came from:

25	Schools in districts outside Seattle
5	Private schools
4	Preschool/day care programs
	Headstart
3	University of Washington departments
	University of Washington Student Housing
2	Schools in neighboring states
	California Seismic Safety Commission Distribution to all California public schools
	Archdiocese of San Francisco Distribution to all Archdiocese schools
	School districts in British Columbia, Canada
	Ministry of Education, British Columbia, Canada

Seventeen School Earthquake Emergency Planning Workshops were given for the school community. Workshops were designed for specific target groups and sponsored by:

--Seattle School District (Staff, Parents, Administrators)
--Highline School District (Administrators)
--Snohomish County Department of Emergency Management
  (Staff, Parents, Administrators)
--Mason County Department of Emergency Management
  (Emergency Responders, School Personnel; Included Participants from Thurston and Lewis Counties)
--North/West Vancouver, B.C.,Emergency Program
  (Area School Districts and Public Officials)
--Greater Victoria, B.C., School District #61
  (Area School Districts, Parents, Public Officials)
--Educ. Serv. District #189, Mount Vernon (Administrators)
--Educ. Serv. District #113, Olympia (Administrators,Staff)
--School Earthquake Safety & Education Project
  (Staff, Parents, Administrators, Public Officials)
  Plus: Pilot School Planning Workshops
  Volunteer Training Workshops

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A REVIEW OF THE REGIONAL EARTHQUAKE HAZARDS ASSESSMENT PROGRAM FOR THE WASATCH FRONT AREA, UTAH -- WILL UTAH MEET THE CHALLENGE ?

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INTRODUCTION

The goal of the "Regional Earthquake Hazards Assessment" program for the Wasatch Front area, one of eight components of the National Earthquake Hazards Reduction Program (NEHRP), is to implement hazard-reduction measures throughout the intermountain seismic belt of Utah, emphasizing the most populous areas along the Wasatch fault zone. The challenge is to incorporate and implement effective earthquake loss-reduction measures by key users groups and decisionmakers before the next damaging earthquake occurs somewhere along the Wasatch fault. Will Utah meet the challenge?

Now that the program in Utah is beginning Phase II of research and implementation, it appears Utah is getting closer to achieving the goal and meeting the challenge. Hays and Gori (1987, p. 16) state that the Wasatch Front program is the only region where all 5 interrelated components are being conducted. But will Utah meet the challenge? Before that question can be explored, it seems appropriate to reflect on the program, to celebrate its accomplishments, and to discuss the players, strategies, activities, and other factors that made the difference and contributed toward its current level of success. This paper does not intend to give a full historical account of the Wasatch Front program and its objectives. Nor will it attempt to summarize scientific findings. Hays and Gori (1984, 1987) details the program's history, discusses its objectives and strategies, and summarizes some of the significant scientific conclusions. Instead, this paper hopes to present a state perspective of what aspects of the "Regional Earthquakes Hazards Assessment" program have made a difference for the Wasatch Front area. Reviewing the program from this perspective will serve somewhat as a self examination to reaffirm the UGMS's commitment and direction. This exercise should also shed some insight for other components of NEHRP so they are able to learn from the Wasatch Front program to avoid areas that are not as successful and take advantage of areas that are successful.

CONTRIBUTING FACTORS, PLAYERS, AND PROCESSES IN THE PRE-PROGRAM PHASE

The Wasatch Front area is the urban corridor of Utah where approximately ninety percent of Utah's population resides. The spectacular mountain front scenery that bounds the eastern margin of the Wasatch Front area is a desirable attribute for many of its residents, but is also testimonial to the seismic activity generated from the Wasatch fault zone which cuts through the urban area. Although the Wasatch Front has not experienced a major earthquake since the Mormon Pioneers entered the Salt Lake Valley in 1847, evidence indicates this area of Utah has experienced multiple earthquake events of magnitude 7.0-7.5 repeatedly since the end of the Pleistocene, and the dominating tectonic regime has not changed, suggesting the Wasatch Front will experience a major earthquake sometime in the future. The combination of a large damaging earthquake occurring in a highly populated area where there is great potential for a substantial loss of life and property made the Wasatch Front an obvious target area by the USGS.

A factor that may have contributed toward the USGS targeting Utah for the "Regional Earthquake Hazards Assessment" program was the existence of a core group of Utahn's who recognized Utah's vulnerability to large-magnitude earthquake events (as well as other geologic hazards) and were involved early in seismic safety issues at the state level. Utah's Seismic Safety Advisory Council (1977-1981) addressed many of these issues during its tenure. With its demise in 1981, the core group of "true believers" had been developed, but no longer had the Utah Seismic Safety Advisory Council (USSAC) to coordinate and focus their efforts. They were eager for a joint federal/state program. These key players represented scientific, architectural, planning, emergency response, and political communities concerned about Utah's need to adopt loss-reduction measures. Most of them continue to be leaders in the current effort, most notably Delbert Ward, Lawrence Reaveley, Robert Smith, and Lorayne Frank.

Several important factors transpired in 1982 that laid the foundation on which the joint USGS/UGMS earthquake program was built. First, in 1981, Genevieve Atwood was appointed Director of the Utah Geological and Mineral Survey. Genevieve has been a long-time advocate of adopting measures that would reduce the loss of lives and property resulting from geologic hazards, particularly earthquake hazards. She had been a member of the Seismic Safety Advisory Council and a member of the Utah Legislature. Thus, her background and newly-appointed position seemed propitious to provide the leadership at the state level. Second, Don Mabey had just recently retired from the U. S. Geological Survey and joined the Utah Geological and Mineral Survey in 1982 as Senior Geologist of Applied Geology. He later became the Deputy Director. Don's knowledge of the USGS structure and desire to see research results applied to reduce risks from earthquakes provided a comfortable link between the USGS and UGMS. Third, Walter Hays of the USGS, who had served as an ex-officio USGS representative to USSAC, brimmed with enthusiasm for implementing the goals of NEHRP in Utah and provided vision and leadership at the federal level. Thus, all three shared similar philosophies although they hadn't worked together in the past and, therefore, a symbiotic relationship formed between state and federal agencies to forge a strong partnership with a common understanding of the goals and equal level of energy directed toward achieving the goals.

Early planning by Walter Hays (USGS), Al Rogers (USGS), Genevieve Atwood (UGMS), and Don Mabey (UGMS) during a series of meetings held in 1983 was essential to focus energy on defining goals and outlining strategies of the earthquake program in Utah. Three elements emerged from the meeting that now appear as crucial factors that would help ensure success of the program. First, both the USGS and UGMS had an equal hand in formulating the Utah program. There was a mutual "buy-in" on the program's size, goals, needs, and definition of what mattered. The state's early input in the planning stage reinforced the sense of equal partnership and strengthened its commitment. There was no feeling that this was a self-serving federal bureaucratic program being forced on the state for the good of the state.

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Secondly, the earthquake program was to be science driven. The consensus was (and still is) that science must drive the program to ensure the credibility of the program and keep it moving forward in a positive manner. Finally, other key players in the state were identified as sympathizers that could significantly contribute toward the success of the program. Each player's expertise was matched to a specific area of the program where critical information was needed. Matching talents to tasks expanded the sense of making a difference at another level, wove expertise into the fabric of the program, and satisfied the goal to keep the program science-driven. It also defined areas of responsibilities which minimized territoriality. The support and contribution made by the keys players in the early planning stage and during phase I of the research and implementation was instrumental in keeping the program moving forward. A listing of players can be found in Hays and Gori (1984, 1987).

Despite the magnitude of an identified problem and the dedication to solve it, the commitment of funding is an economic fact of life for most governmental programs. The National Earthquake Hazard Reduction Program is no different, it requires federal funding to operate. The methodology and distribution of funds through the USGS has offered an alternative approach to manage a program and accomplish goals. The USGS has an internal and external funding program which commits a part of its funds for internal projects that utilize the expertise and resources within the USGS. This provides an opportunity for USGS scientists to work with state geologists and create an avenue to transfer skills and knowledge. They also award research grants through the external funding program by the Request For Proposals (RFP) process. The RFP process is an excellent method to support research projects and motivate research into areas where additional information is needed. The USGS has consciously utilized the external funding program that benefits NEHRP to obtain new information and achieve its goals.

The UGMS has always been concerned about the potential threat earthquakes posed to Utah's citizens, but did not have a well-coordinated earthquake program that systematically addressed earthquake hazards. Its efforts consisted of individual investigations driven by the researcher's interest of a specific earthquake hazard. In addition, a program within the Applied Geology Program conducted routine inspections of building site excavations noting evidence of faulting. Prior to 1983, earthquake hazards studies were conducted by a variety of talented people on the UGMS staff, including many investigations conducted by Bruce Kaliser (formerly UGMS). The USGS/NEHRP program, "Regional Earthquake Hazards Assessment: Wasatch Front " gave Utah the ability to establish the well-coordinated program it needed to systematically address earthquake hazards throughout the state. It also gave the UGMS the organizational structure required to continue the program once NEHRP funding is discontinued. Most of UGMS' earthquake-related activities were derived from NEHRP funding through the USGS. A measure of the success of the program is the investment by the legislature of state funding into the program. Prior to NEHRP, Utah had provided very little state funding toward the program. In 1987, the Utah Legislature approved funds for an Earthquake Scientist position beginning in July 1987 to work on translation and dissemination of earthquake hazards information. This is a major step in Utah's earthquake program because it indicates the state's level of commitment and sense of responsibility.

PHASE I OF RESEARCH AND IMPLEMENTATION, WASATCH FRONT PROGRAM

Phase I of research and implementation for the "Regional Earthquake Hazards Assessment: Wasatch Front, Utah" program commenced in 1984. Its primary purpose was to provide a comprehensive data base of earthquake hazards information derived from scientific studies and presented in a manner that potential user groups could directly use to adopt measures that would result in the reduction of losses from future earthquakes in Utah. The direction of the program was guided by five interrelated components outlined in the Draft Work Plan: FY 84-86 (Hays and Gori, 1984). In other words, the five components focused on theoretical earthquake research and earthquake hazards definition, translation of earthquake hazards information, and finally, dissemination of earthquake hazards information to potential users. Much progress was realized during the three years of Phase I, particularly in research, hazard definition, and translation areas. This progress was the product of careful planning, providing new scientific information in a timely manner, building on past accomplishments, taking advantage of current and past geologic events, and utilizing the positive effects of the media to raise and maintain public awareness of geologic hazards, particularly earthquake hazards. These five factors were common to all components and is believed to be the overriding link between between researchers, translators, and potential users in Utah.

Significant contributions were made in the areas of research and translation during Phase I. Significant geologic events also occurred during Phase I that directly increased understanding of earthquake behavior and elevated public awareness of the Wasatch Front's susceptibility to earthquakes hazards and the amount of damage they can inflict on communities. A discussion of these events seems appropriate because they furnished important data on mechanisms and effects of geologic hazards. They also served as the catalyst for dissemination between researchers and potential users because of the innate curiosity, concerns, and demands of the general public, which were affected by geologic hazards.

<u>Significant Geologic Events</u> — Utah, and particularly the Wasatch Front, was adversely affected by four years of above-average precipitation beginning in the fall of 1982. The wet cycle initiated hundreds of slope failures statewide from 1983 to 1985, most notably was the Thistle landslide in April 1983 and the debris flow-debris flood events along the Wasatch Front in May and June 1983. The wet cycle was also responsible for the rapid rise of the Great Salt Lake that culminated at the historic high level of 4211.85 ft in the spring of 1986 and spring of 1987. These events affected numerous communities and drew the fascination of others. By the end of 1986, the effects and mitigation of these hazards caused the demise of Thistle, Utah, permanently severed rail service to some central Utah counties (Sanpete, Sevier, and Piute), cost Utah taxpayers hundreds of millions of dollars, and were responsible for one fatality. By the end of 1986 most Utahn's were sensitized to the effects of geologic hazards.

In October 1983, a 7.3 magnitude earthquake occurred in the sparsely populated area of central Idaho. The Borah Peak earthquake was a significant event for the Utah program and even though it occurred about 250 miles from Salt Lake City it provided many technical lessons that directly applied to the Wasatch Front. It offered scientists an opportunity to make first-hand, detailed observations of fault behavior and earthquake generated-features of a large-magnitude earthquake within the intermountain seismic belt. Although the Borah Peak earthquake occurred in a remote area of Idaho, it still caused an estimated 12.5 million dollars in damages and killed two children in Challis (Mabey, 1985). It serves as the prototype event for the Wasatch Front because it typifies the maximum credible earthquake expected for the Wasatch fault zone and provides some insight on regional extent of earthquake hazards. The Borah Peak earthquake gave scientists the best example of the kind of earthquake the Wasatch Front could experience and gave decisionmakers and the public an event they could easily identify with.

Another important event occurred in September 1985 when an earthquake of magnitude 8.1 severely damaged a portion of Mexico City, Mexico, killing and injuring tens of thousands of its residents. Most Utahn's, like the rest of the country's population, were riveted to the nightly broadcasts of national and local television news which revealed the human drama that often results from earthquakes. The technical lessons learned from the Mexico earthquake had a direct scientific and emotional impact on Utah. Mexico City, like most of the Wasatch Front cities, is built upon a thick sequence of lacustrine rocks that amplifies ground acceleration, thus, much of the Wasatch Front could experience ground shaking intensities similar to intensities experienced in Mexico City. Many of the local television news departments aired the analogy depicting Utah's vulnerability to intense ground shaking following news reports on the Mexico earthquake. Again scientists in Utah could use an event that occurred outside of Utah, like the identifiable Mexico experience, and translate its effects to Utah.

Research -- Research is the basic driving mechanism of the Wasatch Front program. Many scientists from the USGS, UGMS, university communities, other state and federal agencies, and the private sector have made significant contributions toward understanding the nature of earthquakes and earthquake hazards. The successful work of each scientist is the foundation on which subsequent scientists build. The following discussion is by no means a comprehensive list of researchers and projects associated with the Wasatch Front program. Nor does the sequence imply importance. This discussion offers a perspective of projects that have direct application to earthquake hazard assessment and are considered fundamental information for adopting loss-reduction measures.

Essential to any program is the network of seismograph stations and strong motion accelerographs. The University of Utah Seismograph Stations (UUSS) operates a network of seismographs under the leadership of Dr. Walter J. Arabasz and Dr. Robert B. Smith. The first seismograph was installed at the University of Utah in 1907 because of interest in earthquakes following the 1906 San Francisco earthquake, and establishment of the modern seismic network occurred in 1966 from modest beginnings in 1961 (Mabey, 1985). The information derived from the University of Utah provides an historic and current picture of Utah's seismicity (Arabasz, 1979; Arabasz and others, 1979; Richins and others, 1981, 1984; Brown and others, 1986) and is in the forefront of seismologic and regional tectonic research (Smith and Bruhn, 1984; Smith and Richins, 1986). Utah also has a network of strong motion accelerographs operated by the USGS. Unfortunately, only one strong motion

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record exists for Utah. It is from the 1962 Cache Valley earthquake. Continued monitoring of earthquakes is neccesary to understand source zone parameters and ground response, which is essential for loss-estimation models.

G.K. Gilbert recognized the potential for a devastating earthquake to occur along the Wasatch fault zone as early as 1883 (Mabey, 1985). Since then, the Wasatch fault has been mapped as a zone of faults extending continuously from just south of Nephi to near the Utah-Idaho state line (Marsell, 1964). The prevailing idea of a continuous fault was challenged by Schwartz and Coppersmith (1984). They proposed that the Wasatch fault zone consisted of six discrete segments. Detailed mapping of Holocene fault scarps on the Wasatch fault zone by Michael Machette (in progress), Alan Nelson (in progress), and Steven Personius (in progress) has accumulated structural and stratigraphic evidence that expanded the fault segmentation concept and Machette and others (1986) proposed ten segments for the Wasatch fault zone. Fault segmentation is an important concept for earthquake hazards assessment because it tends to limit potential source zone area, and amount of energy released. It suggests that each segment behaves independently, restricts rupture length to one segment, and limits the maximum earthquake magnitude to 7.5. Although fault segmentation restricts maximum earthquake magnitude per event, it creates the opportunity for more of these events to occur. The probabilistic implication is the entire Wasatch Front is more likely to be affected by intense ground shaking more often, whereas surface ground rupture will only affect the segment from which the event was generated.

Other research applications that contributed toward assessing earthquake hazards include fault trenching studies, ground shaking studies, liquefaction susceptibility and other slope stability studies, segment boundary and rupture propagation studies, and loss estimation models. The results of these studies have greatly added to deterministic and probabilistic hazard analysis along the Wasatch Front urban corridor.

Fault trenching studies, both on and off the Wasatch fault zone, have revealed critical information on faulting histories and fault behavior. Most of the investigations on the Wasatch fault zone were joint efforts by USGS and UGMS researchers. Researchers include Michael Machette (USGS), David Schwartz (USGS), Alan Nelson (USGS), Steven Personius (USGS), William Lund (UGMS), Robert Klauk (UGMS), and Harold Gill (formerly UGMS). Preliminary results of their findings were presented at the 40th annual meeting of the Rocky Mountain Section of the Geological Society of America (Machette, 1987; Machette and Lund, 1987; Lund and Schwartz, 1987; Nelson and others, 1987; Personius and Gill, 1987). Other trenching studies were conducted by McCalpin (1987) on the East Cache fault zone and Keaton and others (in press) on the West Valley fault. The West Valley fault is of particular interest because it is considered an antithetic fault on the Salt Lake segment, and evidence suggests it, too, is capable of generating an earthquake of equal magnitude to the main trace of the Wasatch fault zone. Researchers are uncertain of other buried antithetic faults locations, and if they are present, do they also have the potential to generate a major earthquake event?

Ground shaking hazard undoubtedly causes the greatest amount of damage, injuries, and loss of life during a single earthquake event. Understanding ground motion is a critical factor in developing accurate loss estimates. As mentioned earlier, the intense ground shaking from the September 1985 Mexico earthquake was responsible for all of the damages, injuries, and deaths in Mexico City. Current thinking suggests that portions of the Wasatch Front could experience the kind of ground response experienced in Mexico City because of similarities in geologic setting. Much of the current information on ground motion was presented at a 1984 USGS workshop on "Evaluation of Regional and Urban Earthquake Hazards and Risks in Utah" (Hays and Gori, 1984). Additional work needs to continue to refine ground motion models on a site-specific basis. This area of research should see the greatest amount of progress made by USGS, university, and the private sector in the near future.

Completion of a series of liquefaction potential maps (Anderson and others, 1982; Anderson and others, 1986a; Anderson and others, 1986b) provided a detailed probabilistic assessment of liquefaction in Weber, Davis, Salt Lake, and Utah counties. These maps represent areas considered to have very high to low liquefaction potential expressed in probabilistic terms. These maps also represent a new generation of scientific products that translate scientific information so planners, decisionmakers, and other public officials in those counties can use the information on the maps to help with decisions concerning issues of land-use planning and implementing loss reduction measures.

Translation Efforts -- Translation efforts in Utah embody a broad spectrum of tasks that encompasses collecting, organizing, and managing scientific data, as well as translated information related to geologic hazards (including earthquake hazards). It also implies a process by which the information can be retrieved and effectively transfered to user groups. Two components of the "Regional Earthquake Hazards Assessments, Wasatch Front, Utah", Information Systems and Implementation, describe important tasks and objectives concerning translation efforts of Phase I (Hays and Gori, 1984, 1987). There were several bright spots in the translation effort of Phase I and accomplishing some of the more critical elements was essential for the successful transition into Phase II.

Tarr and Mabey (1984) discussed needs and objectives of the Information Systems for the Wasatch Front program and believed there should be a "clearinghouse" of quality geologic hazard information available for researchers and policymakers. Much of what they envisioned is now reality. The UGMS was considered by many to be the logical place to establish a data base of geologic hazard information. The UGMS has spent the past three years compiling a comprehensive bibliography of geologic hazards of Utah. References were collected statewide by Suzanne Hecker (UGMS) and Kimm Harty (UGMS) from conventional sources of published information. They also recovered some information from unconventional sources. Many of the geological engineering firms in Utah permitted a review of their files for more site-specific geologic hazard information. The references were keyworded and are now being inputted by Janine Jarva (UGMS) into a computerized data base system for easy manipulation and retrieval. Tarr and Mabey (1984) also indicated the need for a newsletter containing items of interest for participants of the Wasatch Front program. The Wasatch Front Forum was established to provide a format for news items, progress reports, new publications, and other pertinent information that was primarily of interest to the scientific community involved in the Wasatch Front program. It was edited by Wendy Hassibe (USGS) and published quarterly by the USGS-UGMS. The Wasatch Front Forum has recently redefined its emphasis to reflect the additional dimension of implementation of translated geologic hazard information. It will maintain its newsletter format and continue to provide news on scientific projects along the Wasatch Front, but it will also contain information of interest to a wide variety of potential implementers of loss-reduction measures. The Wasatch Front Forum will primarily be a product of the UGMS, with cooperation from USGS and Utah Comprehensive Emergency Management (CEM). Janine Jarva (UGMS) is the current Editor with Arthur Tarr (USGS), James Tingey (CEM), Gary Christenson (UGMS), and Douglas Sprinkel (UGMS) as co-editors.

An outstanding element of the translation component is the County Geologist program. Many county planning commissions deal with land-use issues where the effects of geologic hazards are a concern. Many counties require geologic studies be conducted and a report submitted as a part of the permitting process prior to development. But most county commissions are not technically trained to fully evaluate the merits of the reports. In addition, only some of the more common hazards are addressed. Many Wasatch Front county commissions are faced with the dilemma of expanding into more hazard-sensitive areas as the population grows and the pressure to develop increases. Genevieve Atwood, Gary Christenson, and William Lund thought county planning commissions would be more apt to use geologic hazard information if they had a geologist on their staff to rely on for advise. The county geologist program was implemented by placing three geologist in a five-county area along the Wasatch Front. These positions are funded until June 1988 by the USGS/NEHRP through the UGMS to the counties to cover salaries. The UGMS manages the progress and gives technical support, and the counties provides them with offices within the county planning commission. Since the program began, the county geologists have compiled an extensive library of geologic hazards for the counties, provide technical review of geological reports, and have interacted with planners on land-use decisions. They are also preparing a report and detailed multihazard maps for their counties. Some of the counties considered utilizing the county geologists to help with writing geologic hazard ordinances. The county geologists program, from the UGMS perspective, is an effective method of translating and implementing loss-reduction measures at the county level. The geologists that have made the program a success are Mike Lowe, Weber-Davis Counties; Craig Nelson, Salt Lake County; and Robert Robison, Utah-Juab Counties. The ultimate test of success will come in December 1987 when each of the counties will have to decide if they will fund the county geologist position or let the program lapse.

The end of Phase I of research and implementation saw the completion of a number of translated geologic hazard products. Two studies, one in Utah County (Robison and others, 1987) and in one Salt Lake County (Alexander and others, 1987) produced detailed multihazard maps (1:24,000) overlaying geological and geographical information using a computer-based GIS. Both studies involved Utah's Automated Geographic Reference system (AGR), a state agency that was a direct recipient of transfered skills and increased capabilities. The procedures learned from these exercises also benefited the UGMS and CEM, and will have a positive impact on the state in the future because it is a cost-effective method of updating information. Other USGS/NEHRP funded projects include studies by Phillip Emmi (University of Utah) and West Valley City.

How scientific data is presented or translated is important if planners, decisionmakers, and other public officials are going to implement the information. If the information is not clear and concise, potential user groups will not use it or, even worse, misuse it. How information is presented almost becomes more important than what information is presented. Guidance on "how" came, in part, from potential users such as planners, county commissioners, and politicians telling scientists what their needs are to make decisions. But most of the guidance was derived from USGS personnel. A key figure in transferring translation skills to Utah state agencies and workers was William Kockelman (USGS). He provided many of the concepts of what constitutes translated products and the basic information they should contain to be effective. Much of the information William Kockelman provided has expedited the translation process in the Wasatch Front program.

Dissemination — Disseminating translated geologic hazard information is another step in the implementation process. It is used to educate and raise awareness among targeted user groups. Several methods are available to disseminate information. Often it is accomplished through the daily interaction between the producers and the users of the information. It sometimes take a more formal approach through press releases or media interviews. Part of the success of the Wasatch Front program can be attributed to excellent media coverage throughout the program. Some of the media coverage was discussed earlier related to geologic events. Of equal effectiveness, however, was the well-planned press releases and timely interviews. The UGMS, USGS, and CEM targeted the news media as an effective means to inform the public of the positive accomplishments of the earthquake program, and raise public awareness of the potential threat earthquakes and earthquake hazards pose to the citizens of Utah. Much of the work to ensure good press coverage was performed by Dottie Brockbank, Utah Department of Natural Resources (DNR). There was also an eagerness by the press community in Utah to cover most of the earthquake-related stories. The result was an increased level of public understanding and awareness of Utah's susceptibility to earthquakes and earthquake hazards along the Wasatch Front.

Other Geologic Events — Our understanding of triggering mechanisms of geologic events is generally good, but it's often the timing of these events that is uncertain. Earthquakes are generally thought to occur as random events, but one earthquake-related event occurs regularly and contributes significantly to the earthquake knowledge base. These geologic events are the USGS earthquake workshops. The workshops are organized by Walter Hays and Paula Gori who bring together scientists, planners, architects, emergency response personnel, and other participants of the program. The purpose of the workshops is to create a forum for participants and potential users to disseminate information, share accomplishments, and discuss dilemmas. It is an opportunity to celebrate successes and reaffirm commitments to the philosophy and direction of the earthquake program.

These workshops and workshop proceedings serve as the historical account of the problems, solutions, and progress for the different program components. Much of the progress realized in Phase I is directly resulted from these workshops.

WILL UTAH MEET THE CHALLENGE ?

Will Utahn's fully implement measures to significantly reduce losses from earthquakes before the first major historic event occurs somewhere along the Wasatch Front? Historically, the odds are against it because most legislators, decisionmakers, and other public officials tend to react to events instead of preparing for events. In most other states, such as California, loss-reduction measures generally have been introduced and enacted shortly after the event. The impact to communities from the effects of the recent wet cycle in Utah demonstrates similar thinking.

Much progress has been made toward our goal in large measures because of the work related to Phase I of the "Earthquake Hazards Assessment: Wasatch Front, Utah" program. As Phase II commences, the program has a good foundation and there is much broader base of enthusiasm and interest from a variety of participants. The emphasis of Phase II is translation and dissemination of geologic hazard information, and providing them to user groups that can get loss-reduction measures adopted. It appears Utah has an excellent opportunity to be the first state to adopt measures that will reduce losses from earthquakes before a major event occurs.

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RESEARCH APPLICATIONS AND THE UTAH EARTHQUAKE PREPAREDNESS PROGRAM

BY

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The Utah Division of Comprehensive Emergency Management (CEM) receives guidance and funding for the Utah Earthquake Preparedness Program through the Federal Emergency Management Agency (FEMA). Specifically the State program is directed by precepts and policy contained in FEMA publication CPG 2-18, 1985, "State and Local Earthquake Hazards Reduction: Implementation of FEMA Funding and Support." This document establishes specific parameters and conditions which should be observed by an emergency management organization in implementing an earthquake program. Interpretation and Federal to State support and guidance is furnished to Utah by the Natural and Technological Hazards Division, FEMA Region VIII, Denver Colorado.

The Utah CEM Earthquake Preparedness Program is product and result oriented as is required by FEMA both under CPG 2-18 and the Comprehensive Cooperative Agreement (CCA) which outlines and facilitates funding from FEMA to the State of Utah for all emergency management programs.

All earthquake related activities also fall under the guidance of the Utah Earthquake Program, Five Year Plan and Preparedness Elements as outlined by CEM in conjunction with the UGMS and University of Utah Seismograph Stations in 1983. Although the action plan has not been strictly followed, most of the planning elements have been addressed since 1984. These elements are: Hazard Analysis; Emergency Response Plans; Warning and Notification (as applicable to precursor shocks and possible dam failure); Training Emergency Response Forces; Public Awareness/Education; Educational Curricula and School Courses; Mutual Aid Agreements; Improved Media Involvement; Public and Private Sector Involvement; Structural Engineering Assessment; and Legislative Implementation.

Activities and results from the CEM earthquake program 1982 through 1986 were submitted to the USGS for publication in a Professional Paper on "Evaluation of Urban and Regional Earthquake Hazards in Utah." I will therefore only detail the specific activities, results and applications which have occurred or are in progress during the 1987 Federal Fiscal Year.

PAST ACTIVITIES

A summary of past activities (pre-FY 87) includes the publication, dissemination, integration and exercise of the State of Utah/Four County Earthquake Response Plan. This plan ties together the response capabilities, resources and plans of the state and the four most populous counties along the Wasatch Front/High Risk Seismic Corridor (Weber, Davis, Salt Lake and Utah Counties). Mutual Aid agreements were signed between the four counties and

CEM, naming CEM as the coordinating agency and committing the resources of the contiguous districts. The agreements are effective in any disaster or emergency situation where municipalities become depleted of resources.

The County to County Mutual Aid Agreements required an arduous legal review by the State Attorney Generals Office, each County Attorneys Office and Emergency Management Office. Iterative procedures were complex and time consuming and reiterative documents were reviewed by CEM and a final document written and executed by CEM and the counties in 1985.

Other Mutual Aid, Cooperative Agreements or Memorandums of Understanding were accomplished between CEM and the University of Utah Seismograph Station, American Red Cross, Church of Jesus Christ of Latter Day Saints, and the U.S. Sixth Army. Negotiations which were ongoing between CEM and other Federal agencies have become superfluous and anachronous with the development of the Plan for Federal Response to a Catastrophic Earthquake (Draft, April 1987), which commits aid by Federal mandate under PL 93-288.

To my knowledge no specific research funded under the NEHRP has produced specific guidelines for Mutual Aid Agreements. However, FEMA has encouraged such multi-party alignments for years and has produced generic outlines which may be tailored to the local situation under legal guidance. Without question the execution of the Mutual Aid Agreements and the impetus for the integration of the response plan and State/County mock earthquake exercises, would have been impossible without the current geologic hazard and risk information generated by the NEHRP and earlier research products. This research evidence was used to convince bureaucratic and private entities to adopt the plan and begin their own "in-house" planning efforts.

Public awareness programs which include the distribution of pamphlets which give a simplified explanation of geologic processes and safety information, public presentations both planned and spontaneous; television and radio spots, and workshop sessions for a specific audience i.e. planners, building inspectors, and architects, have been successful in raising the level of understanding of various groups along the Wasatch Front. Public presentations especially those to church groups, produce a domino effect which keeps the CEM staff busy throughout the year. Serendipitous opportunities also arise due to our on-going training and education activities.

The majority of these activities were planned by myself in conjunction with the CEM, Chief of Plans and Preparedness, Mr. Ralph Findlay and CEM's Director, Lorayne Frank. Other key players which offered invaluable help include Mr. Wesley Dewsnup, the Utah Multi-Hazards Project Manager, the Director and staff of the Utah Geological and Mineral Survey (UGMS), the USGS and members of private industry with interest and expertise in seismic hazard research.

Research products which were used in my initial efforts in planning and public awareness programs included the following: Environmental Geology of the Wasatch Front, 1971, Utah Geological Association, Publication 1, 1972; A Study of Earthquake Losses in the Salt Lake City, Utah Area, USGS Open File Report 76-89; USGS Sugar House Map Folio, I 766 A-O by Van Horn, et. al.; Woodward

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Translational products which cannot properly be termed "research" are used extensively by CEM to satisfy public inquiry and supplement more sophisticated information. These products include simple earthquake process and safety literature produced by FEMA, USGS, the American Red Cross, CEM, UGMS, SCEPP and jointly produced products by FEMA/Red Cross.

RECENT ACTIVITIES AND RESULTS

During the past year to eighteen months, emphasis has been placed on public and private sector awareness and education and the beginnings of a more detailed risk assessment program.

One project task slated for completion during FY 1986 was the production of a television program (video format) which could succinctly cover the earthquake hazard, risk and safety concepts specific to the Wasatch Front. In order to produce a program which could be televised over the educational or major broadcasting network, it was imperative that we have a highly professional production company produce the video. Because we were working with a lean FEMA/NEHRP budget, we began to solicit subsidies from the educational/university stations. Their initial interest seemed high but because I indicated that CEM wanted a true educational product containing special effects, and dramatic vignettes; not a simple documentary with interviews taking up the bulk of the time, they along with all but one of the major broadcasting companies declined the opportunity of working on the project. Near the end of the fiscal year the local CBS affiliate, KSL Television, was contracted and produced an excellent half hour program ("Not If. . . But When") which was shown twice, in response to public reaction, during January of 1987. The program won a Regional Emmy Award out of one hundred-fifty entrants from seven western states. Several copies of the video are constantly being checked-out of our office for schools, church groups, business and other interested parties.

Integrated in the video were results of the latest research work on fault surface expression, segmentation, rupture and geometry; ground shaking and amplification, liquefaction and loss estimates for model events. Translation of this research was accomplished by myself, the UGMS, scientific and public safety oriented agencies and the producer of the video program (fortunately this individual had a terrific feel for the material and was able to distill complex ideas into mass media understandable concepts). Funds to subsidize the program were also successfully solicited from large private corporations by myself and Ralph Findlay.

Precipitated by the 1986 USGS National Mapping Division Project on the Utah Sugar House 7 1/2" quadrangle, CEM has begun a project under the auspices and funding from FEMA to expand this type of hazard and risk assessment to contiguous quadrangles. Two major difficulties were encountered in this project: 1) Collection of data which is at different scales, registered to different coordinate systems and considered proprietary by the contributing agency and 2) Digitizing of this same data by the State Automated Geographic Reference Section (AGR) to a common standard base map and maintaining accuracy during printing.

Because of an informal agreement between CEM and the UGMS, the geotechnical data to be digitized by the CEM project will be limited. The UGMS has indicated that geologic data will be integrated into this data base when they feel confident of the data's accuracy.

Themes and systems to be digitized by AGR from CEM collected data are locations of critical facilities, major lifelines, priority transportation routes and political jurisdiction boundaries.

Previous research which has helped in the process is the USGS Sugar House Quad project and the Utah County Multi-Hazard Study of 1986-87 by Wes Dewsnup of our office. The Utah County project was funded by Utah County and cities within the county utilizing AGR as the main computer mapping agency.

Justification of the project falls under risk assessment and the purpose of the final map products range from public education to emergency management. The project establishes AGR (a state agency) as the data repository and makes the information available to other agencies for access or modeling purposes.

In the hazard/risk awareness area two major target audiences were identified for 1987. Primary and Secondary Educational Institutions and public officials (policy makers). Workshops for these groups have been held and their role in the implementation process discussed. Leverage in getting results from educators was found in recent state legislation requiring emergency plans and drills on a regular basis. FEMA, USGS, CEM and UGMS material is being translated for the appropriate grade levels for use in the science, social studies or safety curricula of the schools.

Schools seem anxious to use the latest information to enlighten faculty, administration and students. Most helpful have been the loss estimation studies by Algermissen and Steinbrugge for Salt Lake City (Seismic Hazard and Risk Assessment; Some Case studies, the Geneva Papers of Risk and Insurance, Vol 9 Number 30, January 1984) and the 1986 study by Taylor, Wiggens, Haber and Ward (A Systems Approach to Wasatch Front Seismic Risk Problems, USGS sponsored study, 1986). These recent studies in combination with those previously mentioned make up the bulk of CEM's awareness and educational material. Much of the material needs very little translation if explained by one who can relate both to a totally lay audience and the research results.

Before presenting this material I often contact other geologists and researchers to gain a clearer understanding of its meaning, accuracy and applicability.

RESEARCH DISSEMINATION

It has been my experience that the groups most open to earthquake hazard education and implementation are those who have a natural tendency to want to be informed, i.e. the public at large and educational institutions; and those with much to lose in a damaging seismic event, i.e. financial institutions, data processing and utility companies. Those with the least interest or ability to implement any mitigation strategies are city and county planning groups and short term political officials.

It is probably necessary to find a strong political champion to back change or public pressure fueled by awareness programs to pressure static political entities into action. In a survey I conducted in 1986 of county and city, planning departments along the Wasatch Front, I discovered that virtually all municipalities had ordinances which required some type of geotechnical investigation for development sites. Many required a geologic hazard report. This information indicates true implementation of research data and an attempt to mitigate hazards including the effects of seismic events. The breakdown in these ordinances may be that the developer may be the only one to ever see the hard facts, planning departments and permitting agencies may lack the knowledge or staff to analyze such data and structures may be built regardless of the required geotechnical site information.

IMPROVEMENT OF APPLICATION PROCESS

It would be advantageous as one involved in public awareness, education, emergency response and mitigation planning to have flexibility to follow the flow of interest from various groups as I work on the yearly predetermined CCA objectives. However, so much time can be spent in such pursuits that major project goals are not met. This looks bad from a planning, product and results standpoint, but may actually indicate more interaction with ad hoc groups which may pave the way to important future goals.

With the addition of the County Geologists I have been more efficient in dealing with public and private groups. The County Geologists provide a professional resource for translation, education and consultation which complements CEM's efforts in earthquake preparedness planning.

DEFINITION OF TERMS

Because I recently became aware that there are those involved in NEHRP activities who do not understand the terms Implementation and Mitigation , I will give my definition as it relates to the NEHRP.

Implementation: The execution and application of research data which raises the level of understanding of the earthquake hazard. Implementation also includes a vehicle, process or tool for carrying out this application. An example is a lobbing group which uses political leverage to apply in a particular way, the knowledge gained by research. The dissemination and effect of this knowledge is part of the implementation process.

Mitigation: Preventing or reducing the impact of the earthquake hazard. Enforcement is pure mitigation and implementation reveals the process to reach mitigation. An easily understood (if perhaps simplistic) example is that of a bowling ball coming down the alley and the pins at the end of the alley. The bowling ball represents the hazard, the pins the objects or structures at risk. Mitigating the hazard can involve several approaches. You can divert the ball away from the pins before it strikes, you can stop the ball with a strong barricade (not possible with earthquakes) or you can analyze the spin, bearing and velocity of the ball to decide what steps should be taken. Perhaps it will be decided that the ball will only take out the 1 and 3 pins, this may be an acceptable risk if the cost of blocking or diverting the ball appear too high. Another step involving the former analysis would be to move the pins to an area of lower risk. By implementing your knowledge you mitigate the hazard and reduce the risk.

APPLICATION OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM THROUGH AN EARTHQUAKE EDUCATION CENTER AT CHARLESTON, SOUTH CAROLINA

BY

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Description of research application

The pilot projects of two Earthquake Education Centers initiated by the Federal Emergency Management Agency (FEMA) in FY 83 were based on the findings set forth in the Earthquake Hazards Reduction Act of 1977. The Earthquake Education Centers (EEC) were to test the recommendations from the research in order to tailor materials for specific locations and audiences, and establish community outreach activities.

The Tennessee Earthquake Information Center in Memphis and the Baptist College at Charleston, Charleston, South Carolina were invited to submit proposals. The potential EEC directors at these institutions were responsible for monitoring seismic networks and were viewed by the scientific community, State and local emergency managers, the media, and the public as authoritative providers of earthquake information.

This paper gives the planned and actual outcomes of the pilot Earthquake Education Center of the Baptist College at Charleston. The College borders the three South Carolina counties of Berkeley, Charleston, and Dorchester. The population is about 456,000. By the end of the pilot project, the outreach activities had reached 32,000 persons directly through 381 earthquake preparedness workshops or programs. From September, 1986- September, 1987, 7,000 more individuals had participated in 114 programs or workshops presented by the EEC and trained volunteer teachers. The outreach activities had generated interest throughout the State of South Carolina and beyond.

Key Players

The key players in establishing the Earthquake Education Center at the Baptist College were (1) the FEMA project officer, Marilyn MacCabe who had the experience of having worked with the education program in California, (2) the writer of this paper, and (3) Dr. David Hodge, Director of Grants for Baptist College.

The first key player, the FEMA project officer, had the responsibility to write the statement of work and guide the program to stay on target. The second key player, the writer, saw the need to close the gap between the special knowledge of the scientific community and the

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general public. The third key player, Dr. David Hodge, made it possible to respond to FEMA's invitation to write a proposal. The task would have been impossible if it had not been for Dr. Hodge's ability to take ideas and express them in the right proposal language.

Funding

The level of funding for the first year of the Earthquake Education Center of the Baptist College was $67,000. The second year was $55,000, and the third year was $60,000. At the end of the third year (August, 1986), the impact of the program upon the State of South Carolina was reflected in continued requests for earthquake preparedness programs. The State Emergency Preparedness Division and the Baptist College at Charleston supported the continuance of the EEC. The State provided $15,000 through their public earthquake education funds from FEMA for FY86-87 and plan for $23,000 in FY87-88. The Baptist College at Charleston allowed faculty release time for the Director and paid her salary.

Goals, Objectives, and Action

The Earthquake Education Center set its goal and objectives to reach the target audiences of the general public, special needs groups (elderly, disabled, non-English speaking), youth groups, school populations, neighborhoods, public officials, hospital, fire, and other emergency response personnel, business and industry, volunteer agencies, community service groups, and the media.

The program objectives were to :

> Make known and available the best of existing products and services which address the information and education needs of the target audiences.
>
> Enhance the use of products and services by ensuring that they were appropriately tailored to various earthquake study areasand audiences and distributed through existing community channels.
>
> Establish a network of trained volunteers to extend community outreach capability.
>
> Provide a solid foundation for short- and long-term program evaluation activities.

The organization of a staff (director, coordinator, and secretary) was followed by establishing an Advisory Board of leaders in the communities. The tasks of assessing the available materials (brochures, audio-visual aids) and determining the priorities were followed by planning two required workshops. The Train-the-Trainer Workshop facilitated by Libby Lafferty, CHES of California, and the Environmental Volunteers Hands-On Earthquake Learning Package Workshop provided the foundation for the outreach program. Sixty representatives from the target audiences attended the workshops. The County Science Coordinators were invaluable in gaining support of the school administration for the program. The school districts shared the expenses of paying substitute teachers for key teachers to attend the workshop.

The nucleus for the outreach program was generated from the two workshops held in November, 1983 and March, 1984. As of September 30, 1987, the EEC had records of 495 workshops and programs presented to 39,000 individuals. The ripple effect that happened from the presented workshops and programs was difficult to measure. The modified, tailored versions of the initial workshops have not saturated the area yet, as evidenced by the continued mail and telephone requests for information.

Early in the pilot program the school population was the target of the EEC's concentrated efforts. The decision was based on (1) the high interest of teachers in the educational value of the materials, (2) volunteer support of the Science Coordinators, and (3) an invitation to present the Hands-on Earthquake Learning Package to the South Carolina Science Council Conference in the Fall of 1984.

Through the programs and workshops that the EEC Staff presented to teachers in the Teacher In-Service Training Programs, Teacher Re-Certification Classes, Critical Issues in Science graduate classes, principals' workshops, school board presentations, faculty meetings, and Parent-Teacher Association meetings, the method of teaching earthquake drills and safety evolved. The method was the integration of teaching the science of earthquakes and earthquake safety with teaching the basic skills.

The participants in all workshops and most programs were given a pre-test, post-test, and an evalution of the workshop. The information provided the EEC Staff with the input on how to improve presentations and identified the needs of the participants for earthquake information within their specific disciplines. The perceived needs of the audience were important to them and to the pilot program. For example, the needs for first aid and cardio pulmonary resuscitation (CPR) courses were listed by some teachers at two different schools. One of the EEC workshop participants from the Red Cross was contacted, and the first aid courses were given for the teachers at the particular schools.

The design of the EEC was to create and generate ideas of how to carry out the objectives. Suggestions began snowballing. Some of the ideas tried were better than others. But they were tried. Carrying out the planned ideas demanded time and innovative planning. The success of the plans were dependent on cooperation from merchants, public and private officials, and individuals willing to donate time, energy, and funds to make the various ideas work. There were good suggestions that were not done because of the money and time factors.

There were instances when the planned idea was not felt to be "worth the effort", but there always appeared to be a peripheral outcome that overwhelmed the original intent and succeeded in producing an institutional change. (What institutional changes occur in an educational program are measureable qualities that should be considered in a planned program.) The best example of a planned idea that was felt at first not to be "worth the effort" as a method of raising earthquake awareness, and yet produced unexpected success in other ways was the Saturday Shopping Mall Earthquake Preparedness Display and Puppet Show.

> In one of the largest shopping malls in the North Charleston area, an elaborate display of earthquake information was set up. A five-minute video presentation played periodically. Volunteers distributed literature and answered questions about earthquakes. The volunteers were teachers that had been trained in the EEC workshops. They worked in shifts along with the EEC Staff manning the booth and answering questions.
>
> Two puppet shows were given in the center of the mall by a professional puppeteer. Children were invited to sit on the stage to see the puppet show starring HAPET (an unorthodox ostrich whose name stands for Hazard Awareness Preparedness Earthquake Teacher). The acoustics were terrible. The adults standing around could not hear very well. The volunteers and EEC Staff felt that it was not successful. Near the end of the second show, however, the television stations came. Hapet, the EEC Director, and random members of the audience were interviewed. One television interviewer put Hapet on her arm and talked about earthquake preparedness. The unpredicted happened. No, not an earthquake, but the television reporting of the activities reached thousands on the evening news with Hapet telling about earthquake preparedness. The private industry, Westvaco, that provided the funds for the puppet show, later invited the EEC Director to present a program to their employees at one of their monthly safety meetings on earthquake preparedness. The final outcome, after several such programs were given to the various branches of the company, came three years later, September, 1987, when an earthquake preparedness plan for the Westvaco Industry was presented to the EEC Director for review.
>
> A service club of Baptist College Students volunteered to interview the audience after the puppet show to get opinions of what was gained from the show. The students were later instrumental in incorporating earthquake information to the dormitory stduents on campus.

The tracking mechanisms devised as a requirement of the EEC pilot program and in-depth quarterly reports to FEMA (as agonizing as they were) provided the accurate record of the number of workshops and programs presented by the EEC Staff or volunteer, the names of the individuals or target audiences reached, the numbers of persons present, the numbers and kinds of literature given out, and, most importantly, how the information was utilized. Record keeping was an important time consuming factor on 2,948 incoming telephone calls, 1,388 pieces of incoming mail, 7,670 pieces of outgoing mail, 636 EEC Library Check-outs (including film and model loan requests). Daily logs were the only way to avoid a person's request from not falling through the cracks.

The EEC Staff consisted of a part-time director, a part-time coordinator, and a full-time secreatary. The total hours required to accomplish the task far exceeded the compensations. After the end of the pilot project in August, 1986, the position of the secretary was eliminated because of budget reduction. The Director and Coordinator became more efficient on the word-processor. The disadvantage of this situation was the reduced amount of time available for planning and coordinating activities. Contact and follow-up work with volunteers probably suffered the most in FY86-87.

The schools that made the most progress in the integration of earthquake preparedness were those where a teacher or teachers had participated in the EEC workshops. After initial guidance by the EEC staff and explanation of FEMA's <u>Guidebook for Developing a School Earthquake Safety Program</u>, the committees who had a "shaker or mover" made the most progress. During the three years 1200 teachers were trained in the EEC program.

<u>Description of research which contributed to application</u>

The scientific research in the Charleston, South Carolina area to determine the mechanism of the 1886 Charleston Earthquake began in 1973 by the U. S. Geological Survey , the Nuclear Regulatory Commission, and the University of South Carolina. The November 22, 1974 magnitude 3.8 earthquake in the Middleton Place area (15 km northwest of Charleston, S. C.) involved the Baptist College personnel in helping the University of South Carolina with aftershock studies. Another earthquake of magnitude 2.5 in the same area in April, 1975, resulted in Dr. Pradeep Talwani of the University of South Carolina conducting intensity surveys with support from the Baptist College and the communities in the South Carolina Lowcountry. Kenneth King of the USGS began installation of a five-station network in an eight-mile radius around the Middleton Place area in late 1975 with funding from the Nuclear Regulatory Commission. The writer conducted the noise level surveys for the site determinations. In March, 1976 the seismic stations were in place with the master helicorders operating in the laboratory at the Baptist College.

In 1977, four of the twelve local earthquakes (magnitudes ranged from 1.0 - 3.0) that were felt by area residents generated interest from the media and the public. The Baptist College was called for explanations of the earth tremors. The public responded to the intensity surveys that were conducted door-to-door by the Baptist College geology students who were under direct supervision of the writer. Isoseismal maps of the events were drawn from the data that the public had provided. During this same year, there were incidents of sonic booms occurring. There was confusion within the community as to what they were experiencing. The seismic network at the Baptist College provided the data on what was a boom and what was an earthquake.

In 1981, the USGS, FEMA, the Nuclear Regulatory Commission (NRC), National Bureau of Standards, and the National Science Foundation hosted a meeting at Knoxville, Tennessee. Multi-disciplinary representatives addressed the issue of earthquake risk and mitigation in eastern U.S. The impact of the meeting focused the attention of participants on earthquake awareness and preparedness for the eastern U.S. and motivated individuals to begin taking steps to correct the problem. The establishment of the Southeastern Seismic Safety Consortium Ad-Hoc Committee led to the involvement of individuals volunteering time and effort to provide local seminars to raise the level of earthquake awareness and preparedness.

Description of activities that facilitated application of research

The workshops presented to the target audiences other than schools caused the audiences to take action at varying levels. The EEC provided the information applicable to their needs. There were significant "success" stories, such as the safety officer of the Charleston Naval Base upgrading their plans, Westvaco's plans to include earthquakes, and the South Carolina State Ports Authority's request for information to secure their files.

The State and County Emergency Preparedness Coordinators, safety officers of industry, business, hospitals, fire fighters, emergency medical services, church leaders, government officials, Girl Scout leaders, the media, civic leaders, and Red Cross Volunteers who were participants in the EEC workshops were provided with earthquake preparedness information.

Other translation activities were:

1. The modification of the model Train-the-Trainer workshop and the Hands-on Earthquake Learning Package.

2. The lesson plans designed for the South Carolina Emergency Preparedness Coordinators' workshop provided material adaptable for other workshop audiences.

3. The upper South Carolina earthquake of February 13, 1986, magnitude 3.5, provided the Oconee Emergency Preparedness Coordinator the opportunity to use the information learned in the EEC workshop.

4. The EEC Advisory Board provided contact persons in specific target audiences for workshops.

5. The establishment of earthquake safety committees in the three pilot schools resulted in school earthquake drills and classroom hazard hunts.

6. Trained teachers utilized the EEC's facilities by borrowing equipment, films, and materials.

7. The Earthquake Engineering Research Institute supported the EEC's Poster/Art Contest on Earthquake History, Causes, Effects, and Preparedness in the 100th anniversary of the Charleston 1886

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activities. The activity allowed a channel for transferring earthquake safety to some 20,000 students in 40 different schools in 1986.

8. A local earthquake of magnitude 3.3 occurred November 6, 1983 and stimulated interest by the general public to seek earthquake information from the EEC.

9. The media's coverage of the September 19, 1985 Mexico earthquake caused individuals in South Carolina to request information about the risk of earthquakes in South Carolina and what should one do in the event of a local earthquake. The television interviews of the EEC Director on the local T.V. channels raised the public's interest in calling the EEC for earthquake information. The October 1, 1987 Los Angeles, California resulted in the same kind of activity.

10. The South Carolina Seismic Safety Consortium sponsored a workshop at the Baptist College in January, 1986. As a result the Safety Office of the Charleston Naval Base updated safety plans to include earthquake preparedness and mitigation measures. The U.S. Geological survey had provided seed money for the Consortium.

11. The media workshop sponsored by the Earthquake Education Center provided information and correct terminology about earthquakes to the media. Review of the chosen terms by Dr. Timothy Long (Professor and Seismologist from Georgia Tech) and FEMA Project Officer, Marilyn MacCabe, provided assurance of the accuracy of the information.

12. The development of a Quake Safe Badge for Girl Scouts by a Girl Scout executive attending an EEC workshop contributed to the knowledge base of teaching earthquake preparedness. Every week there is a Girl Scout or Brownie troop visiting the EEC to view the seismic equipment and be given a 45-minute Earthquake Preparedness Program. An earthquake drill is conducted at each program.

13. The Charleston Museum earthquake display reached 30,000 visitors in five months with the history, causes, effects, and preparedness of earthquakes. The EEC provided the museum with a portable seismograph, teaching models, and information.

Description of dissemination of research

Prior to Earthquake Safety Week, 5,000 bulletin board brochures were mailed to school principals. The brochures were on "Quake-Safe Actions at School" and Classroom Hazard Hunt Checklist. The EEC staff used the material from FEMA's Guidebook for Developing a School Earthquake Safety Program.

The traveling 1886 Charleston Earthquake Photo Show was loaned to schools that would conduct earthquake drills and discuss earthquakes with the students. This was one of the EEC's very successful ideas. The photos were enlargements measuring 2 ft. by 3 ft. from the Charleston Museum's collection. The photos have been used in numerous teaching situations.

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Insurance Agencies provided their clients with information that earthquakes are not covered by a person's home-owners policy.

A school official of one pilot school became an advocate of incorporating earthquake safety within the schools. His plain talk and "tell-it-as-it-is" approach for the problems he had within his school reached the attention of other principals, officials (state and national), the EEC Advisory Board, and any other group the EEC Staff could encourage to hear him.

A local hardware store allowed the EEC staff and volunteers to set up an information booth and display on two different Saturdays. The manager (1) provided for a sale on preparedness items, (2) paid for the advertisement in the newspaper and radio about the Earthquake materials being displayed, and (3) provided for a $39.95 Earthquake Survival Kit to be given away in a drawing. The persons registering for the door prize gave their names and addresses to the EEC staff to use in tracking the effectiveness of the materials.

The EEC planned with the Earthquake Engineering Research Institute and the South Carolina Seismic Safety Consortium an Earthquake Safety Week during the week of the 100th anniversary of the Charleston 1886 Earthquake. The Governor of South Carolina signed the proclamation. The week's activities raised the level of earthquake awareness for all of South Carolina. The work of the personnel of the agencies mentioned resulted in an effective outreach program. Dr. James Beavers, National EERI Conference Chairman, incorporated activities to involve the local groups. Planning for the conference activities was coordinated beginning in the summer of 1984.

The radio, television, and newspaper coverage of the Earthquake Engineering Research Institue's national convention in Charleston during Eathquake Safety Week provided the EEC an opportunity to become known as a resource center for public earthquake education and information. Five reporters of widely known newspapers spent time at the EEC Library researching background information for their stories.

The EEC designed and published twelve newsletters. The newsletters were mailed to 500 individuals or organizations during the three-year pilot program.

Publication of articles on earthquake preparedness in national magazines by EEC-trained teachers extended the dissemination of earthquake safety material to teachers beyond South Carolina.

The EEC designed and published brochures on earthquake preparedness and safety called <u>Emergency Q Tips</u>.

The Commission of Public Water Works consulted with the EEC staff and FEMA on the design of an emergency water supply brochure and mailed it out to 60,000 customers along with the monthly water bill.

A local television station responded to requests for earthquake safety brochures from community residents who mailed in a stamped envelope requesting information. This service was offered after a 30-minute midday television interview with the EEC Director about earthquakes.

The South Carolina Emergency Preparedness Division distributed the *Guidelines for Developing a School Earthquake Safety Program* to all county emergency coordinators and supplied them with additional copies upon request.

The South Carolina Emergency Preparedness Division designed an Earthquake Safety poster and distributed copies throughout South Carolina during Earthquake Safety Week.

Through Partners of the Americas, workshops were presented by the EEC to nineteen representatives of Caribbean Countries on two different occasions. The State Geologist, Norman Olson, and John Doyle of the State Emergency Preparedness Division participated with the EEC Staff in faciliating the workshops. In February, 1987, eight different workshops were provided to 800 teachers, government officials, and other target groups in Kingston and Montego Bay, Jamaica by the EEC Director.

How could the application process have been improved?

A stable staff from the beginning would have helped considerably. The turnover in the secretarial and coordinator positions during the first year was a disadvantage. The strain of teaching new staff members hindered the productivity of the program.

The staff should have included an additional person as a trained manager of the volunteers. The possibility that an increase in staff would have increased the expectations of what could be done should be recognized.

The trained volunteers were predominantly teachers. This was excellent for the school program, but the teachers were not available to provide programs for other audiences. The staff had a difficult time in trying to realize that they could not be all things to all people.

THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM--THE CHALLENGE OF OBSOLESCENCE THROUGH PROGRESS

Charles Lindbergh
The Citadel
Charleston, S.C.

The sense of national purpose, direction, and contribution of the National Earthquake Hazards Reduction Program has emerged. During its first decade, the work of post-war research pioneers has been augmented and a significant national earthquake engineering technology base established. The seeds of public awareness of the hazard and mitigation measures have been planted. Already, creditable seismic safety policy development and application of hazard reduction technology have been achieved in the West.

However, perhaps the major progress of the program is that it has defined a still greater problem. It has bought into clear focus the sobering vast dimensions of the national needs in natural hazards reduction. First, earthquakes are now seen as a national problem, having occurred in almost every state of the nation and being of a potential to strike now more highly developed communities at any time in the future without warning. A nation has been awakened to its risks and companion demands for sensible safety policy and mitigation measures. Joseph P. Riley, Jr., President of the United States Conference of Mayors, reflected this evolved public concern in proclaiming August 24-31, 1986 as National Earthquake Safety Week as he welcomed last year the Third U.S. National Conference on Earthquake Engineering. Second, no matter how individually significant they are, earthquakes are but an element of the much larger collective threat of natural hazards. The more dominant of these; earthquakes, wind, and water, have many common characteristics. One of the most important is the largely lateral dynamic forces they unleash against the man-made environment. Mitigation measures must be developed, presented and applied that address the collective natural hazard threat. If ever there was a period during which building codes and other public safety issues could be approached considering earthquakes in isolation it is not that of today..nor will it be in the future. Third, the nationwide distribution of effective mitigation technology is grossly inadequate to support essential safety policy developments and public information and awareness programs. Locally entrenched technology is prerequisite to these developments. For example, acceptable building construction practices and standards must be e established and administered by local engineers and technicians. At least in the eastern regions, the technical tools of natural hazard mitigation are not yet in the hands of the community engineer and technician at the grassroots level. A regional technology base must be developed. Once established, it must be kept current through aggressive competent national engineering research institutions. Unfortunately, the national technology base has not been regionally distributed. Regional technology centers have been spawned to meet this need, but are still in early stages of development.

The national technology situation is very much like the amphibious assaults of World War II. Technology beachheads have been established and local support is being developed. However, continuing reinforcement and other backup from "offshore" national technology transfer support units are critical. They must be provided on a responsive basis if the beachheads are to expand and become permanent rather than instead to loose their credibility and effectiveness. Once lost, beachheads are difficult if not impossible to reestablish. The need for "offshore" technology support does not end once a beachhead stabilizes and inroad progress commences. The "offshore" technology transfer supply element merely shifts into a more permanent operational mode, placing increased demands upon the national "industrial" research development centers. These research centers that once launched the initial beachheads of technology transfer must now strive to sustain their technical qualification and effectiveness. Technology transfer and research become equivalent in terms of national need and priority. Their effective integration of purpose and unity of effort become crucial to the national interest.

The preceding factors dimension the challenges of the new decade of the National Earthquake Hazards Reduction Program. They are of a new and far higher tier in technical and social complexity as well as national urgency and demand. The next ten year period must be approached through integrated local, regional, and national actions moving in higher gear. It must be accepted and confronted as it is --a period of national crisis in natural hazards technology transfer. And as we organize and act, our perspective must be international in scope. Certainly, while priority must be given to national needs, there is much to gain through a combined international campaign against a host of natural hazards that know no geographical boundaries.

There are many reasons to believe that our national programs have been postured to successfully meet these demands of the new decade. One is the establishment of the National Earthquake Research Center at Buffalo, N.Y. by the National Science Foundation. The combined efforts of it and the Earthquake Engineering Research Center at Berkeley, California, should ensure adequate technology generation by a research infrastructure accessible to all national regions. Another reason are the newer FEMA-supported NEHRP programs to develop adequate technologies for the strengthening of existing buildings, the design of lifelines, and effective utilization of new NEHRP building design technology. The Building Seismic Safety Council and Applied Technology Council are accepting greater leadership responsibilities in these efforts. The Earthquake Engineering Research Institute is continuing significant growth in public service. Other federal agencies such as the National Science Foundation, U.S. Gelogical Survey, Bureau of Standards and the Nuclear Regulatory Commission are maintaining aggressive programs of technology development and transfer. Regional centers like the Central United States Earthquake Consortium, Tennessee Earthquake Information Center, and the South Carolina Seismic Safety Consortium are taking hold. Still greater contributions in long-overdue technology transfer are emerging in the form of the International Decade for Natural Hazards Mitigation program. Originated in concept by the National Academy of Sciences and to be launched through the United Nations, this program would place major emphasis on the transfer of natural hazards

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mitigation technology to the end users. Finally, in the exercise of its responsibilities for overall NEHRP leadership, the Federal Emergency Management Agency is requesting an expanded budget authorization for natural hazards mitigation programs. This increased funding and effective resource utilization are of paramount importance to the national welfare and must be given nationwide support.

These initiatives are broad and bolder in nature. Collectively, they appear to anticipate the aggravated demands of the new decade of crisis in mitigation technology transfer. However, based upon our experiences in the southeastern United States, greater organization, unity of effort, and broadbased contribution will be essential if minimum essential natural hazards awareness and mitigation are to be achieved throughout our national communities. A national Natural Hazards Safety Consortium should be formed to advance mitigation technology and education. The national consortium should build upon and support a network of regional technology centers that operate individually at the community level. The Earthquake Engineering Research Institute (EERI) should accept the role as national integrator. Our many other national organizations including the new National Earthquake Research Center should provide continued vital support for this grassroots national structure. The American Society of Civil Engineers could serve as an effective national partner for the consortium. Certainly, this role would be consistent with the Society's professional responsibilities to the improvement of the public environment. I have recently discussed this possible teaming with the incoming national ASCE president, Mr. Albert A. Grant. He stated his interest and requested that we provide him a white paper outlining the potential partnership. However, primary reliance should not be placed upon the federal government. Expanded funding should be collectively sought from private, industrial, state governments and trade organizations. Starting with this workshop, we should quickly form a national task force to develop the national consortium. We should respond to the new generation of public welfare needs with a new national program initiative that moves us out beyond our current regional technology beachheads. Through this and the other national initiatives, we should be able to successfully meet the decade of crisis in technology transfer.

SOUTHEASTERN UNITED STATES

BY

Charles Lindbergh

The Citadel

CHARLESTON, SOUTH CAROLINA

Description of research application

The South Carolina Seismic Safety Consortium (SCSSC) was formed in February 1982 to develop and influence the implementation of a 5-year comprehensive action plan for earthquake preparedness and mitigation in South Carolina with emphasis on the low country region. The Consortium was an important outcome of the U.S. Geological Survey workshop on "Preparing for and responding to a damaging earthquake in the Eastern United States" held in Knoxville in September 1981. A sister regionally focused seismic safety consortium, the Southeastern United States Seismic Safety Consortium (SEUSSSC) was formed in ADHOC form. The objectives and subsequent activities of these consortia are described in the attached copy of "Earthquake Hazards, Risk, and Mitigation in South Carolina and the Southeastern United States" prepared by the South Carolina Seismic Safety Consortium and dated August 1986.

As originally intended, the seismic safety consortia would collectively enhance the technology and experience transfer required by the Southeastern states in addition to conducting the other less technical activities for seismic safety and hazards mitigation. However, it soon became clear that essentially no earthquake mitigation technology base existed in the southeastern region. Very few engineers practicing in the Southeastern United States have been adequately trained in earthquake engineering. No professional engineering examinations included seismic design exercises. These professional certification processes were not adequately protecting the public welfare. Little if any continuing education courses in seismic engineering analysis and design was available. No professional peer design review processes existed. In summary, the technology base was totally inadequate to support either the implementation or maintenance of effective seismic safety policy. A technology barrier to the development of adequate policy was found to exist. Subsequent consortia activities were faced with being limited to the promotion of awareness and non-technical mitigation measures. As later discussed in Congressional hearings, this longstanding absence of effective technical support was the most serious impediment to the evolution of seismic safety policy and its implementation.

The Technology Transfer and Development Council (TTDC) was formed to meet this need by raising the earthquake engineering technology base in the Southeastern United States to a level commensurable with perceived earthquake hazard and the national state-of-technology. The TTDC consists of leading regional engineers and scientists engaged in

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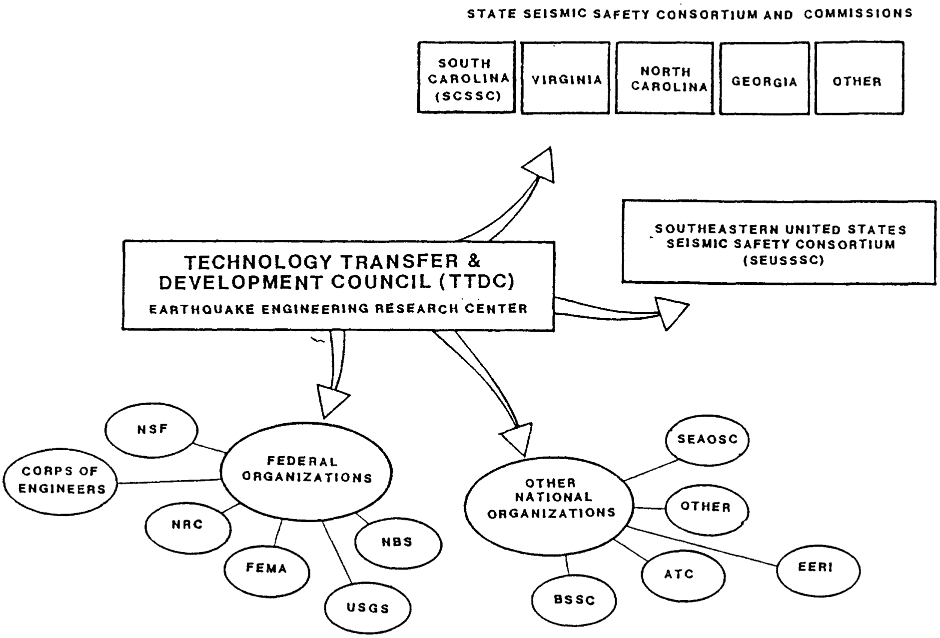

Figure 1

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TECHNOLOGY TRANSFER AND DEVELOPMENT COUNCIL (TTDC)

State	*Name*	*Affiliation*
AL	Dr. David Elton Geotechnical Engineer	Department of Civil Engineering Auburn University
FL	Dr. Winfred O. Carter Structural Engineer	Department of Civil Engineering FA&MU/Florida State University
GA	Dr. Lawrence F. Kahn Structural Engineer	School of Civil Engineering Georgia Institute of Technology
GA	Dr. Barry Goodno Structural Engineer	School of Civil Engineering Georgia Institute of Technology
GA	Dr. Leland T. Long	School of Geophysical Sciences Georgia Institute of Technology
NC	Dr. John J. Dwyer Geotechnical Engineer	Law Engineering & Testing Co. Charlotte, North Carolina
NC	Mr. S. B. Hager Nuclear Engineer	Duke Power Company Charlotte, North Carolina
NC	Dr. M. F. Schaeffer Geologist	Duke Power Company Raleigh, North Carolina
NC	Dr. Gregory Richardson Geotechnical Engineer	Soil Material Engineers, Inc. Raleigh, North Carolina
NC	Mr. Clay Sams Geotechnical Engineer	Law Engineering & Testing Co. Charlotte, North Carolina
TN	Dr. James E. Beavers Nuclear Engineer	Martin Marietta Oakridge, Tennessee
SC	Mr. Coley Altman Engineer	Enwright Associates Greenville, South Carolina
SC	Mr. John Doyle Preparedness Coordinator	S.C. Emergency-Preparedness Division Columbia, South Carolina
SC	Dr. Rudolph E. Elling Structural Engineer	Department of Civil Engineering Clemson, South Carolina
SC	Mr. Maurice R. Harlan Civil Engineer	Department of Civil Engineering The Citadel
SC	Dr. Charles Lindbergh Structural Engineer	Department of Civil Engineering The Citadel
SC	Dr. James B. Radziminski Structural Engineer	College of Engineering University of South Carolina
SC	Robert A. Shoolbred Structural Engineer	Robert A. Shoolbred, Inc. Charleston, South Carolina
SC	Mr. Edward H. Stehmeyer, Jr. Structural Engineer	Naval Facilities Engineering Command, Southern Division
SC	I. D. Smith Civil Engineer	Soil Consultants Charleston, South Carolina
SC	Dr. Peter Sparks Structural Engineer	Department of Civil Engineering Clemson University
SC	Dr. Pradeep Talwani Seismologist	Department of Geology University of South Carolina
SC	Mr. Robert B. Whorton Engineer	South Carolina Electric & Gas Columbia, South Carolina
VA	Dr. Richard M. Barker Structural Engineer	Department of Civil Engineering Virginia Polytechnic Institute and State University
VA	Dr. Gerald Wayne Clough Geotechnical Engineer	Department of Civil Engineering Virginia Polytechnic Institute and State University
National	Dr. Robert V. Whitman Geotechnical Engineer	Earthquake Engineering Research Institute (EERI) Massachusetts Institute of Technology
National	Mr. Henry J. Degenkolb Structural Engineer	Applied Technical Council (ATC) Earthquake Engineering Research Institute (EERI) Structural Engineering Association of California (SEAOC) H.J. Degenholk Associates

Table 1

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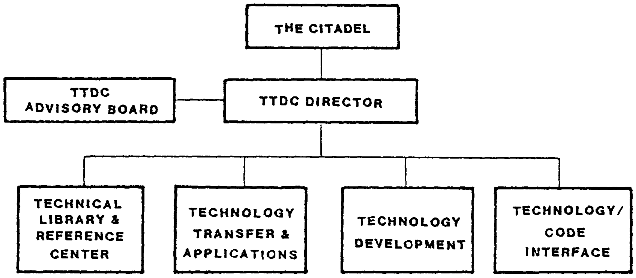

TTDC

Figure 2

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earthquake engineering application and research. They represent seismic technology activities in Alabama, Florida, Georgia, North Carolina, South Carolina, Tennessee and Virginia. The objectives of the Council include (1) to establish and maintain a technology baseline; (2) to disseminate technical information pertaining to earthquake effects; (3) to develop technical information pertaining to earthquake effects; and (4) to review, analyze, and provide technical support for applicable building code requirements and standards.

These activities will assist the Southeastern United States Seismic Safety Consortium, the South Carolina and other seismic safety consortia to achieve their objectives of effective seismic safety policy and programs within the southeastern national region. As such, the TTDC will cooperate with the Applied Technology Council, Federal Emergency Management Agency, National Science Foundation, United States Geological Survey, Nuclear Regulatory Commission, Building Seismic Safety Council, Earthquake Engineering Research Institute and others to promote effective national benefit of these organizations. Figure 1 illustates this functioning. Table 1 identifies the distinguished individuals serve on the TTDC. The Council consists of these 23 members who represent, in a balanced manner, the various geographical areas within the southeastern region and several technical disciplines concerned with earthquake hazard mitigation and preparedness. Many are also members of a regional seismic safety consortium and one is a member of the S.C. Governor's staff involved with emergency preparedness, further ensuring effective technology transfer will be achieved through TTDC activities. I serve as the Chairman of the Council. It is headquartered at The Citadel within its Department of Civil Engineering. Once fully implemented, it will act as an advisory board to the Earthquake/Wind Engineering Research Center. Reflecting the necessity to collectively consider all relevant natural hazards, a companion Coastal Engineering Center has been established. Both Centers exist in embryonic form and constitute the Multihazards Technology Transfer Institute at The Citadel.

During the past three years, two attempts to achieve two-year TTDC operational funding from the National Science Foundation and the Federal Emergency Management Agency have been unsuccessful. In accordance with these requests, the Earthquake/Wind Engineering Research Center at The Citadel would provide full-time technology support for the TTDC. In accordance with advice from the TTDC, the Center would in technology transfer, technical education and scientific activities pertaining to the effects of earthquakes, wind and associated natural hazards on people and property. Figure 2 illustrates its organization and functioning. It is hoped that support arrangements can be soon resolved with the National Earthquake Research Center at Bufffalo, N.Y. to permit the full operations of the TTDC and companion Earthquake/Wind Engineering Research Center as the NERC technology transfer element for the southeastern United States.

In the meanwhile, the TTDC/Center will continue to function within limited fractional funding from the U.S. Geological Survey, the Federal Emergency Management Agency, and the Citadel Development Foundation and

Table 2

TTDC/CENTER ACTIVITIES

1. Seismic Strengthening of Unreinforced Masonry Buildings.
2. Technology Development and Transfer Program.
3. Strong Motion Instrumentation in the Southeastern United States.
4. State Building Code Initiatives.
5. Public School State Building Code Initiative.
6. Development of Earthquake Engineering Technical Design Continuing Education Course Program.
7. Third U.S. National Conference on Earthquake Engineering.
8. Achieve Early Understanding of Eastern Earthquakes.
9. Congressional Testimony on the NEHRP.
10. Charleston, S.C. Vulnerability Study.

important cooperation provided by the Earthquake Engineering Research Institute and other national associates. The TTDC/Center operates in cooperation with the Structural Engineering Technical Group, South Carolina Section, American Society of Civil Engineers.

Some of the recent and ongoing TTDC/Center activities include those listed in Table 2. Each one will now be discussed in detail according to workshop format.

Seismic Strengthening of Unreinforced Masonry Buildings.

There are many existing unreinforced masonry buildings in South Carolina and the southeastern region. Many of these are of historic importance. Currently, there are no building codes or acceptable design standards for this type facility. A recently completed earthquake vulnerability study of Charleston, S.C. underscores the large number of critical facilities which are of this most vulnerable type of construction. New construction and retrofit design technology and building code provisions are urgently required.

The TTDC/Center is in the process of leading the regional adaptation of relevant NEHRP provisions and National Science Foundation methodology to retrofit unreinforced masonry buildings. This includes the development and sponsorship of appropriate Standard Building Code revisions.

The unreinforced masonry retrofit methodology developed by the ABK Joint Venture of California was presented at a January 1985 TTDC Conference at The Citadel. Approximately 150 engineers attended this two day conference. The National Science Foundation and the Citadel Development Foundation provided critical support funding. Agreement in-principle was reached that the ABK Joint Venture would participate with the TTDC in extension and adaptation for application of this technology, given adequate fund support. The Building Seismic Safety Council has started a FEMA funded program to develop design provisions for existing buildings. Through the trial design program, the BSSC has also worked to promote the use of the NEHRP provisions for new construction. Recently, Dr. Jim Harris representing the BSSC presented the NEHRP provisions to the Structural Engineering Technical Group, South Carolina Section, American Society of Civil Engineers. The catalyst for initial public acceptance is expected to result from a beginning FEMA funded project to apply NEHRP to certain masonry building designs common to the Charleston, S.C. school district. This project will be discussed later.

Within the past few weeks, a disasterous fire has resulted in immediate opportunity for the TTDC/Center to expedite application of the technology to a historically important unreinforced masonry building in downtown Charleston that was gutted by the fire. A successfull application could significantly accelerate public awareness and acceptance of the new design methodology. Fortunately, the opportunity has found the TTDC/Center equipped with the necessary responsive national support to provide this highly visible and important community service.

Technology Development and Transfer Program

The TTDC conducted its first full Council meeting at The Citadel during January 16-17, 1986. Earthquake engineering technology was reviewed and a preliminary technical program resolved. Organizational structure was established. NSF, FEMA, NSF, USGS, and NBS representatives participated. A delegate from the Structural Engineers Association of Southern California presented the Associations revised "Blue Book" on earthquake engineering design standards and criteria. Through continued periodic regional technology update meetings, the TTDC would be better able to manage the transfer of technology into the southeast region and to encourage that national research reflect regional differences and needs.

Strong Motion Instrumentation in the Southeastern United States.

The strong motion instrumentation of structures in the Southeastern United States has been initiated in August 1986 with the instrumentation of the Charleston Place, a major new convention center, in Charleston, South Carolina. The responsible U.S. Geological Survey Advisory Committee for Strong Motion in the Southeastern United States consists of TTDC members complemented by USGS personnel. I served as Chairman. Dr. M. Celebi was the U.S.G.S. coordinator. The U.S. Geological Survey provided project funding and design. Other project locations in South Carolina have been defined, however further work is pending additional funding.

State Building Code Initiative.

The TTDC/Center developed and presented to the South Carolina Building Codes Council on 28 May 1986, a multi-hazards recommendation that the Standard Building Code with seismic design provisions, be made mandatory in South Carolina. Certain continued code improvements were also recommended and TTDC support pledged to the Code Council. The S.C. Building Council passed a formal proclamation supporting the proposed TTDC/Center actions which included the following:

a. Achieve legislation that would require all cities, counties, state agencies to adopt and enforce the Standard Building Code;

b. Achieve legislation in part (a) such that the currently optional seismic design provisions are made mandatory building code requirements throughout the state of South Carolina;

c. Resolve training in wind/seismic design and construction procedures for building officials or their professional representatives;

d. Enhance qualifications of professional engineers in the nature and practice of wind/seismic design;

e. Resolve and sponsor prudent code revisions for the wind/seismic strengthening of existing buildings;

f. Effectively participate in the development of emerging multiple hazard building code technology, especially that of the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings;

Currently, the TTDC/Center is actively working with others to introduce legislation that would mandate the Standard Building Code throughout South Carolina and make the seismic design requirements part of the basic code provisions.

Public School State Building Code Initiative.

The South Carolina Department of Education directs school construction within the state. Currently, the Department has advised local school districts of the seismic threat to the State but only recommends the use of seismic strengthening provisions. Final decision authority for adopting such provisions is left with the local school district authorities. As the Charleston Vulnerability study reveals, seismic provisions are largely ignored.

The TTDC/Center is encouraging the adoption of seismic and wind resistive design standards through the results of the vulnerability study and by offering its technical support to the Department and Charleston County school district in developing design standards based on the NEHRP provisions and West Coast technology in unreinforced masonry construction adapted to the Charleston area. Mr. J. C. Kariotis, Kariotis and Associates, Los Angeles, California and Mr. Donald Jephcott will be the special consultants for this technology adaptation. Until his recent retirement, Mr. Jephcott headed the public school seismic design program for the State of California. The School District planning officer Ray Anderson will participate. The project includes the trial design of four school buildings (2 new, 2 existing), cost analysis, and recommendations to the School District. Depending upon continued funds availability, the action plan projects completion of the design technology and its application to new school construction by the end of 1988. FEMA is funding the study with the cooperation of BSSC. Technology for the strengthening of unreinforced masonry buildings developed by NSF sponsored

Development of Earthquake Engineering Technical Design Continuing Education Courses.

Through a new formal cooperative agreement, the Earthquake Engineering Research Institution and the TTDC/Center are working to develop and administer a 5-year continuing education program to establish a basic technology baseline in multihazards design within the southeastern United States. The various trade organization and other federal agencies are expected to contribute. The first workshop will be held in Charleston, S.C. during January 15-16, 1988. A mixture of national, regional, and local engineers and scientists will present a program on earthquake engineering design in the southeastern United States.

Third U.S. National Conference on Earthquake Engineering.

The TTDC/Center was one of the Cooperating Organizations for the Third U.S. National Conference on Earthquake Engineering held in Charleston, South Carolina during August 24-27, 1986. In concert with the South Carolina Seismic Safety Consortium, the TTDC/Center provided strong support of Local Arrangements for the Conference and the Public Awareness Activities throughout the Southeastern United States that preceded the event. Members of the TTDC served as Regional State Chairmen for Local Activities in Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia. As such, they managed college and secondary school student earthquake building and paper contests conducted in these states and otherwise participated in conference planning arrangements. The Earthquake Engineering Research Institute conducted the conference. The Citadel Development Foundation supported the many student contests and other special projects that preceded the conference.

Achieve Early Explanation of Eastern Earthquakes

Reference 1 provides the early assessment of earthquake hazards, risk, and mitigation in South Carolina and the southeastern United States conducted by the South Carolina Seismic Safety Consortium. The TTDC/Center seeks to establish an adequate early explanation of regional major seismic events and a refinement of the preceding threat assessment. During the past several years, two notable research events have contributed to this improved understanding. The first event was the May 1983 USGS workshop, "The 1886 Charleston, South Carolina, Earthquake and its Implications for Today," in Charleston, South Carolina. This workshop was one of a subseries specifically designed to define the earthquake threat in the Eastern United States and to improve earthquake preparedness. It was the second national workshop directly addressing South Carolina. In summarizing the workshop conclusions, Dr. W. W. Hays, USGS, declared that the earlier seismic threat assessment by the SCSSC remained valid and consistent with the state-of-knowledge. The second event are USGS and NRC studies of sandblow sites along the South Carolina Coast to establish evidence of pre-1886 moderate to strong earthquakes. Through liquefaction studies conducted in the Charleston area from 1984 to 1986, USGS and University of South Carolina research team investigations have established that the 1886 Charleston great earthquake was not an isolated event - that at least four liquefaction-producing earthquakes have occurred over the past 7,200 years near Charleston, South Carolina. These careful studies are convincing evidence that South Carolina will experience other major and greater numbers of smaller but damaging earthquakes. The question is not where or whether, but when the next event will occur and will we be ready? These seismic threat updating events are reported in Reference 1.

Congressional Testimony

Twice since 1983, the seismic hazard to the Southeastern United States and the serious lack of adequate mitigation technology have been presented to the Congress of the United States. Both times, I presented the testimony on behalf of the TTDC/Center, the South Carolina Seismic Safety Consortium, and the Southeastern United States Seismic Safety Consortium. In March 1983, testimony was presented to a U. S. House of Representatives subcommittee reviewing the effectiveness of the 1977 Earthquake Hazards Reduction Act, that the major accomplishments in earthquake hazard reduction and mitigation achieved under the provisions of the National Earthquake Hazard Reduction Program (NEHRP) have not materially benefited the Southeastern United States. This statement was reiterated in March 1985, to the Subcommittee on Science, Technology, and Space; Committee on Commerce, Science, and Transportation; United States Senate. Eight initiatives were presented which must be achieved to bring the Southeastern region abreast of California and other leading Western states in regard to effective earthquake hazard reduction and mitigation. Although little attention was focused on the Eastern United States at the 1983 House hearing, the Senate hearings in 1985 reflected a broad new national awareness and concern.

Charleston, South Carolina, Vulnerability Study

One result of these hearings was the funding by FEMA of the first vulnerability study in the Southeast - one of the Charleston, South Carolina, area. Led by Maurice R. Harlan, the study's purpose is to develop and document the potential seismic hazard to the Charleston tri-county region, including people, structures, and lifeline functions, so that federal, state, and local agencies will have the necessary basis for planning earthquake disaster relief and recovery operations and implementing effective mitigation measures. The basic methodology used in the vulnerability study consists of three essential elements:

1) Postulate an earthquake that may reasonably be expected to occur;

2) Develop an inventory of facilities that will be critical to disaster response and recovery operations, and other facilities important to the community welfare, such as schools; and

3) Develop estimates of damage factors and assess the impact such damage would have on the community.

The study has been completed and the report is being written. Its results are already supporting several initiatives of the South Carolina Seismic Safety Consortium and the Technology Transfer and Development Council. When released next January, the study will provide a sound basis for follow-on actions, such as:

1) Federal, State, and local plans for earthquake disaster response;

2) Earthquake hazard mitigation studies;

3) Implementing appropriate public policies;

4) Conducting public awareness and education programs; and importantly

5) Use as a prototype for the conduct of similar studies for other South Carolina and Southeastern United States localities.

How could the application process have been improved

Despite program efforts over the past six years, the southeastern United States remains at least as unprepared to cope with the social and economic impacts stemming from a major damaging earthquake. However, if the process could start over, I would probably change very little. The experiences of the past six years have been valuable at least in that they have underscored for the southeastern United States those technology transfer processes and assets that are essential and prepared it to take full advantage of them as they are provided. They have confirmed that no significant improvements in regional seismic or other natural hazards safety policy can be achieved without major improvements in mitigation technology. They have given technology transfer at least equal priority with continued research. However, they have spawned several technology and building code initiatives that, if developed through substantial technology transfer to implementation could result in significant early hazard mitigation improvements throughout the Southeast. They have also made clear that the program focus must be broadened to include all relevant natural hazards. Policy and technical detail can not effectively address with to the exclusion of the others. Their natures and characteristics are too similar. The need for cost economy is too compeling.

Given the currently defined national initiatives including the request for increased appropriations by FEMA, the most important change in the application process for the southeastern United States would be for the National Earthquake Research Center to establish the Technology Transfer and Development Council and the Earthquake/Wind Engineering Research Center at The Citadel as its technology transfer associate for the southeastern United States. The most important change in the process for the national effort would be the establishment of a national consortium for natural hazards technology transfer consisting of independent regional technology transfer centers integrated through the Earthquake Engineering Research Institute and underpinned by the national research centers, federal agencies, and other national organizations such as the BSSC, ATC, and SEAOC. This twofold improvement is essential to the future worth of the NEHRP no matter what program resource levels may be achieved. A position paper on the establishment of a National Consortium for Natural Hazards Technology Transfer is attached.

A Regional Earthquake Information Center

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The primary function of an earthquake information or education center, whether local, regional or national is the transfer of knowledge gained from research to the members of the community who need it. Because the effects of earthquakes are so widespread, comprehensive and involve so many secondary hazards, this means that every member of the community needs some level of information on how to prepare for earthquakes. However, to be most effective, this information must be specifically tailored to the level of understanding of various segments of the community and different age groups, and to the specialized informational needs of those who have responsibility for the safety of others or particular circumstances which must be addressed.

From its inception, the Center for Earthquake Research and Information (CERI) at Memphis State University, (formerly the Tennessee Earthquake Information Center, TEIC) has had a mandate from the state legislature to provide: "accurate, immediate reports and background information on the occurrence of regional earthquakes" as well as "advice to the populace, business, government and insurance groups on methods, means and the feasibility of reducing earthquake damage." This is an important public service function, but a passive one. In August 1983, the Center began an active public education program on earthquake preparedness under Cooperative Agreement EMW-83-K-1236 with the Federal Emergency Management Agency. This paper examines the progress of that program during its 3-year lifetime in an effort to define the most effective elements of the program and to learn from its failures as well as its successes. In Section One, the initial plans, their evolution as theory met the real world, and the measurable outcome are reviewed. Section Two identifies the research studies which contributed to the knowledge base used by the program staff and the agencies which funded those studies. The process of translation from research results to readily accessible public information is discussed in Section Three, while Section Four is a comparison of dissemination methods. Finally, with the benefit of hindsight, some suggestions are made as to how several of the problems encountered could have been alleviated, if not completely avoided.

1. Program Design, History and Scope

The establishment of the Earthquake Education Project (EEP) at CERI had its roots in the provisions of the National Earthquake Hazards Reduction Program and in the general recognition by scientists and disaster planning officials that the New Madrid seismic zone and the surrounding region comprise the highest earthquake risk zone east of the Rocky Mountains. Although an average of 150 earthquakes per year with magnitudes greater than one have been recorded, only about seven per year are reported as felt (Johnston, 1982). Thus, many of the inhabitants of the area were not aware that they live in "earthquake country."

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The overall goal of the earthquake education project was to reduce personal and community vulnerability to earthquake risk through enhancing the public's ability to understand earthquake phenomena and risk, to identify hazards to life and property, and to effect measures to reduce those hazards. The design of the project sought to benefit from lessons learned from existing earthquake education projects in California and to utilize the information/education materials already developed, while recognizing that major differences in the geology, seismicity and public awareness levels in the different regions would require considerable adaptation.

The Memphis EEP began operation in mid-August 1983 with a one-year Cooperative Agreement and a budget of $75,000. FEMA subsequently exercised its option to renew the agreement for a further two years, and the budget for the three year program totaled $190,000. Four program objectives were defined as follows:

- Make known and available the best of existing products and services appropriate to the general public and specific target audiences;
- Enhance the use of these products and services by assuring that they are tailored to the earthquake study area and audiences and are distributed through existing community channels;
- Establish a network of trained volunteers to extend community outreach capability and maintain a library of educational materials (slides, films, tapes, three-dimensional models, books, reports and pamphlets) to be used by staff and volunteers;
- Provide a solid foundation for short and long term program evaluation.

A variety of specific tasks were then required, which helped guide the development of the program so as to meet these objectives. The most helpful of these tasks assured the early establishment of an Advisory Council, the development of mechanisms for field testing materials and for tracking use and dissemination of products and services, the acquisition of materials for the resource library, and the formulation of long range planning which incorporated identification of target audiences specific to the area and possible channels to these audiences.

We recognized on the front end, that the low level of earthquake hazard awareness posed a variety of problems:

1. There are no seismic requirements in the local building codes, hence very few buildings incorporate seismic resistance.
2. The general public as well as disaster response planning agencies tended to focus on the more visible prospects of floods, tornadoes and hazardous material spills.
3. People would need to be convinced that there really is an earthquake hazard before they would be willing to learn how to protect themselves, their families and their property from earthquakes.

This last factor was responsible for a major problem that was totally unanticipated. There were very, very few people in this region of unspectacular geology who had a pre-existing interest in geology and/or earthquakes, making the recruitment and training of volunteers far more difficult. It also meant–particularly during the first half of the project–that the volunteers we did have were not able to answer the types of questions that target audiences wanted answered. Our solutions to this problem and suggested improved approaches will be discussed in the final section.

The second major problem we faced was acquiring the educational materials needed. Although FEMA provided a wealth of materials and information on sources, as well as a complete set of the three-dimensional models developed by the EV of California for teaching earthquake causes and effects, there were gaping holes. At that time, there were few materials readily available for tailoring presentations for hospital staffs, business and industry, computer facilities and utilities. It also took far longer than anticipated to develop the region-specific teaching tools that were needed. Fortunately, most of theses needs have now been filled, and the most important sources of information will be given in Section Two.

The third major limiting factor to the effectiveness of the EEP was the size of the staff. All staff members worked only part time on the project, and at the highest level attained were equivalent to 1.45 full time personnel. However, having several part-time positions is one way of broadening the range of staff expertise and is seen as an advantage. There are a number of ways to extend the size of the staff. Among those that were most effective in Memphis were the close cooperation and sharing of materials and ideas among the EEC's in Seattle, WA. and Charleston, S.C.; and the generosity of the Southern California Earthquake Preparedness Project (SCEPP), the California Earthquake Education Project (CALEEP) and the Bay Area Earthquake Preparedness Project (BAYREPP).

Our Advisory Council was such an asset to the Project that it deserves particular consideration. Members were selected from segments of the community having interests that would make association with the EEP mutually advantageous, and where possible, were people already known to have an interest in the earthquake problem. The resulting group of educators, emergency management and disaster response experts, engineers with knowledge of seismic problems, a geophysicist and industry representatives provided a broad range of expertise and liaison with community elements important to project goals. Demands on the members' time were kept to a minimum by holding only two meetings per year at which progress reports were given and advice on program development sought. Thus, their main input came when we called on specific members for assistance with various aspects of the program, which they unfailingly supplied. To give just a few examples: seven members reviewed the field test version of the School Safety Planning Guidebook and made valuable suggestions for improvement; the city and county school representatives were instrumental in getting teachers released to attend workshops and in guiding us through appropriate channels for various school programs; one member arranged for his firm to print the leaders' guides and girls' workbooks for the Girl Scouts Natural Hazards Preparedness Patch Program; many of them supplied us with information and materials and provided us with access to various segments of the community; and the member from the fire department provided firemen to instruct school safety committees on evacuation and search and rescue techniques. A significant number of the members attended workshops and gave talks. In short, they became an extension of the EEP staff and were instrumental to our success in many areas.

We were also fortunate to be working within an organization having additional staff members who could assist in project activities. The graduate students gave tours of the

Center to a variety of school and community groups. The technical staff replicated the most used 3-dimensional models and kept them all in working order. The research staff gave numerous talks throughout the community, and almost everyone, including secretaries helped man the Mid-South Fair exhibits.

The internal motivating events that guided the program were primarily the trial and error process of finding the most efficient and effective ways to meet the defined program goals. External motivating events fall into two categories– the activities of other agencies involved in the earthquake risk mitigation effort and natural events, i.e. earthquakes that occurred in other areas, but were well-covered by the media and stimulated the public to seek earthquake preparedness information. Hearing about earthquake risk from more than one source adds credibility to the reality of the risk.

How well did we succeed in meeting our stated goal? It is relatively straight-forward to cite statistics. Three times as many presentations were given during the first year of the EEP as in the preceding year, and these increased a further 61% each year. Our cumulative audience for the three year program was more than 31,000, without attempting to estimate the number of people who viewed exhibits or were reached by media coverage. More than 103,500 items of earthquake and earthquake preparedness information were distributed, in addition to almost three million grocery bags bearing earthquake safety procedures. More subtle indications can be found in the fact that requests for presentations now focus on preparedness information rather than risk information and that media coverage of earthquakes, wherever they occur, has increased dramatically. For example, CERI staff responded to 81 media interview requests during the past year as opposed to 43 during the final year of the EEP.

2. Research Studies Utilized

A wide range of research studies were utilized by the staff in the course of the EEP, and can be divided into four categories: A. Geology and Seismicity of the New Madrid Region; B. Damage Assessment; C. Earthquake Preparedness; and D. Studies by social scientists which addressed the human factors important for developing strategies and motivational techniques. While it is impossible to list all of these studies, a few of the major sources, with funding agencies are briefly discussed below.

A. A collection of papers edited by McKeown and Pakiser, 1982,*Investigations of the New Madrid, Missouri, Earthquake Region*, Geological Survey Professional Paper 1236, and *The Proceedings of the Symposium on the New Madrid Seismic Zone*, edited by Gori and Hays, 1984, USGS. Open File Report 84-770 were two major sources of information on the geology and seismicity of the New Madrid Region. The research studies presented in these volumes were variously funded by the USGS, the NSF and the NASA. James L. Penick, Jr.'s charming book "The New Madrid Earthquakes" was a favorite source of historical material.

B. Among the most used studies on damage assessment are:

- *Regional Earthquake Risk Study*, 1974, by M & H Engineering and Memphis State University, funded by the Mississippi Arkansas-Tennessee Council of Governments.
- *An Assessment of Damage and Casualties for Six Cities in the Central United States Resulting from Earthquakes in the New Madrid Seismic Zone*, 1985, Central

U.S. Earthquake Preparedness Project (CUSEPP), funded by the Federal Emergency Management Agency (FEMA).

- *Earthquake Hazard Analysis for Commercial Buildings in Memphis*, 1982, by A.S. Nowak and E.L.R. Morrison, funded by the USGS.
- *Estimation of Earthquake Effects Associated with a Great Earthquake in the New Madrid Seismic Zone*, 1982, by M.G. Hopper, S.T. Algermissen and E.E. Dobrovolny, CUSEPP Report 82-3, funded by the USGS.

C. The scope of earthquake preparedness materials now available covers almost every aspect of community vulnerability, from concise pamphlets on home preparedness to more lengthy planning guidelines for schools, city and county governments, large corporations and small businesses, and special needs audiences such as the disabled. Most of these have been developed by FEMA, the Red Cross and California's three earthquake education/preparedness projects: SCEPP, CALEEP and BAYREPP. Other very useful publications include: *Hospitals and the San Fernando Earthquake*, 1983, by C. Arnold and M. Durkin, funded by the N.S.F.; Assessing Your External Disaster Plan and Disaster Drills, 1983, by J. Chien and M.E. Avila, funded by the Hospital Council of Southern California, Reducing the Risks of Non-Structural Earthquake Damage: A Practical Guide, 1983, by R. Reitherman, funded by SCEPP and FEMA.

D. Studies of the social, economic and political aspects of earthquake hazard mitigation give direction for planning approaches to various segments of the community as well as providing motivation tools. Among those we found helpful are:

- *Social and Economic Aspects of Earthquakes*, 1982, edited by B.G. Jones and M. Tomazevic, Proceedings of the Third International Conference: The Social and Economic Aspects of Earthquakes and Planning to Mitigate their Impacts, sponsored by the NSF and the U.S.-Yugoslav Joint Board on Scientific and Technological Cooperation.
- *The Politics and Economics of Earthquake Hazard Mitigation*, 1986, by D.J. Alesch and W.J. Petak, funded by the NSF and published by the University of Colorado Institute of Behavioral Science.
- *Earthquake Mitigation Policy: The Experience of Two States*, 1983, by T.E. Drabek, A.H. Mushkatel and T.S. Kilijanek, also funded by the NSF and published by the University of Colorado Institute of Behavioral Science.

These are only a few of the more than 500 titles listed in the EEP Resource Library Inventory. It should also be noted the Proceedings of the USGS-FEMA sponsored workshops on reducing losses from earthquakes that have been held in many areas of the U.S. are a prime source of information for all four of the categories listed above. Ongoing sources of information of materials available are the Natural Hazards Observer published by the University of Colorado Institute of Behavioral Science, and the FEMA and BAYREPP newsletters.

3. Translation Activities

An earthquake information center is in essence an ongoing process of translating research results into readily applicable information for the public. Wherever possible we took advantage of the work already accomplished–primarily in California–in converting reports of actual earthquake damage into specific recommendations on techniques that could prevent much nonstructural damage and that individuals could easily and economically effect. Thus most of the earthquake safety translation was done by various agencies funded by FEMA, the Red Cross and the state of California.

The educational materials and models developed by the EV's of California explained the process of plate tectonics and earthquake causes and effects in understandable and interesting terms for elementary and junior high level students (not to mention adults). Thus the EEP staff was left with the task of transforming region-specific information on geology, seismicity and risk into a similarly effective format. The interaction of presenters and participants in the EV and Creative Home Economics Services workshops conducted during the first year of the EEP was one highly productive translation activity. Another was a three-week seminar for earth science teachers in which the teachers drew on materials provided by EEP staff to develop lesson plans and classroom activities that were specific to the New Madrid area. A lesson plan on the formation of Reelfoot Lake designed by geologists at CALEEP has also been well utilized.

Other useful products include the film strip "Time to Prepare: Emergency Disaster Procedure" produced by the Los Angeles Unified School District, the EV videotape demonstrating use of the three dimensional models, and a variety of commercially available films produced by the Encyclopedia Britannica and other companies.

In another line, the Department of Housing and Urban Development underwrote the interpretation of Applied Technology Council recommendations into a layman's booklet, the Homebuilder's Guide to Earthquake Resistant Construction. The Building Seismic Safety Council, funded by FEMA, has also produced many publications which can be used by engineers and builders in earthquake prone areas.

Clearly, many agencies have participated in making research results accessible for diverse segments of the community. The material currently available is much broader in scope than that which existed even three or four years ago.

4. Effective Dissemination of Information

The salience of earthquake risk in a given area exerts a strong influence not only on which dissemination methods are most effective, but also places limitations on the possible avenues to both specific segments of the community and to the general public. It is difficult to get cooperation from the media until they are convinced that earthquake preparedness is relevant to their audiences, and appeals to the general public are most likely to elicit calls from program chairmen seeking free speakers for their club meetings. Maintaining exhibits achieves a measure of recognition, but they are probably not an effective way to motivate individuals to implement preparedness measures without an external trigger. (For example, our 1984 Mid-South Fair exhibit probably led to a dozen requests for presentations, while the aftermath of the 1985 exhibit, which immediately followed the Mexico City earthquake, kept us busy for months.)

In Memphis, the crucial factors in getting the EEP launched were the inter- agency links that were established and finding the people within a particular organization whose interests most closely coincided with ours. The members of our Advisory Council played a major role in opening doors for us. In the schools, the science coordinators arranged for earth science teachers to attend workshops, and in time we were asked to provide in-service training not only for teachers, but also for administrative staff. Eventually the Board of Education added earthquakes to the Health and Safety curriculum, but not until after the earthquake awareness level of the general public had been raised. Other inter-agency links which were particularly beneficial to the project were those with the Red Cross, the Tennessee Emergency Management Agency, the Memphis and Shelby County Emergency Management Agency, the Girl Scouts and the Fire Department. As for finding the appropriate contacts within an agency, those with a risk management, safety or training role invariably proved to be our most effective contacts. These contacts led to our participation in the Hospital Disaster Planning Committee, the city-wide earthquake response exercise and the participation of many local industries in activities during Earthquake Safety Week.

While 2-3 hour workshops and in-service training sessions were the most effective dissemination methods for reaching the school population, Earthquake Safety Week undoubtedly was the most powerful means of reaching the entire community. The week's activities included the proclamation of Earthquake Safety Week by the Memphis and Shelby County Mayors, 10-12 appearances by CERI staff on TV and radio shows, the presentation of earthquake safety information by TV weathermen several times each day, poster and essay contests in the schools, distribution of Earthquake Safety Checklists to hospital and industry employees, an all day series of lectures, films and demonstrations at the Memphis Pink Palace Museum, and the use of grocery bags printed with earthquake safety tips by many area grocery stores.

Another very effective dissemination effort was the Girl Scouts Natural Hazards Preparedness Patch. Once the materials for the program were developed, (with generous contributions from the Santa Clara Co., CA., Girl Scout Council) the program ran without much input from the EEP staff. Since one of the requirements for earning the Patch was to share lessons learned with family and neighbors or classmates, there was also a significant ripple effect. Many of the scouts who had earned the Patch contributed hours of volunteer work during Earthquake Safety Week, also.

5. Hindsight

Many of the lessons learned as the EEP progressed have been discussed in the previous section, leaving the two major problem areas to be addressed here.

The first of these involved obtaining and developing the materials needed for the program. It took far longer than anticipated to review materials available and obtain those judged most useful, to locate information needed to tailor presentations to specific target audiences and to translate the technical material on regional geology and seismicity into a form suitable for the wide variety of age groups and interests within the community. Although the Resource Library eventually became a particular strength of our program, it took an entire year to acquire even the most essential needs. The inventory published by BAYREPP was a prime source of information and all three California projects were generous in filling our requests. Many of the information gaps of the EEP's early years have since been filled by FEMA publications as well as those by BAYREPP, CALEEP and SCEPP. We also produced a Resource Library inventory which is available upon request and have provided copies of regional information to neighboring state agencies involved in similar activities.

The second problem area was the volunteer program. The task of recruiting, training and maintaining a volunteer group is not a simple one. Moreover, the specialized needs of the EEP present some difficulties not encountered in more typical volunteer organizations. The low salience of earthquake risk in the region meant that few people viewed earthquake preparedness education as a community need, and that those few who did volunteer had no background training to help them assimilate the scientific information. It also meant that audiences wanted scientific evidence of earthquake risk before they were amenable to preparedness information. The participants in the three train-the-trainer workshops held 6-7 months after start-up fell into two categories: 1) teachers and professionals who could put their new knowledge to work in their jobs, but did not consider themselves EEP volunteers, and 2) volunteers who had mastered the earthquake safety training, but had difficulty with the scientific material. The latter were understandably reluctant to face audiences almost certain to ask questions they couldn't answer. Thus we were faced with a problem of finding meaningful work for the volunteers to do and providing further training.

Once a program is well-developed, it may be possible to integrate volunteer activity into the program on a regular basis. Our needs tended to be episodic, usually related to workshops, Earthquake Safety Week or exhibits. It was sometimes difficult to find space for volunteers to work or to have access to needed equipment without interfering with other work in progress at TEIC. We were fortunate in finding a network of special people who were willing to come in on short notice and work hard. The volunteers made many valuable contributions to project, but the staff was left with the uncomfortable feeling that much of the work we asked of them did not provide the rewards that volunteering should. It is significant that the most successful part of the volunteer program–maintaining exhibits–was an activity to which they were essential and one in which there was interaction with the public.

> Therefore, we recommend that before attempting to initiate a volunteer program, an Earthquake Education Center should have its overall program well enough developed so that:
>
> - all materials needed for training and implementation are available;
> - the most likely sources of volunteers have been identified;
> - training programs can be tailored to specific groups, i.e. laymen, teachers, or people who will use the knowledge in job related activities;
> - there is meaningful and rewarding work for the volunteers to do.

For centers with small staffs, inter-agency links and a small number volunteers with particular skills may be more effective than a more formalized volunteer organization. Alternatively, interesting an existing volunteer group in participating in the EEP along with their other activities would solve the most of the problems we encountered in trying to run our own volunteer program.

We conclude this three-year effort with a substantial sense of accomplishment. Community involvement exceeded our initial expectations. Although it will take time to reach system-wide earthquake safety planning in the schools, the groundwork has been laid and we made significant progress in introducing the issue to school populations.

A change in attitude has come about in the Memphis area during the past four years. Both Advisory Council members and EEP staff found that the government and private sector have moved away from detailed discussion of earthquake risk toward placing emphasis on what needs to be done.

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TAKING ADVANTAGE OF THE FEBRUARY 9, 1971, SAN FERNANDO, CALIFORNIA, EARTHQUAKE

by

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Summary*

The Moderate-magnitude (M_S = 6.4) San Fernando earthquake which struck the edge of a major metropolitan area on February 9, 1971, served as a catalyst for data acquisition and analysis, applications, and changes in public policy--probably more so than any other earthquake in the United States, both before and after 1971. The earthquake occurred on a thrust fault, which had not been recognized previously as tectonically active and potentially capable of generating a moderate earthquake. The earthquake produced more than 200 strong motion accelerograms; whereas, each prior U.S. earthquake had produced only a few records. These records of free-field ground motion and building motions provided a technical basis for comprehensive studies of damage, ground response, and seismic wave propagation and ultimately were disseminated throughout the World.

One of the records was the famous Pacoima dam accelerogram, which was on rock in the epicentral region and had a peak value of 1.24 g. This record stimulated research on: 1) the effect of topography on ground motion, 2) ground response, 3) duration of shaking, 4) effective peak acceleration, and 5) the "killer pulse," a characteristic of the ground motion associated with the "fling" of the fault.

The increase in quantity and quality of the strong motion data sample, coupled with the new structural response and damage data, led to the re-evalaution of seismic design criteria for buildings, critical facilities (hospitals, dams, and nuclear power plants), and lifeline systems (highways, bridges, gas, water, and electric utilities). Lifeline earthquake engineering began as an institutionalized activity as a result of the nature and extent of damage sustained by lifelines in the San Fernando earthquake.

The concept of a seismic safety element as a part of a community's general plan was introduced after the earthquake, and legislation was passed to implement it. The earthquake also provided a "window of opportunity" for many other pieces of seismic safety legislation.

Editor's Note: This summary was prepared from the oral presentation.

1979 IMPERIAL VALLEY EARTHQUAKE - ITS IMMEDIATE, SHORT-AND LONG-TERM IMPACT ON SEISMIC DESIGN PRACTICE

BY

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1979 Imperial Valley (IV) earthquake was the most well recorded earthquake at the time. The strong motion recording from this earthquake provided data for immediate, short - and long - term application into practice. One of the immediate application focused on answering questions related to influence of seismic source directivity on strong ground motion for Diablo Canyon nuclear power plant. It was the very first recorded data set that put bounds on the theoretical perdiction of the effects of source directivity on strong ground motion. Some of the other immediate applications were made to design of dams and offshore structures. The immediate application of information to dams and nuclear power plants is strongly driven by the safety whereas the usage by the offshore industry is driven by the industries desire to stay at the leading edge of the technology.

Some of the more short term demands on the data came from the innovative technology. For example, the design of base isolated structures demand nothing but the best research and technological advancements in base isolation systems as well as the ground motion input. Because the design of base isolated structures is sensitive to the long period responses of the ground motion close to the natural period of isolation system, it requires understanding of the long period ground motions above and beyond those prescribed by the codes. The research into the Fourier amplitude and Fourier phase of the records obtained from the IV earthquake provided new insights into generation of synthetic time histories that appropriately preserve the charateristic site strong ground motion.

List of long term applications can be long. However two important ones that come to mind are (1) educating professionals and policy makers especially those who are skeptics and always want somebody else to be the first and (2) making the information part of the regulations and codes.

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Based on the IV earthquake data, Seismic Zonation Subcommittee of the Seismology Committee of Structural Engineers Association of California (SEAOC) proposed a new Seismic Zone 5 to reflect the characteristics of ground motions in the near field. Although not quite successful in getting it accepted, the intent of the Seismic Zone 5 is now contained in the commentary of the latest version of the SEAOC recommendations.

From the foregoing, it is obvious that the timeframe of transfer of research in the practice can be quite varied. The slowest pace is found in getting research incorporated into codes and regulations. However, it does not imply that if research results have not found their way into the codes and regulations that the current state-of-practice does not use the results of research. It does but the results are mixed. A more "well informed" consumer will go above and beyond the then current regulations to apply research results into his practice. However, on the other hand a consumer "content" with then the current codes and regulations may strongly discourage use of new advances. I believe one of the aims of this workshop is to expedite the acceptance of research and find avenues to make the acceptance equally attractive to "well informed" and "content" consumers.

How can we do this? I do not think it is easy, but I strongly believe that this is a job well suited to researchers and practioners with (a) multi disciplinary backgrounds (b) abilities to identify and understand needs of different disciplines (c) abilities to separate issues and to discuss interaction among different disciplines and (d) abilities to communicate research results on a timely basis in form of simple concepts.

What impedes the acceptance of research into practice? I believe one of the major roadblocks is either intensive research or intensive practice by individuals in a given discipline. This makes the focus narrow for exchange of information. I strongly feel that this roadblock can be removed by cross training these individuals into the related disciplines of their research or practice through multidisciplinary education.

What should the strategy be? I believe a core group of interdisciplinary researchers and practioners should be formed whose main job should be to expedite research application process. Special funding should be allocated from the National Earthquake Hazard Reduction Program for this purpose.

Here are some of my experiences:

Funding: I have not seen any funding to support such interdisciplinary efforts. Most of the funding goes to academia or to narrowly focused research. The results of narrowly focused research get lost or delayed if a proper match for their need is not found in practice.

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Motivating factors: My motivations to continue applied research have been strongly driven by the philosophy (a) to stay at the leading edge and (b) to continually stay abreast of the needs of the industry to find areas that require transfer of research into practice. My strong cross training in different disciplines permits me to transcend boundaries of different disciplines and thus make interdisciplinary applications of research into practice easier.

Specific Research: Here are some of the research efforts following the 1979 IV earthquake that contributed to my advancement in this field: (1) Interpretation of strong ground motion records (2) Understanding of the moving source and rupture processes (3) Role of seismic source directivity in strong ground motion seismology (4) Synthetic generation of non stationary time histories (5) Understanding of coherent and incoherent seismic energy (6) Evaluation and application of in-phase and out-of-phase motions (7) Application of truly three dimensional seismic input in soil structure interaction studies (8) Understanding of source, travel path and local soil effects on strong ground motion (9) Solution of large deformation problems using nonlinear soil models and realistic seismic inputs.

Source of Funding: The external sources of R & D funding were almost nonexistant. Most of my research is based on funds from projects or from internal R and D funds.

Research and Application of Research: The research and application of research in my case was strongly driven by both research as well as the needs of the industry. There was always a consistent effort to identify a marketplace where the research could be melded together with needs of the industry to enhance the state of practice.

My recommendations: I strongly feel that the disemination of research information has to take place at different levels ranging from scientific meetings to continuing education seminars in order to accomplish a timely transfer of research results to application. Education of consumers of this information is of paramount importance because they have to be convinced that they are buying the best technology at the time. This process is best accomplished through continuing education where research can be exchanged with a consumer in form of simple concepts.

For research results that have to find their way to application, I would be more inclined to fund individuals who are researchers as well as practioners cross trained in different disciplines. I would recommend holding workshops for these individuals at frequent intervals to keeps them strongly cross trained and to make them continually aware of changes and findings in different disciplines.

I would use the group of cross trained individuals to give continuing educational seminars to researchers, practioneers and policy makers to emphasize the need for broader interdisciplinary understanding to focus the future research needs and to expedite the application to National Earthquake Hazards Reduction programs.

THE COALINGA EARTHQUAKE: FOUR YEARS LATER

By

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Introduction

The occurrence of moderate-sized earthquakes (M6 to M7) in California is not uncommon. Events comparable in size to the May 2, 1983 Coalinga event occur somewhere in the state on the average of once every two years. Temblors of roughly the same magnitude occurred in Imperial County in 1979, Mammoth Lakes in 1980, and Morgan Hill in 1984. However, the Coalinga event was the subject of many more studies than these other events; in fact, it was one of the most extensively studied of all U.S. earthquakes. The only recent California earthquake that generated comparable interest among researchers was the 1971 San Fernando event.

The Coalinga earthquake produced a large volume of research for several reasons. First, its social impact was substantial. The earthquake caused over two hundred major and minor injuries, some very dramatic damage, and extensive social disruption. Unlike many small and moderate earthquakes, the Coalinga event was a true community-wide disaster that attracted researchers from a wide range of disciplines, including earth sciences, engineering, architecture, planning and sociology. Second, Coalinga's central location in California made it readily (and inexpensively) accessible by automobile to researchers and other interested persons living in the state. In fact, many individuals went to the site within hours after impact. Third, the intense media coverage of the May 2 earthquake increased its perceived importance for various groups, including political leaders and members of the research community. Finally, such a large number of studies were conducted on Coalinga because a "critical mass" of individuals had funds available at the time or were able to obtain supplementary funding to collect data on the event.

Although I have made an effort to identify all the studies on Coalinga that were funded by the National Earthquake Hazards Reduction Program, my list is probably incomplete. Studies of which I am aware include the following: the work of Aroni and his associates on earthquake-generated injuries; a study by Arnold, Baird, and Durkin, on the post-impact behavior and information needs of hospital staff in the impacted area; Bolin and Bolton's study of minority family recovery; Durkin's study of business impacts; French, Ewing, and Isaacson's work on short-term recovery; Nigg and Mushkatel's study of the community response and the earthquake's impact on households; Reitherman's project on the performance of unreinforced masonry buildings; the work of Rubin and her associates on community recovery; Sood's work on communications in the emergency period; and a number of engineering, geologic, and related studies compiled in the Earthquake Engineering Research Institute's report on Coalinga (Scholl and Stratta, 1984). Research findings have been disseminated in the case of most, but not all, of these studies. In addition to these projects, which have involved the provision of funds to investigators outside the government, the U.S. Geological Survey conducted various studies and published a special report on the earthquake (Borcherdt, 1983).

This paper will attempt to discuss and advance hypotheses about how findings from studies on the Coalinga earthquake have been applied in the four years since that event. Before discussing the impact of this research, however, it is necessary to introduce some qualifications and clarifications.

First, I have been asked to make a presentation on "The Coalinga Earthquake--Four Years Later," which implies that the application of research findings on this particular earthquake should be the main focus; however, studies on the Coalinga event did not, in and of themselves, have an impact on programs, laws, and policies. Instead, as the discussions that follow illustrate, they tended to complement or reinforce other work. I suspect that this is the most common pattern with respect to research findings. It is probably highly unusual to find a single study or a set of studies on a single event that, in isolation, have led to the development of a knowledge base that could then be applied. Rather, the material that is involved in research applications is the cumulative product of a whole body of work. Similarly, it is difficult to assess the separate, independent contribution to the knowledge base of studies funded by the National Earthquake Hazards Reduction Program, as distinct from research funded by other sources. For example, the California Division of Mines and Geology published an important volume on the Coalinga event (Bennett and Sherbourne, 1983) that contributed to the knowledge base. Some research reports were independently sponsored, but incorporated the findings of studies undertaken by NEHRP-funded investigators. The Earthquake Engineering Research Institute's Reconnaissance Report (Scholl and Stratta, 1984) is an example. Approximately half of the thirty-three papers contributed to that volume were prepared with some degree of NEHRP support. My own report on Coalinga (Tierney, 1985) was funded by a state agency, the Seismic Safety Commission, but many of the findings discussed extensively in the report are based on NEHRP research, and several of those investigators shared data and findings with me.

Second, at least in the case of Coalinga, it is not really possible to say that research on an event--as opposed to other more immediate sources of information--is the main element that has been incorporated into application efforts. Several individuals I spoke with during the writing of this paper referred less to research than to the event itself when discussing subsequent changes in awareness, policy, and practice. Simply observing how the

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earthquake affected unreinforced masonry buildings in Coalinga was a learning experience for California residents and decision-makers. Newspaper reports, photographs, and slides used in subsequent presentations doubtless had a greater impact on public awareness than systematic research on building failures. This material was being used in a variety of ways long before research results were made public.

Third, since the Coalinga event occurred fairly recently, it is too soon in many cases to know the outcomes of some efforts to apply the knowledge obtained from that event. For example, while California's earthquake preparedness programs and new state legislation stress the importance of pre-earthquake planning for post-earthquake recovery--one of Coalinga's lessons--it is obviously too soon to see these changes reflected in practice at the local level. Thus, at some points I will be describing attempts to apply knowledge rather than discussing the results of those efforts.

The fourth and perhaps most important point I want to make has to do with how research findings get applied, particularly in the policy process. It is necessary to keep in mind how decision-making and agenda-setting in government work and the role that research results play in this process. Some views of policy-making stress rationality, linearity, and incrementalism. However, other more credible approaches are process-oriented, non-linear, and non-incremental. The "garbage can" theory developed by Cohen, March, and Olsen (1972) to explain organizational choice is an example of this kind of perspective. In their view, it is appropriate to think of some types of organizations as "organized anarchies" in which problems, solutions, opportunities for choice, and organizational actors are mixed and combined. Far from being determined in a rational, step-by-step manner, outcomes (e.g., decisions) are highly indeterminate. For example, a particular decision may be made largely because a ready-made solution exists that has the support of key actors, not because a deliberate effort has been made to find the best alternative. Kingdon (1984) has demonstrated that the garbage can perspective is useful for understanding government policy-making. According to his formulation, problem definitions, policy alternatives, and the political activities of participants in the process are very loosely coupled in government. They become linked when a "policy window" opens. Policy windows, or opportunities for action, have some degree of predictability. For example, on the national level, a change of administration typically opens a policy window. Other policy windows are not predictable. Kingdon argues that academics and researchers have an important influence on the decisions that are made in government; however, he sees their activities as having the most impact on the alternatives that are considered. They do not have a comparable degree of influence on the agenda itself. In the short run at least, he argues that (1984: 59) "policy makers in government listen to academics most when their analyses and proposals are directly related to problems that are already occupying officials' attention." In other words, while research findings are used in the decision-making process, how and when they are used--and, of course, what effect they have--depends on the politics of the situation and on the fortuitious coupling of other factors.

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This is a useful way of looking at the application of research on natural hazards, as my USC colleagues have demonstrated (Petak, 1986; Mittler, in press). As is the case with natural hazards in general, issues related to earthquake hazard mitigation are not particularly salient to decision-makers. Research findings exist that have the potential for influencing decision-making, but before they can receive serious attention, key actors in the policy process must define earthquake hazards as important, alternative approaches must be identified, and a policy window must open. Frequently, the policy window during which seismic safety is placed on the political agenda is the time immediately following a major earthquake. It is during such periods that reaseach is most likely to affect decision-making. I believe this point has been demonstrated with respect to research on the Coalinga event.

Having stated these caveats, I will now go on to discuss attempts that have been made to apply the knowledge gained from studies of the Coalinga earthquake. The points emphasized and hypotheses advanced in this paper are based on discussions with the principals involved in the translation and application of research findings in California and on my own experience as a consultant to the Seismic Safety Commission for a one year period, 1983-1984. In general, the individuals with whom I spoke suggested that, rather than having a strong independent influence, the findings from much of the research on Coalinga further verified what was already known about earthquake impacts. They all suggested that the earthquake itself seems to have had a strong effect on agenda-setting; its occurrence made seismic safety a more salient issue in California. Following the guidelines issued for this workshop, I will discuss three categories of research applications: enlightenment uses, decision-making uses, and practice uses.

Enlightenment and Public Awareness

Research the Coalinga earthquake provided information that has been used in a variety of efforts to increase awareness of the earthquake hazard in the general public and among local officials and emergency responders. This section will discuss efforts at applying specific lessons learned in Coalinga by two regional earthquake preparedness programs and by emergency response training centers.

Coalinga was the first major damaging earthquake that occurred in California since the two regional earthquake preparedness programs, SCEPP and BAREPP, were established. Knowledge transfer is a main focus of these programs; they constitute a major market for research findings. The fact that the regional preparedness programs exist is one reason why research on Coalinga was rather widely disseminated. Key individuals in SCEPP and BAREPP have indicated that there are several ways in which findings from research on Coalinga have influenced the content and direction of their programs.

Unreinforced masonry buildings in the downtown commericial district sustained considerable damage in this earthquake. The majority of these buildings were so severly damaged that they were subsequently demolished.

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This meant that the downtown area would essentially have to be rebuilt. Because there had been no thought given to recovery planning in Coalinga, commercial reconstruction was undertaken hastily after the event. One major point that research on Coalinga have brought out and that the two preparedness projects now stress is the need for pre-event reconstruction and recovery planning. A SCEPP official stated that, when the event occurred, SCEPP was already involved in a planning partnership with the City of Los Angeles, but following the earthquake pre-event recovery planning began to assume a much greater significance in the overall effort. Of course, prior to the event, other reports had stressed the importance of having recovery plans already drawn up before an earthquake happens. The California Governor's Task Force, set up to address various aspects of the earthquake problem, had produced a report that emphasized the necessity of such planning. The Pre-Earthquake Planning for Post-Earthquake Rebuilding (PEPPER) project had already developed a series of damage projections for the greater Los Angeles area based on anticipated earthquakes on the San Andreas and Newport-Inglewood Faults that could assist with decision-making on post-earthquake reconstruction. However, the Coalinga event and the research that was subsequently conducted brought home the point that there are costs associated with not having a reconstruction strategy. SCEPP and BAREPP were able to convey this message more effectively because of the research on Coalinga.

On a related note, research conducted on business enterprises following the Coalinga earthquake (Durkin, 1984) revealed that post-earthquake recovery was particularly difficult for those businesses that had been located in unreinforced masonry buildings. These enterprises lost some or all of their inventories, suffered business interruption, had to resume business in less desirable locations, and had to take on additional debt to cover earthquake losses. On the basis of the data on small business impacts, SCEPP subsequently made an emphasis on small business preparedness a formal element in its work plan. SCEPP went on to do several things to disseminate information on possible earthquake impacts on businesses. First, it held a workshop in March, 1984 for small business owners to stress the importance of earthquake hazard mitigation, explain the Los Angeles program for retrofitting hazardous buildings, and discuss how building rehabilitation can be financed. Data on how the Coalinga earthquake affected small business were used at this conference. Second, SCEPP initiated a contract for a survey of businesses in its planning area and for analysis of that data. Third, SCEPP regularly includes as a conference speaker a Coalinga business owner who describes how the earthquake and the recovery process affected her business.

Both regional preparedness programs indicated that post-earthquake investigations on hazards associated with unreinforced masonry buildings provided excellent data that could be used extensively in public education programs. This information was, of course, not new; many other studies have shown that unreinforced masonry buildings are a major life-safety hazard. However, the Coalinga data were dramatic and unequivocal.

SCEPP officials also indicated that research on the Coalinga event brought about a more subtle change in that project's emphasis. Prior to Coalinga, SCEPP emphasized the probability of and preparedness for a major catastrophic Southern California earthquake; planning scenarios and preparedness materials were based on the 8.3 San Andreas event that had been forecasted for the region. The Coalinga case led the project to place *more emphasis on moderate events* in its public pronouncements and to stress the idea that, since even moderate earthquakes can produce substantial damage, such events warrant increased attention.

The California Specialized Training Institute (CSTI) is a branch of the California Office of Emergency Services that develops and conducts training workshops throughout California for local personnel with emergency management responsibilities. The Director of CSTI indicates that the Coalinga earthquake did not lead to substantial additions to the CSTI curriculum but did significantly reinforce what was already being taught. For example, the *convergence of mass media personnel* was a major problem in the 1983 event. CSTI uses the Coalinga case to illustrate the importance of media relations in its training courses for public information officers. Several of the public schools in Coalinga had significant earthquake damage; broken windows and chemical lab spills produced major life-safety hazards. CSTI has used speakers from Coalinga, particularly the Superintendent of Schools, to emphasize the importance of *earthquake preparedness in schools*. Another lesson that CSTI has emphasized involves the importance of strenghtening *local, state, and county co-ordination* following a major earthquake.

In 1985, the National Emergency Training Center, which is located in Emmitsburg, Maryland and operated by the Federal Emergency Management Agency, developed and piloted an integrated emergency management course on earthquake hazards. The earthquake course has been offered several times since then. Findings from research on a number of earthquakes, including the 1964 Alaska, 1971 San Fernando, 1979 Imperial County and 1983 Coalinga events were incorporated into the curriculum of the new four-day course. NEHRP-sponsored research on Coalinga used in the earthquake pilot course included Aroni's research on *earthquake-related injuries* (Durkin, Aroni, and Coulson, 1985; Aroni and Durkin, 1985) and Rubin's work (Rubin, et al., 1985) on factors associated with *community recovery fron natural disasters*, which used the Coalinga event as one of its case studies.

Decision-Making Applications

In the introduction to this paper, I made the point that the relationship between research findings and agenda-setting in the public sector is far from straightforward. Research may suggest the appropriate solution to a problem, but until that problem is defined and framed by key decision-makers, the research will have no impact. At the same time, research can be a necessary element in decision-making, e.g., by suggesting which alternatives are most feasible and cost-effective or by providing evidence to support a particular position.

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There are several instances in which a case can be made that research on the Coalinga event had an impact on laws and policies in California. Persons familiar with the legislative process have indicated that research on that event has an important influence on the passage of <u>S.B. 547</u>, the 1986 state law that requires cities and counties in Seismic Zone 4 to conduct inventories of unreinforced masonry buildings and establish programs to mitigate the hazards associated with such structures. Data on damage to such structures in the May, 1983 event were used in lobbying activities and hearings on that bill.

Research on the Coalinga event was of course not the only influence on that legislation, but the event did signal the opening of a policy window during which seismic safety legislation would be given a higher priority. Although an earlier version of the bill passed the legislature following the earthquake, that version was vetoed by the governor because it called for the allocation of state funds to reimburse local jurisdictions for programs. The version that was eventually passed and signed by the governor contained a stipulation that local jurisdictions could finance their programs by charging a fee. In the meantime, the salience of the issue had further increased as a result of the 1985 Mexico City earthquake. Passage of the legislation was also encourged by NEHRP-sponsored research by ABK Associates that described approaches to retrofitting hazardous buildings and developed a methodology for estimating the costs associated with rehabilitation.

Another important piece of recent legislation that was influenced in some degree by research on the Coalinga experience, <u>S.B. 1920</u>, focuses on actions to be taken to facilitate recovery from a major damaging earthquake. This bill, passed in 1986, authorizes and encourages local jurisdictions statewide to do pre-disaster recovery planning. Actions authorized by the bill include: preparing plans for post-disaster recovery; evaluating hazards in specific geographic areas of the community; drafting and adopting recovery ordinances prior to the disaster; and setting up special reconstruction agencies that are similar to community redevelopment agencies. Although the legislation specifically mentions the 1985 Mexico City earthquake as providing strong justification for the bill, it is apparent that the Coalinga event also had an influence on those who drafed the bill and worked for its passage.

The year 1986 also saw the passage of the <u>California Earthquake Hazards Reduction Act</u>, which authorizes the Seismic Safety Commission to develop a comprehensive five-year program to reduce earthquake hazards. The first five-year plan developed under that legislation, entitled <u>California at Risk</u> (Seismic Safety Commission, 1986), contains several recommended initiatives that appear to have been based, at least in part, on lessons learned from Coalinga. Examples include the priority placed on the mitigation of nonstructural hazards, particularly in critical facilities; the recommendation that legislation be enacted to ensure that mobile homes are adequately braced to resist seismic forces; and the emphasis placed on pre-earthquake recovery planning.

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The Coalinga experience appears also to have had an impact on California legislation on earthquake insurance. At the time of the earthquake, court decisions regarding concurrent causation had the insurance industry worried. Under this rule, where two perils (e.g. an earthquake and negligence on the part of builders) both contribute to a loss, but only one is explicitly covered by the property owner's policy while the other is excluded, an insurance company would still be required to pay for the loss. Following the Coalinga earthquake, several homeowners without earthquake insurance collected or attempted to collect money to cover their earthquake-related losses, claiming other contributing factors such as lax enforcement of building codes as concurrent causes. In part as a result of the issues raised by Coalinga, one year later, in 1984, the legislature passed _A. B. 2865_, which requires insurance carriers to inform homeowners that earthquake insurance is available. Under this law, property owners are also told that if they decline to purchase earthquake coverage, subsequent earthquake losses will not be covered under their policies.

Impact on Practice

The question of whether the actions of the general public, the government, and the professions have changed as a result of lessons learned from the Coalinga earthquake is quite broad and complex. Without having done a systematic study on this question, the best that I can do is to offer some general observations on the likely impact of that event.

One practical outcome that appears to be attributable in part to this earthquake is that SCEPP, which was slated for termination in 1983, received a one-year extension. Since the May, 1983 event made the earthquake hazard very salient in California, allowing a major preparedness program to go out of existence apparently would have been a politically unpopular move. In 1984, the legislature did pass A.B. 2662, which further extended SCEPP, but the 1983 law provided the interim funding that allowed the project to continue.

The evidence concerning the impact of the event on earthquake preparedness in the stricken area is somewhat mixed. My research (Tierney, 1985), which focused only on the eighteen month period after the earthquake, suggested that: (1) household earthquake preparedness increased; (2) land use and zoning practices did not change; (3) the seismic resistance of the new commercial buildings was increased simply because they were built to code; and (4) although there was certainly an increase in awareness of the earthquake hazard on the part of local (i.e. city and county) officials as a result of the 1983 experience, the earthquake did not have a significant effect on local earthquake preparedness practices. Some recent evidence suggests that Fresno County may be even less committed than before to emergency management; reportedly, a decision was made to eliminate the position of emergency services co-ordinator and reassign those duties to an individual in another county department.

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Conclusions

This paper has discussed some of the ways in which research on the Coalinga earthquake has influenced earthquake awareness programs, California legislation, and emergency preparedness. Throughout the paper, the point has been emphasized that it is rare for individual studies <u>or</u> individual earthquake events to have an impact in these areas; instead, they have a cumulative effect. Coalinga was a typical earthquake in this respect. While some of the topics studied (e.g., earthquake effects on small businesses, occupant behavior and injuries) were new, many of the findings from research on this event simply reinforced what scientists already knew. The importance of Coalinga was that it made the earthquake problem more salient by showing how destructive even moderate-sized earthquakes can be. This message was emphasized the very next year when the Morgan Hill event occurred. In 1985, the devastating Mexico City earthquake greatly raised the level of concern among both the public and policy-makers. The cumulative effect of Coalinga, Mexico City, and other smaller events was to strengthen the position of earthquake hazards on the policy agenda. Together, they opened a "policy window," producing an atmosphere where there was a more receptive audience for knowledge about earthquake hazards.

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PERSPECTIVE 28 YEARS AFTER THE AUGUST 18, 1959 HEBGEN LAKE EARTHQUAKE

by

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INTRODUCTION

To understand where Montana is today, 28 years after the Hebgen Lake earthquake (and 4 years after the equally relevant Borah Peak earthquake) changes in legislation, policies, and preparedness need to be examined relative to advances in research related to reduction of earthquake hazards for the growing population of the state of Montana. Legislative and policy changes have evolved slowly in this state and preparedness is very low key--better in some local areas than in others. Similarly, earthquake-related research has sporadically, but slowly, evolved to its present stage where, with a significant increase in the size of the skeletal seismograph network, MBMG may be able to provide new data sufficient for development of meaningful legislation and policies aimed at reduction of earthquake hazards in Montana. MBMG, as a nonregulatory agency, has largely been concerned with the research side of earthquake hazards in Montana and has only recently (1985) received legislative appropriations for such research. Thus the role of "sponsored" research, particularly under the NEHRP of the U.S. Geological Survey, although small has been vital to our program. MBMG staff have received three grants during the last nine years ($38,000 in 1979; $30,000 in 1985; $4,000 in 1986) which have funded most of the research on earthquake hazards.

Part of the problem in obtaining funding is the past perception that Montana lacked the population necessary to be considered to have serious earthquake hazards when compared to other states; this perception needs reassessment. Both statistics (Table 1) and the fact that two major earthquakes (magnitudes of 7.5 and 7.3) have occurred within the Centennial Tectonic Belt (Figure 1) during the last 28 years indicate that southwestern Montana is a region of high seismic hazard. Moreover, a large percentage of Montana's population and the four million yearly visitors are attracted to this quarter of the state. Increasing development of this region to accomodate both permanent-resident needs and recreational facilities for tourists means that Montana needs to accelerate its efforts to reduce earthquake hazards here, if not elsewhere in the state. Another aspect of the funding problem in Montana is that as far as disasters go, earthquakes are not perceived as significant as floods and hazardous materials accidents which are more newsworthy because of their frequency.

TABLE 1

State	Earthquake-related deaths since 1900[1]	
	Total deaths	per 100,000 people[2]
California	921	3.87
Montana	32	4.07
Washington	15	0.36
Idaho	2	0.21
Utah	0	0.00
Nevada	0	0.00
Wyoming	0	0.00
Colorado	0	0.00
New Mexico	0	0.00
Oregon	0	0.00

[1] -data from Ganse and Nelson (1981)
[2] -1980 population

LEGISLATION

Legislation is perhaps the easiest item to evaluate. Since the 1959 Hebgen Lake earthquake, which resulted in 28 deaths, the Montana Legislature has enacted very little legislation directly or indirectly

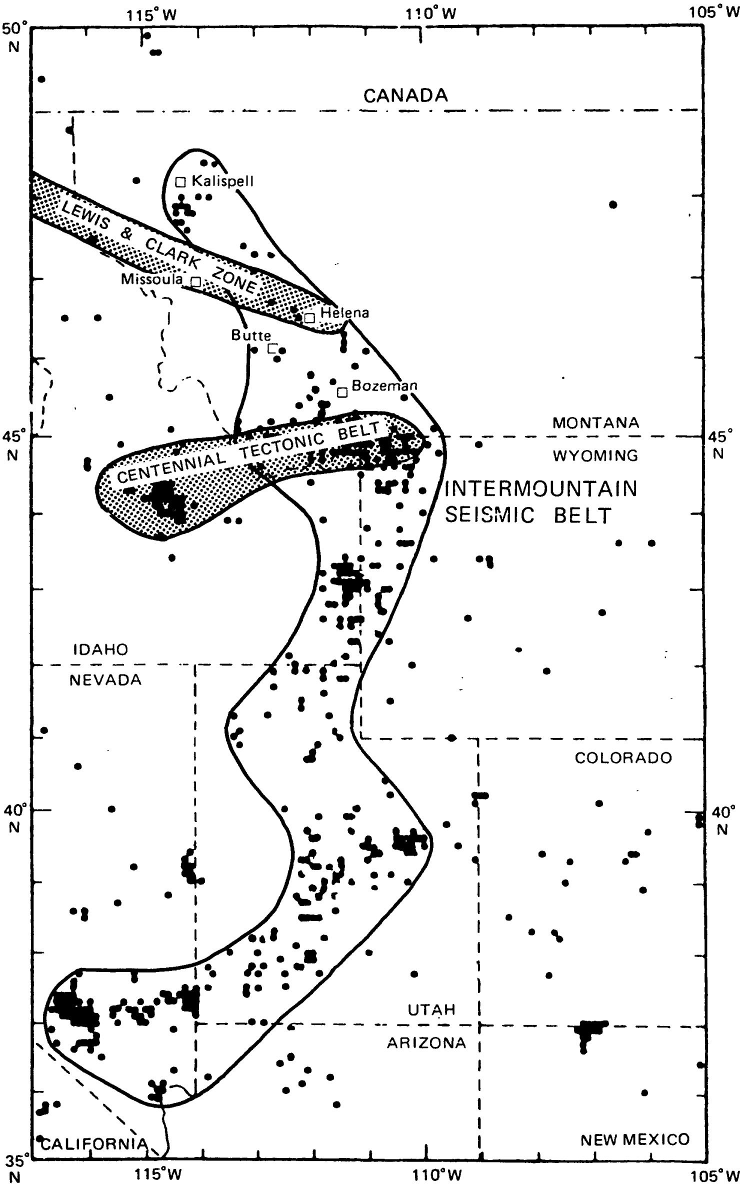

Figure 1. Map showing geographic relationships of the Intermountain Seismic Belt, Centennial Tectonic Belt and the Lewis and Clark Zone.

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related to earthquake hazards reduction. Perhaps most significant among legislative acts are those which called for the formation of the State's Disaster and Emergency Services Division currently under the direction of George M. Dewolf. Many cosmetic changes have been made in this legislation (DESD, 1987b), the most recent was shifting more responsibility for coping with disasters to local governmental units, (cities and counties). In 1985 the legislature appropriated funds specifically for support of the MBMG's Earthquake Studies Office (ESO) (under the direction of Michael C. Stickney). Through this office, MBMG now maintains a skeletal 9-station seismic network in western Montana and produces annual seismicity catalogs. Also, by using portable seismographs, the ESO conducts detailed studies of larger earthquakes and earthquake swarms and provides information on earthquakes and active faults to federal, state and local agencies seeking to develop policies and preparedness.

RESEARCH

Research has been an important, if not the crucial, aspect in recent years toward earthquake hazards reduction in Montana. The early mapping by the U.S. Geological Survey (Witkind, 1964, 1972, 1975 was followed, in 1970, by the first microearthquake study in Montana. The Geology Department at the University of Montana installed an eight-station seismograph network near Libby in northwestern Montana. The Libby network was designed to monitor background seismicity near the Libby Dam both before Lake Kocanusa began to fill and after the reservoir filled. Natural seismicity in the Libby region was very low before construction of the Libby dam and remained so after filling of the reservoir. The Libby network contributed relatively little to our knowledge of seismic hazards in western Montana but did provide useful data on regional crustal structure. In 1974, funding of a NEHRP proposal allowed the University of Montana to install an eight-station seismograph network (comprised of four stations from the Libby net and four from a similar net in Idaho) along the Intermountain Seismic Belt between Helena and Missoula. During the two years the Helena network operated, over 400 earthquakes were located (Qamar and Stickney, 1983). Both the Helena and Libby networks were closed in October 1974.

In 1983, the University of Utah took over recording and data analysis of the 16-station Yellowstone Park seismograph network (Smith and others, 1987). The operation of the Yellowstone network is jointly supported by the U.S. Geological Survey and the National Park Service. Arrival time and first motion data recorded by the Yellowstone network are used by MBMG to supplement hypocenter locations and first motion studies for larger events in Montana.

The MBMG became actively involved in earthquake hazard research in 1979. Completion of the 1979 USGS funded Quaternary geology mapping project in the Helena Valley (Stickney, 1987) coupled with close coordination between M. C. Stickney and Lewis and Clark County emergency coordinator, Paul Spengler, has enabled that county to develop the state's best local policy and preparedness situation.

Also, because of earthquake-generated landslides in Montana (Hadley, 1964), the 1985 USGS-funded project on landslides had, as an integral part of it, the delineation of all late Quaternary faults in Montana (Stickney and Bartholomew, 1987a,b). This study substantially revised MBMG's outlook on Active faults in western

Montana and MBMG plans to publish additional material describing the state's 21 known Active faults (Figure 2) and their segmentation in more detail. That report will also include MBMG's new Earthquake Hazard map (Figure 3) as well as a Landslide Hazard map. All of this data, however, is currently being made available to state and local agencies for policy and preparedness development.

POLICIES AND PREPAREDNESS

DESD is currently revising their "Montana Hazard/Vulnerability Analysis" The last analysis was done in 1976 (DESD, 1976) when the seismicity and active fault patterns in the state were more poorly understood. The two recommendations -- regarding earthquake hazards -- then were: 1) the establishment of seismograph networks; and 2) study of Quaternary fault activity in the state with such study to include trenching.

In the early 80's MBMG established its seismograph network and has augmented it as funds are available. Only during the last few years has MBMG systematically begun identifying, mapping and trenching late Quaternary faults. The initial results of this research are such that a new earthquake hazard map is warranted (Figure 3).

Because of its recent work on earthquakes, active faults and landslides, the MBMG is now working closely with DESD on these aspects of their revision of the "Montana Hazard/Vulnerability Analysis" (DESD, 1987a). It is hoped that the recommendations of this new analysis can be used to obtain funding at the 1989 legislative session both to increase MBMG's research efforts and to assist DESD's efforts to reduce hazards through public awareness and preparedness.

DESD's public awareness and preparedness activities regarding

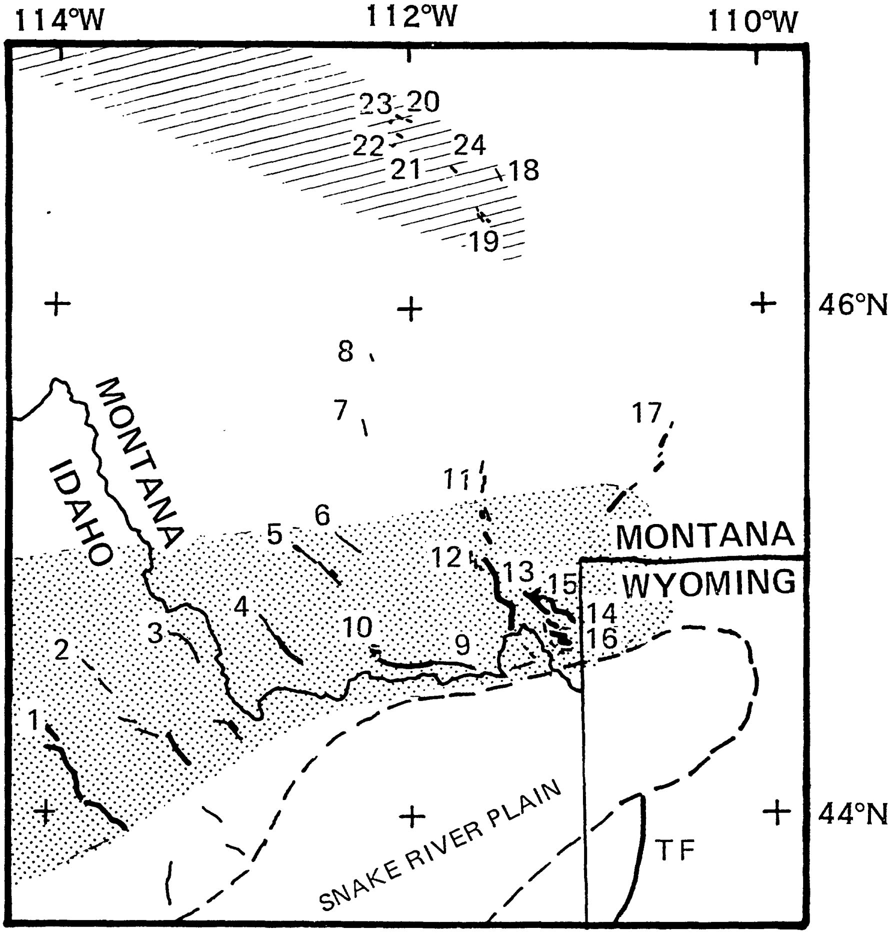

Figure 2. Map showing distribution of identified Active (late Quaternary) faults in Montana and Idaho north of the Snake River Plain; numbers correspond to those in Table 1 of Stickney and Bartholomew (1987); heavy and light fault lines show age of last movement as Holocene and late Pleistocene respectively; lined area is Lewis and Clark Zone and stippled area is the Centennial Tectonic Belt.

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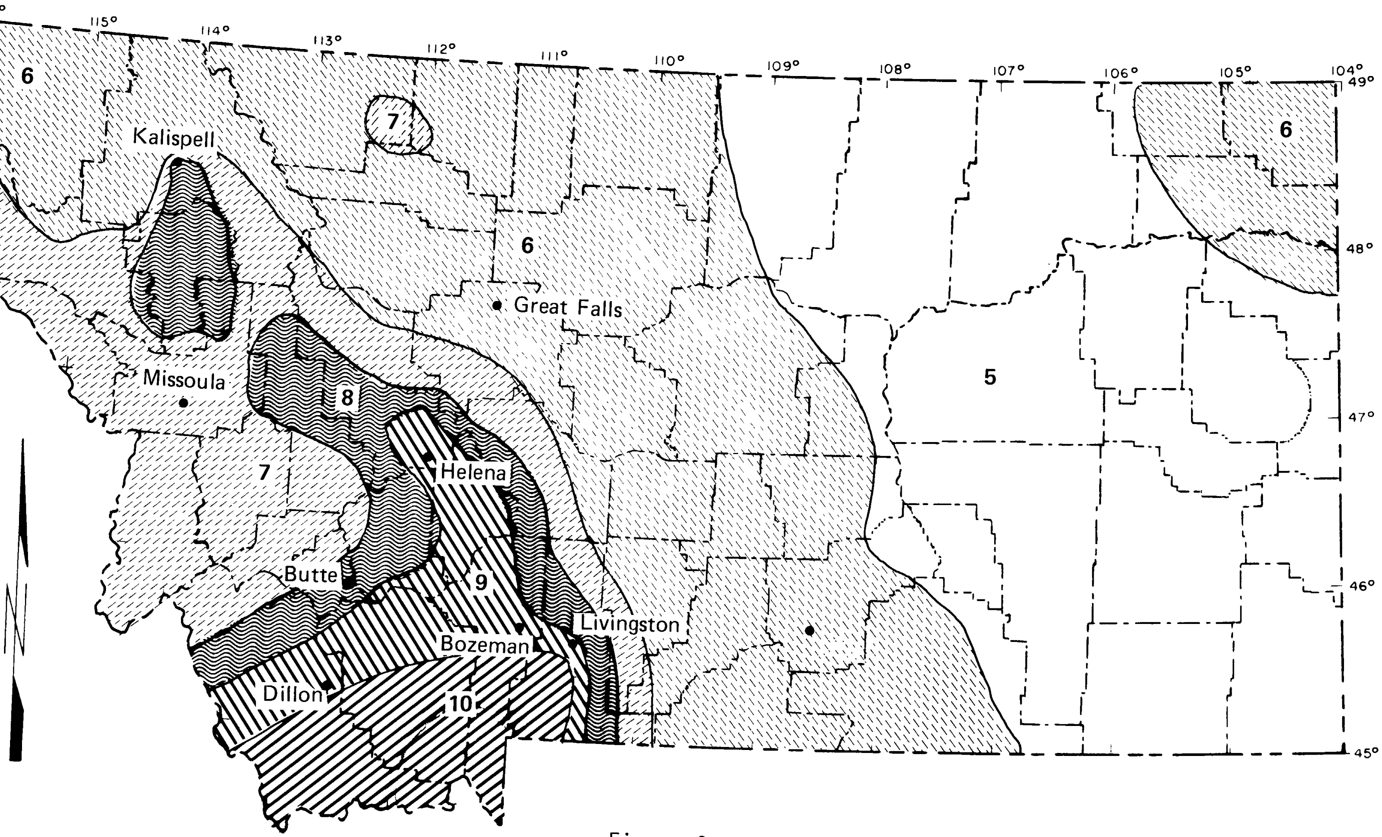

Figure 3. Earthquake hazard areas of Montana based on both seismicity and distribution of active faults. Patterns show expected Modified Mercalli Intensities for bedrock (Arabic numerals used for clarity). (Horner and Hasegawa, 1978; Qamar and Stickney, 1983; Stickney and Bartholomew, 1987).

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earthquake hazards began about three years ago after the September 19, 1985 Mexico earthquake when local interest was still high due to the 1983 Borah Peak earthquake. Since then, DESD (Jan Henry) has made presentations on earthquake awareness and mitigation in six of the twelve counties in western Montana (Figure 3) which have significant earthquake hazard. DESD talks are presented to the schools (grades K through 8) and local governments as well as to administrative staff of such facilities as nursing homes and hospitals. Their efforts are directed toward providing both technical and planning assistance to both reduce hazards and reduce vulnerability.

On the local level, the application of research to development of local policies has been successfully done by Lewis and Clark County (includes city of Helena). A preliminary map of the Quaternary geology and faults of the Helena Valley was completed in 1981 and a hand-colored copy of the map was then presented to the Lewis and Clark County disaster coordinator. A more recent, revised map (Stickney, 1987) was also supplied to the coordinator. Since receiving this map and the accompanying final project report (Stickney and Bingler, 1981), the county has adopted a number of measures to increase public awareness of earthquake hazards and implement earthquake hazards mitigations.

The Lewis and Clark County emergency coordinator proclaimed October to be earthquake preparedness month. During each of the last five Octobers a media campaign has been conducted to promote public awareness of earthquake hazards. This media campaign attracted the attention of county school officials and now earthquake drills are routinely conducted. This school year the county disaster coordinator

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together with the superintendent of schools will visit all schools in the county to conduct a nonstructural hazard analysis, talk to teachers and students about earthquake hazards, and make recommendations for nonstructural hazards mitigation.

The Helena Valley map has been incorporated in the county land-use plan. A 100-foot set back from known active faults is required for new construction. Plans for a church soon to be constructed were modified to include structural changes to make it more earthquake resistant after the architect learned of a nearby active fault.

Both St. Peter's hospital and the county nursing home have sent employees to a FEMA sponsored earthquake hazards training workshop. A FEMA help kit is used to teach school children (grades 3 to high school) about the geologic reasons for earthquakes and what to do during and after an earthquake. Next July a group of FEMA instructors will go to Helena and conduct a workshop with county and city personnel on response to, and recovery from a major earthquake.

The Bureau's work in the Helena Valley lead to an increased awareness of earthquake awareness by city and county personnel and in turn to greater public awareness and preparedness. The level of public consciousness is greater in Lewis and Clark County and specifically in the city of Helena as a result of the Helena Valley mapping project.

GOALS

One of the objectives of the MBMG is to obtain sufficient funding to install a state-wide 45 station seismograph net with digital recording capabilities. At the present time Montana is effectively excluded from seeking matching funds under Elements I and III of the

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NEHRP. Moreover, because the federal government (i.e., USGS) does not appear to recognize a serious earthquake hazard in Montana, there is a perception in the state's legislature that no serious hazard exists, and therefore state funds need not be directed toward research or preparedness nor toward susceptibility and vulnerability studies. MBMG is presently seeking matching funds to install the net from other federal agencies.

Another MBMG objective is to systematically map and trench all of the known active faults. By then utilizing movement histories and segmentation of these faults with better seismic data and lithologic information we expect to develop better earthquake hazard and susceptibility maps for each county as well as for the entire state. This research will, of course, have broader application throughout the Intermountain Seismic Belt.

It is a goal of both MBMG and DESD to promote greater public awareness concerning earthquake hazards as well as to promote preparedness and reduce vulnerability through talks and pamphlets.

Hopefully, these goals may be achieved before another Hebgen Lake or Borah Peak earthquake occurs in southwestern Montana. The recurrence rate is about 10 years for large earthquakes (magnitude $\geq$6) in the Montana-Idaho Basin and Range.

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GEOLOGICAL, GEOPHYSICAL, AND SEISMOLOGICAL STUDIES RELATED TO THE 1755 CAPE ANN, MASSACHUSETTS EARTHQUAKE

By

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INTRODUCTION

> "In some parts of the country, particularly at Pembroke and Scituate, about 25 miles S.E. from hence, there were several chasms or openings made in the earth, from some of which water has issued, and many cart-loads of a fine whitish sort of sand...
>
> Hence it appears, that our buildings were rocked with a kind of angular motion, like that of a cradle; the upper parts of them moving swifter, or thro' greater spaces in the same time, than the lower; the natural consequence of an undulatory motion of the earth.
>
> But the agitation occasioned by this earthquake was not confined to the land: it was very sensible on the water, and even at considerable distances in the ocean. The vessels in our harbours were so shaken, that it seemed to those, who were in them, as if they were beating on the bottom. Some, that were in the bay, coming in from sea, thought they had run upon rocks or sands. One very uncommon effect of this concussion is related by several of our seafaring men, that almost immediately after the earthquake, large numbers of fish of different sorts, both great and small, came up to the surface of the water, some dead, and other dying". - John Winthrop II, Cambridge, Massachusetts, 10 January 1756.

Considering the early historical setting for the Cape Ann earthquake which occurred shortly after 4:00 a.m. on November 18, 1755, the event was very well documented particularly by the naturalists of the day such as Professor Winthrop cited above. This earthquake governs design considerations for New England, particularly in the densely populated coastal areas. Winthrop's description implies high frequency, high acceleration ground motion which caused the liquefaction and fish kill effects; only recently have we measured such motions.

Because of its importance relative to the design of nuclear power plants in the region, particularly at Seabrook, New Hampshire and Plymouth, Massachusetts, an exhaustive analysis was made of historical records, including ship logs from New England and Great Britain, to establish the location and size of the 1755 earthquake. In addition, wide-scale regional as well as detailed geological, geophysical, and seismological data were taken in an attempt to identify any distinctive geological characteristics of its setting such as individual faults, tectonic structures, fracturing, specific lithologies and their stress history.

Drawing on this background, and the comparison of the 1755 earthquake geological setting with other large northeastern United States-eastern Canadian earthquakes, is instructive relative to our present knowledge and future need for information to achieve protection against earthquakes. These data and the conclusions drawn, have not been widely disseminated because the work was in response to regulatory requirements of the U.S. Nuclear Regulatory Commission and its purpose was prompted by a specific need to license a plant.

In forming a perspective of the 1755 earthquake, two vantage points are selected: [1] the beginning of 1976 when the United States Nuclear Regulatory Commission [NRC] had asked whether or not an earthquake similar in size to the 1755 Cape Ann earthquake should be considered for design of a proposed unit #2 of the Pilgrim Plant at Plymouth, Massachusetts; [2] the perspective in 1987 after having explored, studied, or reviewed the geological settings for several northeastern U.S.-eastern Canada earthquakes [Figure 1] in response to other basic questions particularly after the occurrence of the 1982 New Brunswick earthquake.

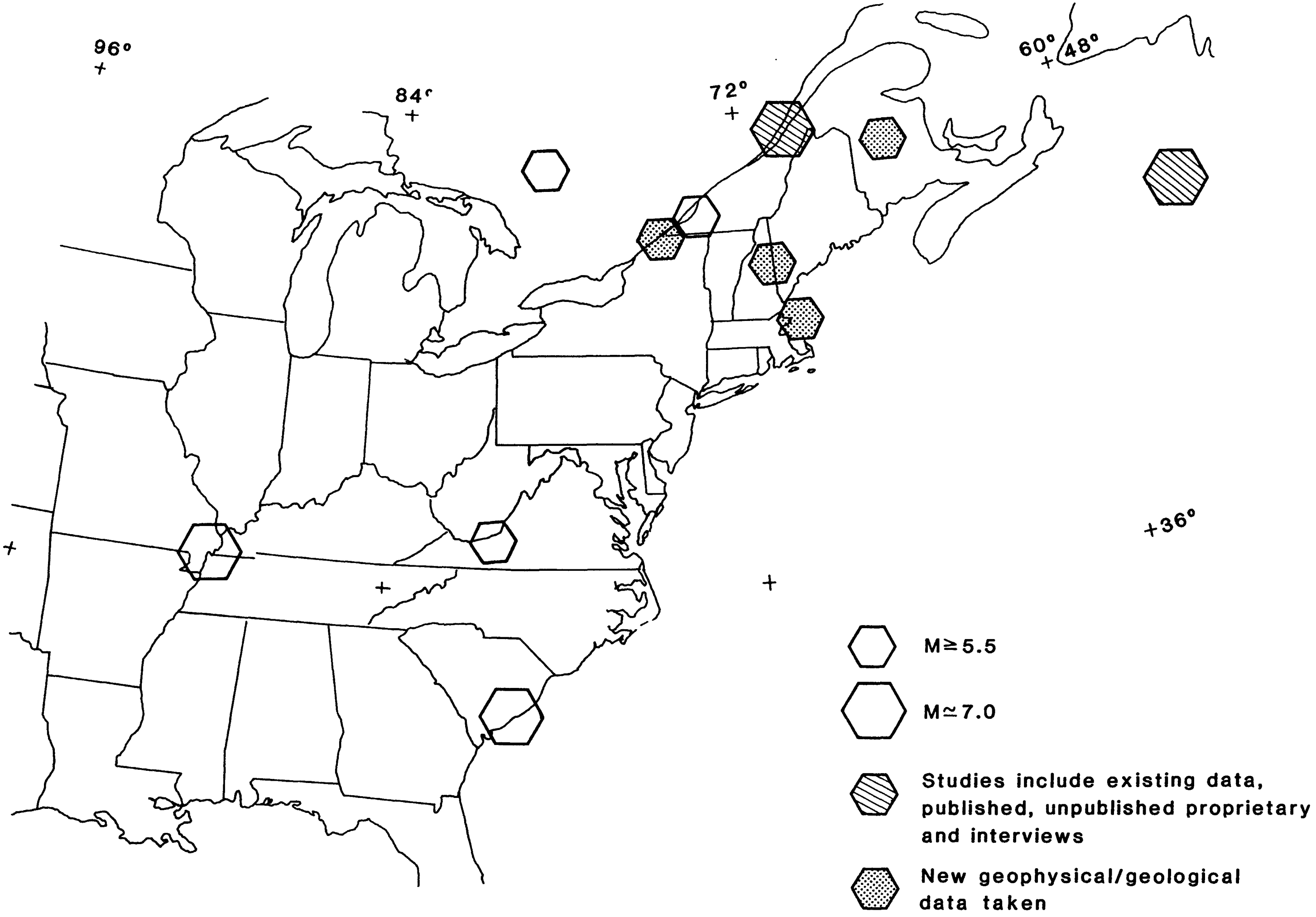
1976 Perspective

In 1976, prior to beginning detailed and regional studies of the Cape Ann earthquake, hypotheses concerning the causes of New England earthquakes were limited to two: one posed by Leet, Linehan and Billings, that the 1940 Ossipee, New Hampshire earthquakes were somehow related to the Mesozoic pluton at Ossipee; the second was a loose association of the earthquake[s] with the so called Boston-Ottawa, Kelvin sea-mount trend. The data were not then available to test either of those hypotheses; that is, whether or not Cape Ann might be linked to a pluton, or "sea-mount" or a structure which controlled them.

Existing data on-shore at Cape Ann revealed little, and off-shore data consisted of widely spaced aero-magnetic data shown on Figure 2. An early phase, detailed marine magnetic survey data as shown on Figure 3 revealed two plutonic bodies not shown on the wider spaced pre-existing aero-magnetic data. Our vantage point in early 1976 indicated that the existing geophysical data base necessary to examine the deeper crust and the off-shore areas of New England was clearly deficient; the same was true of Ossipee. Consequently, high resolution detailed aero-magnetic data were taken to provide coverage over both areas. The results for Ossipee along with earthquake epicenters are shown on Figure 4.

In addition, it was clear in 1976 that the seismicity data base had deficiencies consisting of over- and under-estimated earthquake intensity and magnitude values; mis-locations, and double entries as well as non-earthquake data, such as blasts, etc. The results of intensive 1755 research led to a more definitive size and location estimate as shown on Figure 5.

Much of the fundamental data base to assess the earthquake potential for New England was inadequate and the task to fill this deficiency formidable. The project chart to address these issues for Pilgrim Unit #2 is shown on Figure 6.



LARGER EASTERN UNITED STATES EARTHQUAKES

Figure 1

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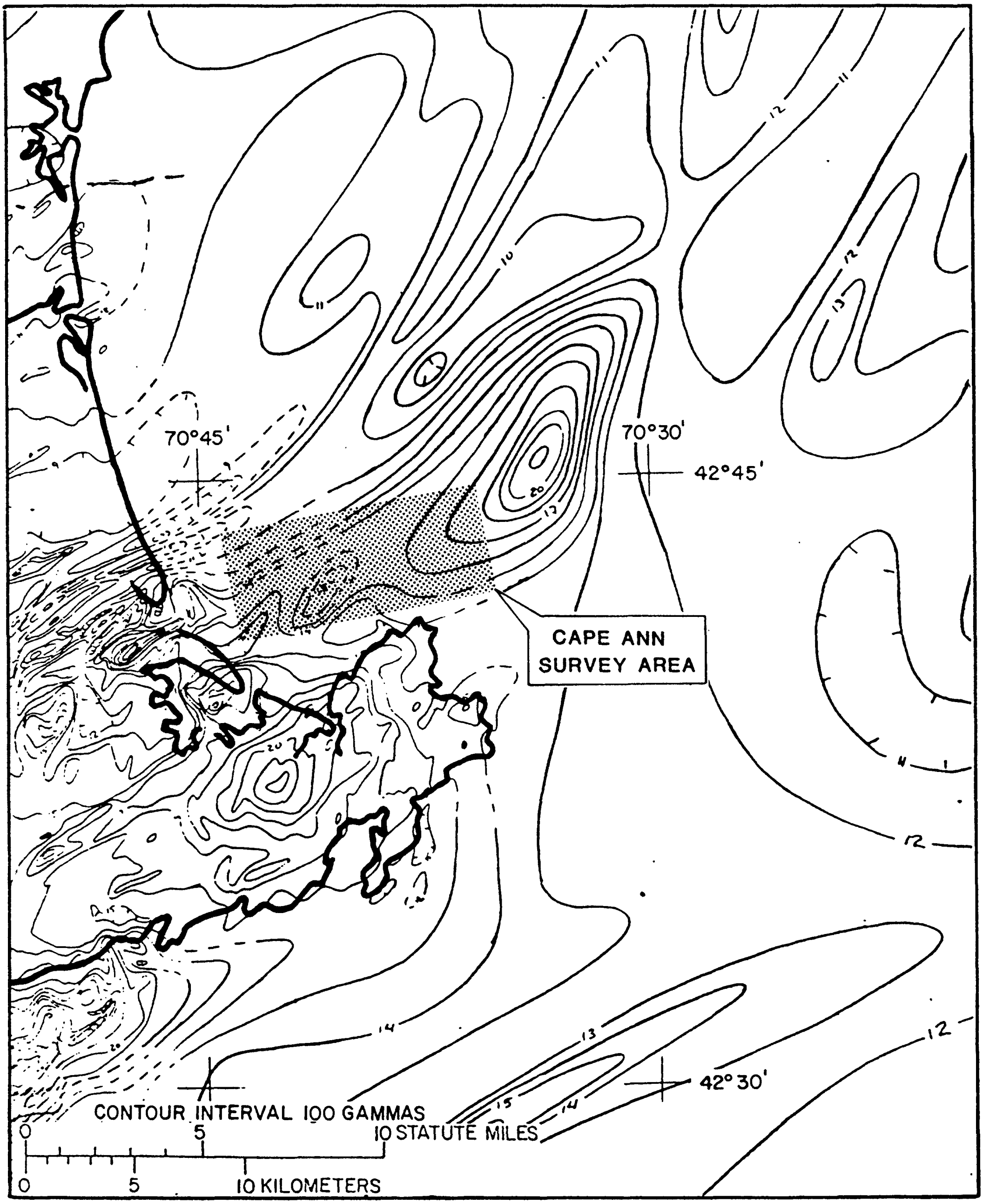

Published by United States Oceanographic Office (1964-1966)

" PROJECT MAGNETIC "
AEROMAGNETIC DATA - CAPE ANN

Figure 2

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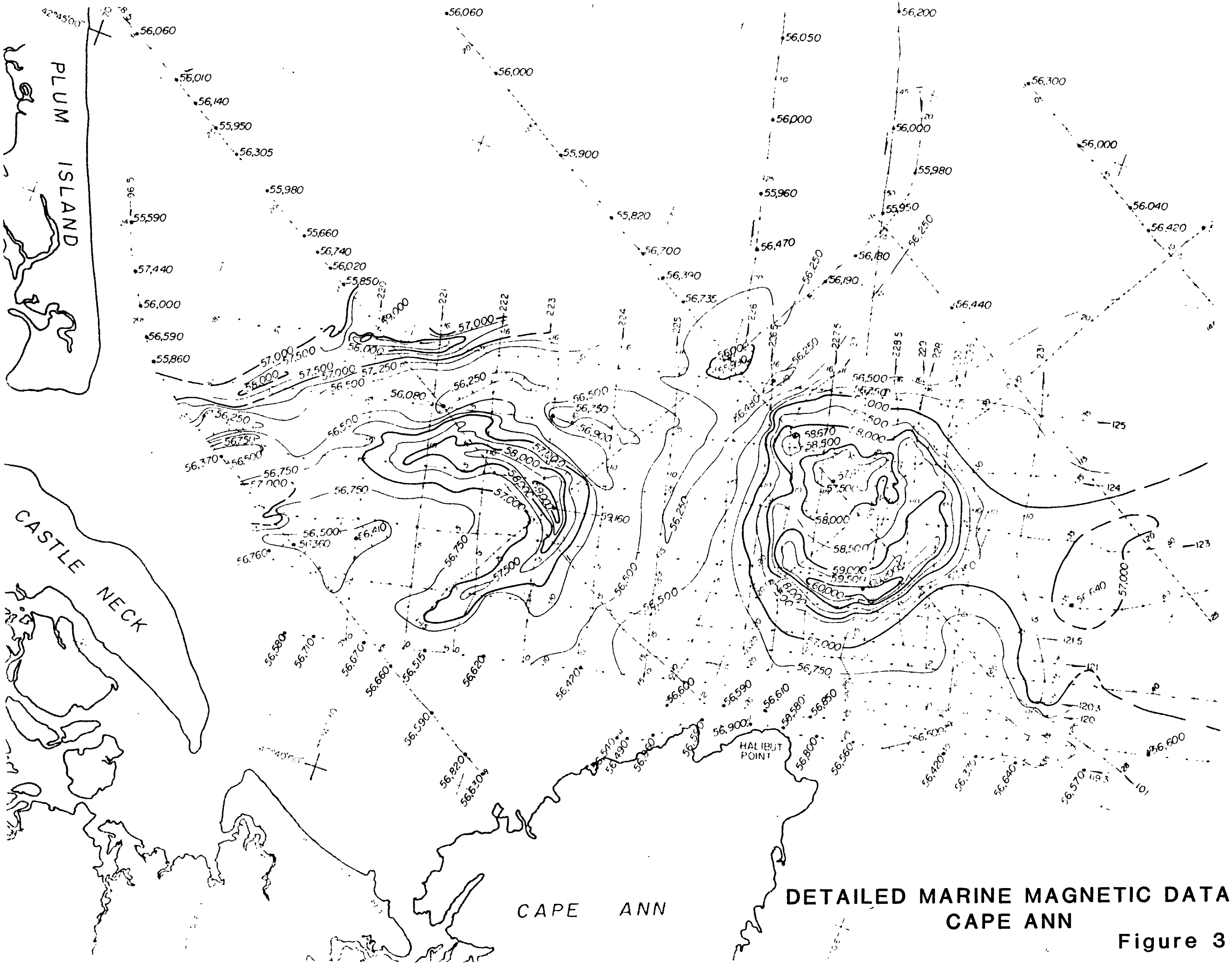

DETAILED MARINE MAGNETIC DATA
CAPE ANN

Figure 3

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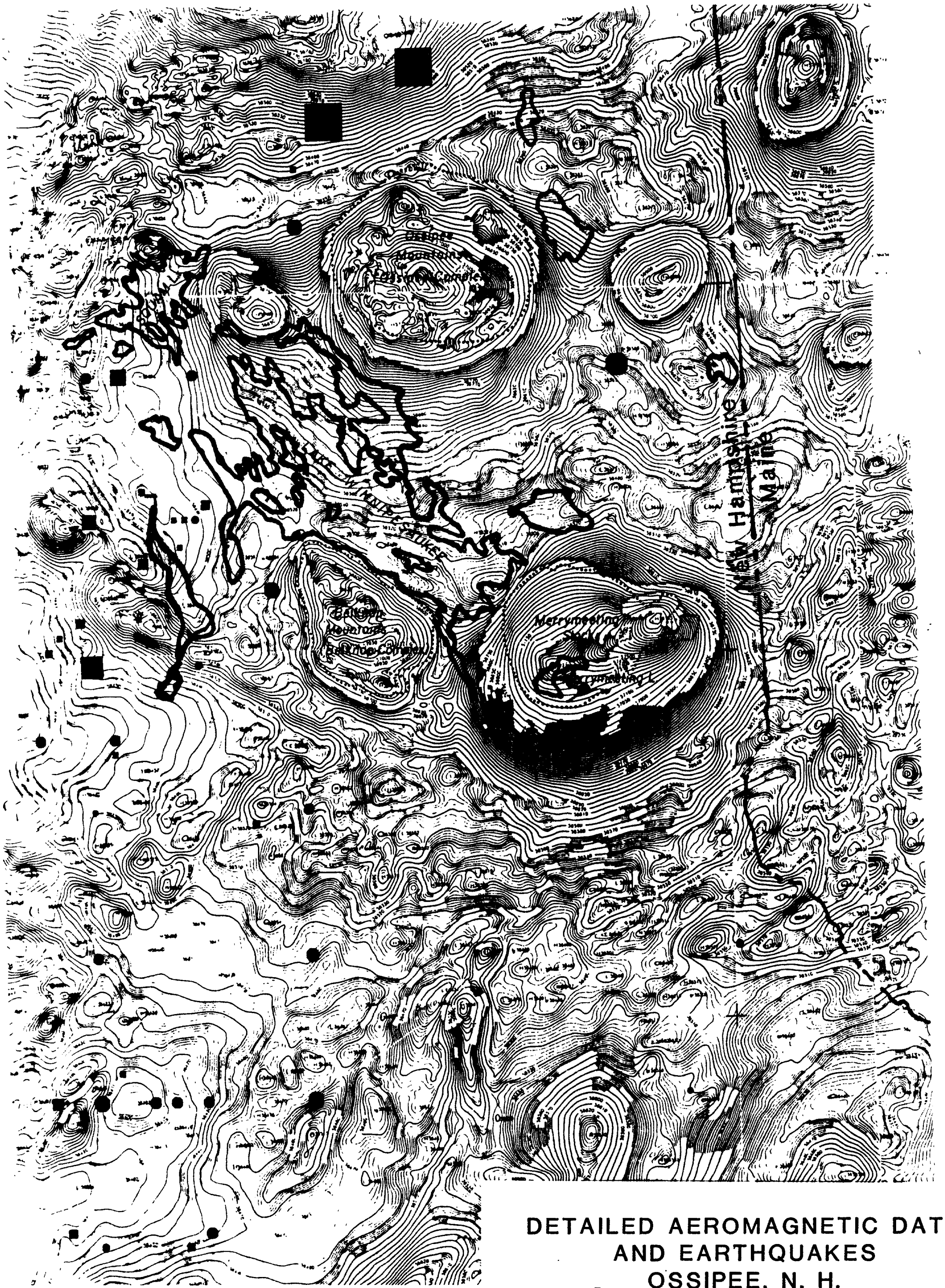

DETAILED AEROMAGNETIC DATA AND EARTHQUAKES OSSIPEE, N. H.

Figure 4

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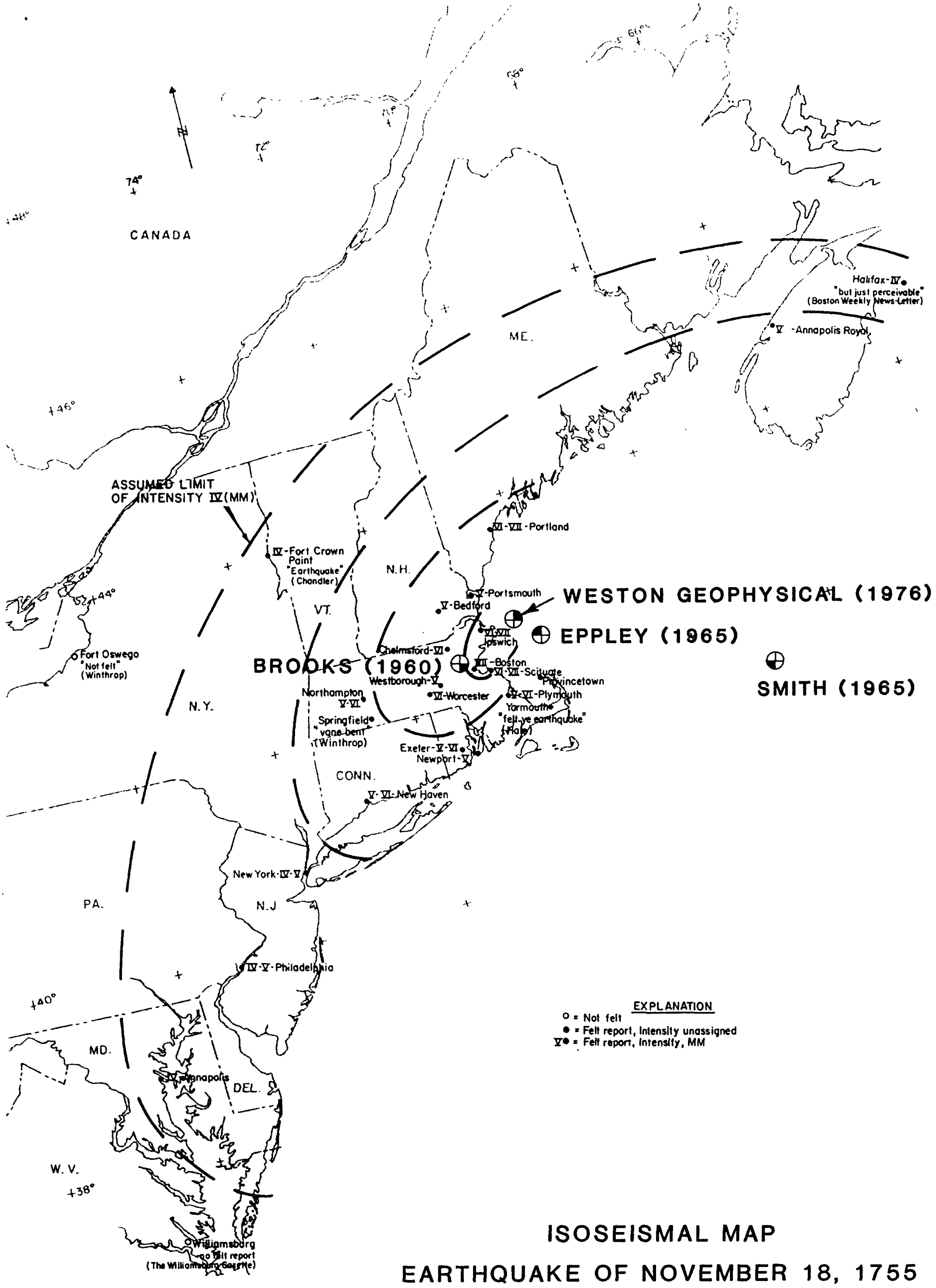

ISOSEISMAL MAP

EARTHQUAKE OF NOVEMBER 18, 1755

Figure 5

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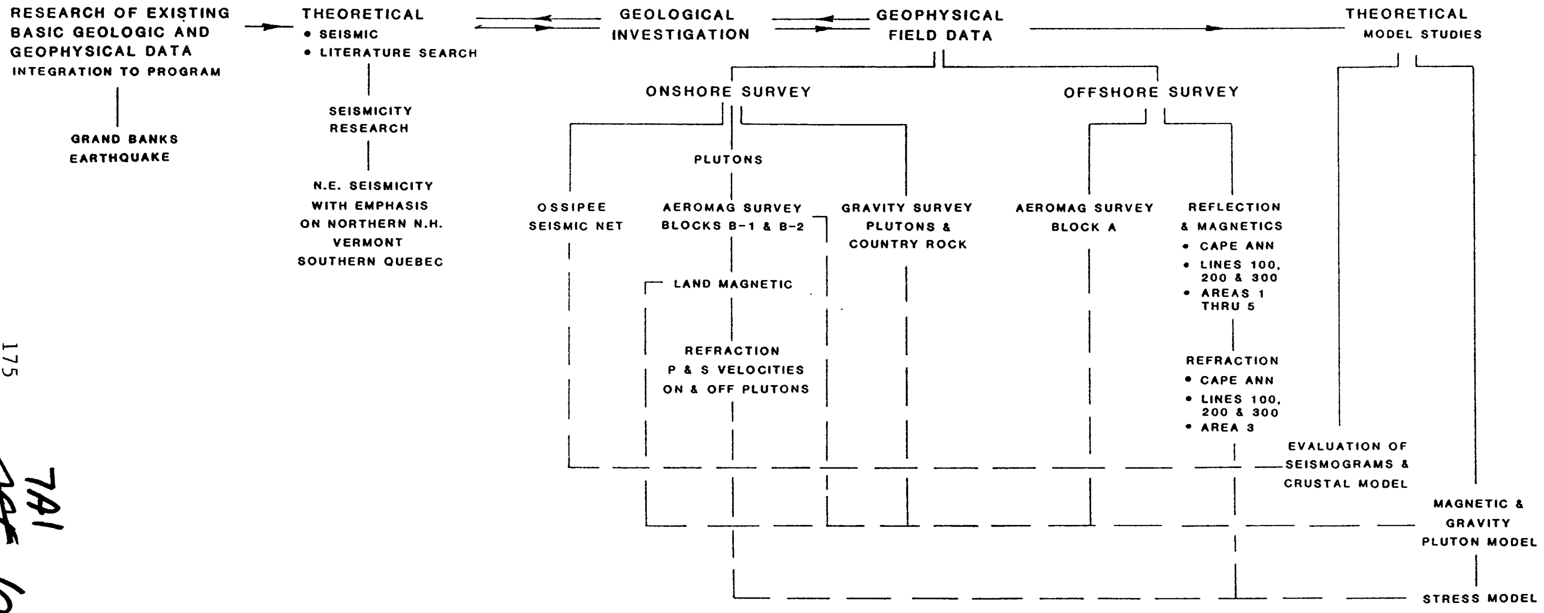

PROJECT STUDIES

PILGRIM NUCLEAR POWER PLANT - UNIT #2

Figure 6

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1987 Perspective

What is our present perspective? Much work has been done relative to the geological setting of earthquake epicentral areas shown on Figure 1. The observations which can be drawn from this work point to several conclusions. Based on geophysical data and geological mapping, the epicentral areas of the larger earthquake occur in complex lithological terrains which appear to have closely spaced faults. These closely spaced faults are on the boundaries of rigid bodies such as at Ossipee, Massena, Cape Ann [Figure 7] and New Brunswick or are coalesced into a weaker crust such as at the LaMalbaie impact crater. These local features are emplaced across long pervasive, northeasterly trending regional fault systems. Some of the features may also be part of more subtle, less well defined northwesterly structural trends.

The data base for seismicity is good, but the high resolution geophysical and geological data base remains wanting in many areas.

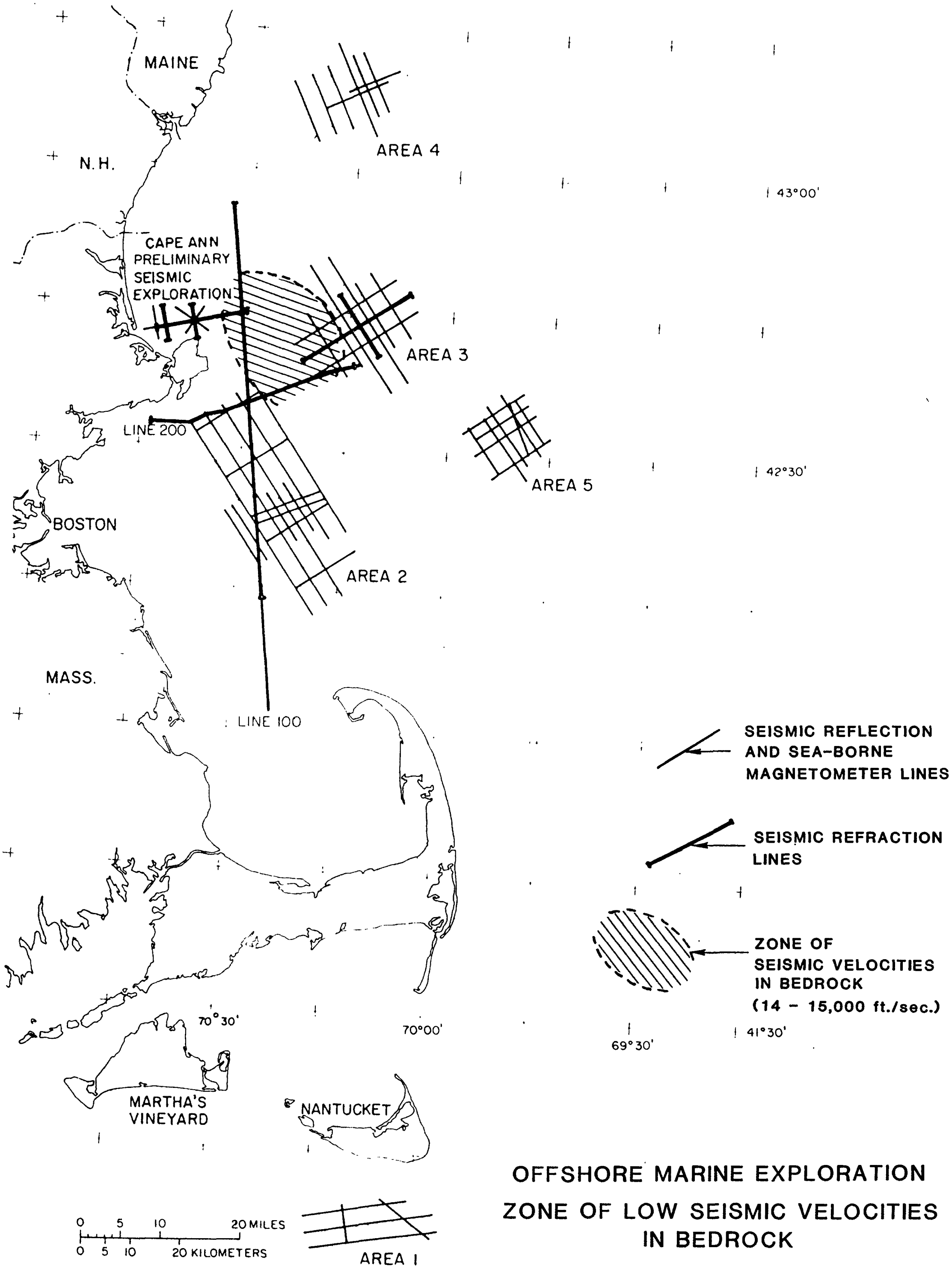
With respect to seismicity, there has been continuous earthquake activity ranging up to magnitude 5.5 at La Malbaie [1925] and Grand Banks [1929] which have had magnitude 7 earthquakes in the years shown in brackets. There has been continued low-level activity in areas where magnitude 5.5 to 5.7 have occurred at Ossipee [1940], New Brunswick [1982], Massena, New York [1944], Timiskaming [1935], but very little activity at Cape Ann [1755] or Montreal [1732]. A return of the largest historical earthquake has not occurred at any one of these epicentral areas.

What then is the average larger earthquake interval? Is it more than the 250 years if we consider Cape Ann? Or is it shorter on the average. Parkfield California at 10 to 20 times the activity rate of New England has an average return period of a little over 20 years for a 5.5 or higher magnitude. Does this mean that the northeastern United States earthquakes at the same location and at a magnitude 5.5 level have return periods of 200-400 years based on a simple multiplication reflective of strain release? Lacking the total seismicity data base for 250-500 years can we extend this data base by using our geological knowledge? Do we have the data base to do this?

Given a relatively short seismic history, and the geological/geophysical data base we have, can a reasonable deterministic model describing the spacial and approximate time return of the larger earthquakes be constructed?

Assuming that these questions have partial answers, can a probabilistic model be constructed that will quantify the risk in such a manner that ground motion design values may be selected based on a risk basis?

The perspective point from 1987 is better than 10 years ago in 1976, but more basic data are desirable. As our population and investment in expensive buildings and critical facilities grows, so must our earthquake prediction and mitigative capabilities. In 1755, the population of Boston was low and generally occupied wooden frame low profile buildings or houses inherently resistant to earthquake ground motion. What would happen with a repeat of that earthquake today?



OFFSHORE MARINE EXPLORATION

ZONE OF LOW SEISMIC VELOCITIES IN BEDROCK

Figure 7

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In response to the specific questions to be addressed as given in the instructions for these presentations, the following are discussed. It should be kept in mind that the research and work briefly discussed here was to fulfill a specific need and application. In that sense, it did not have as its purpose the solution to a hypothesis nor was dissemination of information a driving factor.

RESEARCH APPLICATION

The perceived need was to license a nuclear power plant under the deterministic criteria of Appendix A to 10 CFR part 100 of the United States Nuclear Regulatory Commission.

Specifically, the need was to demonstrate that the design ground motion resulting from a selected hypothetical earthquake as defined by the regulations was sufficient. While it may be inferred that because of the regulations the prescription of work to be performed and the results were sharply defined, this is not the case. Consequently, the program of exploration in all phases had to be updated constantly to accommodate surprises to anticipated results and conclusions.

The U.S. NRC regulations require that the design earthquake be selected on the basis of a capable fault, a tectonic structure or a tectonic province. This is a default tree in which a tectonic province is selected if the first two definitions don't apply. Since capable faults [faults capable of breaking ground surface] are generally non-existent for the area and tectonic structures are difficult to demonstrate, the design earthquake is generally selected on the basis of a tectonic province, the boundaries of which are critical to the design earthquake.

Unless there was good reason to constrain the Cape Ann earthquake to a structure or province, the intensity VIII magnitude 5.7 plus earthquake design values [or something larger] would be applied to the Pilgrim Nuclear Plant site in Plymouth, Massachusetts. So, the perceived need was to conduct a series of studies to determine whether or not geological conditions at Pilgrim required consideration of a Cape Ann size event [Figure 6]. Clearly the outcome could be only guessed since the basic geological and geophysical data were not available in sufficient detail to accurately forecast the final results; the required data base of geophysical information was not available.

A multi-disciplined parallel approach was conceived and carried out [Figure 6]. While it would have been more productive and cost effective to conduct much of the work in a serial fashion [for example, when the results of geophysical investigation were completed such as land gravity or aero-magnetics then detailed geological mapping could begin]. For the most part, however, the time schedule for a completion in approximately nine months did not allow this, and most tasks were performed in parallel.

LENGTH OF TIME AND LEVEL OF EFFORT

As previously stated, a nine month schedule was adopted. From start to completion of a final report, some fourteen months were required. As an example, the level of coverage efforts required a wide scale reconnaissance of glacial geology through Massachusetts and New Hampshire to look for evidence of recent faulting or differential tectonic uplift or subsidence. Geophysical data including ground and airborne magnetics and ground gravity were compiled and supplemented by seismic data and geological mapping.

All of this was complemented with an intense research of literature and conversation with previous workers to guide and enhance the investigations.

SCOPE AND SCALE

The general scope is shown on Figure 6. The intent of much of the work was to examine in detail and compare the two areas of New England which had the largest earthquakes; Cape Ann of 1755, and the area of Ossipee, New Hampshire which had two intensity VII approximate magnitude 5.6 earthquakes in 1940. Extensive geophysical data to define lithologies, faulting, and physical characteristics of the rock, such as rigidity, were undertaken.

KEY PLAYERS

The key players consisted of a number of consultants generally drawn from the local universities because of their specific knowledge in certain aspects. In addition, the various aspects and direction of the program were continually updated based on the expert impact and data results. Direction and management were performed by Weston Geophysical with help and guidance from Boston Edison.

FUNDING

Funding was straight forward; budgets were established ranging over a two year period. These were tracked diligently by tasks. When it became evident that certain tasks could be curtailed and that others should be expanded, this was done. In general, budgets were maintained even with a very accelerated schedule. The key was that sufficient funding and budget allowances were available or committed on the front end and the program suffered no interruption.

RESEARCH WHICH CONTRIBUTED TO THE APPLICATION

The application was to select a design earthquake for Pilgrim Unit #2 [a parallel case was established for Millstone, etc., but is not discussed here] with sufficient data to satisfy NRC regulations and hence was "needs" driven but not research driven.

All of the data contributed to the application or conclusion, some in a negative sense. For example, the studies of glacial geology lake beds, etc., indicated no recent movement or large scale tectonic uplift in central Massachusetts or New Hampshire [Boston-Ottawa trend]. In like manner, within a resolution range of 10 to 20 feet, off-shore reflection data did not indicate recent faulting at Cape Ann.

It was also clear that the geological environment, lithologies, fracturing, large scale faulting, etc., that exist at Cape Ann and Ossipee do not exist in the vicinity of the Plymouth, Massachusetts site.

ACTIVITIES WHICH FACILITATED THE APPLICATION

Obviously there was a need to have seismologists, geologists of several disciplines and geophysicists communicating effectively. In the case of this project, the needs were obvious and the contribution or potential contribution clearly defined. While the project was multi-disciplined, each task was clearly defined so that integration into the total package was facilitated.

DESCRIPTION OF DISSEMINATED RESEARCH

As previously mentioned, because of the nature of the project, the data and conclusions are not widely disseminated, particularly the comparative results of the several earthquake areas.

Again, the applications in this case involved the review and acceptance by NRC and USGS reviewers and their consultants which although influential, constitutes a small number of peer review professionals.

IMPROVEMENT OF THE APPLICATION PROCESS

Since the objective of the program was well defined, the application of the data and conclusions were obvious.

Some basic questions which existed at the start of the program in 1976 are, to some extent, still with us. What does the stress field look like in the epicentral regions? Its amplitude and general direction? How do the ancestral features, faults, etc., react in the stress field? Is there a relationship between the smaller earthquakes and larger ones on a particular fault. In other words, is the relationship of numbers of small events to larger ones used in a regional sense valid for individual fault or fault zone prediction of seismic risk? If this relationship changes drastically for an individual structure or fault [and I suspect it does], then risk studies where near-by active faults exist could be grossly misleading, although possibly valid in a broad or regional sense.

As is generally the case, data solves some problems, but creates others. We must know more detail about the deeper crustal region to establish the validity of both deterministic and probabilistic conclusions. This means expensive wide-scale regional data base surveys, as well as structure specific studies.

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PERSPECTIVES 222 YEARS AFTER THE NOVEMBER 18, 1755 CAPE ANN, MASSACHUSETTS, EARTHQUAKE

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INTRODUCTION

Since the 18th century some of the strongest earthquakes recorded in the United States have occurred in the eastern part of the country. Among these was one centered off Cape Ann, Massachusetts [near Gloucester] on November 18, 1755. It has been estimated to have measured approximately 6.0 on the Richter scale and caused considerable damage in Boston and eastern Massachusetts. A Modified Mercalli Intensity (MMI) range of VI-VIII is generally assigned to the Boston area. [See Figure 1.]

To get the true historical perspective of the impact of the Cape Ann Earthquake it is helpful to look at a comparison of the Boston area in 1755 and now 222 years later in 1987, relative to the physical environment, our knowledge of earthquake causes and potential earthquake losses.

LAND AREA

Whitman (1985) describes the land area of Boston at the time of the earthquake in 1755 as follows:

> . . .occupying essentially only the Shawmut Peninsula connected to the mainland by a narrow neck of land that was sometimes submerged at high tide. The extensive filling of the bay and and Charles River had not yet begun, although there had been some small landfilling in the harbor area.

This landfilling which continued into the 1800's substantially increased the land area of Boston to what it is today in 1987. Boston has one of the largest man-made areas of any city in the United States. Many hundreds of acres of what was water and marsh was filled to add to Boston's original land area, which consisted primarily of the Shawmut peninsula, especially in the Back Bay area of the city. [See Figure 2.]

DEMOGRAPHICS

The population of Boston in 1755 was about 15,000 to 20,000. Today the population is approximately 600,000 or about 30 to 40 times greater. This population includes residents only and does not include large influxes of people that work, shop, attend school or visit in the city.

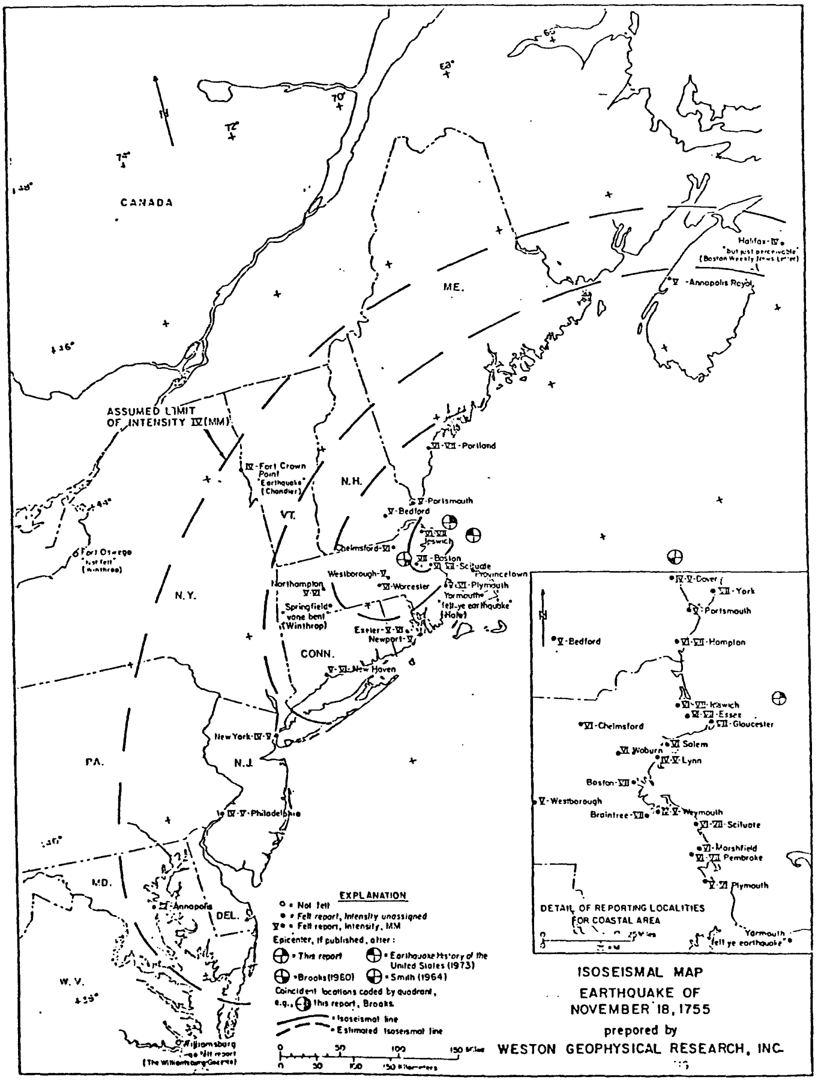

FIGURE 1. Isoseismal Map of 1755 Cape Ann Earthquake

Source: Toksoz, et. al.(1981)

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stipple filled area

Shade along original shore line

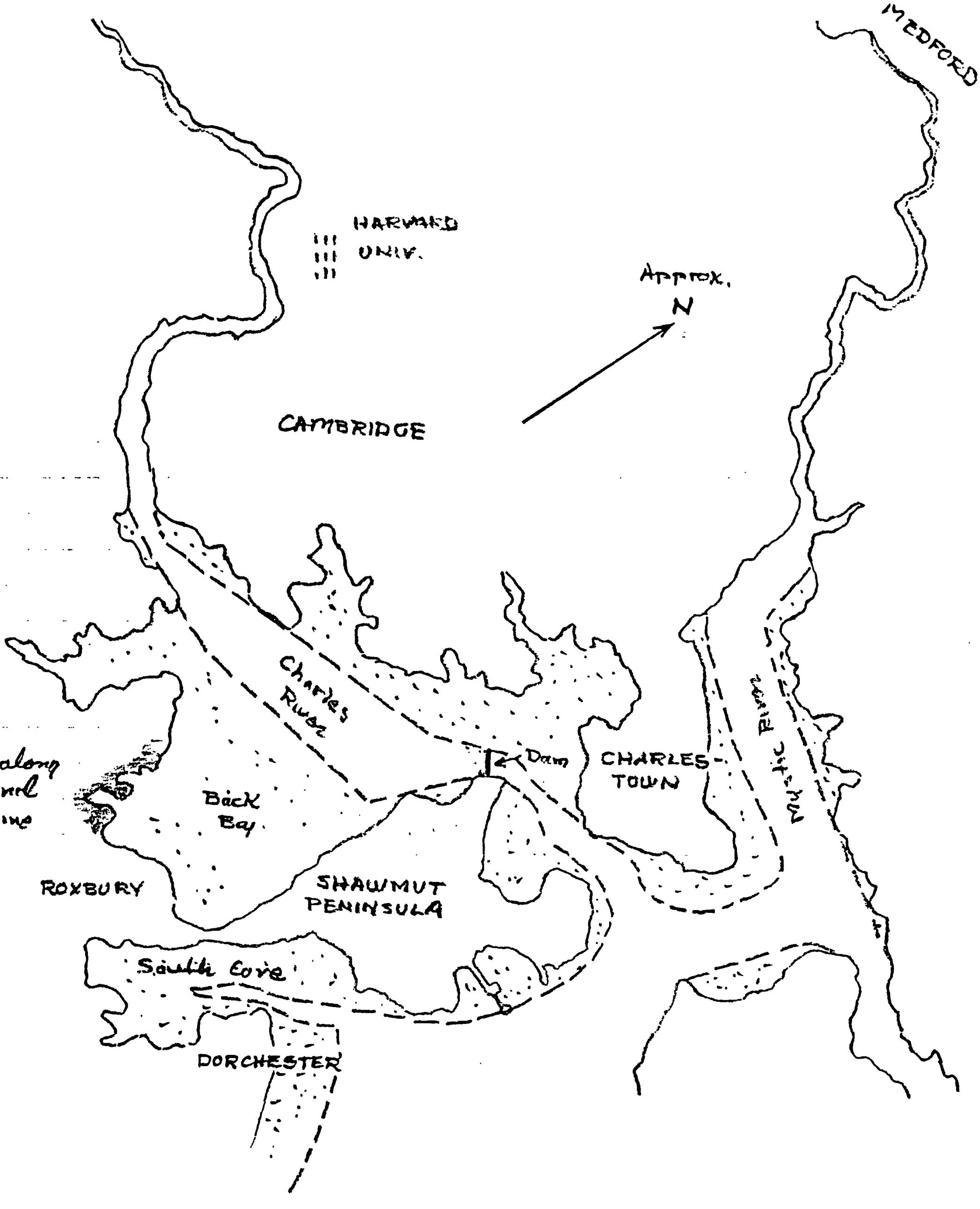

FIGURE 2. Filled Areas of Boston

Source: Whitman (1980)
Unpublished Manuscript

BUILDING STOCK

Whitman (1985) describes the building stock that he was able to estimate existed in Boston at the time of the 1755 earthquake: [See Figure 3 and 4]

> From various maps, records and artists views of the times it has been estimated that there were about 4,000 dwellings and shops on the peninsula. [Boston] Of these 40% were of heavy timber-framed construction adopted by the early colonists. . . By 1755 about 45% of the houses and shops had brick bearing walls. The remaining 15% of the buildings were of early Georgian architecture with wooden framing. In addition there were a dozen or so large structures, some of wood and some of brick masonry and most with steeples. These included Faneuil Hall, the Old State House and Old South Church all of which are standing today.

Whitman (1980) describes the building stock of modern Boston in a 10 mile by 10 mile square study area centered on the State House in downtown Boston: [See Figure 5]

> It was estimated that there were on the order of 125,000 buildings in the study area, with an occupancy of 1,500,000 people by day and 1,200,000 at night . . . Of these there are on the order of 5,000 buildings which are very susceptible to moderate or severe damage during an earthquake similar to that experienced in 1755. These are for the most part unreinforced masonry buildings and poorly reinforced concrete buildings . . . Taken together these particularly vulnerable structures typically shelter from 60,000 to 120,000 people depending on the time of day and week. Another 700,000 to a million people are in buildings which have only modest resistance to ground shaking.

EARTHQUAKE LOSSES

Whitman (1985) after a careful rereading of the contemporary accounts in newspapers, journals, letters and diaries summarizes the damage caused in Boston by the 1755 Cape Ann Earthquake:

> Most chimnies were damaged. Something like 1200 to 1500 were "shattered and thrown down in part". On the order of 100 chimneys were leveled with the roofs.

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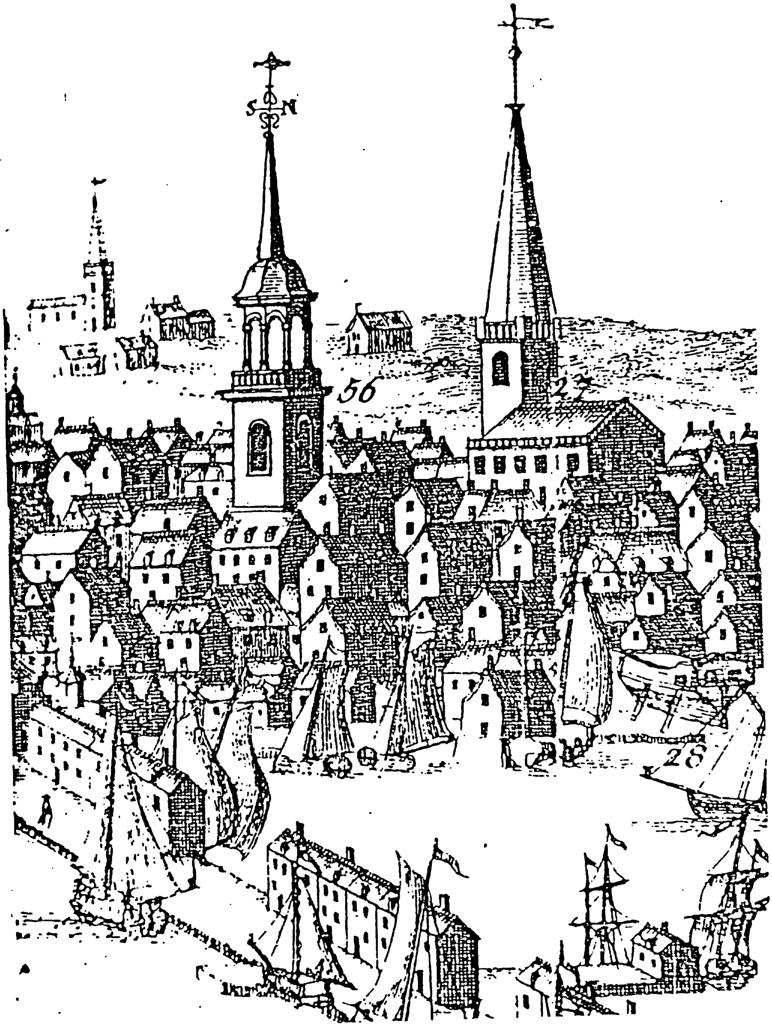
Frontispiece:

"A Southeast View of ye Great Town of Boston". (Boston: Wm. Price, 1743). Boston's waterfront centered on Long Wharf.

FIGURE 3. Boston About the Time of the 1755 Cape Ann Earthquake

Source: Whitman (1980) Unpublished Manuscript



I-46 Original "Steeple" of Faneuil Hall (No. 56) from Burgess-Price "View of Ye Great Town of Boston", 1743.

FIGURE 4. Faneuil Hall Area About the Time of the 1755 Cape Ann Earthquake

Source: Whitman(1980) Unpublished Manuscript

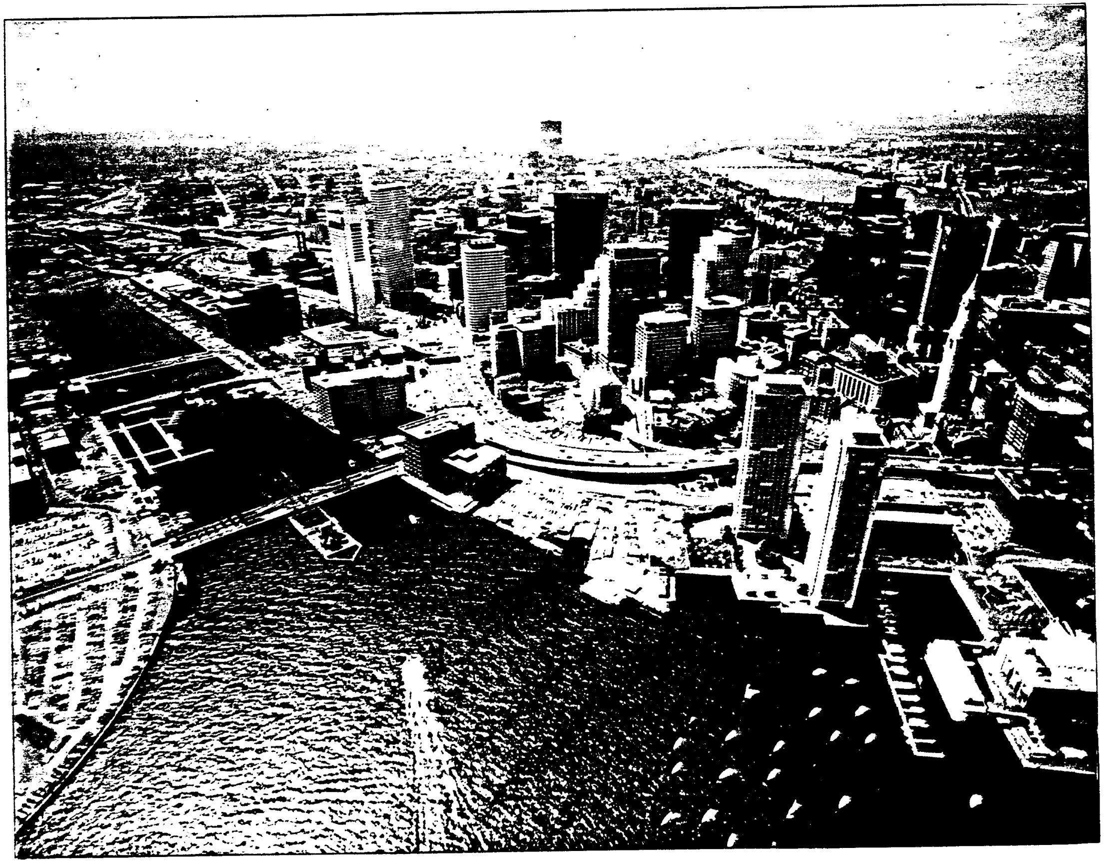


FIGURE 5. Present Day Boston

Source: Boston Globe

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> The gable ends of some 12 to 15 brick buildings were thrown to the ground.
>
> There was cracking of one or more stone basement walls.
>
> The weathervane atop Faneuil Hall broke and fell to the ground.
>
> There were no deaths or injuries. This may have been a fortuitous result of the early morning hour of the earthquake, for the accounts do describe the streets in the most damaged area around the harbor as being covered by fallen bricks.

Whitman (1980) projects the losses on present day Boston based on a repeat scenario of the 1755 earthquake:

> Total or partial collapse of something like 60 buildings, probably including one large building.
>
> Serious damage on the order of 1200 buildings, mostly in the form of fallen parapets, ceilings, light fixtures, etc.
>
> Something like 75 fatalities.[Injuries probably 10 times that number]
>
> A few serious water main breaks, with some reduced water pressure and even localized outages.
>
> A dozen overpasses and bridges out of service.

Whitman discusses the reasonableness of his estimate given that he projects that a repeat of the 1755 event would kill in the order of 75 people while there were no recorded fatalities when the earthquake originally occured. He offers the following considerations:

> The 1755 earthquake occured [in the early morning] when few people were on the streets to be hit by falling chimneys and walls.
>
> The population today is 30 to 40 times that in 1755.
>
> A much greater portion of todays buildings are located over poor soil.
>
> Many of today's buildings are much less resistant to ground shaking than those of 1755 [which by all indication were rather well built] being larger with less redundant structural systems.

Whitman (1985) qualifies his estimates to insure they are properly understood and not misinterpreted:

> These are expected values, and actual numbers might vary considerably from them. They are theresults of a crude analysis, and doubtless will change when the more-refined study - just now beginning - is completed.

The more-refined study Whitman refers to is under the direction of the Massachusetts Civil Defense Agency with funding from the Federal Emergency Management Agency. Nevertheless, until such time as the results of the study are available the Whitman scenario remains the best estimate of losses as a result of a repeat of the 1755 Cape Ann earthquake.

EARTHQUAKE CAUSES

In 1755 many theories abounded to explain the cause of earthquakes in the area. These can be seperated somewhat into two groups; scientific and religious.

New England historian Jordan Houston (1980) discusses the scientific theories and speculation about the causes of earthquakes that arose in the colonies following the 1755 shock. These were some of the first attempts to probe such an event as an earthquake using scientific theory:

> Dr. Thomas Prince, who was pastor of the Old South Church, acknowledged hypotheses by "the projecting Sort of Philosophers both ancient and modern." Then he projected his own theory , adding the phenomenon of electricity, lately described by Benjamin Franklin, to his list of earthquake causes.
>
> God, Dr. Prince explained, had created an earth "of very loose Contexture," in which existed numerous caverns filled with "Sulphurious, nitrous, fiery, mineral, and other Substances such as those in the Clouds, which are the natural Causes of Thunder and Lightning." The underground collission of these substances meant an explosion and, hence, an earthquake.
>
> Prince further refined his theory of electrical causes of earthquakes by suggesting that Boston had suffered worse shocks because of its abundance of lightning rods, then called iron points. The rods had been installed after 1751 at Benjamin Franklin's suggestion, in a city that had last been ravaged by fire as recently as 1747. Prince suggested that they conveyed extra electricity into the earth from the sky and thus imperiled Boston.

Houston (1980) goes further to discuss the religious theory of Harvard Professor John Winthrop IV who scoffed at Dr. Prince's contention that electricity and lightning rods had anything to do with earthquakes:

> . . .the reigning mode of late has been to explain everything by ELECTRICITY . . . .Now, it seems, it is to be the cause of earthquakes." The earth, he noted, was barred by simple laws of

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> physics from creating electricity. And as for Prince's lightning-rod theory, Winthrop answered, "I cannot believe that in the whole town of BOSTON, where so many iron points are erected, there is much as one person, who is so weak, so ignorant, so foolish, or ,to say, all in one word, so
> atheistical, as ever to have entertained a single thought, that is possible, by the help of a few yards of wire, to get out the mighty hand of GOD."

There were many other prominent colonists who supported Winthrop's contention that earthquakes were tokens of God's power and wrath. Houston (1980) summarized this popular theological philosophy of the day:

> Disturbed twice more by the return of a trembling earth felt as far south as Pennsylvania . . . New Englanders took to prayer and fasting to ward off further manifestations of what Bay Colony's Lieutenant Governor Spencer Phips publicly pronounced God's "righteous Anger against the heinous and provoking Sins of Men."

Houston (1980) cites from an anonymous poem distributed after the 1755 earthquake that poignantly characterizes the Divine Providence theory:

> In seventeen hundred and fifty five,
> When vice its empire did revive,
> Consuming fire, a jealous GOD
> Call'd on New-England with his rod.

Our scientific knowledge about the causes of earthquakes has increased greatly in the 222 years since the 1755 Earthquake. Ebel (1985) explains New England seismic activity using the widely accepted theory of plate tectonics:

> What seems to be happening today is that some of the pressures of the moving plates is being transmitted to the plate interiors and reactivating some of the old faults. Unfortunately, the data collected so fart is too sparse and inconsistent to allow scientists to discern which are the active faults in the region. To make matters more complicated most of the earthquakes that do occur do not seem to map onto any known faults. This may be because the earthquakes are causing new faults to form or it may be because there are many more faults in the region that geologists have yet to discover.
> While there are many uncertainties about New England earthquakes, one thing can be stated with confidence is that earthquakes will continue to occur in the region.

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We certainly no longer consider earthquakes punishment from God for our "Evil and Sinful Ways" or caused by lightning rods as we did in 1755. However, despite the fact that we continue to gain knowledge about the causes of New England earthquakes there still remain large uncertainties. Fratto (1985) states, "the actual cause of earthquakes in New England still remains largely a matter of speculation."

IMPACT ON PUBLIC AWARENESS AND EDUCATION

The 1755 Cape Ann Earthquake continues to have a significant impact on public awareness and education efforts in Massachusetts 222 years after its occurence.

The Massachusetts area has one of the longest histories of reported earthquake activity in the nation. Narrative accounts of earthquakes can be found in the diaries and journals of the first exploreres to the area. This 450 year history includes the 1755 event which has caused scientists to classify Massachusetts as an area of moderate seismic hazard with the potential for future damaging shocks. This scientific classification provides a solid and credible foundation for all earthquake public awareness and education activity in Massachusetts and New England. The assumption used is that a major damaging earthquake has occured in the past and therefore can reoccur in the future. This fact is stated in all public awareness presentations, brochures, etc.

More recent significant temblors in the northeast, felt quite extensively in the Boston area occurred at La Malbaie, Quebec, 1925, Ossipee, New Hampshire, 1940, Massena, New York, 1944, Cape Ann, Massachusetts, 1963, New Brunswick, 1982, Laconia, New Hampshire, 1982, and Goodnow, New York, 1983. These events serve as a reminder that the earthquake hazard in the Northeast is real. However, it is safe to assume that absent the 1755 Cape ann event there would be little basis upon which to promote earthquake public awareness and education in Massachusetts.

IMPACT ON PUBLIC POLICY

The 1755 Earthquake continues to have a significant impact on public policy 222 years after it's occurence. Massachusetts is one of the few states east of the Rockies that has mandated earthquake requirements to it's state building code. It is a uniform statewide code that was adopted in 1975. It

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contains seismic provisions for all buildings other than small residential types. The Massachusetts code is based primarily on a recurrence of the 1755 event and applies mostly to new construction. The code does have provisions for existing buildings in cases where the use of the structure dramatically changes. It is a life-safety code intended to prevent building collapse and limit loss of life. It is safe to assume that absent the 1755 Cape Ann Earthquake there would be no seismic building code in Massachusetts.

IMPACT ON EMERGENCY MANAGEMENT

The foundation for all emergency management and earthquake hazard reduction measures in Massachusetts is the 1755 Earthquake. The Federal Emergency Management Agency supports Massachusetts efforts because the 1755 event could occur again. The Metropolitan Boston Area Earthquake Loss Analysis Study is based on a recurrence of the 1755 earthquake. Fratto, et. al. (1986) state the following about a repeat of the 1755 Earthquake:

> A repeat of the 1755 Cape Ann earthquake, near Boston, could be expected to cause serious damage to many structures including fallen chimnies, parapets or ceilings, partial or total collapse of some buildings, damage to water mains, bridges and overpasses, and possibly some fatalities.

The results of the study will drive future federal, state, local and private emergency planning for earthquakes and hazard reduction measures. It is safe to assume that absent the 1755 Cape Ann Earthquake there would be no earthquake preparedness program in Massachusetts.

CONCLUSION

It is reasonable and logical for one to assume that absent the damaging 1755 Cape Ann Earthquake there would be no seismic building code in Massachusetts, there would be no emergency preparedness for earthquakes, there would be no earthquake hazard reduction efforts, there would be no earthquake public awareness in Massachusetts and I would not have the opportunity to present this paper today.

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FOUR YEARS AFTER BORAH PEAK IDAHO EARTHQUAKE
WHAT MITIGATION FOR FUTURE EVENTS HAS OCCURRED?

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Introduction

Approximately four years ago Idaho experienced a major earthquake. With the occurrence of such an event there is always an expectation that hazard reduction activities will be stimulated. This paper will provide a cursory review of what has happened in the area of earthquake mitigation in Idaho since this event. Perceptions to be discussed are related to areas of public awareness and concern, education, government policies, State and local preparedness and legislation.

The Event Revisited

The October 28, 1983, Borah Peak 7.3 magnitude earthquake is the largest event in Idaho and the lower 48 states since the 1959 adjacent (within 12 miles) Montana border event, 7.5 magnitude Hebgen Lake earthquake. The surface rupture was approximately 36 kilometers in length with a maximum offset of three meters in height in the unpopulated and relatively remote area at the base of the Big Lost River Range and the highest mountain peak in Idaho. The event was located in the political jurisdiction of Custer County which is 93.3 percent Federally owned with 4.9% private ownership and a population of approximately 5,000 (this is only .5% of the State population). The vibrational effects (the only significant damage producer) of intensity level VII were experienced by approximately 30 to 40 percent of that population in an area less than 4,000 square kilometers, Figure 1. Intensity VI involved an area of over 55,000 square kilometers and was felt by approximately 225,000 residents (less than one-fourth of the State's population). The most severe damage occurred in Mackay (population 570), Challis (population 1,000), and a rural area north and south of Mackay (population 200) all of which can be generally classified as being economically depressed and of having simple, easygoing and self-reliant life-style with little desire for outside government influence. Thirteen businesses, ten public buildings, and 34 homes sustained major damage with approximately 200 homes having minor to moderate damage. Two lives were lost and 12.5 million dollars damage to buildings and structures was caused. Five secondary schools experienced almost 10 million dollars damage.

The Question

With this brief overview of the event in mind, the natural question follows. Did the Borah Peak earthquake inspire more concern and action for seismic safety in planning and construction along active frontal faults in Idaho? This question is almost as difficult to answer as to when and where the next major earthquake will occur in Idaho. The answer probably lies within the perception, background, interests, discipline and degree of advocacy for earthquake hazard reduction of those who examine the fragmented and complex evidence available. My perception is that the event caused some new

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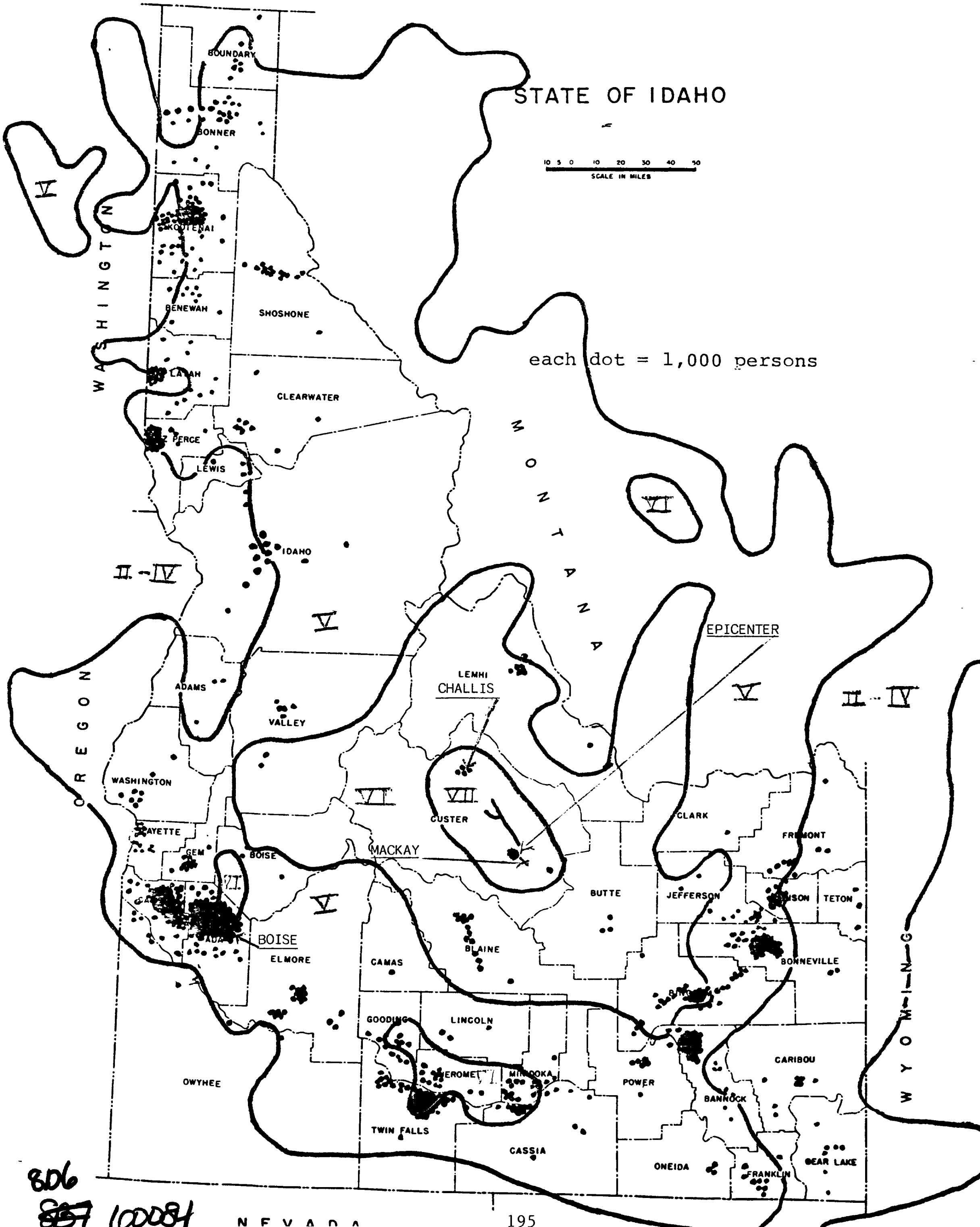
Figure 1 -- Isoseismal map for Borah Peak, Idaho, earthquake (Stover) and county population density, October 28, 1983



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activities to occur and others to continue. It should be noted that earthquake hazard reduction has just begun in Idaho and its continuation will always be an unknown factor. I am convinced, however, that without the Borah Peak event, earthquake reduction in Idaho would have remained stagnant or would not be as far along as it is today.

Public Awareness and Concern

An event as large and as recent as the Borah Peak earthquake has obviously increased public awareness and concern. The level of concern has not, at this time, diminished to the extent that it was prior to the event. Almost everyone who was present in Idaho at that time will relate to anyone who asks exactly what they observed at 8:06 a.m. of the day of the earthquake. This is particularly true in areas mapped as V, VI and VII intensity. In almost all cases, these individuals will relate some form of damage they personally observed. In areas inside intensity level V and above, much of the damage could be classified as minor to major nuisance. Minor nuisance was most frequently described as cracked ceilings and walls, broken glassware and light fixtures, cracked foundations, ground settlement, cracked sidewalks, changes in ground and domestic water supplies and well water contamination. Major nuisance involved repairing broken water pipes, drilling and repairing of domestic water well casings and low cost minor structural repairs to business buildings and residential homes to include cosmetic repairs. No research supports this idea, but it seems likely that nuisance damage losses could easily exceed the officially reported loss. An arbitrary damage number of $100 per person in the intensity level VI area would mean at least 22 million dollars damage.

Concern is almost a separate issue. The level of concern attenuates in a similar pattern as ground motion and is directly related to the recency of the event, distance from the epicenter and severity of loss observed. Only those who experienced intensity level VII seem to have the desired level of concern expected by the hazard reduction advocates. The level of concern also seems to be affected by the aftershocks sequence, because concern increases with aftershock activity. Whereas, in other areas not experiencing the aftershocks, concern began immediately to decline after the main shock. Still, concern is nowhere near as low as prior to the event. The location of the suspected, active faults has had a negative impact on concern. Almost all these identified faults are located in uninhabited and remote areas of Idaho. Thus, the threat seemed very distant to the majority of inhabitants. This event reinforced this perception. It is likely, therefore, that Borah Peak may represent to many Idahoans the worst earthquake scenario, but the remote location of the suspected faults is likely causing lack of proper concern in the more populated areas.

Educational Programs

The optimum time to provide the whole field of earthquake education to the broad sector of public and private audiences is immediately following an earthquake. The event itself provided the demand; unfortunately, adequate supply was not there, nor is it today. In the attempt to fulfill the demand, many spontaneous educational activities did occur. Geologists were in the highest demand for over a year after the event. Self-initiated programs were developed primarily by the Red Cross, emergency management, schools and universities. Primary recipients of these educational activities were the normal professional (public and private) associations, church and volunteer groups, schools, businesses and emergency management. Many of these though could be classified as agenda fillers. Most of these activities seemed to be located in intensity V areas and above. Demand for information has tapered significantly in the last two years. One particular highlight was a FEMA sponsored, two-day workshop for structural engineers in earthquake design presented by preeminent structural engineers. Another was Boise State University, serving the State Capitol and the most populated area in the State, has been the major contributor in providing Idaho earthquake public awareness and hazard education. Their major contribution has been translating earthquake science and research in the Idaho situation for media, public officials, State agencies, private companies and the public-at-large consumption and have spearheaded seismic zoning and construction considerations. There also is an ongoing effort to develop programs for schools through the Idaho Department of Education, the University of Idaho and the Idaho Geological Survey. This program and the Boise State University effort, as with the other earthquake mitigation activities, has been hampered by staff availability, funds, other program activities and the availability of Idaho specific, tailored information and materials. A simple conclusion that can be drawn from this experience is that the fragmented effort met some of the need, but a comprehensive delivery program surely would have heightened awareness and concern substantially. The opportunity was there but now is significantly lost.

In another educational arena, a positive response did develop due to Borah Peak. A cooperative program between the three major state universities (University of Idaho, Boise State University, and Idaho State University) leading to a master's degree in geophysics was established.

Policies of State, local, and Federal government with respect to siting and regulation of construction and land use

There are no new policies in Idaho with respect to siting and regulations of construction and land use that were precipitated because of the Borah Peak earthquake. This is particularly true for state and local government. The state and local governments have accepted the obligations of earthquake hazard mitigation that is mandated by PL 93-288, Disaster Relief Act of 1974. This was the first time that a mitigation plan was required in Idaho by the Federal government as a result of a disaster. That plan has been and remains the primary vehicle for earthquake hazard reduction in the State of Idaho. The plan identified twenty-five measures to be accomplished of which 85% to 90% have been accomplished in some form and the remaining are progressing at various stages. Some of these will go on for years. In some ways, the measures contained in the plan are a form of policy. Two examples of measures reflecting policy are: Reviewing seismic zoning in relation to civil structures and investigating the establishment of seismic safety standards for school construction and school occupancy in the State of Idaho. The seismic zoning measure resulted in an ad hoc committee being formed from multi-disciplines which has recently submitted seismic zoning map recommendations to the International Conference of Building Officials Committee for the 1988 Uniform Building Code (UBC) publication. (These were subsequently adopted after this presentation.) The seismic safety measures relating to schools has resulted in a grant from FEMA to develop standards which are to be submitted to the State Board of Education for adoption. After adoption, they will have the force of law. One measure, directly relating to regulation of construction, was to recommend to the cities of Mackay and Challis the adoption of preventative safety measures. Both cities declined the idea of adoption of the UBC. Some would consider that a failure, but when the situation is examined, there are some reasonable justifications for not adopting it. In this case, justification was likely based on economics and types of structures (single story, wood or metal frame, low occupancy) which would likely be built there. Severity of the economic situation has tremendous weight on this issue and likely ranks higher than "government stay out of our lives."

As a background note relating to the uniform building code status in Idaho, the legislature passed the adoption of the UBC in 1976. This was repealed one year later. In its stead they allowed local jurisdictions to adopt the code on their own. There are still seventeen jurisdictions that have not adopted the code. The Borah Peak earthquake effected no change in this status. There are indications that a statewide UBC adoption may be on the upcoming legislative agenda. The reason for this possibility is not related to the Borah Peak earthquake, but this earthquake could, to some degree, influence the outcome, depending on how it is presented.

Another note related to earthquake reduction policy activities is that in 1983 there was almost an unanimous attitude that you can't mitigate earthquakes because they cannot be stopped. The Borah Peak Earthquake plus the requirement for mitigation has changed this perception to the point that officials will now listen to ideas suggested, if they are reasonably justified.

Federal, State and local emergency preparedness

The preparedness focus in the state has been on all-hazard emergency operations plans and exercises. The Earthquake Hazard Mitigation Plan required a revision of the Custer County Emergency Operations Plan. This was the first local plan in Idaho to have a major revision in 10 years. It is now being used as the model for all other counties. The development process of that plan turned out to be an emergency planner's dream and local cooperation was unparalleled, simply because of the earthquake. The Borah Peak earthquake also prompted and promoted enhancement and revision to the state emergency operations plan. Borah Peak has been a significant contributor to the improved status of emergency management in Idaho.

An essential element of preparedness is having a credible earthquake risk analysis. Idaho Geological Survey and the University of Idaho have made significant strides in this area since Borah Peak. Again, this effort was an in-house, unfunded activity and agreed on the Hazard Mitigation Plan, but accomplished by pure professional dedication and concern for identifying the risks to Idaho citizens. The effort has taken the form of computer generated tools. So far, tools developed are site-specific isomagnitude, intensity charts (maximum ground shaking during historic time and probability of future shaking) and simulated earthquake isointensity maps. These can be used by engineers, emergency planners, emergency plan exercisers, planning and zoning planners, dam safety officials and others in the private and government sector concerned with site-specific earthquake hazard evaluation, training simulations and planning.

Legislation with a goal of saving lives and reducing potential losses from earthquake hazards

Only one piece of legislation can be associated with the Borah Peak Earthquake. In 1986 a modernized Interstate Mutual Aid Compact was enacted. This was an outgrowth of a measure recommended in the Borah Peak Earthquake Hazard Mitigation Plan. The States of Washington, Montana and Idaho are now parties to this compact. Other surrounding states are showing interest.

Conclusion

The Borah Peak Earthquake has had an impact on the earthquake hazard reduction effort in Idaho. Prior to the event, hazard mitigation had never been addressed, nor did it exist with any formal program in the State of Idaho. There now exists a semblance of such a program, although it is virtually unfunded. How long this basically, voluntary program will continue is unknown, but, surely, fading memories will be a detractor to its existence. Federal pressure and support and subsequent events can promote its survivability, but acceptance still depends on all state and local government officials being properly advised.

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PERSPECTIVES 69 YEARS AFTER THE OCTOBER 11, 1918, MAYAGUEZ, PUERTO RICO EARTHQUAKE

By

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INTRODUCTION

On October 11, 1918 a strong earthquake was felt in Puerto Rico, causing great losses in the western part of the island. Mayaguez was badly damaged by the shaking and by a sea wave that destroyed houses and drowned many people.

A total of 116 persons were killed and about $4,000,000 were lost in properties.

Many pictures of the damage taken inmediately after the earthquake are surfacing now in family albums that were unavailable for decades. These pictures together with the accounts of reliable old age citizens that experienced that terrible event are bringing light to many unanswered questions about earthquakes and sea waves (tsunamis) in Puerto Rico.

Although governments, for decades, have been indiferent to earthquake damage mitigation programs, the community, specially in the western part of the island is participating in short seminars about what to do during an earthquake. The Department of Civil Engineering of the University of Puerto Rico is very active in community orientation on natural disasters with emphasis on earthquakes.

EXPECTATIONS:

It is encouraging that the Administration for Rules and Permits has accepted recommendations for a new Building Code. It has been a slow process but the engineering profession will finally have an updated code in Puerto Rico to replace the 1956 one. The major changes are on earthquake design of structures with specific provisions for public buildings, such as schools and hospitals.

ENHANCING UTILIZATION

By

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One of the key issues facing the administration of the National Earthquake Hazards Reduction Program is how to increase the utilization of both new knowledge developed from research and existing information. This paper examines several key issues in the development of a sound utilization strategy and focuses on

- o experience in fostering increased use of science and technology;
- o the decision to make a decision;
- o how to influence the decision, and;
- o what influences the decision, particularly where the information comes from.

The context of such undertakings and the breadth of actions and disciplinary content includes all actions to mitigate, respond and recover from damaging earthquake whether focusing on first cost, continuing cost, losses, disruption, or opportunity costs; the dimensions of the problem are discussed in papers [T2-4].

There has been some recent discussion of utilization of earthquake hazards reduction research and advancement about "Why we know so much and do so little?" I assert that this is a rebuttable presumption that focuses on how much remains to be done rather than the substantial changes that have occurred over the past 15 years: massive changes in earthquake engineering practices in the west; initiation of publicly based preparedness projects in the west, midwest and east; recognition of the nature of the hazard in the midwest and east where there was little if any previously; concern by disciplines other than structural engineers; specific business investment to protect property and provide for business continuity; and the efforts of the military to reinforce existing structure to provide for the dual objectives of maintaining our state of readiness and protect lives, to indicate but a few areas. Not-with-standing, the opportunity to improve the process and effectiveness is great. The purpose of this paper is to explore how the process of encouraging effective utilization can be enhanced.

The key issue to increase utilization of earthquake hazards reduction information is that a person or institution must be convinced to make a decision to do something differently. Thus the root problems are:

- o How to influence the making of a decision?
- o Where does the information come from that influences the decision made?

A key research finding in decision theory as developed by Kenneth Arrow, [A1], and more recently explored by Howard Kunreuther, [K2], in the context of natural hazards is that people use a two step decision process: the first is to decide to make a decision and the second is to collect the information necessary to make the decision. This matches most of our experience: we are all presented with the possibility of making many more decisions than time permits. Mostly of our personal and business problems are not caused because we lack intelligence or are lazy. Rather, the most common cause of failure is that we fail to see and/or otherwise ignore the numerous yellow and red warning signals that are waver before our eyes. Why do we so often miss them? One reason could be that the warning signals are but one of many information inputs vying for our attention. Sociologists calculate that Western man receives 65,000 more stimuli per day than his forbearers did one hundred years ago, [G1]. Another could be that the problem we are presented with is framed in such a way as to encourage a given resolution. We all engage in a kind of "triage" and only select a few problems for decision, even when there is a large penalty or benefit associated with the decision. Thus the problem of enhancing utilization is first to convince that a decision is needed and then to present the information and arguments to influence the actual decision. The first could be characterized as getting attention, while the second is assisting in information gathering, problem assessment and statement, analysis, and option selection.

Influencing the Decision to Decide

One of the most important issues in affecting whether a decision to decide is made is the how alternatives are stated, or framed. Two research efforts are of importance in understanding how this process can be effected. Tversky and Kahneman have addressed the question of how the framing of decisions affects the psychology of choice in risk situations, [T1]. Among the several problems they examined are the following two:

> <u>Problem 1</u>: Imagine that the US is preparing for an outbreak of an unusual Asian disease which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Which of the two programs would you prefer? Assume that the exact scientific estimate of the consequences of the program are as follows (the numbers in brackets are the percentages of respondents choosing the option):
>
> If Program A is adopted, 200 people will be saved. [72%]
>
> If Program B is adopted,there is a 1/3 probability that 600 will be saved, and a 2/3 probability that no people will be saved. [28%]

The choice of the majority in this problem is risk aversion: the prospect of certainly saving 200 lives is more attractive (72%) than a risky prospect of the same expected value (28%). The purpose of this experiment is not to focus on the certain versus probabilistic formulation of the problem but to set the scene for a second question with a different set of alternatives and respondents:

Problem 2: Same problem as number 1.

If Program C is adopted, 400 people will die. [22%]

If Program D is adopted, there is a 1/3 probability that nobody will die, and 2/3 probability that 600 will die. [78%]

The majority choice for this problem is risk taking: the certain death of 400 people is less acceptable than the two-in-three chance that 600 will die. Note that in this case the probabilistic statement is preferred to the certain alternative, thus removing the interpretation that the probabilistic formulation contaminated the response to the first set of alternatives.

Note that the two problems are effectively equivalent, only the way in which the question is asked changed. The only effective difference is that the first emphasizes the saving of lives while the second emphasizes those lost. The clear effect of this experiment is that the framing of a question can dominate the choices made by individuals in risky situations: framing the proposition as an act of saving is vastly preferred to a framing emphasizing losses.

The message of this finding for the National Earthquake Hazards Reduction Program is clear: the persistent emphasis on losses of life and property by those advocating earthquake hazards reduction actions rather than their savings has fostered a risk accepting attitude of those that we wish to influence—the opposite of the effect desired. Clearly a change in approach is desirable if there is to be a more receptive attitude to adopting such actions. The literature on this subject is a rich one that warrants further investigation by those that wish to influence the actions of others through the framing of arguments and presentation of information, see particularly Kahneman [K1], and Kunreuther [K2].

The second major research effort is contained in a recent book, "Taking Risks: The Management Of Uncertainty", focused on the risk attitudes of managers of major corporations, who are one of the groups that the NEHRP wants to influence. They examined management issues of risk taking, not specifically on natural or technological hazards. The following observations abstract a few of their findings. Consistent with Tversky and Kahneman:

> The executives were risk-taking for business decisions involving only losses. Risk aversion was more common when only gains were possible.
>
> When presented with several important attributes of risky investments, managers focused on only one or two attributes.

The analysis included evaluations of both the managers' business and personal decision biases.

> Overall, the executives were strongly risk-adverse for

> both personal and business investments involving major losses.

This suggests that when losses are the point of discussion, they be framed in terms of their catastrophic impacts, e.g. failure of the business, competitors seizing their markets. The analysis indicates that there is a consistent attempt by managers to change the basis of the risk by reframing or adjustments of the way the problem is stated.

> Rather than taking the chances of potential losses, magnitude of loss and exposure as fixed, the managers tended to adjust the risky situations to make them more attractive.

They used a variety of means to try to adjust the risky situation: changing the risk, delay and delegation among others. And lastly, among their many pertinent observations,

> Managers were more willing to take risks once in a risky situation than in entering a risky situation.

This suggests that the focus for change in policy should be for new endeavors, buildings, processes, etc, rather than to focus on correcting old problems as a first priority.

There is some uncertainty about applying these results to the formulation to natural hazards reduction policies and practices, however, the risks seem minimal. The clear implications of this research are that the presentations to managers need to close off the obvious methods to avoid the issue by restatement of the problem and need to focus on the firms positive benefits of alternative actions.

Causing Change

How do you cause change? The Research Applied to National Needs (RANN) Program conducted an extensive, long term program (The Intergovernmental Sciences Program) in attempting to influence the rate of science and technology application, particularly by state and local governments. A substantial number of projects were founded involving expenditures of perhaps over $20 million. This was a carefully conducted and planned program. Among the approaches tried were:

- technology agents, advisors and traveling advocates
- leader-follower models
- top down and bottom up strategies
- political and non-political based strategies
- specific technology development
- diffuse technology adoption

My review of the effectiveness of this program, and there were major successes and failures as befits an experimental undertaking, suggest the following observations:

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1. Success varied all over the place. A successful strategy in one place does not imply success in another place.
2. To assure a reasonable likelihood of success, a multiplicity of approaches is required, often within the same community, industry or professional group, that recognize the systems context of the community or profession and works within this context.
3. Research and researchers were seldom more than a minor player in the melange that leads to success. Espoused critical variables in adopting a change were almost always a minor factor; the major ones were seldom accurately identified except where there was an insider confidence.
4. Leader-follower models seem to be consistently the most successful; that is, in each community, whether geographical or professional, there are certain persons (groups or businesses) that are looked to for leadership in the adoption of new methods or approaches. They are sufficiently well regarded that the notion is that many people will accept their decision to apply as sufficient cause to cause them to start using the advance.

These observations could be argued to be not very profound, if our personal experience outside our profession is examined (particularly, that success of the leader-follower model), however, few programs seem to recognize their applicability.

Most individuals are extremely uncomfortable with uncertainty. To deal with his discomfort, one tends to create a false sense of security by substituting certainty for uncertainty. In the current earthquake environment this leads to following the leader actions, most likely doing nothing: the herd instinct takes over. The preference for certainty is confirmed by another set of experiments reported by Tversky and Kahneman, [T1]. They discovered what they term the certainty effect: a reduction of the probability of an outcome by a constant factor has more impact when the outcome was initially certain than when it was merely probable. In the negative domain they assert:

> ... certainty exaggerates the aversiveness of losses that are certain relative to losses that are merely probable.

In sum they have demonstrated beyond reasonable doubt that expected utility theory does not explain individual's decisions and is therefore a weak foundation on which to base planning.

It is amazing how easily people's opinions are drawn together under the conditions of uncertainty. The actions of a leader, one whose business decisions (or political acumen for public agencies) are respected can cause a particular action to be taken or not taken by example.

Influencing the Decision

Given that a decision maker has been convinced to make a decision, where is the information that the decision is likely to be made on come from, and how can the decision be influenced? An extensive evaluation focused on policy-related research on housing. The conclusions of this study seem to ring true and confirm results for other information diffusion and decision studies. As part of their study, Cogan and Holt [C2] examined the sources of information and degree of influence of different sources and experiences on the making of decisions where the decision maker was not in a position of conclusive knowledge. Their general conclusions are summarized below. (The findings have been slightly recast in terms of earthquake hazards reduction issues.)

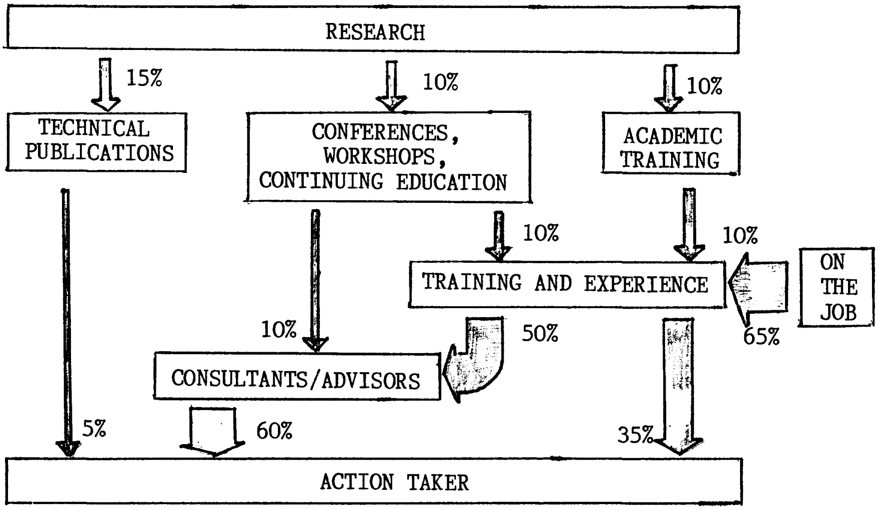
1. Policy makers make little direct use of earthquake hazards reduction research. Too often they find research
    - professionally or politically naive;
    - hard to find on specific issues; and,
    - out of date.
2. Professionals and policy makers rely most frequently on their own training and experience. This consists primarily of on-the-job training and experience. To a lesser extent they cite conferences, workshops and academic training as sources of their training.
3. Professionals and policy makers turn frequently to various advisors for information outside their expertise.
4. The sources of information used by advisors closely follows those of those they advise; they depend to a great degree on their experience, training and other consultants.

Figure 1 is a restatement of their assessment of the interrelationship among different sources of information. It presumes that the professional or policy maker has identified a problem that must be resolved and that she does not have sufficient knowledge or information for its resolution. The relative weights shown were assigned based on the author's experience in earthquake engineering practice, policy formulation and research (the values are not very different from those of Cogan, Holt except for the inversion of the dependence on consultants and experience.) The figure warrants some study. Note first that the time delays are quite different for the relative elements. Second, note that the most effective element is to provide the consultant with experience or on-the-job-training. Indeed on experience is credited with about two-thirds of the influence, compared to research knowledge's one-third. In the fine structure, the most effective type of technical publications is probably not the usual scientific peer publication, but the technology translating or interpreting publication.

The clear message of this assessment is that the most effective and timely actions to increase utilization of new knowledge is to provide experiences for the consultant. By the prior assessment, clearly the desired consultants are those that are viewed in their profession as the leaders. Convince them and the others will follow.

As an additional note, it is the author's observation that the information available to the community on earthquake hazards is so divergent that informed, intelligent individuals can have difficulty in determining what is factual and actionable. They sample the opinions of several individuals (experts or those presented as experts) compare their content and then reject most of what either says if there are points of disagreement (even if they are in substantial agreement except for a few points) since there is no apparent criterion for choice. There is a clear and apparent need for the community of earthquake scholars to get its act together, deliver a few simple messages clearly and uniformly, and act as a community to increase the public's knowledge of the actions that can moderate earthquake impacts and reinforce the veracity of those knowledgeable.

Figure 1 -- Relative importance of different influences on information transfer.



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Conclusions

The clear messages of this research are two: first that the framing of the problem is critical in influencing the utilization of earthquake hazards reduction practices. Current practices seem to encourage risk accepting, or do nothing, actions. Second, technical publication of the results of research and dependence on the user to find and interpret it (or the "toss it through the transom" approach) is not a particularly effective method of getting information to those that need it. Research suggests that the most effective approaches are those that focus on involvement of the nonresearcher, particularly consultants and advisors who are viewed within their communities as leaders, in workshops, prototype studies, priority setting exercises, advisory groups and any other approach that exposes them to the problem, approaches to resolution and/or the details of problem resolution—experience is the key to effecting their future actions. Successful utilization enhancement will depend both on the careful selection of individuals to participate in the "on-the-job experiences" and on constant rotation bringing in new individuals.

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THE CALIFORNIA SEISMIC SAFETY COMMISSION AND KNOWLEDGE-INTO ACTION (1975-1984)

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The California Seismic Safety Commission (CSSC) is a unique organization that has done a great deal to translate knowledge into action or, in the shorthand, transfer technology.[1] It has not done so in the manner of an agricultural extension agent -- "hands-on" -- or in the manner of a NASA, through "spin-offs" or tech-brief information dissemination. Rather, it has performed this function as an "enabling institution." Sitting in Sacramento, it has served as symbol, catalyst, and incubator, and via these roles has stimulated activity along knowledge-to-action/technology transfer lines. The record is not perfect, of course. Each of these roles has limits. But within those limits, which relate mostly to resources, CSSC has done much. We will address each of these roles. In doing so, we must emphasize that this discussion does not go beyond 1984.

Symbol

The symbolic role of CSSC is real and important. There have been other states that have sought to have entities similar to CSSC, and none has succeeded in lasting very long. What a symbol does is provide a focus of attention. It is there, and because it is there it provides attention to a problem. Take it away, and the problem immediately seems less important. So it is with the earthquake issue.

The CSSC was born in 1975 and was a direct result of the San Fernando quake of 1971. This quake triggered two advisory committees which saw the need to continue their work in a more sustained way. While CSSC was not created officially as a "permanent" organization, its establishment very much embodied the notion that the earthquake problem was too important for ad hoc and episodic responses. There had to be an organization dedicated to mitigation, and proclaiming its importance day-in, day-out.

Government had a responsibility for mitigation, and that responsibility had to be embodied in an agency. That embodiment in turn gave hope to those who labored, some for years, on the earthquake front. Now there was an organization that shared their concern, and could better enable them to do what they wanted to do in the field of earthquake mitigation. As symbol, CSSC was critical not for a direct transfer of knowledge, but as an indirect spur to such transfer. Simply by existing, CSSC pointed up the fact that mitigation had to be taken seriously by government and those subject to government.

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[1] Information on which this discussion is based derives, in part, from research supported by the National Science Foundation, Contract No. PFR-8018710. The author is grateful for this support.

Moreover, it had to exist over time because the problem was a continuing one. Surviving was difficult for CSSC, and proponents fought more than one battle to keep the organization alive.

Catalyst

However important CSSC was as a symbol, it was even more important as a catalyst. That is, it caused others to act, in part, through the content of its policy analysis. A small organization, with a handful of staff, and governing board of essentially part-time volunteer commissioners, CSSC was not created to "do" anything itself. That is, it was not an operating agency. Its role was to advise the legislature and executive branch on mitigation policy -- i.e., get them to change policy and to cause others to change because of policy. For reasons owing to its history and certain strong personalities, it led the change process in a particular direction. This was structural safety (Laurin, 1983). CSSC became an access point for those structural engineers who "knew" California could do better by way of mitigation, if only the proper policies were in place. All organizations reflect certain interests, some more than others, and CSSC initially reflected the interests of the structural engineers.

A great deal of the early history of CSSC could be written in terms of its role in the transfer of knowledge in structural safety from the professional engineering community. This was accomplished by means of legislation enacted in part because of the analysis, advice, and lobbying of CSSC. Most of the legislative and administrative change dealt with identification, rehabilitation, and abatement of hazardous structures, including dams. In addition, CSSC conducted a study that resulted in legislation which augmented existing law and established criteria for local government to analyze earthquake risk areas prior to approving development (Laurin, 1983).

What made this catalytic (and indirect technology transfer) role possible was the blending of engineering expertise on the Board, administrative/political skill on the part of the executive director, and legislative clout by CSSC's chief sponsor and supporter in the California senate. As time went on, this unusual coalition diffused somewhat. The Board did so in particular. But in its earlier years, it was quite a strong force behind the interest of mitigation via structural engineering.

Incubator

CSSC was focused, but it was narrow in the view of some -- including the federal government. In the early 1980s, the interests of the CSSC were caused to broaden. The orientation came to include earthquake prediction/preparedness. The state of California and federal government combined to sponsor a joint program, called Southern California Earthquake Preparedness Project (SCEPP) in the early 1980s. SCEPP was the agent of CSSC, but CSSC was not entirely comfortable with this action organization, which sought to transfer prediction response and preparedness planning innovations to the local level. SCEPP had more money than did CSSC, and a federal as well as state sponsor (Lambright, 1985). CSSC acquired an incubator role by default.

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There was nowhere else to place SCEPP -- at least nowhere else politically acceptable at the time. So CSSC took on the job, and after a year of uneasy "learning," rose to the occasion. So well did CSSC do that it was later awarded another entity, the Governor's Task Force, and still another, which was a Bay Area version of SCEPP.

SCEPP eventually was transferred to the Office of Emergency Services (OES), and one assumes that precedent will be followed [if it has not already been followed] for the other satellite entities. CSSC has apparently little interest in expanding its mission far into the domains of other agencies. It has survived by adopting a remarkably non-imperialistic approach to life. At least, that was the case in the period with which I am familiar, the late 1970s and early 1980s.

Conclusions

In discussing the problem of technology transfer and the moving of knowledge into action, there is always the question of appropriate institutions to facilitate the process. The CSSC represents an appropriate institution, one that in the period I studied played an important role. Indeed, it played three roles: symbol, catalyst, and incubator. In every one of these roles, it facilitated change in the direction of seismic safety.

As symbol, it gave more than ad hoc visibility and priority to earthquake mitigation as an issue. It gave continuity. As catalyst, it served as policy-thinker and lobbyist for structural engineering legislation. As incubator, it provided for the initial care and feeding of SCEPP, which in turn transferred knowledge in the field of earthquake prediction response and preparedness at the local level.

All the above represents a positive record. If one is forced to find any fault with this record, it is that CSSC might have more enthusiastically sought and carefully played the incubator role. There was a year that was lost in organizational turmoil. And one could add that it might have tried harder to keep SCEPP, rather than allowing it to shift, with barely a whimper, to another agency. In other words, one might argue that CSSC could have done more to use SCEPP to assume a fourth more direct action-oriented role. It has historically been quite restrained in its bureaucratic power drive, as might be expected of an organization that is an extension of "professional" interests, with limited legislative backing. So, one could cast a stone or two. But my basic view is that CSSC did much with few resources. I regard it as perhaps the single most important institutional model at the state level that came into the earthquake field in the 1970s and which also extended (and expanded) into the 1980s. As an "enabling institution" it provided policy changes that allowed technology to transfer and knowledge to be used.

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RESEARCH APPLICATIONS: PERSPECTIVES ON THE CALIFORNIA SEISMIC SAFETY COMMISSION

by

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Introduction: Some Caveats on Application Models

The models and the rhetoric often employed in discussing the use of research, and even the very choice of words--"application of research"--seems to rest on over-simple assumptions. Moreover the agenda of this workshop and the instructions to those preparing papers appear to assume a clear, straightforward, almost one-to-one relationship between research and its application.

Admittedly, of course, sometimes the relation between research findings and their application is direct and relatively simple. An example is the use of eccentric braced framing to increase the ductility and failure-resistance of steel structures. The concept was developed by Egor Popov and associates at the University of California, Berkeley, was successfully tested on shaking tables, and is beginning to be used in design practice.

In the policy arena, however, this model of research-to-application is much too simplistic to describe the real mechanisms by which knowledge is used and strategies of change developed. Instead of asking--"How do we apply research to achieve our objectives?"--it helps to phrase the question differently. "How do you change things that you want changed, using available knowledge and intelligence in the process?" This broader perspective seems much more appropriate to experiences and examples discussed here, drawn mostly from the activities of the California Seismic Safety Commission.

Many years or decades of past research and practical experience have helped produce a shared "base-line" of knowledge, data and interpretation. In this sense, existing knowledge includes the results of research, and is used constantly. I think much of the real utility of research involves such comparatively indirect routes, i.e., helping to understand phenomena, interpret probable causes, develop a body of knowledge and discourse, and build both a scholarly literature and an improved state-of-the-art practice.

Accordingly an effective way to "apply research" is to facilitate improved use of this large body of knowledge to deal with common problems. Doing that well means identifying needs, establishing priorities, developing strategies, and creating vehicles to meet those needs. Guided by a perception of needs, the sophisticated policy body uses research almost as a matter of course when it dips into the common body of knowledge in seeking help on ways to effect desirable change.

Much more is involved than simply responding to a specific need by finding a specific piece of research that solves a problem. Where new knowledge is essential to a problem's solution, of course, research may be the only source of help. A great deal of the intelligence used to solve real-world problems does not necessarily derive from research findings, however, but represents knowledge based on experience and seasoned judgment, guiding the development of strategies to get things done.

In any event, I believe that the Seismic Safety Commission and organizations it has been associated with provide good examples of the way needs-driven and policy oriented processes can work, and can use research along the way. This is illustrated by discussing six selected topics: (1) the Auburn Dam review, (2) local seismic safety elements, (3) the "1279" report and the "SB 548" program, (4) SCEPP and BAREPP, (5) continuing education and improved earthquake-resistant construction, and (6) the Commission's role in seismic research.

The Auburn Dam Review

The Commission's activity in the Auburn Dam review of about a decade ago is a most interesting example of using state-of-the-art expertise and the best available scientific/technical information to help resolve an issue that could have exploded in controversy.[1] Questions had been raised about the earthquake safety of the high, thin-arch dam the Bureau of Reclamation was proposing to build near Auburn, California, and on which advance site work had begun. Large populations were potentially at risk in areas downstream from the proposed site, including the Sacramento region. The August 1, 1975 Oroville earthquake heightened these concerns, particularly as it prompted geologists to rethink previous assumptions as to the activity or quiescence of the Sierra foothill fault system. Perhaps the region was significantly more active than previously thought.

In any event the controversy began heating up, and the Commission--then a brand-new agency only appointed in May 1975--soon became actively involved. Meanwhile the Bureau, though perhaps uneasy at first, seemed to welcome the Commission's role. The Commission appeared to offer a neutral but well-qualified forum for a public airing of the issues and the evidence. Otherwise the matter might be tried mostly in the media, and the debate could have become acrimonious.

From the outset the Commission held firmly to a basic objective--trying to make sure that the dam's design and the area's seismicity and geology were thoughtfully restudied, and with appropriate state participation and review. The goal was to see whether agreement could be reached on the adequacy of design standards used for the dam,in the light of the best available evidence, and judged by the best available expertise.

For some three years the Commission helped with the review process, encouraging state participation, holding hearings, and generally monitoring developments. There was a thoroughgoing study of the site and the region's geology, and this in turn was reviewed by a special state consulting board, by the California Division of Mines and Geology, and by other appropriate state agencies. There were also contributions by the U.S. Geological Survey. The upshot was that the Department of Interior accepted the state's consensus as to the appropriate seismic loading for the dam, which meant that if it were built, the design would have to be rethought and the site perhaps relocated.

The Auburn Dam review is an intriguing and significant case for several reasons, but particularly because it involved a federal agency voluntarily coming before a state body for hearings on a federal project. Under Commission monitoring and urging, a successful working relationship between federal and state agencies was achieved and maintained. Throughout the process the Commission retained its neutrality, using its influence to get the various other participants to complete their tasks on time, and to reach agreement on the adequacy of the background studies and the design criteria.

Auburn Dam put a lot of demands on all the participants, who had to deal with some very difficult technical questions involving a highly sensitive issue. It is an excellent example of a needs-driven effort using the best in research findings and expert opinion.

Local Seismic Safety Elements

The seismic safety element requirement was one of the early responses to the 1971 San Fernando earthquake, and an outgrowth of work of the Joint Committee on Seismic Safety (1970-74), which preceded the Seismic Safety Commission and recommended its creation.[2] The state's urban planning legislation was amended to require cities and counties to adopt seismic safety elements as part of their general plans. The purpose was to get local governments to consider seismic hazards in their planning processes and development decisions, and to incorporate appropriate information and policy statements into their plans.

Fortified by a reasonably well-drafted seismic safety element, a local government with access to competent technical advice is in an excellent position to use available geotechnical and other information, as well as expert opinion, in making decisions affecting the community's future earthquake safety.

Some local governments have made good use of the possibilities offered. For example, City of Palo Alto staff were able, after some passage of time, to use the element's findings and policies as effective leverage in getting a municipal hazardous buildings ordinance considered, and eventually adopted.[3] Moreover a recent article on the use of geology by decisionmakers singled out the Santa Clara County element and the county's use of geologic/seismic information as and excellent illustration of a strategy that other local governments could emulate.[4]

Committees of the Seismic Safety Commission have twice reviewed the effectiveness of the elements; another evaluation is found in a report based on NSF-funded research.[5] Differing views on the evaluations are held by George Mader, a planner who chaired the SSC committees, and Alan J. Wyner, a political scientist and senior author of the NSF-funded work. Mader has the more positive view, pointing to progress under the elements in getting local

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governments to give more attention to geologic and seismic matters than they would otherwise have done. Wyner argues with considerable justification that most local governments have not shown much initiative in achieving the full potentials of the elements. Mader seems to say, "the elements have helped us make appreciable progress," while Wyner appears to respond, "but we still have a long way to go." Perhaps both are right, the difference lying mostly in what they emphasize, as well as in their experience and disciplinary backgrounds.

In any event, early drafts of the local government supplement to the "SB 548" program (see below), make it clear that improved local use of geotechnical information, including upgrading of the elements and incorporation of stronger policy statements, will be encouraged by that Commission-administered program.

The "1279" Report and the "SB 548" Program

Two earthquake planning efforts--"1279" and "SB 548"[6]--are considered together because one clearly helped set the stage for the other, and because a look at both may tell us something about what can make a program "go."

Senate Bill 1279 passed in 1978. In a sense it was a response to the National Earthquake Hazards Reduction Act of 1977, which had embodied the concept of a five-year plan. The idea of doing something analogous to NEHRP at the state level seemed attractive to Karl Steinbrugge and Robert Olson, the Seismic Safety Commission's chairman and executive director. They took the idea to state Senator Alfred E. Alquist, who carried the legislation and got it passed fairly easily.

The initial plan for the Commission to rely on a major contractor to do most of the work fell through, whereupon the Commission staff took over, putting in a substantial amount of time and also involving many state agencies and private consultants through a large number of smaller contracts. The result was a stretched-out process that took much longer than had been expected.

The effort pulled together a plan and general strategy for the next few years. The "1279 report"--with recommendations on proposed activities, funding and responsibilities--was a useful wish list, and was rather widely distributed. It did not seem to have much impact, however, largely because it did not have a built-in long-term commitment and followup process. In effect the 1279 plan, published in 1982, became a one-shot document that many referred to but few acted upon.

The 1279 report did, however, help set the stage for the SB 548 effort. Moreover its shortcomings, viewed with hindsight, undoubtedly helped ensure that the SB 548 effort would be structured differently. In fact, one problem confronted by those who worked on the 548 bill was the need to convince themselves and others that a new effort would not simply repeat what had already been done in the 1279 report. Their principal rationale was that SB 548 should lay the basis for a <u>continuing</u> process directed toward clearly enunciated goals, to which the state government would commit itself. This rationale was written into the bill, which set the goal of achieving significant reduction of earthquake hazards by the year 2000, and called for a five-year plan of action, to be revised annually.

The original impetus behind SB 548 was pressure from the Federal Emergency Management Agency (FEMA). FEMA's urging, and the initiative of an important Republican state senator, got the Seismic Safety Commission, the Office of Emergency Services (OES) and others to thinking about a longer-term planning process. Required under NEHRP to plan and budget ahead on a five-year basis, FEMA asked California agencies to help by also planning ahead. They were somewhat reluctant at first, fearing that the effort would only represent time-consuming paperwork, and produce little of lasting value that had not already been done. Things soon began to change, however, when Republican Senator Bill Campbell, chairman of a committee on fire, police and disaster services, took the initiative in urging such a bill, and when in early 1984 he and Democratic Senator Alfred Alquist agreed to co-sponsor such legislation. This agreement between unlikely allies, as well as other favorable indications, suggested that a window of opportunity might be opening. A series of drafting and negotiation sessions produced the bill, which got 23 co-sponsors and passed the Senate 39-0 and the Assembly 59-0. Governor Dukemejian signed it in October 1985, two weeks after the Mexico City earthquake.

Work on implementing the new law began almost immediately, and the first version of the five-year plan was completed in September, 1986.[7] The first of the annual revisions is now in draft, as is a local government supplement to the plan, which will take the form of a local government guide to earthquake safety, with "how-to-do-it" recommendations on ways to evaluate local readiness and prepare local seismic safety action programs.

Key features of SB 548 are its firmly stated commitment to achieving hazard reduction, and its introduction of a continuing process to (1) plan programs, priorities, and responsibilities, (2) monitor and report progress, and (3) regularly revise plans in the light of experience.

The new process should enable California to move much more vigorously and over an extended period in developing comprehensive hazard-mitigation efforts aimed at high-priority seismic problems. The program is designed to advance earthquake safety in six major areas: (1) existing development, (2) emergency preparedness and response, (3) new development, (4) long-term recovery, (5) education and public information, and (6) research and its application.[8] California's example may provide a valuable model, whose elements could rather readily be adapted and used elsewhere, e.g., by other states and the federal government.

SCEPP and BAREPP

Formation of the Southern California Earthquake Preparedness Project (SCEPP) was stimulated by several events and activities. The Palmdale Bulge in Southern California, the overoptimistic anticipation of early breakthroughs in earthquake prediction that might affect southern California, and the Mount St. Helens volcanic eruption, had helped focus presidential attention on the west, and this highlighted southern California's seismic vulnerability. Moreover in implementing NEHRP, FEMA was looking for effective ways to stimulate local action, especially in southern California. In 1980 FEMA initiated an exploratory inquiry regarding the establishment of an earthquake preparedness project in southern California.

At first, FEMA had a problem finding local sponsors. OES did not respond to FEMA's invitation to submit a proposal, evidently because what FEMA wanted to do threatened too big a change from the traditional role of OES, which was oriented largely toward immediate emergency response (and to all kinds of disasters), rather than long-term advance planning (with special attention to earthquake preparedness).

Lacking a response from OES, feelers were sent to the Seismic Safety Commission, and an important Assembly committee staffer became active. The upshot was much negotiating in 1980, culminating in a brainstorming session that, after considering and discarding several alternatives, came up with the 5-county SCEPP formula for a policy board and staff operating under the umbrella of the Commission, and jointly funded by the federal and state governments. For some three years, the Commission was responsible for SCEPP. Except for one relatively brief crisis that was resolved by the discharge of the first executive director, SCEPP operated largely independently, run by its own staff and Policy Advisory Board. In 1984, at the end of the three years, SCEPP was transferred to the management of OES, under pressure from FEMA and OES. At the time the move caused quite a few pangs, especially on the part of many associated with SCEPP, and some Commission members.

Meanwhile, however, SCEPP had proven quite successful, and FEMA was considering ways to apply the experience elsewhere, particularly in northern California.[9] Working closely with the Commission, in 1983 FEMA funded a one-year earthquake preparedness study in the San Francisco Bay Area, which in turn led to the Commission taking a lead role in establishing a 10-county Bay Area Regional Earthquake Preparedness Project (BAREPP), with joint state-federal funding. Like SCEPP, BAREPP appears to have developed effective outreach, has contributed significantly to public earthquake awareness, and has furthered innovative local hazard-mitigation and preparedness programs. Also like SCEPP, after some three years BAREPP is now being transferred from the Commission to OES, although making the change at this time was opposed by the Policy Advisory Board and by some Commission members.

Regardless of the management arrangements, however, both SCEPP and BAREPP clearly have achieved effective outreach in their respective regions, encouraging and stimulating local public and private-sector action in hazard mitigation and earthquake preparedness. Under OES administration, SCEPP and BAREPP can also, with luck, contribute to a broadening of that agency's scope and outlook, helping overcome its previous tendencies to focus heavily on "where the shoe pinches now," i.e., responding to current emergencies. Finally, SCEPP and BAREPP are excellent examples whose successful experience can be drawn on by the federal government and other states and regions seeking to further seismic safety and hazard-mitigation.

Continuing Education and Earthquake-Resistant Construction

Continuing education programs offer great promise for conveying new information to and upgrading the standards and practices of key personnel in design, inspection and construction. Such programs were recommended by a committee of the Seismic Safety Commission when reporting its concerns that some potentially hazardous buildings are undoubtedly still being constructed in California.[10] As a followup, another committee is now considering a variety of pilot-project continuing education efforts, to be tried out with building department staff, inspectors, construction personnel, and designers (architects and engineers).

In fact, one initial experiment has recently been completed--a 16-week seminar on plan checking for seismic requirements, given for building department staff in the southern part of the San Francisco Bay Area. The seminar consisted of four hours of lecture and discussion each week, plus one field trip. It covered most of the kinds of structures and major types of seismic-design issues that plan checkers are likely to confront. An outstanding faculty of eight members agreed to give the lectures on a pro bono basis. Each did substantial advance preparation for the lectures, and they also had extensive handout material, plus illustrative slides and graphics. In addition to the faculty's pro bono contribution, the Commission committed a small amount of funding, and each participant paid a $75 registration fee.

Thirty-four plan checkers attended the sessions, which were co-sponsored by the Seismic Safety Commission, the California Building Codes Institute, and BAREPP. The Institute awarded continuing education credits on the basis of 1.0 unit per 10 hours of seminar attended. Most participants attended rather religiously.

The final session on June 5, 1987 was devoted mostly to a review and evaluation of the seminar by the participants, who also prepared written assessments. The seminar was judged an unqualified success, and it was strongly urged that similar seismic-design seminars be given elsewhere in the Bay Area and in other parts of the state. Many also urged similar continuing education offerings for others in design and construction (architects and engineers, inspectors and construction personnel), arguing that effective plan checking would be greatly facilitated if more designers were better informed about state-of-the-art seismic design.

Excerpts from two of the participants' written evaluations follow:

> The course was helpful in that it provided access to observed results of earthquakes. This showed us what details are successful and which are not. This information gives us the background behind the code requirements and makes application of the codes easier. Knowledge of future code requirements allows us to begin to apply the "current thinking" in our plan checking.
>
> The class was effective in several ways:
> 1. It related seismic failures to those code provisions which are or were inadequate.
> 2. It related seismic design to present and future code provisions, which was an excellent learning exercise.

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3. The class benefits extended beyond "just seismic" in that peripheral questions which have troubled engineers and plan checkers for years were raised and discussed.
4. It also afforded plan checkers of differing communities an opportunity to get to know each other and share their problems--some common and some not so common.

This experimental project suggests the promise of carefully prepared and well-presented continuing education programs as effective ways to improve knowledge and practice in design and construction, and to achieve wider application of research findings. Reliable financing would be needed, however, as this first pilot-project was largely a "labor of love" that consumed thousands of dollars worth of uncompensated time.

In any event, we should exploit to the fullest the promise of continuing education, and to that end should give it a high priority among the efforts promoted by a strengthened NEHRP. In searching for examples, models and precedents, the new program to create four regional centers for aquaculture research, development and demonstration deserves a careful look.[11] Building on the time-honored and highly successful model of agricultural extension, it suggests some good ways to achieve closer and more productive relationships between researchers and practitioners, and between education and application in the field.

The Commission's Role in Seismic Research

From the very outset the Commission has been interested in research on earthquakes and seismic hazards, and on society's responses to them. The Commission itself has conducted or commissioned policy research and administrative studies. While such direct research activities have not included work in the "hard" sciences, SSC has had a continuing concern with the directions and focus of geotechnical and other research related to seismic phenomena and their impact. Periodically, at the annual workshops and elsewhere, the Commission has heard reports on research activities, presented by representatives of FEMA, USGS, the National Science Foundation, the California Division of Mines and Geology, and others. It has also occasionally heard reports on social science research related to earthquakes, seismic safety and disaster preparedness.

Prompted by the recommendations of Commissioner Bruce Bolt and other Commissioners having scientific backgrounds, the Commission appointed a committee to consider possible commission roles in research. A 1983 report called for a systematic study of California research needs, and for a review of ways to see that the necessary research gets done. A new task committee chaired by Commissioner Wilfred Iwan recommended that the Commission establish research priorities, develop a five-year research plan for the state, encourage state funding of earthquake research, and promote the use of research results through dissemination, legislation, and other activities to facilitate technology transfer.[12]

In 1986 a standing committee chaired by Commissioner Lloyd Cluff was established to carry out these and other recommendations. This committee has scheduled three workshops in 1987, covering (1) geotechnical research (already held), (2) research on engineering aspects, and (3) social science research. The object is to survey what is going on in these fields, to consider possible Commission influence on future research directions and on research funding, and to develop closer and mutually beneficial working relationships between the Commission, the principal research agencies, and researchers.

Closing Comment

Preparation of this paper has helped reaffirm my belief that NEHRP needs to be strengthened in its relationship to policy bodies and active agents of change. The program could be more effective if it allocated additional resources to the support of promising strategies for improving seismic safety and applying existing or future knowledge. NEHRP should have a major component that actively promotes educational, extension and outreach programs in the interest of seismic safety. The Seismic Safety Commission and its twelve years of experience offer valuable perspectives that should be considered in future attempts to improve the effectiveness of NEHRP.

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Alquist Priolo Legislation on Active Fault Zones

by

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I am especially pleased to have the opportunity to assess the impacts of what has been called the "Alquist-Priolo" legislation on land use in California urban areas. My research interests over the past 12 years have been focussed in the problem of trying to assess the effectiveness of this and related legislation in communicating hazard or risk information to residents of California. This presentation offers me the opportunity to take stock of what this research has found, and the lessons it may teach.

For a social scientist interested in effective risk communication, my summary evaluation of this legislation is that it has not been effective in significantly changing land use. Although California is far ahead of any other state in implementing a number of measures to educate the general public about appropriate earthquake response, to bolster building codes, to create public-private partnerships to improve preparedness, and to begin to grapple with land use issues, it has been difficult to make significant headway. In this brief presentation, I would like to present the evaluation of a human geographer of legislation that is particularly geographic - that is, that would have affected landuse decisions. I want to show that this legislation has been diminished in effectiveness both because of the inertia within the political economy, and also because of an interaction with a changing population structure in the region.

The Legislation and Its Purpose

After the 1971 Sylmar (San Fernando) earthquake, the California State legislature passed what was popularly known as the Alquist-Priolo special studies zones act. As those in this audience well know, the "special studies zone" was a euphemism for an area containing a surface fault rupture that had been active in recent geologic history. The name itself was modified - originally the district had been termed a "geologic hazards zone", but the name was changed along with another modification in a 1975 amendment to the act which also required disclosure by the real estate agent to a prospective buyer that a property was located within the special studies zone. One can well conclude that this renaming was the result not only of a quest for "scientific accuracy" , but also the result of a compromise between the very powerful California real estate lobby and those who sought the disclosure provision. The name "special studies zone" or "Alquist-Priolo Zone" (an informal form of the same term) itself may represent at least part of the problems we will note in its communication.

The legislation involved a requirement that surface fault rupture zones be identified. As I mentioned, in 1975 this legislation was modified to require that real estate agents disclose the locations of these zones to prospective buyers. The purpose of the act was multifold: part of it was

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to set up a program of mapping surface traces of active faults, and another part was to halt the further construction of either large-scale public facilities or large-scale residential projects astride the identified fault traces.

Has the legislation succeeded?

The answer to this question is complex. There is little doubt that the legislation has succeeded in its narrow purpose: maps of the surface fault traces have been drawn, new structures for human habitation are not being built directly astride surface fault traces, and new large-scale housing development have been modified in layout.

The success of the legislation in fulfilling its broader purpose is less clear. The disclosure provisions presumably were intended to inform prospective buyers that the existing structure they were purchasing was within the special studies zone. One would presume the purpose of this provision - intended not only to reach developers of undeveloped land, but also individual purchasers of existing dwellings - was to inform them of the hazard of surface fault rupture that might affect their homes. It is this broader purpose that can be inferred from the 1975 amendment although is unstated in the legislation itself - of informing the general public about surface fault rupture zones - that has been less successful. In order to demonstrate this point, I would like to recount for you the response of a variety of actors in the housing market to this legislation.

The response of real estate developers

The legislation contains a clear directive to developers to respond to the generalized information about locations of surface fault traces uncovered in the geologic investigation required by the act. After all, the purpose of the legislation was to "prohibit the location of developments and structures for human occupancy across the trace of active faults." Cities and counties were to "require prior to the approval of a project a geologic report defining and delineating any hazards of surface fault rupture." The legislation was therefore aimed at developers of four or more units, and intended to prevent further construction of housing on active and known surface fault traces.

Developers have certainly not avoided the special studies zones, as is attested in the numerous geologic reports (that is, the trenching required by the legislation prior to construction within a zone) that have been filed since 1972. Although not each report represents an approved much less a completed development, the volume of reports is some indicator of the interest in development within the zones and gives some notion of the amount of construction activity that has taken place there. Development has not stopped, but remember that was not the purpose of the act.

The real question is whether or not layouts of the developments have been adjusted as a result of the geologic reports. According to surveys of county and state officials and of developers themselves, the answer to this question is mixed.

In order to assess the impacts of the legislation on housing development within the special studies zones, two rounds of interviews were conducted during the spring and summer of 1985. The first was a set of interviews with a small number (8) of key officials responsible for reviewing the reports filed in accordance with the Alquist-Priolo requirements that the State, county, or city levels of government. The purpose of these interviews was the assess the opinions of key individuals in the regulation process, to determine whether these individuals were aware of any influence the legislation has had on site selection for housing projects.

Survey results: officials

The state and county officials charged with reviewing the geologic reports were, in every case, experienced geologists. When asked whether the legislation had "affected building growth and development", most answered that development had not been prevented, but had been slightly modified. Developers rarely made major changes in their plans. One said that generally there had been an improvement in the quality of construction and that the legislation had "resulted in a more thorough investigation of potential building sites." He continued that there has been some "dreambusting" on smaller sites were redesign was not feasible, but on larger sites the developer simply moved buildings around or would align roads with the fault trace. Another official underlined the effect of the legislation to transfer localized risk from the private to the public sector:

> When planning a site to conform to a special studies zone study, developers will put streets or utilities on or near the fault, complying with the mandated setbacks for the houses, but in effect transferring the risk and potential damage from themselves or the homeowner to the city and the taxpayers at large.

The other major impact observed by the government officials is that the requirement of a report has sometimes resulted in a delay in the development, a delay that might be costly to the developer working on a tight schedule and with borrowed capital.

The major problem, from the point of view of city, county and state officials, is the quality of the reports submitted. One said they range from "terrible to excellent . . . most are mediocre to barely acceptable", and another said that "some reports were submitted four and five times until they got it right".

Although none were aware of actual litigation concerning this portion of the law, one official reported that there have been flagrant violations of the requirement. He reported attending a conference at a center directly on the San Andreas fault in which a hotel, many single family homes, and a 200-unit condominium had been constructed, but no report had been filed.

Despite problems, all of the officials agreed that the law has at least had the effect of providing direction and guidelines for local jurisdictions to evaluate the underlying geology and increased awareness of earthquake hazards to these jurisdictions. They felt the law was useful since there is no other way to prevent construction on active fault traces.

Survey results: Developers

The second part of the survey was with twenty of the major residential real estate developers who have developed large-scale single-family projects in the special studies zones since 1975. The purpose of this set of interviews was to get information from those directly impacted by the legislation as to whether they felt it had affected their location decisions or development strategies.

Interviews were conducted with developers with projects in Contra Costa County, Santa Clara County, San Bernardino County, Riverside County, and Orange County. Most had been involved in real estate development for a substantial period of time - none less than five years and one for 30 years.

The developers stated that they usually do not make significant modifications to their plans because of special studies zones requirements, although at times, on the recommendation of consulting engineers, specifications on projects within the zones may exceed the requirements of the building codes in these areas. Almost all felt that developers are not sufficiently discouraged by the special studies zones requirements to abandon their projects, and most claimed that they had never had problems in the filing of the special studies zones reports. Virtually all of the developers interviewed said they felt the legislation was necessary, and that it is important to control development in an active earthquake fault zone.

In short, the developers said that they do comply with the legislation in hiring a consulting geologist to do the required report. From the point of view of the urban administrators, problems come from the quality of these reports and the types of modifications that the developers adopt to comply with the legislation.

The Response of Real Estate Agents

We should remember that the legislation puts the onus on real estate agents to disclose the fact that property is within a special studies zone. How have they responded?

The answer is that they have responded much like the developers - conforming with the mandated disclosure legislation, but ensuring that the legislation does not damage their business. Surveys of real estate agents show that (1) not all real estate agents understand the meaning of the term 1"special studies zone"; (2) few have ever had a client refuse to purchase a home because of the disclosure; (3) most do not believe that the zones represent areas of particular susceptibility to injury or financial loss for residents, and (4) most believe the disclosure should be required by law - mostly because they feel it provides them with protection against any subsequent lawsuit.

The Response of Home Mortgage Lenders

Statistical analysis of home mortgage loan applications and interviews with lenders indicate that there is no relationship between location within a special studies zone and treatment of the loan application. Location in a zone in no way reduces either the probability that a loan will be granted or the value-to-loan ratio.

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location in the zone. Appraisers choose not to incorporate special studies zone location in their estimate of market price (the factor that affects lending decisions as well as the final sales price of the house), despite the fact that they can, if asked, put a notation on the appraisal that the property is located in a zone.

The Response of Residents to the Zones

None of the housing market professionals react to the zones: appraisals do not reflect zone location, loans are available, market value is not affected,and the disclosure by the real estate agent has generally minimized information - they know that the are "in a special studies zone" - whatever that is. They too take few, if any, precautionary measures in comparison with other California residents.

Is This Non-Response Significant?

In order to answer this question, we must remind ourselves about the nature of the population we think should be responding. They are certainly not all middle-class, native-born Americans with fairly long time-horizons for investment decisions. Who are the people who live in the special studies zones then?

The six-county Southern California Association of Governments region (including Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura counties) had a 1980 population of 11.8 million. It includes peoples of extremes in wealth and poverty, with a homeless population of at least 30,000 (Baer, 1986).

Migration to the region is taking place at a high rate. The region grew by almost a million people just between 1980 and 1984. Many of the new immigrants are undocumented aliens, others cannot speak or read English. The Southern California Association of Governments estimates that between 1980 and 2000 there will be 3.2 million more Hispanics in the region, and 1.4 fewer non-Hispanic whites. There will also be more than 700,000 Asians, many from Korea and southeast Asia.

The impoverished immigrants are not being housed in public housing or in new construction. Instead they are, at least in part, living in overcrowded conditions - sometimes in houses that do not meet California building codes. In order to house these people, much nonresidential space is being converted into residential units, and much of this is done illegally (Baer, 1986). Garages and areas above factories are housing unknown numbers of poor immigrant households. Obviously the residential building codes were never intended to cover such units since they were not intended for human habitation.

It should be obvious to us that thoughts of earthquake hazard mitigation are not foremost in the minds of those seeking shelter in converted garages or factories or in those who provide this shelter. Their thoughts are simply on survival - and their time-frames involve weeks, not twenty-year time frames within which earthquakes are discussed. Yet, this is part of the population that is increasingly susceptible to earthquake hazard in Southern California.

Summary

What I have tried to argue is that compliance with the Alquist-Priolo legislation has had an effect on developers, although layout modifications have been only minor. The disclosure legislation, as it affects resale housing, has had virtually no impact on the volume of houses sold or the value of these houses in the market. Furthermore, there is an increasing proportion of the Los Angeles planning area population living in illegally-converted housing, who are not benefiting from this legislation that was aimed at new construction regulation or the repair/retrofit of seismically unsafe buildings for human occupancy.

With perfect hindsight (or even some foresight), I think we must call on one another to take a more complex and realistic view of the problems of reducing the risk of deaths and destruction from earthquake hazards - building into our analysis a more sensitive portrayal of the actual population we are asking to carry out the legislation we design and the target population we think we are addressing. What we have seen in Southern California is the overwhelming influence of the political economy that will always work to mitigate the impacts of any legislation that interferes with its smooth function and that might hinder capitalists from making a profit. If we forget this context, we can only come up with naive and partial solutions to the problems of communicating hazard information or so changing land use to reduce hazard.

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Alquist Priolo Legislation on Active Fault Zones

by

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I am especially pleased to have the opportunity to assess the impacts of what has been called the "Alquist-Priolo" legislation on land use in California urban areas. My research interests over the past 12 years have been focussed in the problem of trying to assess the effectiveness of this and related legislation in communicating hazard or risk information to residents of California. This presentation offers me the opportunity to take stock of what this research has found, and the lessons it may teach.

For a social scientist interested in effective risk communication, my summary evaluation of this legislation is that it has not been effective in significantly changing land use. Although California is far ahead of any other state in implementing a number of measures to educate the general public about appropriate earthquake response, to bolster building codes, to create public-private partnerships to improve preparedness, and to begin to grapple with land use issues, it has been difficult to make significant headway. In this brief presentation, I would like to present the evaluation of a human geographer of legislation that is particularly geographic - that is, that would have affected landuse decisions. I want to show that this legislation has been diminished in effectiveness both because of the inertia within the political economy, and also because of an interaction with a changing population structure in the region.

The Legislation and Its Purpose

After the 1971 Sylmar (San Fernando) earthquake, the California State legislature passed what was popularly known as the Alquist-Priolo special studies zones act. As those in this audience well know, the "special studies zone" was a euphemism for an area containing a surface fault rupture that had been active in recent geologic history. The name itself was modified - originally the district had been termed a "geologic hazards zone", but the name was changed along with another modification in a 1975 amendment to the act which also required disclosure by the real estate agent to a prospective buyer that a property was located within the special studies zone. One can well conclude that this renaming was the result not only of a quest for "scientific accuracy" , but also the result of a compromise between the very powerful California real estate lobby and those who sought the disclosure provision. The name "special studies zone" or "Alquist-Priolo Zone" (an informal form of the same term) itself may represent at least part of the problems we will note in its communication.

The legislation involved a requirement that surface fault rupture zones be identified. As I mentioned, in 1975 this legislation was modified to require that real estate agents disclose the locations of these zones to prospective buyers. The purpose of the act was multifold: part of it was

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to set up a program of mapping surface traces of active faults, and another part was to halt the further construction of either large-scale public facilities or large-scale residential projects astride the identified fault traces.

Has the legislation succeeded?

The answer to this question is complex. There is little doubt that the legislation has succeeded in its narrow purpose: maps of the surface fault traces have been drawn, new structures for human habitation are not being built directly astride surface fault traces, and new large-scale housing development have been modified in layout.

The success of the legislation in fulfilling its broader purpose is less clear. The disclosure provisions presumably were intended to inform prospective buyers that the existing structure they were purchasing was within the special studies zone. One would presume the purpose of this provision - intended not only to reach developers of undeveloped land, but also individual purchasers of existing dwellings - was to inform them of the hazard of surface fault rupture that might affect their homes. It is this broader purpose that can be inferred from the 1975 amendment although is unstated in the legislation itself - of informing the general public about surface fault rupture zones - that has been less successful. In order to demonstrate this point, I would like to recount for you the response of a variety of actors in the housing market to this legislation.

The response of real estate developers

The legislation contains a clear directive to developers to respond to the generalized information about locations of surface fault traces uncovered in the geologic investigation required by the act. After all, the purpose of the legislation was to "prohibit the location of developments and structures for human occupancy across the trace of active faults." Cities and counties were to "require prior to the approval of a project a geologic report defining and delineating any hazards of surface fault rupture." The legislation was therefore aimed at developers of four or more units, and intended to prevent further construction of housing on active and known surface fault traces.

Developers have certainly not avoided the special studies zones, as is attested in the numerous geologic reports (that is, the trenching required by the legislation prior to construction within a zone) that have been filed since 1972. Although not each report represents an approved much less a completed development, the volume of reports is some indicator of the interest in development within the zones and gives some notion of the amount of construction activity that has taken place there. Development has not stopped, but remember that was not the purpose of the act.

The real question is whether or not layouts of the developments have been adjusted as a result of the geologic reports. According to surveys of county and state officials and of developers themselves, the answer to this question is mixed.

In order to assess the impacts of the legislation on housing development within the special studies zones, two rounds of interviews were conducted during the spring and summer of 1985. The first was a set of interviews with a small number (8) of key officials responsible for reviewing the reports filed in accordance with the Alquist-Priolo requirements that the State, county, or city levels of government. The purpose of these interviews was the assess the opinions of key individuals in the regulation process, to determine whether these individuals were aware of any influence the legislation has had on site selection for housing projects.

Survey results: officials

The state and county officials charged with reviewing the geologic reports were, in every case, experienced geologists. When asked whether the legislation had "affected building growth and development", most answered that development had not been prevented, but had been slightly modified. Developers rarely made major changes in their plans. One said that generally there had been an improvement in the quality of construction and that the legislation had "resulted in a more thorough investigation of potential building sites." He continued that there has been some "dreambusting" on smaller sites were redesign was not feasible, but on larger sites the developer simply moved buildings around or would align roads with the fault trace. Another official underlined the effect of the legislation to transfer localized risk from the private to the public sector:

> When planning a site to conform to a special studies zone study, developers will put streets or utilities on or near the fault, complying with the mandated setbacks for the houses, but in effect transferring the risk and potential damage from themselves or the homeowner to the city and the taxpayers at large.

The other major impact observed by the government officials is that the requirement of a report has sometimes resulted in a delay in the development, a delay that might be costly to the developer working on a tight schedule and with borrowed capital.

The major problem, from the point of view of city, county and state officials, is the quality of the reports submitted. One said they range from "terrible to excellent . . . most are mediocre to barely acceptable", and another said that "some reports were submitted four and five times until they got it right".

Although none were aware of actual litigation concerning this portion of the law, one official reported that there have been flagrant violations of the requirement. He reported attending a conference at a center directly on the San Andreas fault in which a hotel, many single family homes, and a 200-unit condominium had been constructed, but no report had been filed.

Despite problems, all of the officials agreed that the law has at least had the effect of providing direction and guidelines for local jurisdictions to evaluate the underlying geology and increased awareness of earthquake hazards to these jurisdictions. They felt the law was useful since there is no other way to prevent construction on active fault traces.

Survey results: Developers

The second part of the survey was with twenty of the major residential real estate developers who have developed large-scale single-family projects in the special studies zones since 1975. The purpose of this set of interviews was to get information from those directly impacted by the legislation as to whether they felt it had affected their location decisions or development strategies.

Interviews were conducted with developers with projects in Contra Costa County, Santa Clara County, San Bernardino County, Riverside County, and Orange County. Most had been involved in real estate development for a substantial period of time - none less than five years and one for 30 years.

The developers stated that they usually do not make significant modifications to their plans because of special studies zones requirements, although at times, on the recommendation of consulting engineers, specifications on projects within the zones may exceed the requirements of the building codes in these areas. Almost all felt that developers are not sufficiently discouraged by the special studies zones requirements to abandon their projects, and most claimed that they had never had problems in the filing of the special studies zones reports. Virtually all of the developers interviewed said they felt the legislation was necessary, and that it is important to control development in an active earthquake fault zone.

In short, the developers said that they do comply with the legislation in hiring a consulting geologist to do the required report. From the point of view of the urban administrators, problems come from the quality of these reports and the types of modifications that the developers adopt to comply with the legislation.

The Response of Real Estate Agents

We should remember that the legislation puts the onus on real estate agents to disclose the fact that property is within a special studies zone. How have they responded?

The answer is that they have responded much like the developers - conforming with the mandated disclosure legislation, but ensuring that the legislation does not damage their business. Surveys of real estate agents show that (1) not all real estate agents understand the meaning of the term l"special studies zone"; (2) few have ever had a client refuse to purchase a home because of the disclosure; (3) most do not believe that the zones represent areas of particular susceptibility to injury or financial loss for residents, and (4) most believe the disclosure should be required by law - mostly because they feel it provides them with protection against any subsequent lawsuit.

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The impoverished immigrants are not being housed in public housing or in new construction. Instead they are, at least in part, living in overcrowded conditions - sometimes in houses that do not meet California building codes. In order to house these people, much nonresidential space is being converted into residential units, and much of this is done illegally (Baer, 1986). Garages and areas above factories are housing unknown numbers of poor immigrant households. Obviously the residential building codes were never intended to cover such units since they were not intended for human habitation.

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SEISMIC SAFETY ELEMENTS IN CALIFORNIA: STATE MANDATE--LOCAL IMPLEMENTATION

BY

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INTRODUCTION

As a result of the 1971 San Fernando Earthquake, the State Planning Law was amended to require that each city and county in the State prepare and adopt a Seismic Safety Element (SSE) as part of its general plan. The requirement was brief, requiring

> A seismic safety element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.

The origins of this law lie in an institutution--the Joint Legislative Committee on Seismic Safety, one of the forerunners of the Seismic Safety Commission, a small group of people--George Mader and others, and a 1972 report--"The San Fernando Earthquake of February 9, 1971 and Public Policy." The Land Use Planning chapter made two significant recommendations:

> 1. The planning process at the local level should be significantly improved with respect to seismic safety.
>
> 2. The state should assume added responsibility in providing guidance and in some cases direct review and approval over land use decisions at the local level.

It also stated that "There is also a clear need for a continuing seismic safety role at the state level."

In 1973 the California Council on Intergovernmental Relations (CIR) adopted advisory guidelines for all required general plan elements, including the SSE. The guidelines emphasized the relationship of the seismic safety element to other elements of general plans:

> The seismic safety element contributes information on the comparative safety of using lands for various purposes, types of structures, and occupancies. It provides primary policy inputs to the land use, housing, open space, circulation and safety elements.

The law was later amended by listing certain types of example ground failures, by allowing cities to adopt portions of county seismic safety elements as their own, and by requiring cities and counties to submit copies of their seismic safety elements to the Division of Mines and Geology.

Major changes were made to the State Planning Law in 1984. One was to combine the required seismic safety and safety elements into a single Safety Element. A major aspect of the change was to indicate that the combined element must address"...the protection of the community from any unreasonable risk..." whereas the earlier version called only for the identification and appraisal of seismic hazards. These two changes, the combination of the seismic safety and safety elements and the requirement of policies for the protection of the community, were consistent with major recommendations adopted by the Seismic Safety Commission.

INTERGOVERNMENTAL MANAGEMENT: A TYPOLOGY

This requirement is a perfect example of one type of public policy: a mandate by the State and implementation at the local level. Such policies are often expressed by the ways programs are administered and by the types of decisions that are affected. There are programs that are locally developed and administered. Examples include the adoption of building codes, local siting and grading requirements, parapet ordinances, and programs to mitigate earthquake hazardous buildings. In such cases, the focus is solely on local governing bodies. Another group of programs are those that have been enacted by the State, but are administered primarily by local government. The requirement to recognize earthquake hazards through the Safety Elements of general land use plans is this example. Another is the Special Studies Zones Act where the decision to issue a building permit is a local one, but requirements are specified by the State.

Another category of policies are those that are both State developed and administered. The group includes the Field Act, Hospital Seismic Safety Act, and the professional registration and licensing programs. In certain other cases, there is almost no role for local and State government since jurisdiction primarily belongs to the national government. The siting, design, and construction of nuclear power plants is the most prominent example. Others include Federally owned dams, office

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buildings, military installations and other facilities.

POLICY PRINCIPLES

The basic principles underlying programs must be recognized. Most difficulties subsequent to the enactment of various public policies involve operational questions, such as the technical standards, the performance levels, processes and procedures to be followed, and other discretionary activities. A few examples of such principles will suffice. The Field Act (governing public school construction in California) recognized that school children were a special population deserving of additional safeguards, and that it was proper for the State to preempt local enforcement to help insure statewide uniformity. The Hospital Seismic Safety Act (which sets statewide standards for the construction of new hospitals and other medical facilities) was based on the principle that hospitals are critical community facilities having increased importance following disasters. It was held important, therefore, that they survive and remain as functional as possible. The Act reinforced the principle of State preemption of certain local responsibilities, and it also introduced into public policy the concept of damage control, which relates directly to keeping these facilities functioning.

The California requirement that local emergency organizations have maps showing the areas that might be inundated should dams fail under earthquake conditions is based on the concept that "fail safe" does not exist. It has to be assumed for planning purposes, that absolute safety is impossible, and this map information will facilitate effective emergency response. As noted, the amendment to the State Planning Act which requires cities and counties to address earthquake safety in their general plans is based on the belief that better decisions will be made if communities are aware of seismic and geologic hazards. The Special Studies Zones Act, which requires geologic reports for most structures planned for construction in major fault zones in California, also is based on a relatively simple principle: it is permissive to build in fault zones, but the builder and the local jurisdiction granting the permit must be aware of the hazard through a "special study" of the geologic conditions of the site as part of the building permit process. Often lost in the language of the law, these examples of "intent" are important to understand during the implementation, evaluation, and modification phases of the policy process.

TOWARD A POLICY ANALYSIS MODEL

Some research has been done to develop a model that helps illuminate the potential effects and political consequences of proposed policies. Testing of this model is needed, and if validated, it could be useful for both researchers and practitioners. The next step for those concerned with seismic safety is to begin to understand what might be called "earthquake politics."

The political nature of seismic safety policies can be determined by asking two major questions: (1) does a policy rely on rewards or on penalties to obtain compliance, and (2) does a policy primarily affect future behavior, or does it actually try to change the results of past behavior (is it retroactive)? Four combinations emerge: Type 1 policies are reward/prospective; Type 2 are reward/retroactive; Type 3 are penalty/prospective; and Type 4 are penalty/retroactive. Political conflict increases rapidly as one moves from Type 1 to Type 4. For example, it is well known that even relatively expensive disaster relief programs (Type 2, reward/retroactive) are politically more attractive and easier to propose, adopt, and implement than major building code changes (Type 3, penalty/prospective), or worse yet, than hazardous structure abatement programs (Type 4, penalty/retroactive). Type 4 programs are especially conflictive because they not only involve government coercion, but also effectively attempt to "change the rules of the game after the game has been played."

Seismic safety elements are closest to the Type 3 program--penalty/prospective. The relatively low level of political conflict can be explained by the fact that this information affects longer range decisions, which are expressed in higher conflict situations, such as zoning or permit decisions. The planning information is largely "technical" data base. However, the level of conflict may increase in the future because of the changes in the law requiring the addressing of the issue of protecting the community "from any unreasonable risk."

CONCLUSION

It is imperative that any policy assessment, including the application of research, define and be sensitive to the context in which the actual or proposed policies be enacted and implemented. The requirement that local governments consider earthquake safety in their plans is one example of a state mandated program that until now at least has been characterized by relatively low level of political conflict. Consequently, it is very difficult to trace the direct application of research through the policy process because what emerges as public policy is the product of many variables, and knowledge is only one ingredient.

SENATE BILL 547:
CALIFORNIA LEGISLATION AS A RESEARCH APPLICATION

by

L. Thomas Tobin
Executive Director
California Seismic Safety Commission
Sacramento, California
June 24, 1987

Introduction

There is an adage that persons who love the law and sausage should watch neither being made. Research results applied through the legislative process may be analogous to ingredients of a fine sausage. The sausage may be named for its main ingredient, but filler is always added.

Research results can dramatically change public policy: A new law can affect governmental and private spending, change government responsibility, impose regulatory requirements, or alter liability rules. The legislative process may be both the ultimate use of this knowledge, and the process in which the knowledge is the most ignored and distorted.

In the objective, measured process of scientific research, results are carefully written, properly qualified, published in journals, and reviewed by peers. Contrast this with the legislative process with its unique rules, last-minute deadlines, and competing interests and political philosophies. In this arena, policy is born from compromise. Research results - often over simplified or exaggerated - are but one element in this process, often not the most important. Researchers can play an important role in the legislative process, but their effectiveness requires learning new procedures, new techniques to communicate, and patience with what may seem to be an illogical process.

This paper will present a brief description of the enactment of Senate Bill 547(1) which was carried by Senator Alfred E. Alquist, passed by the California Legislature and signed into law by Governor George Deukmejian in October 1986. Although a complete case study and analysis of the politics of earthquake safety are beyond the scope of this paper, certain lessons can be drawn on how earthquake engineering and earth science knowledge affected the outcome.

Senate Bill 547, based on commonly understood structural engineering and earth science knowledge, requires all local governments in Seismic Zone 4 (Figure 1) to identify unreinforced masonry buildings built before the building code required seismic considerations in design, and to adopt a mitigation program that must as a minimum include notification of the owner by January 1, 1990. This program is of a scope and scale far beyond that ever attempted in California. It applies to nearly 50,000 buildings located in approximately 350 cities and counties. It applies to unreinforced masonry <u>bearing wall</u> buildings, and concrete or steel frame buildings with unreinforced masonry <u>infill walls</u>, partitions, or stair or elevator-well walls. Carrying out this program will require dozens of officials in hundreds of jurisdictions, thousands of civil and structural engineers and architects and building contractors, tens of thousands of building owners, and hundreds of thousands of tenants in these buildings to understand, to differing degrees, why these buildings are dangerous, and how they can be strengthened.

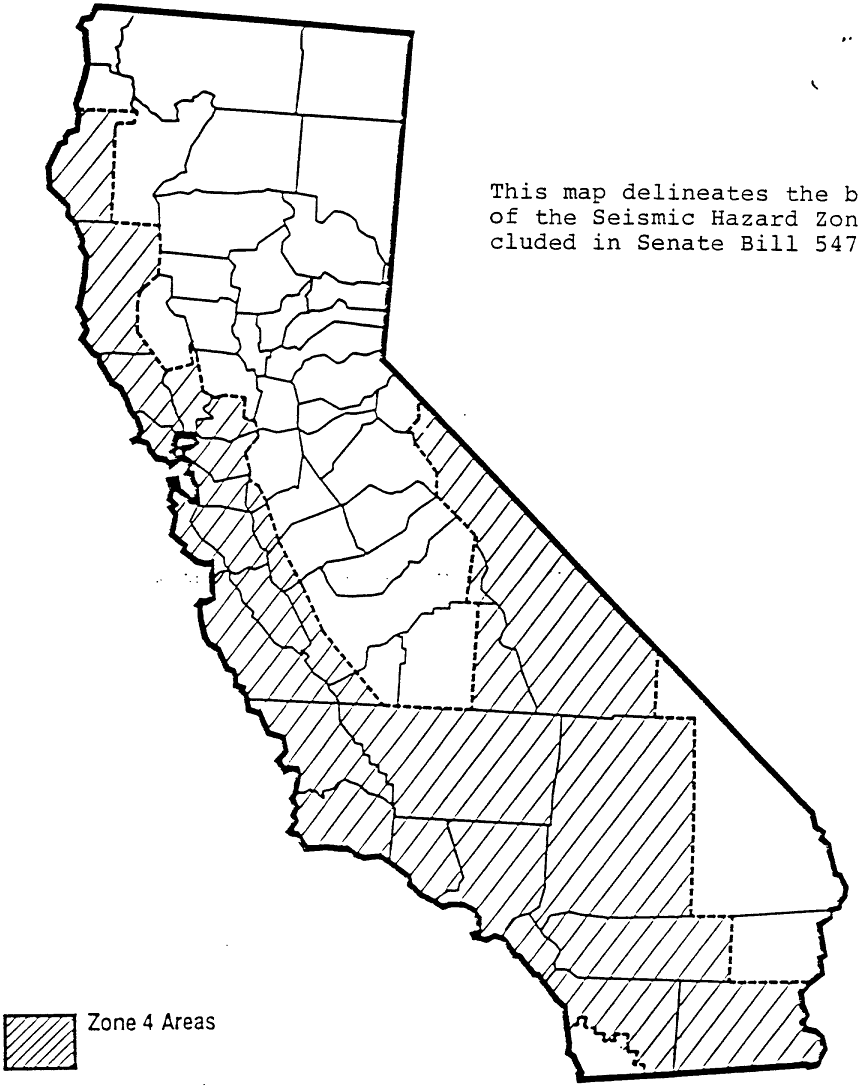
Brief History of Senate Bill 547

Although no new unreinforced masonry buildings had been constructed since 1949, it wasn't until 1979 that the Seismic Safety Commission and Senator Alquist began a push for legislation to address the hazard posed by the tens of thousands of existing unreinforced masonry buildings. That effort culminated in a law that called for a voluntary program to inventory and strengthen unreinforced masonry buildings. The Commission realized by 1983 that the voluntary program was not reducing the hazard rapidly enough, and the Coalinga earthquake demonstrated once again the poor performance of unreinforced masonry buildings. The demonstration was so dramatic that even a reporter, or a governor, could easily see the difference.

In 1983, the Commission and Senator Alquist introduced Senate Bill 1797 to require local governments to identify existing unreinforced masonry buildings and adopt an ordinance to reduce the hazard. Although it was passed by the Legislature, Governor Deukmejian vetoed the measure. The Governor's veto message argued that local governments already had the authority to do what was called for, so that a state mandate was not needed. In 1984, the Commission and Senator Alquist introduced the very similar Senate Bill 547. It was signed into law in 1986. Thus, even though California learned in the 1868 Hayward earthquake that unreinforced masonry buildings are hazardous in earthquake country, it was 118 years until a state law was passed to require mitigation programs to address this most obvious and clear hazard.

The Law-making Process

A law to be enacted in California must pass through both houses of eighty-member assembly. Both houses are currently controlled by the Democratic Party. Senate Bill 547 had to pass four committees.



This map delineates the boundaries of the Seismic Hazard Zones as included in Senate Bill 547

Figure 1. California Seismic Zone Map

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In the senate, its house of origin, it was heard by the Toxics and Public Safety Management Committee, a policy committee, and the Finance Committee, a fiscal committee. It then passed the senate floor on July 11, 1985 with a 28 to 1 vote. In the assembly, the bill was heard by the Government Organization Committee (policy) and the Ways and Means Committee (fiscal). It passed the assembly floor on April 14, 1986 with a 68 to 4 vote. Because of amendments, it was returned to the senate for concurrence. Upon concurrence the bill was enrolled and passed on to the Republican Governor.

The legislative process is a gauntlet with opportunities inviting failure. On the surface, it may seem shallow and irrational, but passage through each step allows 120 legislators, four committee staffs, the press, interested persons, lobbyists representing every conceivable interest, the Governor, and his staff, and administrative agencies an opportunity to review, question, and speak on the matter. Over a thousand persons will scan all bills looking for key words and topics of interest. Well over a hundred persons will read each bill and make a conscious decision regarding it. Any one of these persons can question the cost to the state and others, or the practicality, legality, or fairness of the proposal. These questions need not be logical, scientifically valid, or even fair; but they must be answered, for it is easy to kill a bill by causing doubt among legislators.

Seldom does anyone in the process have time to consider matters in detail. Those asked to testify are not those with a thorough understanding of the science involved. Witnesses are cut off, interrupted, often ignored, asked irrelevant questions, or asked to speak to a committee with many of the seats vacant. When a committee is unable to gather a quorum, those available sit as a "subcommittee," allowing absent members to vote without hearing the testimony, based on information and influences outside of the hearing.

Although this seemingly cavalier approach may anger and frustrate those who know the science and care deeply about issues, the legislative process is a stringent test to weed out bad bills and errors. It is meant to be conservative, to protect the status quo. To participate effectively in the process, or to apply research results through legislation, one must understand and respect the legislative process, and be willing and able to play the game according to the rules.

Principles of Making Hazard Mitigation Policy

The public policy process adroitly described by Alesch and Petak(2) also applies to the legislative process. They proposed several propositions that have been copied, changed and supplemented to the purposes of this paper:

- A reasonably large proportion of the legislature must know there is a problem - that the hazard exists, that the probabilities of loss are more than trivial, and that something can be done about it that will be politically acceptable.

It is common knowledge among California legislators that earthquake hazards exist, and that certain buildings are more prone to collapse than others. According to the California poll, 89 percent of all Californians are aware of earthquake hazards. All members of the legislature also receive publications by BAREPP and SCEPP and Seismic Safety Commission reports.

- The legislation must include a technical solution viewed as practical and efficacious by nontechnical policy makers.

The solution required by Senate Bill 547 is straightforward, and its practicality has been demonstrated by a few California cities, especially Los Angeles, Long Beach, Santa Rosa and Santa Ana. Publicity on these programs and testimonial accounts of their progress were provided to legislators.

- Persistent and tenacious inside policy advocates who have access to and credibility with legislators improve the probability of passage.

In California, the Seismic Safety Commission has access to legislators and committee staff. The credibility of the bill's author among his peers is that of a legislator who carries good bills and knows earthquake safety. The credibility of the bill's sponsor, the Seismic Safety Commission, may also have contributed. The Commission was tenacious in pursuing mandatory legislation a second time. In addition, the Governor's Office of Emergency Services' concern about earthquake damage helps create a receptive climate for earthquake policy in the administration.

- Windows of opportunity can be pried open with enormous, continuing effort, but they open automatically in the event of a damaging earthquake or a credible forecast that demands legislative attention because of geographic proximity or other reasons.

- Most hazard earthquake reduction laws are enacted in the period immediately following an earthquake.

A window of opportunity is always open to a certain extent because legislators are aware of the risk of damaging earthquakes and want to do something about it. During the time when Senate Bill 547 was being considered, the memory of the May 2, 1983 Coalinga earthquake was still fresh in the minds of legislators. The Mexico City earthquakes of September 19 and 21, 1985 occurred after the bill had been passed by the Senate, but before it went to the Assembly.

Figure 2 illustrates the timing relationship between California laws and earthquakes.

- Hazard mitigation is not a technical exercise; it is inherently and often intensely political because mitigation usually involves placing cost burdens on some stakeholders, and may involve a redistribution of resources. Legislation must develop political as well as technical solutions.

Senate Bill 547 first places additional political and financial burdens on local governments by mandating an inventory and adoption of a mitigation program. The political solution was to allow local governments flexibility in adopting mitigation programs rather than imposing a statewide minimum standard.

- Because values and perceptions are so different among stakeholders, it is difficult, if not impossible, to reach consensus about appropriate mitigation policy interventions. Political agreement on a mitigation policy requires that tradeoffs be made among the extent of hazard reduction, the total costs of mitigation, who pays various costs of mitigation, the level of safety achieved, adverse economic impacts, the level of residual hazard, and political possibilities of passage.

Senate Bill 547 deferred these hard choices to local governments by allowing flexibility for locally tailored mitigation programs.

- Hazard mitigation legislation can be enacted even when policy makers have 1) no explicit rationale for government action to mitigate the risk, 2) no information concerning whether the benefits deriving from the mitigation will exceed the costs, and 3) no information about whether the proposed mitigation is more or less cost-effective than alternative interventions.

Although this proposition may be true, don't bet on it. The Seismic Safety Commission is committed to having explicit, rational information on benefits and costs of a proposal, and considers alternatives. Besides, in California the rationale for Senate Bill 547 was developed by the Commission's Hazardous Buildings Committee over several years. The Hazardous Buildings Report(3) provided the approach to identifying and mitigating hazards in 1979. The Governor's Office and legislative committees demand information justifying state intervention, explaining the costs and benefits, and outlining alternative approaches to the problem.

- Legislators tend to look at relatively simple data about financial costs and the allocation of cost burdens, rather than at more sophisticated and complex analyses concerning economic impacts, optimality, net present value, and cost-effectiveness.

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DATE	LOCATION	MAGNITUDE	LIVES LOST
1836	Hayward	6.8 est.	Unknown
1838	Woodside	7.0 est.	Unknown
1857	Fort Tejon	7.9 est.	Unknown
1868	Hayward	6.8 est.	30
1872	Owens Valley	7.8 est.	27
1906	San Francisco	8.25 est.	2500+
1925	Santa Barbara • First Uniform Building Code adopted by ICBO (1927)	6.3 est.	12-14
1933	Long Beach • Seismic code made mandatory by the Riley Act (1933) • New schools required to meet state imposed and enforced standards	6.3 est.	86-102
1940	Imperial Valley	7.1	9
1952	Kern County	7.7	2
1954	Eureka • Joint Legislative Committee on Seismic Safety created in 1969 after concerns raised by the 1964 Anchorage earthquake	6.6	1
1971	San Fernando • Special Studies Zones Act • Hospital Seismic Safety Act • Strong Motion Instrumentation Act • Evaluation of earthquake vulnerable dams accelerated • Law passed requiring preparation of inundation maps and downstream evacuation plans • Program to retrofit highway bridges began	6.6	58
1979	Imperial Valley	6.6	1
1980	Eureka (off shore)	7.0	0
1980	Mammoth Lakes	6.1	0
1980	Mammoth Lakes	6.2	0
1980	Mammoth Lakes (two events)	6.0	0
1983	Coalinga	6.7	1
1984	Morgan Hill • Enactment of Earthquake Hazards Reduction Act (1985) • State standards for essential services facilities (1985) • Enactment of legislation requiring an inventory of unreinforced masonry buildings (1986)	6.2	0

Figure 2. California Earthquakes and Earthquake Programs

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Relatively simple but convincing economic data were used to support Senate Bill 547. Gross estimates of the number of buildings, extrapolations of costs based on the Los Angeles experience, and the fact that the state was not assuming a new financial burden satisfied legislative inquiries. A sophisticated financial analysis was not appropriate since the policy decision ultimately must include social considerations of safe and affordable housing, historic values, and historic and community values as well.

- The probability that legislation policies will be enacted is directly proportional to: 1) the extent to which the science is understood and accepted, 2) the ability of advocates to describe the research results and the consequences of implementation, including the level of costs, who will bear the costs, and what the legislation will accomplish, 3) the number of other similar measures, and 4) the perceived imminence of the hazard.

The Legislative Strategy

In addition to understanding the principles of the process for making public policy, success in enacting legislation depends on the strategy for moving the bill.

The proponent of the measure, whether the author or a sponsor - an individual, organization, or an agency - must be willing and able to draft the measure, consult experts, evaluate the issues, write letters, meet interested parties, advise the author, organize witnesses, and negotiate differences.

The proponents must understand that the issue, according to the scientist and earthquake safety specialist, is not always the issue to the legislator: "The issue ain't the issue." For example, in a recent hearing on whether $120,000 should be appropriated for a study to locate unreinforced masonry buildings and determine the impact of strengthening these buildings on owners and tenants before members of a major city's council, after listening to testimony from seismologists, engineers, and architects regarding earthquake hazards, one council member responded with a "no" vote, explaining that she was more interested in finding money to stimulate jobs, mitigate wildfire hazards, and build jails. The issue of unsafe buildings was not her issue; finding money for her constituents' current concerns was.

The proponents must be willing to settle for less. When differences develop, reasonable compromise is almost a prerequisite. It often is far better to take one step, and to gather support for that step, than to hold out and either lose the bill or lose support of those needed to carry out the new law. A corollary to this rule is, "Get what you can get when you can get it."

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Legislation represents potential change in the way things are done and can increase or decrease the power of special interests. The process can be a test of wills and influence. Anger, intimidation, condemnation, intellectual challenge are all legitimate techniques to test the knowledge, commitment, and power of witnesses. Thin skin has no place in the capitol.

Talking to politicians requires certain techniques. One must communicate with "bumper sticker" messages, briefly and graphically. Proponents must be prepared to meet with legislators and their staffs at times convenient to no one. Committee staffs are spread thin, having to respond quickly to a number of bills on a variety of issues. It is difficult for any staff to develop and maintain detailed knowledge of earthquake hazard reduction programs. Thus, legislators and their staff are usually generalists skilled in policy analysis. Communicating the concepts behind Senate Bill 547 required simplification, especially in oral presentations before committees. For example, the research results that underlie Senate Bill 547 were greatly simplified: Dangerous faults are everywhere. More damaging earthquakes will occur. Old brick buildings fall down in earthquakes and kill people. Engineers know how to identify these buildings. It is a statewide problem, since 60,000 of these buildings are still in use. These buildings can be fixed. The state must act since too few local governments have.

Legislators consider over four thousand bills each session. Committees sometimes must hear dozens of bills covering a variety of topics in an afternoon. In some instances, a member may be expected to attend two or more committee hearings simultaneously. Committee staff persons likewise must prepare an analysis on each bill, respond to actual and proposed amendments, entertain visits from interested persons, and meet incredibly tight deadlines. As a result, each of these individuals must trust others for advice, and be willing to accept another person's judgment.

Controversy can stimulate interest in an issue, but it can also reduce support. Disagreement triggers caution. Legislators motivated by wanting to do the right thing, to avoid harming the interests of their supporters, to solve rather than create problems react to controversy with conservatism and caution. It is far better to be sure of why you cast a controversial vote than to face it on the campaign trail a few months later.

Passage of Senate Bill 547 required persistence. The first bill on unreinforced masonry buildings, Senate Bill 445, passed in 1979, urged local governments to voluntarily identify buildings and require strengthening. After it was realized that the voluntary approach was not working, Senate Bill 1797 was introduced by Senator Alquist. It was vetoed in 1984. Introducing a bill that is nearly identical to a bill vetoed earlier required special consideration. Members of the Governor's party are not inclined to take the chance of embarrassing the Governor by sending him a bill

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that has popular support for another veto. Even members of the opposition party are reluctant to do much for a measure that is destined for veto.

Tough legislative issues need coverage in the press. Editorial support lends credibility and, as a minimum, will cause all involved in the process to at least consider the matter. It also gives the perception that something needs to be done, and a sensible solution is possible. Some believe government leaders communicate more effectively through the press than the traditional bureaucratic means of memoranda, staff meetings, policy statements, and speeches. Press support is not difficult to get when an issue is important.

Senate Bill 547: A Product of Compromise

The final version of the law is much the same as to what the Commission pressed for, but there are significant differences. A number of compromises were made to secure passage.

In California, there is a long tradition of strong local control and local government independence on most matters, especially of building regulation. Although the state has mandated a minimum building code for over fifty years, programs to reduce existing hazards retroactively were virtually nonexistent. The law provides much more flexibility for the jurisdictions regarding the mitigation program compared to the Commission's original desire to require mitigating ordinances. The law is to be carried out by each of the governing bodies of the 485 local jurisdictions in the state rather than as envisioned under state-level control with direction from the Office of the State Architect. That agency, however, was deleted from the bill after it took a position to oppose the bill unless it was amended to appropriate additional funds. The Commission took on the State Architect's responsibility.

Local government representatives, especially the League of California Cities, were concerned with liability exposure that might be created by adopting a retrofit ordinance for existing buildings with standards less than those in the present code. Thus, language was incorporated providing immunity to local jurisdictions when adopting a retrofit ordinance based on life safety standards.

Because the law mandates action by local governments, and the California constitution requires the state to pay the cost of state mandates imposed on local governments, Senate Bill 547 was originally written to appropriate $5,000,000 for reimbursing local governments. The Governor's Office questioned paying local governments for activities that they should already be doing and the equity of providing an incentive, or a reward, to local governments that had done nothing regarding unreinforced masonry buildings while the other jurisdictions that had faced the issue already had borne the full cost. The reimbursement process, known as the SB 90 claims process, was also an issue; state officials believe local governments abuse this process by asking for too much, while local government officials claim the state pays only a portion of legitimate claims. Furthermore, the Department of Finance argued that $5,000,000 was too much money for this effort given a tight state budget and other priorities.

In response, the bill was amended by the Assembly Ways and Means Committee to reduce the appropriation to cover just the first year's claims, with adjustments to be made through the annual budget process. The effective period for claims reimbursement was limited to costs incurred after the law became effective and before the inventory deadline of January 1, 1990. The amount to be claimed was limited to $100 per building. These compromises did not result in support from the Governor's Office, or from several members of the Assembly.

Another amendment suggested by the Department of Finance at the Assembly Ways and Means Committee hearing was intended to avoid the issue by including language that allowed local governments to cover their cost by charging a fee. The author accepted the amendment when it became clear that a majority of the members would not appropriate state general funds to pay for a mandatory program. Up until that moment the League of California Cities and the California Association of Building Officials supported the measure; from then on they opposed it, because they believed it impractical to charge a fee for an inventory and resisted local governments' undertaking a state mandate without state compensation. The amendment was a significant weakening of the bill because the money was the most important incentive for local governments complying in a timely manner.

The bill was amended to apply only to Seismic Zone 4, rather than the entire state. In limiting the application of mandatory requirements to Zone 4, the state could limit its expenditures and spend its limited funds in the areas of greatest risk. When the state funds were deleted, however, the bill was not amended to return to statewide application.

The bill was amended before the Assembly Governmental Organization Committee after a structural engineer testified that it should include unreinforced masonry walls that were nonbearing. The committee approved the amendment and struck the word "bearing" from the definition of potentially hazardous buildings. This amendment extends the bill to thousands of - concrete and steel-frame buildings with unreinforced infill walls, stair wells and elevator shafts. An amendment excluding "historic buildings" was accepted upon the urging of the City of Monterey with the backing of the League of California Cities. Although the purpose of the amendment was to exempt early California adobe buildings, the definition is so broad to potentially be a serious weakness of the law.

It is clear that none of the amendments, nor any of the discussions surrounding the amendments, relied on recent research results.

The Research Behind Senate Bill 547

Senate Bill 547 relies on commonly accepted knowledge derived from a variety of research activities over a variety of time periods. There is no direct or simple linkage between the legislation and any particular research efforts. The development of this knowledge seemingly had no beginning or end. "Researchers" who observed the damage from the 1868 earthquake in Hayward concluded that unreinforced masonry buildings failed in disproportionate numbers, and were hazardous in earthquakes. Again in 1925 and 1933, researchers and the legislature observed that unreinforced masonry buildings suffered a disportionate share of the damage in the Santa Barbara and Long Beach earthquakes. In 1933, the Legislature responded by adopting the Field Act, imposing new standards for public schools, and the Riley Act, mandating a statewide building code. It was 65 years after the Hayward earthquake until California mandated a minimum building code that stopped the use of unreinforced masonry, and it was years more before it was enforced in some jurisdictions. Applying new building safety knowledge to existing buildings is clearly a slow process lagging far behind the application to the construction of new buildings.

Some might argue that the research results have yet to be used since efforts to inventory these buildings, and more importantly efforts to strengthen them have only just begun. Carrying out these efforts will draw on the latest structural engineering research, and knowledge of ground motion. It would be wrong to conclude that identifying and strengthening dangerous buildings is simply a scientific or engineering exercise. Social and political implications are of equal importance.

Carrying out Senate Bill 547 will raise a number of important and controversial issues. Hundreds of city councils and county boards of supervisors must grapple with the policy questions of where to get the money to do the work, how affected property owners will react to having their buildings on a list of potentially hazardous buildings, and what the minimum standards should be to provide an acceptable level of safety while minimizing the cost to owners, the effect on residents and tenant businesses, and protecting the community's architectural and historic fabric. Lawsuits can be anticipated. The political reaction to this new effort has not yet occurred, but the effort is not complete - it may never be complete.

Key Players

Although those who carry out Senate Bill 547 will include city and county officials, bankers, engineers, architects, insurance agents, city planners, housing specialists, and others, the key players in passing the bill included the following:

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- Senator Alfred E. Alquist. A legislator who over twenty years has developed knowledge and leadership in earthquake safety and the legislative stature to successfully significant legislation.

- Legislative staff. Knowledgeable staff members are critically important. Few legislators have time to meet with interested parties or to study issues. Staff members provide the time and expertise needed to make the legislative process work.

- The Seismic Safety Commission. An independent state agency responsible for developing and promoting earthquake safety policy and advising the legislature and the governor, the Commission has developed credibility and a track record as the sponsor of over 35 earthquake safety laws since its inception in 1975. The Commission's Hazardous Buildings Committee wrote the reports that led to the decision to seek legislation. The Commission was the persistent sponsor of Senate Bill 547 and its predecessors.

- One hundred and sixteen legislators, out of a total of 120 in the state senate and assembly who voted for the bill.

- Governor George Deukmejian. The Governor considers public safety one of the highest priorities of his administration and has signed more earthquake safety legislation than any other governor. He personally observed the damage to unreinforced masonry buildings at Coalinga in 1983, and is familiar with efforts in his home town and former senate district, Long Beach, to identify and strengthen hazardous buildings. He was willing to compromise between his philosophical beliefs that local governments should bear the responsibility for building safety in California and the state should not interfere and that local governments already had the authority to carry out the necessary programs, and the fact that unreinforced masonry buildings constitute a significant hazard to the public that is not being addressed at a fast enough pace by local governments.

- The Governor's staff. The Governor's signature on Senate Bill 547 represented a willingness to sign a measure largely similar to a bill he vetoed two years earlier. His change of mind was influenced by his legislative staff and the Director of the Office of Emergency Services.

- Mexico City. The earthquake that struck Mexico City on September 19, 1985 provided ample and graphic evidence of the unquestionable threat of unsafe buildings. The death of each of the ten thousand who perished in that earthquake played a key role in the political consciences of those asked to decide on Senate Bill 547 over the year that followed the earthquake.

- The media. The Los Angeles Times and other influential papers had editorialized in support of the measure. A reporter for the Times asked the governor whether he would sign Senate Bill 547 as the governor viewed the 1986 southern California emergency response exercise. The question provided impetus for the governor to discuss the matter in more depth with his aide later that day. Favorable press will often tilt the scales when decision makers decide between conflicting concerns. Media coverage of Mexico City, although criticized by many as overly sensational, unquestionably gave a boost to efforts to reduce earthquake hazards in California.

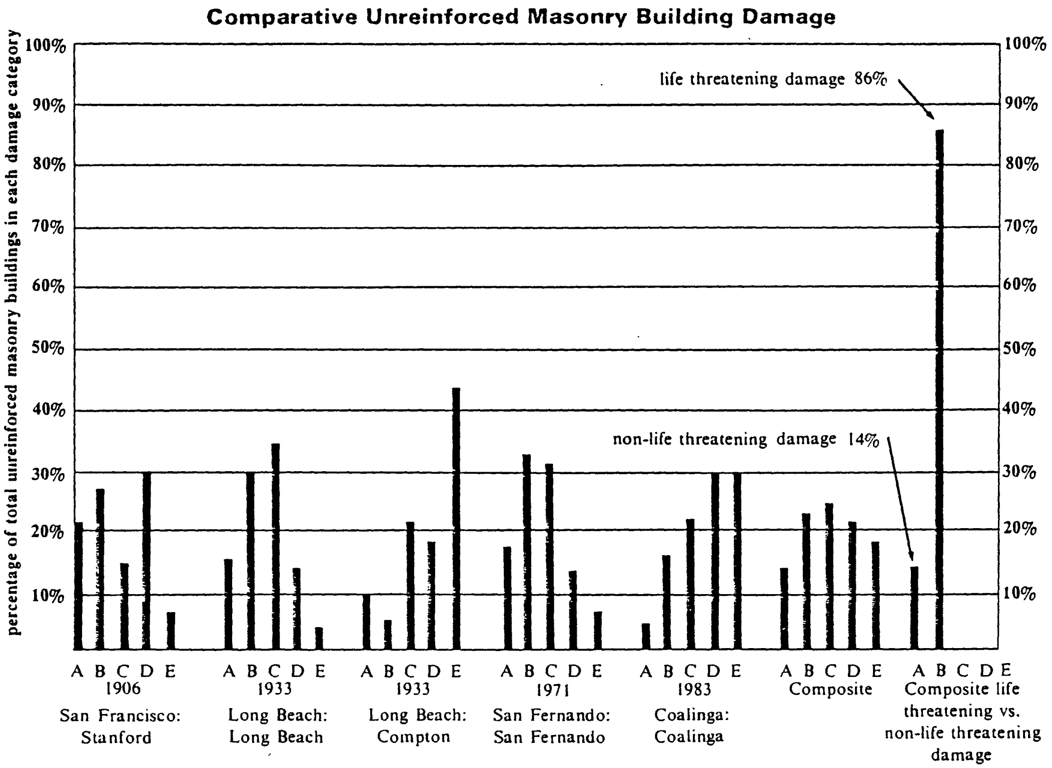
- The Cities of Los Angeles and Long Beach. These cities initiated efforts to identify and strengthen unreinforced masonry buildings. Both programs have been regarded as well run and gave credence that a similar statewide program would work. The existence of these programs gave credibility to the practicality of Senate Bill 547.

Contributing Research

Research results from a number of fields have been important to the passage of Senate Bill 547. Although our knowledge of how unreinforced masonry behaves in earthquakes is foremost, research results on California seismology, propagation of ground shaking, law, sociology, and other topics have been considered. Earthquake safety involves many policy issues and topics, and should not be viewed as relying on research from a single intellectual field.

Structural engineering studies of failures in past earthquakes coalesced observations into useable information and led to a consensus by the profession that unreinforced masonry buildings are hazardous. Although knowledge about rehabilitating these buildings is still in an embryonic stage, evidence that helped in the political arena simply stated that 86 percent of unreinforced masonry buildings in strong earthquakes suffer life-threatening failures(4) (Figure 3) and that a person in a well built single-story wood frame house is 2000 times safer than a person in an unreinforced masonry building(5). Clearly, structural engineering concepts were greatly simplified, doubt and complications were swept aside, and exaggeration was tolerated to construct a politically meaningful message.

Evidence that there is a threat to life resulted from vunerability studies. The 1980 USGS publication 81-113(6) updating earlier



Damage Categories:

A—Undamaged or small cracks

B—Parapets fell; veneer separated from backing

C—Major damage to less than 50% of bearing wall

D—Major damage, more than 50% of bearing wall

E—Total loss; damage requiring demolition

Source: Robert Reitherman, principal investigator, "Case Studies of the Earthquake Performance of Unreinforced Masonry Buildings," Scientific Service, Inc., Redwood City, California, a National Science Foundation sponsored research project.

Figure 3. Comparative Unreinforced Masonry Building Damage

studies of possible losses from great earthquakes in the San Francisco Bay Area and in southern California were amply quoted, and their error ranges were conveniently forgotten in efforts to stress that dangerous buildings pose statewide threats that have implications deserving state-level attention.

Reports on progress in the pioneering hazardous building programs carried out by Los Angeles and Long Beach in particular and in Santa Rosa, Palo Alto, and Santa Ana as well were often quoted to demonstrate that the program outlined in Senate Bill 547 was practical, that efforts to require strengthening would not wipe out the historic and architectural fabric of our older cities, and that owners could afford to strengthen their buildings.

Research efforts that identified active faults throughout California and attempted to quantify recurrence intervals or probability of occurrence were used to demonstrate the statewide nature and reality of the problem. Although geologists and seismologists publish detailed opinions on each of these faults, in the political arena a line on the map indicating a fault is perceived as a real danger. Nuances like recency of rupture, recurrence, capability, or volcanoes are not of major interest until the spotlight of public policy aims at a particular city or a project.

Research on continental drift has done as much as any other area of research in the political arena. In less than twenty years, "drifters" have painted an understandable model involving measurable movements expressed in visual images of fault zones, continental shapes, and volcanoes. The "ring of fire" that has caught the imagination of virtually every decisionmaker and made "low probability events" more real, ongoing, and visible. One may not understand the science or statistics, but can still visualize the destructive power unleashed as North America grinds by the Pacific Plate.

Each of these research areas contributed to the passage of the bill, and some will be applied to a greater extent as Senate Bill 547 is carried out. The research that contributed to passage of the bill was driven by researchers' quest for understanding. Senate Bill 547 is a resulted from that research, rather than responding to a need and then stimulating research.

Facilitating Activities

A number of facilitating activities come to play in considering the passage of legislation as a means to apply research. In California, one of the most important activities was the professional association of persons interested in earthquakes whose interest was grounded in a number of disciplines and areas of application. In time, those with knowledge joined with those who make public policy. Although beyond the scope of this paper, the formation of the Structural Engineers Association of California, the Earthquake Engineering Research Institute, California Emergency Managers Association and other organizations led the way.

Earthquakes are facilitators. Since 1960, earthquakes in California have been frequent enough to maintain interest and promote widespread awareness, even if they have not been frequent and damaging enough to cause all of its citizens and government agencies to spring into action. Specific facilitating events were not individually important to passage of Senate Bill 547, but cumulatively the programs carried out by professional organizations and government agencies and stories in the media have all helped create a climate where earthquake safety is regarded seriously. New opportunities will be present after the next damaging earthquake; proponents must be ready with their legislation when this occurs.

Improving the Process

Researchers can improve the application of research through the legislative process in a number of ways. They must be willing to become familiar with public policy issues and information needs. They must be willing to interpret their results in ways that can apply to public policy issues, and to publish in magazines read by public policymakers. Interpretive work and research compilations make the information more useable. Although researchers are often most uncomfortable in the legislative setting because of the seeming illogic of the public process, the high probability of wasted time, the type of questions, the exposure to misinterpretation by the press, and the inadequate time available to cover the topic, it should be recognized that lawmakers appreciate hearing directly from leading scientists, and the credibility of an issue is improved when a witness motivated by interest in public wellbeing is present to provide facts and professional judgment rather than appearing to seek a handout, new mandate, more power, more staff, or more money for his agency or program.

Success Story or Not?

Work to carry out the application of research results through enactment of Senate Bill 547 has just begun. It remains to motivate hundreds of jurisdictions, run by over three thousand elected officials with good intentions, to move from awareness of the hazard caused by unreinforced masonry buildings to funding inventory programs and enacting ordinances to force renovation of these dangerous buildings. The message from the state to local governments contained in Senate Bill 547 is not a mandate. The legislation does not include funds to help local governments cover the cost of inventories, and it does not include sanctions if a jurisdiction does not comply. A major effort will be needed for the next several years to carry this through.

Senate Bill 547 creates new and potentially controversial programs.

Dangerous buildings provide housing to persons of low income, they include historically and architecturally important structures for dozens of communities, they provide attractive structures for businesses, and they provide low-cost space for marginal businesses. Strengthening programs will cost money, add to social problems, and cause political repercussions and litigation. Without question, legislators will be asked to amend the measure, to extend the time deadlines, to narrow its scope, to broaden the exceptions. Some changes will also be suggested that will improve the measure. In short, it will continue to be in the legislative spotlight. In the meantime, those of us who understand the reality of earthquake hazards must do all that can be done to make it work. Reseachers are encouraged to continue their work, to participate in local government efforts. Research must be continued on identifying faults in urban areas, on determining recurrence intervals, on understanding building performance, on strengthening techniques, on public finance, on insurance and liability. Passage of Senate Bill 547 is a challenge to the research community to fill a new and insatiable need for knowledge.

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APPLICATIONS: SEISMIC SAFETY ORGANIZATIONS

South Carolina Seismic Safety Consortium

by

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Description of research application

The South Carolina Seismic Safety Consortium was formed in February 1982 with a simple, direct purpose: establish and implement a seismic safety policy, coupled with a five-year action plan for earthquake preparedness and mitigation with emphasis on the three-county metropolitan Charleston area.

The impetus for beginning the SCSSC came from the Knoxville Earthquake Workshop, co-sponsored by the U. S. Geological Survey and the Federal Emergency Management Agency, in September 1981. That conference, called "A Workshop on 'Preparing for and Responding to a Damaging Earthquake in the Eastern United States'", was the first of its kind ever convened in the eastern United States. The proceedings were published as USGS Open-File Report 82-220.

Lt. Col. Charles Lindbergh, Ph.D., P. E. and Head, Department of Civil Engineering, The Citadel, and Professor Joyce B. Bagwell, Department of Chemistry and Geology, Baptist College at Charleston, agreed to co-chair a new seismic safety consortium for South Carolina as a result of their attending the Knoxville workshop. The scale of the project was envisioned to begin with addressing the needs for a seismic safety policy in South Carolina, and then have the SCSSC be a pilot for a Southeastern Seismic Safety Consortium. The scope of this activity is expressed in how the Consortium (unless otherwise specified, "Consortium" and "SCSSC" mean South Carolina Seismic Safety Consortium) is organized into five task groups, each with a chairman as follows:

- Hazard Awareness and Public Information Task Group;
- Local Earthquake-Resistant Design Task Group;
- Response to a Damaging Earthquake Task Group;
- Intergovernmental and Organizational Relations Task Group; and
- Public Sector Participation Task Group.

As originally conceived and documented in the introduction to SCSSC Document Number 1, the Program Plan called for three phases as follows:

- Phase I - Organization (late 1981-early 1982);
- Phase II - Technology and Experience Transfer and Program Development (early 1982-early 1983); and

- Phase III- State Seismic Safety Program Implementation (mid-early 1983-ongoing).

The perceived needs of the fledgling consortium were synonymous with its three major objectives:

1. To develop and influence the implementation of a comprehensive state seismic safety policy, using a five-year action plan for earthquake preparedness and mitigation in South Carolina with emphasis on the lowcountry region.

2. To promote interdisciplinary cooperation and technical competence among engineers, geologists, seismologists, planners, governmental leaders and the public as necessary to ensure adequate, sustained implementation of seismic safety policy.

3. To ensure that federal and state seismic research and development programs adequately address the technical needs of South Carolina and the southeastern United States.

The five-year action plan (1982-1987), stated in the first objective, had its strengths and weaknesses.

<u>Strengths</u>

1. Primary responsibility for individual SCSSC workshops alternated between the co-chairpersons, thereby providing a "breathing spell" for each leader. The additional time helped assure better planning for the events.

2. Communication with, and participation from, earthquake experts (mostly seismologists and engineers) was maintained at a very high level—enough to produce significant benefits in the quality of the results from the SCSSC seminars.

3. The topics covered a wide range of issues related to seismic safety; there was truly "something for everyone".

4. Administratively, in 1987 the Consortium received (1) the services of an Executive Director, to work at the SCSSC headquarters at The Citadel in Charleston; and (2) a commitment for managing the future funding, hopefully from FEMA and other sources, from the South Carolina Emergency Preparedness Division, Office of the Adjutant General.

5. A number of significant associated activities and accomplishments resulted from the success and visibility of the Consortium in its initial style of organization and workshops. Examples of some of those accomplishments will be listed and described in a succeeding part of this paper.

6. The Earthquake Education Center, its director, staff and many volunteers, have documented examples of rewards as a result of their training others: new seismic safety policy and procedures implemented by private industry, schools and governmental groups. The EEC, although a part of the Consortium, is almost entirely funded by FEMA.

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7. The Technology Transfer and Development Council of the Consortium made measurable progress with both the South Carolina Building Codes Council and the Southern Building Codes Congress, International (SCSSC Document Number 1, pages 106 and 104, respectively) in its proposal to mandate (presently, an option) wind and seismic design provisions in building code.

Weaknesses

1. At the end of the five-year program there is still no appropriation for the SCSSC from the South Carolina General Assembly. More effort is needed to lobby the program with key State legislators.

2. Among the five program sessions originally planned (Document Number 1, page 5), only sessions 1, 2 and 3 were actually conducted. Other Consortium priorities, such as the building codes initiative by the TTDC, occupied the time of the SCSSC personnel.

3. Two important SCSSC conferences, "Seismic Retrofit of Existing Unreinforced Masonry Buildings" (January 1985), and "The Role of the Public and Private Sectors in Earthquake Preparedness" (January 1986), both held in Charleston, do not have a published record of the proceedings. Copies of each printed agenda, however, are available.

Financial support began with a USGS cost-reimbursible contract for $20,000 to the South Carolina Geological Survey, an office of the Division of Research and Statistical Services, State Budget and Control Board. Three modifications to the original contract (beginning May 1985 and ending August 1987) brought the total funds to $51,640. The Citadel Development Foundation, the Baptist College Development Board, the Federal Emergency Management Agency and the National Science Foundation provided additional funding. Contributions of personnel time for management and secretarial services were made by the South Carolina Geological Survey, the Department of Civil Engineering, The Citadel, and the Department of Chemistry and Geology, Baptist College at Charleston; accounting services were partially donated by the Division of Research and Statistical Services, and entirely donated by the Office of the Controller, The Citadel.

Description of research which contributed to application

The SCSSC conducted only one original research study under the USGS contract and another one under a FEMA grant. The former project was called "Site Period Study for Charleston, SC", by David J. Elton and James R. Martin, II, an investigation of the dynamic site periods of soil profiles in peninsular Charleston. Research was the motivating force for this project. The latter project was a vulnerability study of old, historic buildings in Charleston, evaluating them structurally for their capability to withstand the stresses, especially lateral, of a damaging earthquake. The investigation was led by Col. Maurice Harlan, then professor in the Department of Civil Engineering, The Citadel. The needs were the motivation in this project.

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Description of activities that facilitated application of research

Events such as workshops, seminars, panel discussions and related conferences were conducted by the SCSSC, or in some instances, other groups hosted the activity and invited SCSSC members. Examples of the latter type are presented as part of the next section covering dissemination events. A common objective of the former events was for SCSSC members to learn from guest speakers (invited earthquake experts) and from each other (multiple disciplines within the SCSSC). At first, we as Consortium members could teach very little about seismic safety and its related aspects to anyone else. We acquired the learning from 1982 onward in a "train-the-trainer" mode. Results of those sessions are summarized in Table 1. For many months we were not prepared to conduct training sessions or accept speaking and writing requests for the general public--sessions which the writer classifies as dissemination events.

Description of dissemination of research

Guest lectures, invited panel discussions, Consortium-hosted events for the public, distribution of publications, published guest articles, newspaper interviews, talk shows on radio and television, Public Awareness Program posters (EERI model-building, poster/art and essay contests), proclamations, resolutions and congressional testimony are examples of methods used by the SCSSC members to inform the general public of earthquake preparedness and mitigation. Once the Consortium members had achieved sufficient knowledge through the series of "train-the trainer" sessions previously mentioned, they were ready to "spread the word". The work of the Earthquake Education Center and the Technology Transfer and Development Council have already been fully described by Professor Bagwell and Dr. Lindbergh, respectively. The primary dissemination activities have evolved into these two entities within the Consortium, with members taking part in events of both groups.

Among all the methods previously cited for distributing earthquake information, speaking engagements and published reports and proceedings are the most common the Consortium has employed to inform the public. Table 2 lists the dissemination accomplishments of the SCSSC.

How the application process could have been improved

If the application process for a South Carolina Seismic Safety Consortium were to begin again, the writer would recommend more specific planning, including dates, for workshops or seminars for certain task groups. During the five-year period (1982-1987) for the SCSSC, members within three task groups--Response to a Damaging Earthquake, Public Sector Participation, and Intergovernmental and Organizational Relations--should have hosted or co-hosted a minimum of one workshop. The actual situation was that two task groups--Hazard Awareness and Public Information, and Local Earthquake-Resistant Design--shared nearly all the activity.

A detailed plan of translational ("train-the-trainer") activities should perhaps have the advance commitment--specific date(s), place and outline of agenda--a year or more in advance. One suggestion: hold at least <u>one seminar</u>, hosted (or co-hosted) by a <u>different task group</u> during the first 12-18 months of consortium program activity. Then in the second year involve task group chairpersons in "cross-training" activity with

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Table 1. Summary of funding and deadlines for Grant No. 14-08-0001-G986 from U. S. Geological Survey to South Carolina Seismic Safety Consortium.

Document	Date Approved	Amount	Remarks
Original contract	3 May 1985	$20,000*	Title: "Continued Seismic Safety Program Development within the Southeastern United States." Expiration date: August 31, 1986.
Modification No. 1	11 July 1985	-0-	Allowed for redistribution of funds to include adding Task V (to the original four tasks) entitled: "Geotechnical Study of Effects of Ground Condition on Facility Damage in Charleston, South Carolina 1886 Earthquake" by Professor David Elton, The Citadel. Also provided for a minor change in each of two addresses, one for USGS and one for S. C. Geological Survey.
Modification No. 2	20 Feb. 1987	$24,640	Extended contract deadline from August 31, 1986 to June 30, 1987, and approved proposal dated December 29, 1986. Proposal requested additional funds ($24,640) and more time for (1) conducting an additional workshop on vulnerability of lifelines to a damaging earthquake and (2) implementing a transitional phase for the Technology Transfer and Development Council—that of effecting amended standards for seismic and wind design of structures.
Modification No. 3	13 July 1987	$7,000	Amount requested ($7,000) was for the supplement to the printing invoice from The Citadel to produce SCSSC Document No. 1. No extension of time was requested.

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*Contract specified "Not to exceed $20,000."

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Table 2. Summary of translation activities within the South Carolina Seismic Safety Consortium, 1982-1987 [1]

Activity	Results	Key Personnel	Funding Support	Motivating Force
1. SCSSC Session 1, May 17-18, 1982	Publication, Earthquake Hazards and Risk in South Carolina and the Southeastern United States: A White Paper on Seismic Threat, 1982; limited circulation.	Dr. Charles Lindbergh, editor; Prof. Joyce Bagwell, Members of Hazardous Awareness and Public Information Task Group.	USGS[2] ; The Citadel Development Foundation.	Needs
2. SCSSC Session 2, November 15-16, 1982	Publication, Document Number 2, Workshop on Lessons from California and Utah, 1986.	Prof. Joyce Bagwell, editor.	USGS; FEMA; Baptist College Development Board.	Needs
3. SCSSC and TTDC workshop, January 28-29, 1985	"Seismic Retrofit of Existing Unreinforced Masonry Buildings." Dr. William S. Butcher, Director, Division of Civil and Environmental, National Science Foundation, Keynote Speaker. (No proceedings, but copy of printed brochure available.)	Dr. Charles Lindbergh	USGS; NSF.	Needs and research
4. SCSSC workshop, January 23, 1986	"The Role of the Public and Private Sectors in Earthquake Preparedness." Dr. Edgar V. Leyendecker, Keynote Speaker. (No proceedings, but copy of printed brochure available.)	Prof. Joyce Bagwell, Marlene Roberts, SCSSC contributing panelists/ speakers.	USGS; FEMA; Baptist College Development Board.	Needs

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[1] Activities hosted entirely, or in part, by SCSSC. Table 2 lists companion activities. [2] USGS Grant No. 14-08-0001-G986 provided all USGS support in this project.

described by Professor Bagwell and Dr. Lindbergh, respectively. The primary dissemination activities have evolved into these two entities within the Consortium, with members taking part in events of both groups.

Among all the methods previously cited for distributing earthquake information, speaking engagements and published reports and proceedings are the most common the Consortium has employed to inform the public. Table 3 lists the dissemination accomplishhments of the SCSSC.

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Table 3. Summary of dissemination events and products, South Carolina Seismic Safety Consortium, 1982-1987.

	Activity	Results	Key Personnel	Funding Support	Motivating Force
1.	Testimony: Subcommittee on Science, Research and Technology, U. S. House of Representatives, March 15, 1983.	<u>Congressional Record</u> testimony included fact that the major accomplishments in earthquake hazard reduction and mitigation achieved under the provisions of the National Earthquake Hazards Reduction Program have not yet materially benefited the southeastern United States. Seismic safety developments remain those common to California several decades ago. (SCSSC Document Number 1, page 69.)[1]	Dr. Charles Lindbergh	USGS	Needs
2.	Workshop on the Charleston Earthquake of 1886, Charleston, May 23-26, 1983.	Invited paper, "Tectonic Models - Old and New", <u>in</u> USGS Open-File Report 83-843, A Workshop on "The 1886 Charleston, South Carolina, Earthquake and its Implications for Today", 1983, Walter W. Hays and Paula L. Gori, editors; convened under aupices of National Earthquake Hazards Reduction Program.	Dr. Pradeep Talwani	USGS; Nuclear Regulatory Commission; Federal Emergency Management Agency; National Science Foundation; National Bureau of Standards; City of Charleston; Berkeley-Charleston-Dorchester Council of Governments.	Research
3.	Same as Activity #2.	Invited paper, "The Current State of Earthquake Hazard Awareness in the Southeastern United States", <u>in</u> USGS Open-File Report 83-843; same as Activity #2.	Prof. Joyce Bagwell	Same as Activity #2.	Research

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Table 3. (continued)

	Activity	Results	Key Personnel	Funding Support	Motivating Force
4.	Same as Activity #2.	Invited paper, "Earthquake Hazard Preparedness in the Southeastern United States: A Patient Revolution", in USGS Open-File Report 83-843; same as Activity #2.	Dr. Charles Lindbergh	Same as Activity #2.	Research
5.	Same as Activity #2.	Invited paper, "Goals Concerning Earthquake Hazard Awareness", in USGS Open-File Report 83-843; same as Activity #2.	Steve Kinard	Same as Activity #2.	Research
6.	National Seismic Policy Conference, Seattle, WA, Novemember 1-3, 1983.	Invited paper (unpublished), "Earthquake Awareness and Preparedness in South Carolina."	Prof. Joyce Bagwell and Cynthia Evans	Baptist College at Charleston (partial)	Research
7.	A Workshop on Geologic Hazards in Puerto Rico, San Juan, April 4-6, 1984.	Invited paper, "How to Plan an Effective Program of Public Education and Increased Hazard Awareness", in USGS Open-File Report 84-761, A Workshop on Geologic Hazards in Puerto Rico, 1984, Paula L. Gori and Walter W. Hays, editors.	Prof. Joyce Bagwell	USGS; FEMA;	Needs and research
8.	Testimony: Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, U. S. Senate, March 19, 1985.	Most parts very similar to Activity #1. (SCSSC Document Number 1, page 77.)[1]	Dr. Charles Lindbergh	USGS	Needs

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Table 3. (continued)

	Activity	Results	Key Personnel	Funding Support	Motivating Force
9.	Article on earthquake preparedness in the schools.	"A Common Sense Insurance Policy for Teachers", in Alpha Delta Kappan, vol. 15, no. 1 (May 1985).	Prof. Joyce Bagwell	None	Needs
10.	American Red Cross Southeastern Disaster Preparedness Workshop, Francis Marion Collage, Florance, June 1986.	Conducted workshop on earthquake history, causes, effects and preparedness.	Prof. Joyce Bagwell; Marlene Roberts	USGS; FEMA	Needs
11.	Integrated Emergency Management Course: Earthquake Response, Emmitsburg, MD, August 4-7, 1986.	Presented guest lecture to approximately 60 attendees, mostly from Charleston, SC area, on the topic, "Earthquake Hazard in the Charleston Area." (No published proceedings. Classes held at National Emergency Training Center, owned and operated by FEMA.)	Norman Olson	FEMA	Needs
12.	Public Awareness Program, Third U. S. Conference on Earthquake Engineering, Earthquake Engineering Research Institute (EERI), Charleston, SC, August 24-28, 1986.	Publicity distributed to public schools and colleges in South Carolina. Events included contests in poster-making, art, essays, scientific/engineering papers, and engineering structural models. Awards were presented at a "Town Meeting" for Charleston citizens. This conference observed the Charleston Earthquake Centennial and also marked the first time the EERI had ever held its annual meeting in the eastern half of the United States.[1]	Dr. Charles Lindbergh; Prof. Joyce Begwell; Dr. Mike Woo and Prof. Russell Stout (The Citadel); Dr. Rudolf Elling (Clemson University). Prof. Maurice Harlan;(The Citadel)	USGS; FEMA; NSF; The Citadel Development Foundaion	Needs

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Table 3. (continued)

	Activity	Results	Key Personnel	Funding Support	Motivating Force
13.	SCSSC Session 1; events related to Third U. S. Conference on Earthquake Engineering, EERI, Charleston, SC, August 24-28, 1986.	Publication, Document Number 1, Earthquake Hazards, Risk and Mitigation in South Carolina and the Southeastern United States, 1986; revision of "white paper". Other dissemination events: Charleston Town Meeting; radio and television talk shows, and newspaper interviews; and Charleston Museum earthquake display, viewed by 30,000 visitors, Aug.-Dec., 1987.	Dr. Charles Lindbergh, contributing editor; Prof. Joyce Bagwell; others same as in Activity #1.	USGS; FEMA; National Science Foundation; The Citadel Foundation.	Needs
14.	South Carolina Building Codes Council, regular meeting, September 24, 1986.	Presentation by Technology Transfer and Development Council (TTDC) to SCBCC resulted in a resolution passed by the SCBCC supporting the TTDC's building code revision efforts (Doc. No. 1, p. 106).	Dr. Charles Lindbergh	USGS	Needs
15.	Partners of the Americas, Washington, DC, November 19-20, 1986.	Seminar was held at Radisson Francis Marion, Charleston, and Baptist College at Charleston, for 19 emergency preparedness workers from approximately 15 Latin American nations.	Prof. Joyce Bagwell; John Doyle; Norman Olson.	USGS; FEMA	Needs
16.	Master of Public Administration Program, University of South Carolina, Columbia, March 5, 1987.	Guest lecture was presented on South Carolina earthquakes and earthquake preparedness to graduate students enrolled in MPA program.	John Doyle and Norman Olson	USGS	Research

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Table 3. (continued)

	Activity	Results	Key Personnel	Funding Support	Motivating Force
17.	International Earthquake Conference, Los Angeles, April 6-7, 1987.	Presented invited paper on the role of the Earthquake Education Center as part of a panel with representatives from China, Mexico and the USA (California and South Carolina).	Prof. Joyce Bagwell	USGS; FEMA	Needs and research
18.	The First Coastal Growth Industries Forum, Charleston, June 10-11, 1987.	Publication, Coastal Construction: Building in a Hazardous Place, The First Coastal Growth Industries Forum Report, 1987.	Dr. Charles Lindbergh; Robert B. Whorton.	S. C. Sea Grant Consortium	Needs and research
19.	American Red Cross Southeastern Disaster Preparedness Workshop, Appalachian State University, Boone, NC, June 1987.	Conducted workshop on earthquake history, causes, effects and preparedness.	Prof. Joyce Bagwell Marlene Roberts	USGS; FEMA	Needs

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[1] See Appendix for additional information.

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merged task groups. From the second year onward, expect to become increasingly involved, as a consortium (not just one task group), in dissemination activities, both active and passive (that is, generate some, respond to other) activities.

The South Carolina Seismic Safety Consortium has been fortunate, indeed, to have two interested and dedicated co-chairpersons in Dr. Charles Lindbergh and Prof. Joyce Bagwell. They alternately shared the duties and responsibilities of the SCSSC, a multi-disciplinary program which, in South Carolina, demanded more energy than one leader logically should have had to give.

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CENTRAL UNITED STATES EARTHQUAKE CONSORTIUM

by
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Marion, Illinois 62959

THE REASON FOR BEING

In times of great stress, by God's hand or man's, people and communities must rely on one another for comfort and assistance. Physical, political, and legal barriers exist; however, that can interfere with efforts to lend support and resources. Recognition of the problem gave rise to the notion that a penumbral organization could coordinate harmonious actions among the separated parts.

THE RISK TO A FRAGILE SOCIETY

Literature from the scientific community published during the last two decades and historical accounts of seismic events in the Central United States clearly define the high probability of a severe earthquake occurring in the region. Findings indicate that a major earthquake in the Central United States would have wider and more devastating effects than would a similar earthquake in the Western United States.

In jeopardy in the Central United States are vital facilities such as roads, pipelines, and waterways, and resources such as electricity generating stations, military installations and industries. It is a center of agriculture, transportation, industry, communications, energy production, and commerce. The fragile socioeconomic balance would be lost, affecting an estimated 12 million residents.

THE CREATION OF THE CENTRAL UNITED STATES EARTHQUAKE CONSORTIUM (CUSEC)

The Central United States Earthquake Consortium was born of a need to protect residents and property in the Central United States seismic zone from the devastation of a major earthquake. The interstate nature of resources, combined with the high risk, necessitated the establishment of a coordinating body with the authority and ability to integrate, coordinate and initiate preparedness activities and response mechanisms in a multi-State region.

The National Earthquake Hazards Reduction Act

Recognizing that earthquakes are potentially the greatest single-event natural hazard threatening the Nation, Congress in 1977 passed the National Earthquake Hazards Reduction Act. The Act instructed the President to "establish and maintain an effective earthquake hazards reduction program."

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[1] Board of Directors: Lacy Suiter, Chairman; James E. Maher, Vice-Chairman; Wilbur R. Buntin, Jr., Secretary Treasurer; Leon McGoogan, Member; Charles D. Jones, Member; William J. Patterson, Member; Richard D. Ross, Member; E. Erie Jones Executive Director

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The Earthquake Hazards Reduction Program

Congress then established the National Earthquake Hazard Reduction Program, which directed the Federal Government to lead, coordinate, and conduct earthquake research, and hazard mitigation and disaster preparedness efforts.

Four Federal agencies--the Federal Emergency Management Agency, the United States Geological Survey (USGS), the National Science Foundation, and the National Bureau of Standards--were given specific roles in earthquake hazards reduction efforts. Recommendations, were made defining the duties of State and local governments, individual and private organizations.

The Central United States Earthquake Preparedness Project

The Federal Emergency Management Agency initiated the Central United States Earthquake Preparedness Project in 1981 to assist State governments in planning responses to damaging earthquakes, to encourage mitigation activities, and to further cooperation among the States in regional planning.

The Central United States Earthquake Consortium

While national and international attention focused on other high-risk areas, leaders from seven equally high-risk States recognized the vulnerability of their area to a major earthquake. Emergency management officials from Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee in October 1983 joined to form CUSES and agreed to plan a regional response to earthquakes, to share technical and scientific information that would affect those plans, and to cooperate in educational and preparedness activities.

The Federal Emergency Management Agency, to which Congress gave the responsibility of coordinating regional programs and efforts to minimize the risks inherent in earthquakes, made available support and funds for CUSEC. A bench mark in the Federal Government's growing awareness of the extremely high risk to life and property in the Central United States seismic zone was the awarding of a contract on April 11, 1984, to fund the Consortium. Emergency management officials from the seven-States already involved in earthquake preparedness efforts in the Central United States formally organized CUSEC.

A MANDATE: DEFINING THE TRUST

The CUSEC, a nonprofit entity, was incorporated by the directors of emergency services of seven-States most at risk from seismic activity in the Central United States. The Consortium, as stated in its charter, was formed expressly for charitable, scientific, and educational purposes.

The Consortium, more specifically, is entrusted with the responsibility of promoting and supporting earthquake preparedness in the Central United States, formulating and improving the administration of earthquake preparedness affairs through the departments and agencies of the respective States, and addressing the needs stated in the Earthquake Hazard Reduction Act of 1977: planning, public education, and mitigation.

Preparedness efforts include protecting people from death and injury, and property from physical destruction or damage; and rendering to people, organizations, and other entities aid and assistance as needed in the event of a major earthquake.

THE CUSEC BOARD OF DIRECTORS

Responsibility for the activities of the consortium is vested in the CUSEC Board of Directors, which is composed of the emergency services directors from each of the seven-States and the executive director of CUSEC. The Board of Directors, acting in concert, is the legal guardian and policy formulator for the Consortium's activities, and the custodian of the program and organization.

THE CENTRAL UNITED STATES SEISMIC ZONE

The Central United States seismic zone, a regional seismic network includes the New Madrid fault zone and numerous other fault systems.

The New Madrid Fault Zone

Scientists have defined the location of the New Madrid zone as extending from about 25 miles northwest of Memphis to the Reelfoot Lake area in western Tennessee where it turns northwest toward New Madrid, Missouri, and then continues northeast to southern Illinois. It is thought to be up to 40 miles wide and about 200 miles long.

The 1811-12 Mew Madrid Earthquakes

The Central United States seismic zone, particularly the New Madrid fault zone, is one of the most active and dangerous seismic areas in the world. The three great earthquakes centered near the Missouri town of New Madrid that occurred in 1811-12 and measured 8.5 or greater on the Richter scale have the distinction of being the greatest series of earthquakes in the history of the United States.

The sequence of earthquakes, which continued for about six years after the initial great quakes, also included five earthquakes that measured 7.8 on the Richter scale, ten of 7.0, and at least 1,850 of lesser magnitude. The energy released by the series is thought to be greater than that released by all other earthquakes that have occurred east of the Rocky Mountains in the United States and Canada combined from the mid-1700's to the present. In more modern comparative terms, the energy released is estimated to be equal to that of 12,000 atomic bombs the size of those dropped on Harioshima, or 150 million tons of TNT.

Seismic Trends in the Central United States

Earthquakes, the magnitude of those in 1811-12 are estimated to occur about every 670 years. Although the New Madrid fault has been relatively quiet since 1812, lesser earthquakes occur quite frequently. The last earthquake of damaging proportions along the New Madrid fault, which measured 6.2 on the Richter scale, occurred in 1895. Its epicenter was near Charleston, Missouri, at the northern end of the New madrid fault. An earthquake of similar magnitude with an epicenter near Memphis, Tennessee, occurred in 1843.

The entire seven-State region is laced with a network of smaller active faults located in the Wabash Valley, the Illinois Basin, the St. Francois Uplift and the Ouachita-Wichita Mountains, among others.

The largest earthquake to occur in the Central United States since 1895 was centered in south central Illinois, north of the New Madrid fault zone. Scientists relate the Richter 5.5 earthquake to the Wabash valley fault system located in southern Illinois. The quake was felt in an area of 580,000 square miles -- all or portions of 23 States.

The Imminent Danger

Earthquakes in the 6 to 7+ range on the Richter scale occur in the Central United States seismic zone about every 90 years. Scientists say the region may be overdue for an earthquake in this range, and agree that it would be prudent to expect it to occur in the near future.

Earthquakes of about 4.5 on the Richter scale occur in the Central United States at the rate of approximately one in ten years. Small earthquakes, most of them imperceptible to residents, occur daily. Since 1974, scientists have detected 200 earthquakes a year of at least 1.0 on the Richter scale.

Since the cataclysmic release of stored energy along the New Madrid fault in 1811-12, strain energy has been building. If it were released today, it is estimated that the result would be an earthquake of 7.6 in magnitude. The longer it takes, the greater the earthquake.

EFFECTS: AN UNSTABLE EARTH

The effects of an earthquake the size scientists say could occur at any time have been explained in terms of the region's subsurface structure and composition. The Earth in the Central United States allows earthquakes to have a far wider effect than would one of a similar magnitude elsewhere in the Nation.

A lack of Attenuation

The Earth's crust in the seven-State region generally is thick and even; shock waves that radiate from an earthquake are not readily lessened or stopped. Geological conditions that can influence attenuation include topographical scope, geological materials and water saturation levels.

The great earthquakes of 1811-12 were reported to have been felt in the entire Eastern United States and parts of Canada -- more than 600,000 square miles. In comparison, the 1906 San Francisco earthquake, which measured 8.3 on the Richter Scale, was felt only in California and extreme western Nevada and caused damage in 40,000 square miles.

Not only will shock waves ripple unhindered, great damage from an earthquake in the Central United States will be caused by liquefaction, which occurs when the shaking from an earthquake causes water-ladden, loose sand below the

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Earth's surface to become fluid. The unstable substructure, which underlies a high percentage of the seven-State region, will lose the strength to support whatever lies above it. The result will be severe tilting and settling of structures, landslides, and the collapse of man-made dikes.

The Phenomenon of Liquefaction

Not only will shock waves ripple unhindered, great damage from an earthquake in the Central United States will be caused by liquefaction, which occurs when the shaking from an earthquake causes water-ladden, loose sand below the Earth's surface to become fluid. The unstable substructure, which underlies a high percentage of the seven-State region, will lose the strength to support whatever lies above it. The result will be severe tilting and settling of structures, landslides, and the collapse of man-made dikes.

The USGS scientists have concluded that, in areas where the Earth's substructure makes it susceptible, liquefaction is possible as far as 93 miles from the epicenter of a great earthquake. The findings were part of a 1983 study on the vulnerability of six cities in the Central United States.

THE CONSEQUENCES: THE PEOPLE AND THEIR NEEDS

The great New Madrid earthquakes of 1811-12 occurred when a mere 5,000 residents were sparsely scattered throughout Missouri and Arkansas; no major population centers had yet been established in those States or the rest of the region. Most of the dwellings were small, wooden houses, the safest type of structure during a major earthquake.

Today, the area at risk from earthquakes in the Central United States region encompasses 11 States: Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kentucky, Mississippi, Missouri, Ohio, and Tennessee. It includes high population centers such as Chicago, Memphis, St. Louis, Louisville, and Little Rock. Scientists say that earthquakes in heavily populated areas represent perhaps the most severe threat to life today.

A Low Awareness, A High Risk

Numerous studies and reports, based on scientific investigations and observations of earthquakes, have yielded a generally accepted scenario of what is likely to happen when a major earthquake occurs in the Central United States seismic zone. The script is predicted on the knowledge that the public is abysmally unaware of the threat of earthquakes in the Central United States and has done little or nothing to protect itself from the potential danger. Among the consequences expected are the following:

- The earthquake will occur without warning. Although extensive research on prediction methods is being conducted, scientists are not yet ready to declare any of them reliable.
- The earthquake and aftershocks will trigger numerous secondary events including fires, floods, landslides, dam failures, and the release of hazardous materials.

- The death and injury rate will likely be painfully high. Rubble and debris may restrict or prevent the rescue of persons trapped in or near collapsed structures.

- The death and injury rate will likely be painfully high. Rubble and debris may restrict or prevent the rescue of persons trapped in or near collapsed structures.

- As many as 12 million people could be affected; the projected cost in property damage is estimated to be more than $50 billion.

- Lifeline systems, including utilities, communications, transportation, and emergency services may be impaired if not destroyed. Restoration of services will likely take several days, perhaps even months.

- Roads and bridges may be impassable; railroad tracks could buckle. River barges may not be able to travel the major waterways.

- With transportation impaired, vital commodities such as food, medical supplies, and materials to rebuild will be in critically short supply.

- There likely will be no electricity, water, or sewer facilities.

- Natural gaslines may rupture; should the earthquake occur during a cold winter, people could freeze to death due to lack of heat.

- Without electricity and computers, banking will virtually stop.

- Emergency facilities, such as hospitals, and fire and police stations, are apt to be extensively damaged or destroyed.

- The demand on State and local government and volunteer agencies will be overwhelming.

- The Federal Government will not be able to respond with physical and financial help for up to 72 hours. Communities will have to survive for about two days without any outside assistance.

THE CUSEC PROGRAM

The CUSEC is the central coordinating agency for matters related to the earthquake hazard in the Central United States. The Consortium is concerned with earthquake preparedness, recovery, and response efforts that involve the seven-State region.

The program includes five major areas of work:

- The development of the Interstate Earthquake Emergency Compact.

- The establishment of a Multi-State Earthquake Data Management Resource Inventory.

- The refinement of multi-State plans and the coordination of activities related to State earthquake disaster preparedness, response, and recovery.
- The dissemination and sharing of earthquake-related information among disaster preparedness planners, educators and others.
- The maintenance of the CUSEC office and the supportive coordination of operations.

The Interstate Earthquake Emergency Compact

The proposed Interstate Earthquake Emergency Compact will provide the conceptual bases for CUSEC-coordinated earthquake annexes to the existing individual State comprehensive response and recovery disaster plan. Goals to be addressed through the Compact include an agreement among the States concerning short-term earthquake disaster assistance. Immediate aid to neighboring States in the event of a damaging earthquake will likely involve sharing equipment, supplies, facilities, and personnel in the fields of medicine, security, law enforcement, and firefighting.

A second goal of the Compact is to provide some assurance of protection for those who render professional services during a disaster in States other than their own. Also tom be defined in the Compact are procedures for the States to maintain current resource inventories, and to exchange and share information about emergencies and disasters that cause them.

The Multi-State Earthquake Data Management Resource Inventory

The Multi-State Earthquake Data Management Resource Inventory, when completed, will establish a comprehensive, exhaustive listing of all resources in the seven-State region that might be needed during an earthquake disaster. The seven member States each will maintain a bank of standardized data to be used for the inventory, which will be shared among them in the event of an earthquake or other emergency.

Basic to this capability will be the development, maintenance, and management of a digitized map listing the resources in all of the counties at risk in the CUSEC member States.

Response and Recovery Planning Initiatives

One of the Consortium's founding goals, in the interest of saving lives, was to maximize the understanding among the member States of one another's emergency management problems and efforts. Members recognized that unrelated and untested plans implemented during a multi-State emergency could interfere with and impede efforts to help people and protect property.

The Response and Recover Planning Initiatives will include integrating each of the seven-States' emergency management plans into a common response strategy. Central to achieving the goals is establishing a communications system through which member States can immediately receive information and utilize the resource inventory and digitized mapping systems. A series of

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proposed earthquake preparedness exercises will be developed to provide an opportunity to test and evaluate the integrated emergency management plan.

Public Affairs Awareness Program

The Consortium holds among its primary responsibilities the heightening of the public's awareness that a major earthquake is likely to occur in the Central United States before the end of this century. The threat of earthquakes is known by most residents of the seven-State region, but the quality of that knowledge must be enhanced and sustained. The Consortium recognizes that only through mitigation and preparation, achieved as a result of a well-informed population, can the anticipated death and injury rate be dramatically reduced.

The Public Affairs Awareness Program involving the government and private sector will include: 1) developing educational materials, 2) participating in earthquake-oriented government, professional and public meetings, 3) maintaining an earthquake information resource library, 4) involving the media in public information and educational goals, 5) and providing information on Consortium programs.

To fulfill the goal of acquiring and sharing earthquake-related information, yearly meetings will be held involving representatives from government, business, and the public; an earthquake advisory committee will be formed comprised of members from parallel disciplines; and State public information projects will be developed to address earthquake preparedness, mitigation, and recovery issues.

IN SUMMARY

The CUSEC consortium exists solely to protect the citizens of the seven member States to the best of its abilities and to the extent of its resources from the pending disaster of a major earthquake. All resources, funds, talents, and time are expended on protecting people and their property in anticipation of an earthquake, as well as during and following the occurrence of an earthquake.

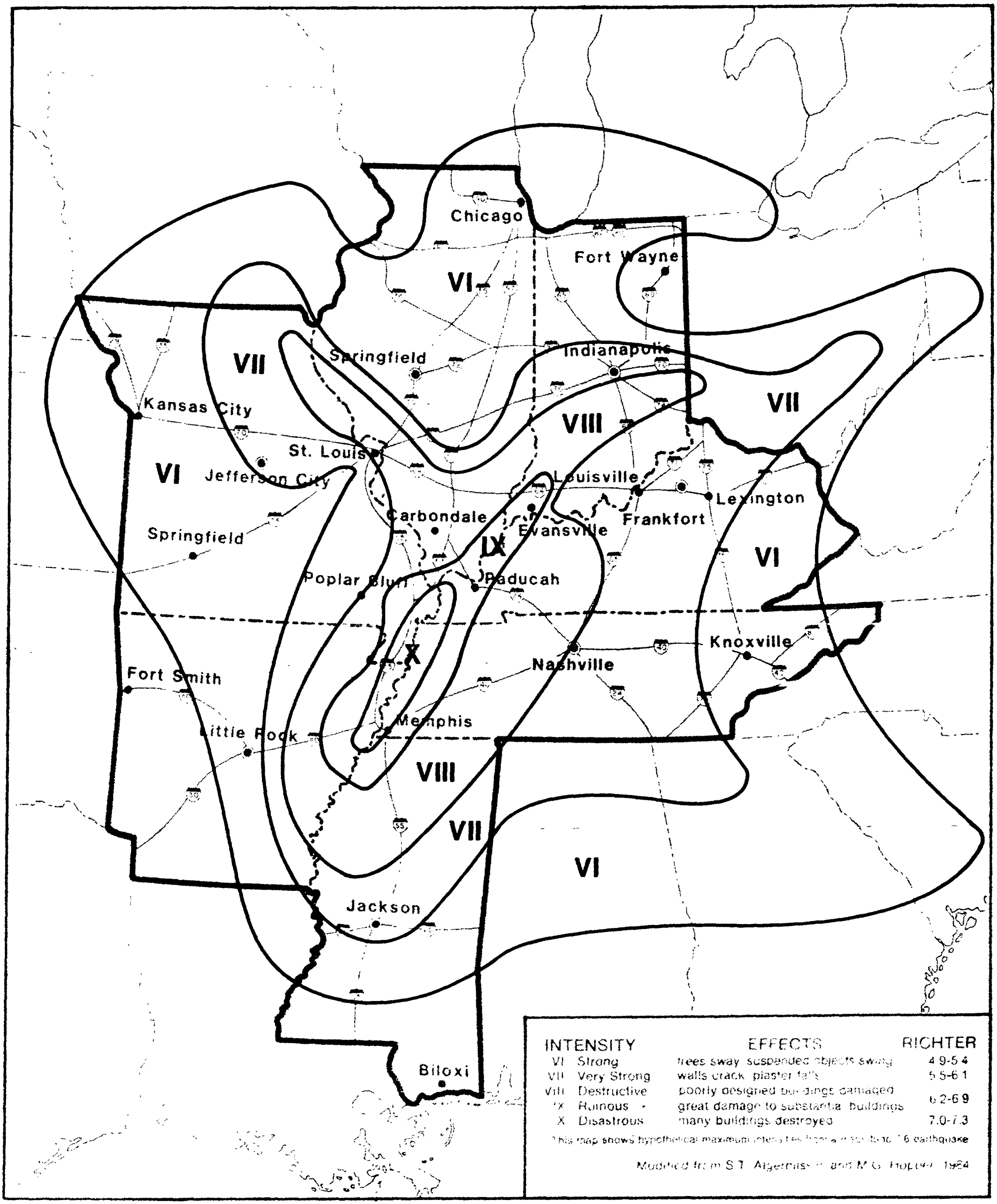
Chicago
Fort Wayne
VI
VII
Springfield
Indianapolis
VII
Kansas City
VIII
St. Louis
VI
Jefferson City
Louisville
Lexington
Frankfort
Carbondale
Evansville
Springfield
IX
VI
Poplar Bluff
Paducah
Knoxville
X
Nashville
Fort Smith
Memphis
Little Rock
VIII
VII
VI
Jackson
Biloxi
INTENSITY
EFFECTS
RICHTER
VI Strong
trees sway suspended objects swing
4.9-5.4
VII Very Strong
walls crack plaster falls
5.5-6.1
VIII Destructive
poorly designed buildings damaged
6.2-6.9
IX Ruinous
great damage to substantial buildings
X Disastrous
many buildings destroyed
7.0-7.3
This map shows hypothetical maximum intensities from a magnitude 7.6 earthquake
Modified from S.T. Algermissen and M.G. Hopper, 1984

Figure 1.

THE WESTERN STATES SEISMIC POLICY COUNCIL

By

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Golden, Colorado

Introduction

This is a research application process using the formation of an inter-state regional organization to improve understanding about earthquakes and to formulate policy to lessen their impact on society. A description of the relationship between the original purpose and the contemporary outcome of this process follows.

Description of Planned and Actual Outcomes.

The Western States Seismic Policy Council (WSSPC) was formed as an organization in 1979 through the initiative of three Western States: California, Nevada and Utah. The organizational purpose in the formative years was to exchange technical knowledge relating to seismic events so as to better deal with real and expected impacts. The organization met to exchange information through annual conferences in which geologists essentially presented technical papers. As the need to mitigate societal impacts through better preparedness became more apparent, the Federal Emergency Management Agency (FEMA) began to financially support the annual conference, other western states because involved and emergency management agencies began to participate in conferences.

The proceedings of each conference were recorded and distributed, but primary sharing of knowledge was through conference discussions. Perspectives of the various states as well as technical and managerial advances were discussed in successive conferences by representatives from the member states. Policy issues were developed at business meetings at each conference; conference locations and leadership were shared each year among the member states to insure diversity and information dissemination. FEMA financial support covered limited conference costs to include transportation for one representative per state and the expenses of selected speakers. States contributed other expenses for state participants as well as planning and program implementation.

Key players in this information and policy development process include: state representatives (geologists, preparedness officials or both), WSSPC leadership from the various states and FEMA's overall management. FEMA funding was accompanied by limited control requirements which permitted state initiative and flexibility. Funding increased roughly in correlation with inflation so that support is currently $15,000 per federal fiscal year.

Important motivating events internal and external to the organization have been the recurrence of significant scale earthquakes throughout the western region including Mexico, the prediction of the likelihood of future large scale events and the growing threat awareness of western states. The obvious need for better preparedness - technical, social and political has been a strong incentive.

Description of Research Which Contributed to Application

Research presented at conferences has been widely varied on the basis of state initiative, the selectivity of the WSSPC's Executive Board, FEMA's interests and participating member feedback from conference results. A very broad range of technical and managerial research has been presented so that a strong interchange has developed between technicians, preparedness officials and private business interests.

Description of Activities that Facilitated Application of Research

Research application has been left to the states in one sense, but from another perspective, policy formulation has matured among the cooperating western states. Application has developed through a range of policies such as:

- improved mitigation methodology and management
- interstate assistance compacts
- the need for a balanced federal preparedness funding through all states that are faced with a seismic threat rather than only those with apparent high risks.

Dissemination of Research

Technical papers are supplied to each participating state as part of the conference "proceedings" (published following the conference).

Potential Process Improvement

This particular "research application" has been highly cost beneficial. Low annual costs have stimulated interest and awareness and substantially improved preparedness at the state and local levels. Earthquake preparedness programs within the member states vary considerably, but most have made significant improvements in both technical and preparedness planning, exercising, programming and budgeting as a direct consequence of this process. A key element of change was FEMA's absorption of this program and the inclusion of state preparedness officials along with geologists.

From a historical perspective the formation of WSSPC as an interest group should continue to result in new advances in national earthquake policy. Significant progress was achieved through federal foresight in spending "seed" money to stimulate state's interest in their own behalf and in helping each other. Since WSSPC's formation, progress has been demonstrated through continuing growth to 14 member states and through continually increasing coordination with other similar groups elsewhere in the nation.

Member States

Alaska
Arizona
California
Colorado
Hawaii
Idaho
Montana
Nevada
New Mexico
Oregon
Texas
Utah
Washington
Wyoming

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PUGET SOUND EARTHQUAKE PREPAREDNESS PROJECT

By

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Federal Emergency Management Agency
Bothell, Washington

DESCRIPTION OF THE PROJECT

The project was in two phases. First was an earthquake vulnerability analysis for six counties in the vicinity of Puget Sound. The second was a Federal, State and local earthquake response preparedness effort.

The vulnerability analysis was done by USGS and was published in November of 1975 as a 297 page book entitled A Study of Earthquake Losses in the Puget Sound, Washington, Area. The work was performed during the period April 1974 to October 1975. The seismological analysis was performed in-house by USGS. The engineering analysis was performed under the direction of Karl Steinbrugge, Henry Lagorio and Bruce Olsen (of the firm Olsen, Ratti and Fossatti, Consulting Engineers).

The Puget Sound Earthquake Preparedness Project was the third of four earthquake projects sponsored by the Federal Disaster Assistance Administration (FDAA), or the Office of Emergency Preparedness,--FEMA's predecessors. The purpose of the vulnerability analysis is succinctly stated in the report: "This study is intended to inform those agencies serving the region of potential hazard to people, structures and lifeline functions, in such a way that the administrators of emergency services can proceed with confidence in planning response to earthquake disaster."

The study produced a damage and injury profile for two hypothetical earthquakes at the maximum credible magnitude of 7.5; one with an epicenter near Seattle and one with the epicenter near Olympia.

The four studies (San Francisco, Los Angeles, Puget Sound and Salt Lake City) were the result of decisions made by the President's Office of Emergency Preparedness, heavily influenced by advice from a group of California engineers, USGS and its experience with the San Fernando Earthquake of 1971 and the Alaska Earthquake of 1964. The key player in the Puget Sound study was Karl Steinbrugge, a California structural engineer. On the seismological side there was heavy involvement by S.T. Algermissen and other members of the USGS staff in Golden.

Description of Contributing Research

Various USGS ground motion studies of western Washington were used to create isoseismals for the two hypothetical events. The damage profile was developed through a methodology developed by Karl Steinbrugge based on the investigations of earthquake damage throughout the world.

Translation Methodology

The published report itself was designed for easy access to decision-makers. At the beginning of the report was a simplified summary of the findings for each county. Table 1 of the original report is reproduced as an attachment to this report. The report is in two sections. The first covers seismology. Although it is somewhat technical it is designed to be read by non-experts. The second part is the analysis of damage, which is written in laymen's terms--primarily giving numbers of dead and injured, homeless and numbers or percentages of structures and systems destroyed or damaged.

The report was introduced to the public through a press release; the report itself was available to the media upon request. It was picked up by all the major newspapers and television stations in the area. A press conference was held by the principal investigators, which was attended by the major television stations and newspapers.

Following that, the FDAA staff produced a 12 minute slide/sound show summarizing the study results and went on a road show throughout the Puget Sound area, speaking to city councils, county commissions, State agencies and Federal agencies. Officials at all levels were urged by the FDAA staff to consider the study and upgrade their level of preparedness to meet the earthquake hazard.

Application of the Research

The intended result of the project was to initiate disaster response preparedness actions at the Federal, State and local levels of government that would build a disaster response capability adequate to handle a catastrophic earthquake. It was recognized that response to an earthquake is not unique; that it is similar to response to other disasters. However, an earthquake is particularly taxing on a response system because the damage is widespread geographically, it affects the major utility systems, and it causes serious degradation to the various facilities (such as fire stations and hospitals) needed in disaster response. Therefore, an earthquake is a good scenario against which to build a response system.

FDAA took the leadership in developing a Federal response plan for a major Puget Sound earthquake. Other agencies were involved through workshops and seminars. The plan was completed after six months of intensive effort, and an exercise conducted. The excise included mobilization of Army units from Ft. Lewis and deployment to the Seattle Area. Play on the part of State agencies and the City of Seattle was limited to that needed to provide input to the Federal exercise. Agencies were encouraged to develop their own internal plans. The only organization to do so was Ft. Lewis.

The Washington State Department of Emergency Services was encouraged to initiate a similar effort at the State level and was offered $100,000 in matching funds for the project. Negotiations on the use of the funds broke down, and the State did not take up earthquake planning until 100% funding was offered many years later through the National Earthquake Hazards Reduction Act.

We encouraged local government to initiate preparedness programs, but offered no funding. No specific new programs resulted during the first years after the study, but the study became the basis of scenarios used by local government in disaster exercises. Recently, Whatcom County--a county not included in the original study--has completed an isoseismal mapping project on its own and made some real strides in addressing the areas within the county where the earthquake damage would be the greatest. The City of Tacoma also has just completed a project.

The Washington National Guard in January of 1985 conducted an exercise whose scenario closely followed the study and held a training session to sensitize its officers and NCOs to the problems that might be faced in a major earthquake.

The most effective vehicle for conveying the results of the study turned out to be the sound/slide presentation. In 12 minutes it was possible to effectively convey the essence of the study. Over the years there have been many requests to show the presentation and to make copies of it.

The study report has become the standard reference for everyone with an interest in the Puget Sound earthquake problem. I have heard it referred to by governmental officials and scientists alike. It is still the most requested publication in FEMA Region X.

Yet, the specific concrete results of the study are few. Except for the Federal Earthquake Response Plan, there was no immediate initiation of effort to address the earthquake program.

What the study has done primarily is define the problem for the laymen in the Puget Sound Area. I believe it has had far-reaching effects on the public's understanding of the earthquake problem. Each year the major newspapers and the television stations do earthquake programs. Often the study is mentioned and its major conclusions repeated. The effects of the study may be great indeed, but they are subtle, and long-term. They relate more to an underlying awareness of the problem.

It is difficult to isolate the effects of the study from other factors. The State Legislature passed a bill to establish a seismic safety commission two years ago. This was the immediate outcome of a lobbying effort by concerned citizens. How much of this positive outcome was the result of the existence of a definitive report on the earthquake problem? We have no way of knowing.

This year funds were made available for the Department of Education to survey schools for seismic hazards. Did the study have an effect on this?

Ways of Improving the Application Process

At the first USGS conference I attended on the subject of research applications (which was in May of 1978 in Denver), I presented a critique of the Puget Sound project. At that time I concluded that an intermediate level of analysis was needed between the scientists/engineers and the users. This level of analysis would use other disciplines (such as management science, economics, political science, sociology and psychology) to assess the effects of the earthquake on the infrastructure of the society. This level of analysis would state the problem in system degradation terms that would be immediately usable by governmental decision-makers.

In 1979 and 1980 a hazard vulnerability analysis was done for Alaska under the guidance of Karl Steinbrugge. We were able to implement some of our ideas about reporting damage in terms of system degradation. For instance, electrical system and natural gas system damage was stated in terms of buildings without service over time--which recognizes the loss due to damage by the event and the time required by the utilities to make repairs.

The analysis of housing losses is a particularly good illustration of the methodology. The results are stated in terms of the need for emergency shelters, because that is the primary housing concern of emergency responders. The sheltering need is a function of the following:

a. housing damage, and the time required for repairs to housing;

b. damage to utility systems and the time required for utility repairs;

c. people's attitudes about mass shelters;

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d. the availability of Federal aid;

e. survival skills in the general population and the availability of camping equipment;

f. individual tolerance of adverse circumstances;

As you see, this analysis goes far beyond the engineering evaluation of the likelihood of various degrees of housing damage in an earthquake. It required an analysis of supply lines for repair supplies, ability to get skilled workers, management skill in making repairs, psychological and sociological profiles of the people in Anchorage, analysis of the speed of Federal aid, and a survey of camping equipment ownership in Anchorage. Table 2 is a summary of the housing analysis from the Alaska study.

Even though we succeeded in doing much of the intermediate level of analysis we thought the emergency planner needed, the specific outcomes of these analyses have not been used extensively in Federal, State or local planning. The document produced has been used more as a standard reference guide for defining the earthquake problem in Alaska.

Conclusions

1. The earthquake hazard analyses have long-term and sometimes unexpected results. While they may not be used intensively by our target audience, they affect other audiences. This has a positive, but less demonstrable, value.

2. I am still convinced that our Alaska approach was a good one, but there is a missing element in our knowledge. We have a good idea of the type of information that ought to be used by emergency planners--mainly through working with them and discussing the topic with them. But we do not know what they are likely to use. There is a distinction between that ought to be useful and information that will actually be used. More research is needed in this area. It would essentially be survey research and relates more to predicting behavior than report attitudes.

3. We have been guilty of producing a lot of information without having any idea whether or not it will be used. I am not suggesting that we accept the status quo. We should be willing to try to sell earthquake preparedness and to try to change attitudes and behavior. I suggest we would be more successful if we know what the attitudes and predicted behavior patterns are prior to our intervention.

THE MASSACHUSETTS EARTHQUAKE VULNERABILITY AND RISK ASSESSMENTS

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INTRODUCTION

The history of seismic events in California is well documented. It is a record of numerous significant earthquakes including several great earthquakes within the past 150 years. Although the frequency of significant and great earthquakes in the East is much lower than in California, since the 18th century some of the greatest earthquakes recorded in the United States have occurred in the East. (see Figure1) Among the significant earthquakes was one epicentered off of Cape Ann, near Gloucester, Massachusetts on November 6, 1755. (see Figure 2) Based on that earthquake and a continuing history of lesser seismic events in the northeast, studies (Whitman et. al. 1975 and Toksoz et. al. 1981) have shown that there is a recognized potential for a serious and damaging earthquake affecting Massachusetts.

Reviews of construction sites in the area (Ochshorn and Schumaker 1976) demonstrate that most buildings and the surrounding infrastructure were designed and built before there was any serious concern for the effects of a damaging earthquake.[1] Consequently, the region has a serious risk of damage, injury and disruption if subjected to an earthquake equal to the one that occurred in 1755.

Recognizing the need for a comprehensive emergency management program to mitigate a potentially damaging earthquake, the Massachusetts Civil Defense Agency, in cooperation with and utilizing funds provided by the Federal Emergency Management Agency, commissioned a series of studies to assess the earthquake risk and potential losses in Massachusetts.

The objective of this paper is to examine the specific earthquake research-applications process in Massachusetts to determine what happened, why it happened, how long it took, what problems were or were not overcome and what is proposed for the immediate future. The format of this paper is designed to answer a series of 5 explicit questions as prescribed by the U.S. Geological Survey. The questions have been modified as necessary to address the specifics of the particular research.

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[1] Please note that the Massachusetts State Legislature added seismic provisions to the State Building Code in 1975.

SIGNIFICANT EARTHQUAKES
OF THE
UNITED STATES

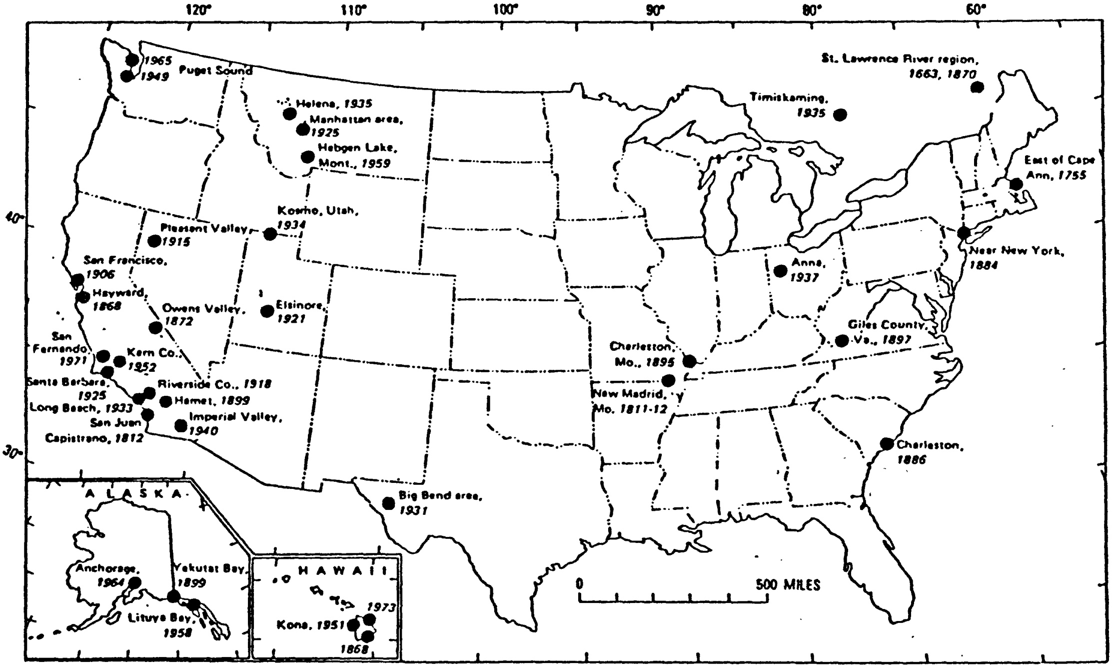

FIGURE 1.

Source:USGS

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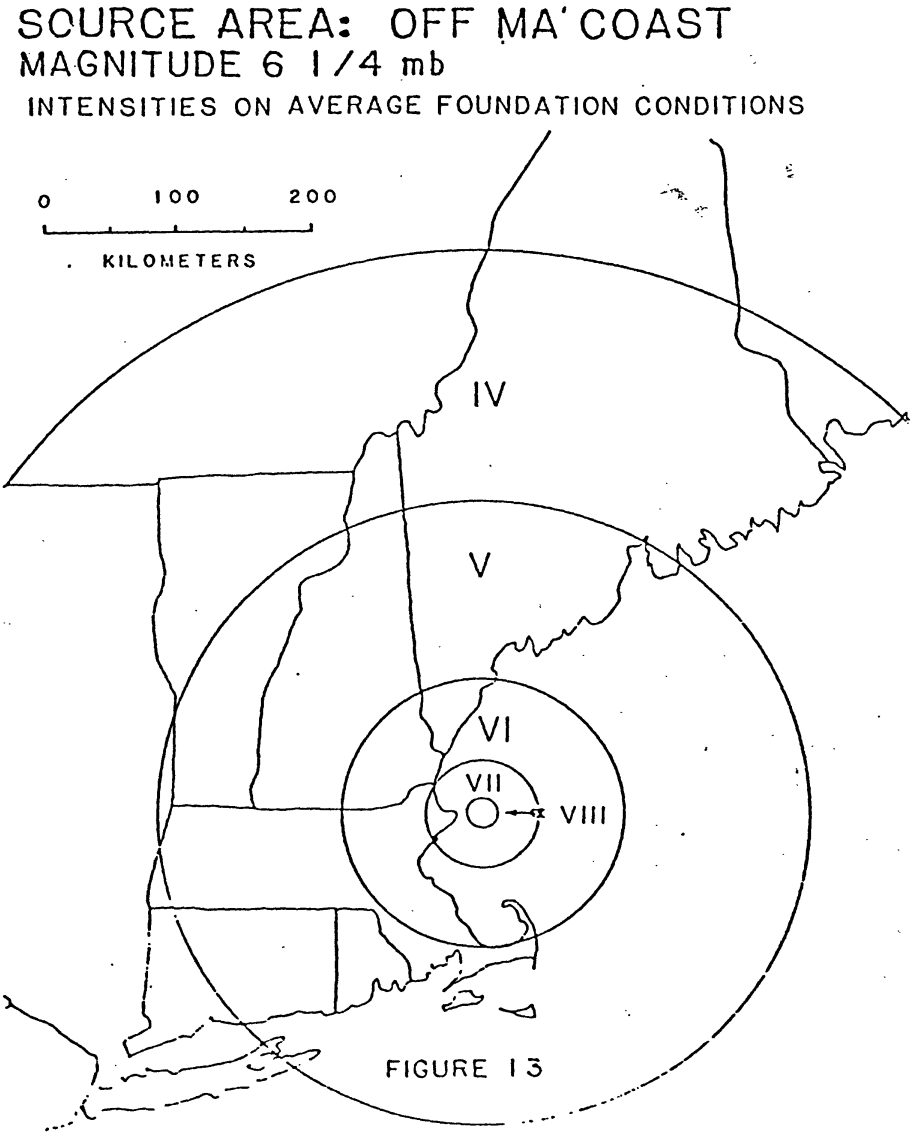

FIGURE 2.

Source: Toksoz, et. al.,1981

1. WHAT WERE THE PLANNED AND ACTUAL OUTCOMES OF THE SPECIFIC APPLICATION ?

a) What were the perceived needs at the outset and at later points in time ? How were they defined?

The perceived needs at the outset of the research were 1) to conduct an assessment of the earthquake hazard in New England with a particular focus on Massachusetts; 2) to determine a "Maximum Credible Earthquake" to be utilized in a loss analysis study; and 3) to conduct an evaluation of the potential losses and impact of the "Maximum Credible Earthquake" in Massachusetts. This information was to be used primarily to provide a foundation for emergency preparedness and earthquake hazard mitigation measures in Massachusetts.

b) What length of time and level of effort were involved?

The research project has been conducted in 3 phases, the time and level of effort of which are as follows:

Phase	Level of Effort	Time
I Hazard Assessment	Intense	1 year
II Hazard Mapping	Moderate	1 year
III Loss Analysis Study	Intense	2 years(in-process)

c) What were the scope and scale of the application ?

Phase	Scope	Scale
I Hazard Analysis	Analyse earthquake hazard	Massachusetts, New England, Southern Canada

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II Hazard Mapping	Analyse the potential increase in ground shaking due to soils conditions	Eastern Massachusetts
III Loss Analysis Study	Analyse impact on persons, property and infrastructure	Metropolitan Boston area

d) <u>Who were the key players ? Why ?</u>

The key players varied from phase to phase as follows:

Phase	Key Players	Why
I Hazard Analysis	M. Nafi Toksoz (MIT) Adam Dziewonski (Harvard) Pat Barosh (BC) John Ebel (BC) George Klimkiewicz and Gabriel Leblanc (Weston Geophysical Research Inc.) Jay Pulli (MIT) Eugene Williams (SMU)	Boston based world reknown experts
II Hazard Mapping	Haley and Aldrich, Inc. Cambridge, MA	Soils experts
III Loss Analysis Study	URS Corporation San Francisco, CA Simpson,Gumpertz & Heger Arlington, MA Panel of local consulants headed by Dr. Robert V. Whitman (MIT)	California and Massachusetts earthquake loss experts

e) What was the funding amount ?

Phase	Cost
I Hazard Analysis	Volunteer effort estimated at $150,000 - $200,000
II Hazard Mapping	$14,200
III Loss Analysis Study	$178,750

2. WHAT SPECIFIC RESEARCH STUDIES CONTRIBUTED TO THE KNOWLEDGE BASE ?

a) Who funded them ?

There were many specific research studies that contributed to the knowledge base required to conduct the 3 phases of the Massachusetts study. These studies were conducted by government agencies such as the U.S. Geological Survey, the Corps of Army Engineers and NOAA. Private organizations such as Weston Geophysical Research, Inc. have also greatly contributed to the data base. In terms of seismology and geology, the research and seismic monitoring undertaken by both Weston Observatory at Boston College and the Massachusetts Institute of Technology form the cornerstone of all related earthquake research in the Northeast. These programs are funded by the U.S. Nuclear Regulatory Commission. Absent Nuclear Regulatory Commission funding in the northeast one could speculate that the existing scientific data base would have been inadequate to support the studies undertaken by the Massachusetts Civil Defense Agency. In regard to the potential impact of an earthquake in the Boston area the research conducted by Dr. Robert Whitman at MIT, some of which was funded by the National Science Foundation, has been instrumental in support of the more recent research. It is also important to mention that absent funding and technical support from the Federal Emergency Management Agency the 3 phase process described herein would probably not have been undertaken.

b) What drove the application - the research or the needs ?

The most intense application of the research will take place when the third phase of the project, the loss analysis study, is complete and available for dissemination early in 1988. The proposed application will likely be driven by the research for there is a need to make decision makers and the public in Massachusetts aware of the earthquake hazard and its potential impact. The loss study research will provide the foundation for this public awareness effort. The need for action on the part of the decision makers and the public is not something that they are necessarily aware of at this time.

3. WHAT SPECIFIC TRANSLATION ACTIVITIES HAVE HELPED TO FACILITATE APPLICATION ? WHO PERFORMED THEM ?

The specific translation activities that have thus far facilitated application have been conducted by a small group in the Boston area who have been advocates for earthquake hazard reduction measures. A specific significant application, resulting directly from the efforts of this small group, was the enactment of seismic provisions to the Massachusetts State Building Code by the State Legislature in 1975. In addition, many organizations and individuals such as the Weston Observatory, MIT, the Massachusetts Civil Defense Agency, the Federal Emergency Management Agency, the U.S. Geological Survey, the New England Seismic Advisory Council and others continue to work to facilitate application of research. Some of this activity is in the form of public awareness and education.

4. WHAT SPECIFIC DISSEMINATION EVENTS ARE ANTICIPATED TO CONTRIBUTE TO THE EVENTUAL SUCCESS OF THE APPLICATION ?

Loss studies similar to the one under development for the Boston area have been completed in different parts of the country. Users of some of these studies have indicated that once the research was completed it was not adequately disseminated.[2] This inhibited the eventual successful application of the study. It can result in a research study that sits on a shelf and is not put to its intended use.

[2] Discussions between the author and users of similar studies

There is one major obstacle that must be overcome before information contained in the Massachusetts Study can be expected to influence public and private decisions regarding earthquake hazard reduction.

This obstacle is public awareness.

A loss study can be an excellent means of raising awareness about earthquakes if it is properly disseminated. This is especially true in the east where damaging earthquakes are infrequent events. Even if a community or private organization acknowledges that devastating earthquakes can occur, whether or not they will be moved to take approporiate action is a key factor in terms of earthquake hazard reduction.

Mushkatel and Nigg (1986) studied this issue in the Central U.S. which they termed "Seismic Hazard Awareness and Support for Mitigation Policies" They generalized that their findings regarding lifeline managers (utility officials) were transferrable to other regions of low seismicity in the United States that are exposed to potentially large and damaging events. This would include Massachusetts. Mushkatel and Nigg (1986) concluded that managers of lifeline systems tend to have the following characteristics:

- Very little objective or technical knowledge about the earthquake threat, especially in moderate risk areas.
- Little personal experience with the consequences of earthquake events, even moderately sized ones, on their lifeline systems.
- Low levels of concern, especially among utility managers about the possibility of their communities experiencing a damaging event any time in the near future.
- Managers spend virtually no time on seismic safety issues or planning.
- Although there is general belief in the effectiveness of response and preparedness planning, the majority of managers, especially in moderate risk areas and in utility companies, do not believe the danger to their communities warrants the development of such plans.

Based on the findings of Mushkatel and Nigg, it is reasonable to assume that similar characteristics typify utility and lifeline operators and other managers in Massachusetts. This is a significant obstacle that must be overcome if application is to be successful.

Rossi, et. al. (1982) found a similar low level of perceived seriousness of earthquakes on the part of public and private decision makers in Massachusetts.

Rossi focused not on mass public opinion, rather he chose to define and study disaster mitigation "Elites". His sampling techniques and strategy selected 2,300 politically instrumental individuals from twenty hazard prone states and 100 hazard prone communities. The "Elites" interviewed were drawn from two general classes of decision makers; persons occupying formal positions that had the authority to legislate on hazard mitigation issues or were in charge of governmental agencies that had jurisdiction over hazard emergencies and mitigation policies; and persons occupying private sector positions in organizations whose interests would likely be engaged by hazard mitigation issues.

Among other questions respondents were asked to rank order groups of problems facing the state. Massachusetts "elites" rank order of natural hazards contained in the survey were as follows:

Hazard	Rank (1 high-18 low)
Flood	13
Hurricane	15
Tornado	16
EARTHQUAKE	18

The following can generally be concluded as a result of the research of Rossi et. al. (1982)

- In the minds of the most politically influential state and local "elites" in Massachusetts, natural hazard problems were not considered especially serious, absolutely and in relation to other problems.
- Natural hazard issues were consistently seen by Massachusetts officials as slightly more serious when viewed from the state perspective than from that of the local communities.
- There was general agreement among Massachusetts officials that floods were the most serious natural hazard and earthquakeswere the least serious.[3]

Atkinson and Petak (1981) in a report prepared for the Federal Emergency Management Agency observed the following about the history of earthquake awareness in Massachusetts:

> As of 1970 it could reasonably be said that earthquakes were virtually ignored in the design of conventional buildings in the commonwealth. Though records were available documenting the major earthquakes of 1727 and 1755, which affected large areas of Massachusetts, it was not common knowledge for the public, public policy makers or even the engineering community that Massachusetts was in a potentially active seismic area. . .Yet what has happened within the Boston area over the period of the past decade (1970-1980) is of potentially enormous significance. Without significant conflict or opposition, seismic safety provisions have at least been included in enforceable building codes [provisions to the state building code in 1975] the professional community of engineers and architects has been sensitized to the potential earthquake risk within the area, and much professional agreement has been reached concerning the seismicity of the area, the general dimensions of potential earthquake related problems, and the means for mitigating the impacts of such risks

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[3] With the exception of Los Angeles, there is not a single community in the U.S. that views earthquake as its most serious natural hazard problem.

They go further to state:

> **Given the almost imeasurable level of policy-maker and policy-influential interest in earthquake risk, what is surprising about Boston is that anything at all was done to deal with this potential community problem.**

This statement by Atkinson and Petak underscores the paradox concerning the potential for the eventual successful application of earthquake hazard reduction measures in Massachusetts. As the authors state it was surprising that anything at all was done to deal with earthquake risk in the Boston area. The fact is that Massachusetts, despite little perceived public and political support and absent a recent damaging earthquake, is one of a very limited number of states in the East that has included seismic provisions in its state building code. This was accomplished with the active involvement of a small number of influential and dedicated individuals in the earthquake profession.

There is a great potential for the application of research, and resulting earthquake hazard reduction in Massachusetts if these key individuals are actively involved in the process.

PROPOSED DISSEMINATION STRATEGY

There is obviously no simple way to motivate state and local government, the private sector and the general public to take the results of the Massachusetts earthquake risk and vulnerability research and apply it to prepare for earthquakes. This is a challenge in areas of high seismic risk, and in Massachusetts as well as other areas in the East the task is significantly more difficult.

The goal of the dissemination strategy in Massachusetts will be to give the opportunity to all affected groups to evaluate the research and to make an educated decision as to whether or not to take or support mitigating action. To accomplish this we propose to insure adequate dissemination of research results supported by an educational or awareness program.

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To accomplish this the following steps are proposed:

Pre-dissemination awareness assessment

The first step that is necessary is to assess the present level of earthquake awareness in Massachusetts, and the level of support for earthquake hazard mitigation. This paper refers to several studies that looked at the level of awareness, however, these studies are dated or not specific to Massachusetts. A study similar to the one conducted by Mushkatel and Nigg (1986) should be undertaken for Massachusetts.[4] It is essential to establish the current status of earthquake awareness prior to implementing a dissemination program. This research could answer such questions such as as what is the present level of awareness, who are the likely audiences for the research, what are their opinions and attitudes, how can they be reached and what are reasonable and achievable goals for earthquake hazard mitigation in Massachusetts.

All to often earthquake hazard mitigation programs fail because inadequate assumptions are made about the potential users of information, the appropriate target audiences, the current base level of awareness, etc.

It is simply not prudent to market something as obscure as earthquakes in Massachusetts based on feelings or impressions.

To have the best chance for success, earthquake hazard mitigation in Massachusetts must begin with proper dissemination of research results based on current and valid information about the potential user groups and target audiences.

Dissemination strategy

Once a preliminary public awareness study has been completed alternative strategies for targeting the dissemination of research

[4] The Central U.S. study was funded by the National Science Foundation in the approximate amount of $250,000.

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results can be developed. Specific long and short term goals can be defined and objectives established. These goals, objectives and strategies will be based on reasonable and validated assumptions about the target audiences and therefore have the best chances for success.

Involvement and support of key individuals

Most important is the involvement of key Massachusetts earthquake professionals throughout the entire dissemination and public awareness program. This group probably consists of about a dozen or so influential individuals without whose involvement and support the entire effort will likely fail.

5. IF THE SPECIFIC PROCESS FOR A GIVEN APPLICATION COULD START OVER, WHAT FACTORS WOULD YOU CHANGE ?

The only thing I would have done differently up to this point would have have been to more actively solicite the involvement,at the onset, of federal agencies such as the U.S Geological Survey, the National Science Foundation, state and local agencies, elected officials and the general public. In looking back, I would have built a broader based and larger coallition in support of earthquake hazard reduction early on in the program.

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Application of a Liquefaction Potential Map for Charleston, SC

by

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Auburn, AL 36849

Description of the Research Application

This project presents a efficient probabilistic method for assessing liquefaction hazard and applies it to Charleston, SC. The method is based on the empirical relationship between the Standard Penetration Test resistance (SPT) and the cyclic stress ratio required to cause liquefaction developed by Seed and his coworkers. The project was undertaken because reports of liquefaction resulting from the 1886 event indicated that there was a threat. Both photographic and written descriptions of liquefaction were located in the literature.

The project is almost complete, and a first draft of the liquefaction threat has been completed. This draft indicates that there is a significant liquefaction threat to Charleston. The project will be completed in December 1987.

The project has been application oriented from the beginning. The principal investigators have required one year of effort at the 20% level to develop this work. The liquefaction potential map is intended to cover the downtown area of Charleston, SC, approximately 4 square miles. Funding for the project began and ended with this above named grant from USGS, under the NEHRP. Some soils data were acquired and compiled under a previous grant from the USGS, for a project related to determining the site periods in Charleston. This data compilation saved many man-months of effort.

The external motivating events for this research included:

1. a desire to increase the seismic safety of Charleston, by providing the city with a map of liquefaction potential that could be used in city planning,
2. the increased activity by USGS in the Charleston area indicating continuing major seismicity in the area, and
3. the formation of the South Carolina Seismic Safety Consortium, which provides a forum for identifying and discussing seismic concerns.

Description of Research Which Contributed to Application

Youd and Perkins did the original outline for development of ground failure maps in 1978. Their procedures were incorporated in the research on liquefaction potential mapping for San Francisco, CA, and for Davis County, UT, and set the framework for this type of study. The probabilistic framework for this type of mapping has since been modified and used.

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Two research projects aided in preparing the principal investigators to perform this research. The first is the FEMA funded vulnerability study for Charleston, SC, headed by Maurice Harlan. This study collected soil boring data for the study area, for an entirely different purpose. In a more general sense, the above study prepared the way for the current research by raising the issue of the seismic vulnerability of Charleston.

More general research on seismic sources in the southeastern U.S. has been useful in defining the seismic threat (liquefaction opportunity).

Description of Activities that Facilitated Application of Research

These activities are yet to be determined.

Description of Dissemination of Research

This research has yet to be completed and disseminated. It is expected that the dissemination will be facilitated by the following:

1. publicity that brings the research results to public and governmental attention. Such publicity will most likely include newspapers, television and radio. Proper attention and endorsement by by professional and state organizations will aid in the dissemination. In this case, the Technology Transfer Development Council, the South Carolina Seismic Safety Consortium, and the South Carolina State Geologists office will be very useful. This will aid in bringing the research results to the attention of political bodies who have the mandate to take the proper actions to protect the public by implementing the results of this research in the form of appropriate building or zoning codes.

2. publication in technical journals and presentation at professional meetings will aid in informing the profession of the research results.

How Could the Application Process Have Been Improved?

Because the present research in incomplete, and has yet to be applied, it is difficult to address this question. The application process could be improved if application was the original and terminal focus of the research. Proposals for this program should indicate that the researcher has specific application plans. Such an indication would help the researcher focus his efforts from the start to develop results in a form that could be applied, and involve his research efforts with those that will aid in the dissemination of results.

The process of application can be enhanced by expanded interaction with those potentially influenced by the research, as well as by governmental bodies responsible for proper application of the research.

From the current standpoint, the most important change that could have been made is to devote more effort to planning the applications process.

THE EARTHQUAKE VULNERABILITY STUDY FOR THE METROPOLITAN AREA OF SAN JUAN
RESEARCH - APPLICATIONS

by

Jose Molinelli Freytes, Director of the Environmental Science Program, University of Puerto Rico, Rio Piedras, Puerto Rico

DESCRIPTION OF RESEARCH APPLICATION

1. WHAT WERE THE PLANNED AND ACTUAL OUTCOMES OF THE SPECIFIC APPLICATION ?

The actual outcome of the Earthquake Vulnerability Study for the Metropolitan Area of San Juan was as planned: to prepare an earthquake induced geologic hazard map for this area. Risk situations were identified, thus providing the necessary information for local disaster preparedness, land use planning, estimation of economic losses, identification of measures for reducing expected economic loss and for the selection and implementation of mitigation strategies.

2. WHAT WERE THE PERCEIVED NEEDS AT THE OUTSET AND LATER POINTS IN TIME ? HOW WERE THEY DEFINED ?

Ideally the earthquake vulnerability study should include the whole island of Puerto Rico. Limited funding required setting up priorities according to the perceived needs. It was decided to begin this process with the metropolitan area of San Juan because its high population density and large concentration of economic activity make it the area with the greatest risk. Once the methodologies were developed for San Juan, they could very easily be transferred to other areas of Puerto Rico. Currently a similar study is being conducted for the metropolitan areas of Ponce, Arecibo and Aguadilla.

Another need was to estimate the degree of risk of important structures such as hospitals, health centers, schools, police and fire stations, dock facilities, airports, telephone stations, radio and television facilities, electric and water distribution facilities etc.. This was done by overlaying the earthquake induced geologic hazard map over infrastructure and census maps. This information was used by an economic consultant to feed a mathematical model to estimate the cost of a Modified Mercalli Intensity VIII earthquake (probable 100 year event) affecting San Juan. The study concluded that such event would produce damages of 2.15 billion. This represents 13% of the capital stock of San Juan.

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We are very far from being properly prepared for a large earthquake in Puerto Rico. Among other things we need to incorporate geologic hazard maps into the land use planning process, eliminate or retrofit hazardous building structures, improve hazard preparedness, educate the population and government officials. The earthquake vulnerability study is one of the first steps in preparing the Island for such event.

3. WHAT LENGTH OF TIME AND LEVEL OF EFFORT WERE INVOLVED ?

The study was completed in April 1985, after 15 months of intense work. The researcher worked for this period at a 35% level to complete the project. Personnel from the Hazard Mitigation Office of the Department of Natural Resources were very helpful by providing valuable data concerning the infrastructure and lifelines of the metropolitan area of San Juan as well as facilitating a draftperson to prepare the hazard maps.

4. WHAT WERE THE SCOPE AND SCALE OF THE APPLICATION ?

The scope of the study was to examine the seismic vulnerability of the San Juan metropolitan area by mapping the spatial distribution of geologic hazards and estimating the likely damage in these zones. Three important earthquake induced geologic hazards were considered: ground shaking, liquefaction and landsliding. Each geologic hazard was mapped according to three levels of susceptibility determined by the geologic, hydrologic and geomorphic characteristics of each zone. The study tasks were to:

1. define the tectonic setting and regional seismicity
2. identify sources of seismicity
3. define regional attenuation
4. select an earthquake hazard level for the analysis
5. define the geology of the study area
6. define and map ground shaking hazard
7. define and map liquefaction hazard
8. define and map landslide hazard
9. estimate damage for each of the hazard zones

The mapping of earthquake induced geologic hazards was done at a scale 1:20,000 using the USGS 7.5 minutes series topographic quadrangles as base maps. The tectonic setting and regional seismicity were examined at a scale 1:250,000.

5. WHO WERE THE KEY PLAYERS? WHY?

The key players were the Federal Emergency Management Agency, Department of Natural Resources and the consultant. FEMA made the project possible by providing funds as part of its Earthquake Hazard Mitigation Program since Puerto Rico is located in a tectonically active region and has experienced large earthquakes of magnitude equal or greater than 7.5 Richter in 1918, 1867 and 1787.

The Department of Natural Resources, among many other reponsabilities, is the agency in charge of hazard mitigation in Puerto Rico. Although most of its work was related to floods and hurricanes, it was logical to add earthquake hazard mitigation to its agenda in order to facilitate integrated natural hazard mitigation and preparedness planning. Because of the lack of adequately trained personnel and expertise on the area of earthquake hazards within the agency, a consultant was contracted to develop the methodologies to evaluate the earthquake vulnerability of the Metropolitan area of San Juan.

6. WHAT WAS THE FUNDING HISTORY ?

The Earthquake Vulnerability Study for the Metropolitan Area of San Juan was financed by the Federal Emergency Management Agency - Region II, Earthquake Vulnerability Program, Project FEMA 3, EMN - K -0017 and the Department of Natural Resources. Total funding amount for the San Juan, Ponce, Aguadilla and Arecibo urban areas was $36,000.

7. WHAT WERE THE INTERNAL AND EXTERNAL MOTIVATING EVENTS (IF ANY) THAT STIMULATED THE PROCESS ?

The joint USGS/FEMA/DNR workshops in Puerto Rico created the appropriate climate that increased earthquake hazard awareness of all interests, public and private. The workshops promoted the interaction among geologists, geomorphologists, engineers, seismologists, planners, geographers, social scientists and other individuals in Puerto Rico. The workshops gave a tremendous momentum and estimulated the interaction among these researchers.

The 1985 Mexico earthquake was a major external motivating event that increased earthquake hazard awareness throughout the whole population of Puerto Rico. The press played a major role by publishing in the headlines the results of the Earthquake Vulnerability Study for the Metropolitan Area of San Juan. Many radio and T.V. programs were dedicated to the problem of earthquake hazards in Puerto Rico.

Then, one month after the earthquake, Puerto Rico was declared a disaster zone after the 100 year rainfall caused a landslide that buried more than 100 people. Subsequently, news from the Nevado del Ruiz disaster in Colombia, Dupont Plaza Hotel fire disaster in San Juan, and additional flood and landslide damages in Puerto Rico prompted a commission of the Senate of Puerto Rico to look deeply into the hazard problem. This commission is currently examining various alternatives to reduce the loss of life and property.

DESCRIPTION OF RESEARCH WHICH CONTRIBUTED TO THE APPLICATION

8. WHAT SPECIFIC RESEARCH STUDIES CONTRIBUTED TO THE KNOWLEDGE BASE REQUIRED FOR THE APPLICATION ? WHO FUNDED THEM ?

Research studies that contributed to the knowledge base required for the application are of two types:

1. those that provide information about the local tectonics, geology, geomorphology and engineering properties of the geologic materials in the study area.
2. those that provide state of the art methodologies to evaluate earthquake induced geologic hazards.

The first group included among others, USGS profesional papers, master and Ph.D. dissertations, local engineering reports on subsoil conditions, USGS geologic and topographic maps, nuclear plant siting studies, earthquakes catalogues and articles published in professional journals.

The second group included USGS professional papers, USGS technical reports for the evaluation of site hazards as part of the Interagency Committee on Seismic Safety on Construction, articles published in professional journals, insurance company studies, conference proceedings and technical reports for earthquake risk analysis and land use planning among others.

Most of the local professional papers and maps has been funded jointly by the USGS and the Commonwealth of Puerto Rico. The nuclear plant siting studies by the Puerto Rico Electric Power Authority. Most of the journal articles, technical reports, conference prooceedings used were funded by universities, USGS, federal and local government, United Nations and insurance companies.

DESCRIPTION OF ACTIVITIES THAT FACILITATED THE APPLICATION OF RESEARCH ?

9. WHAT SPECIFIC TRANSLATION ACTIVITIES HELPED TO FACILITATE THE APPLICATION ? WHO PERFORMED THEM ?

The consultant translated data related to the geologic deposit type, thickness, age, topography, landform and standard penetration test among others, into different ground shaking amplification, liquefaction potential and landslide susceptibility classes. An earthquake catalogue was used to establish earthquake recurrence probabilities and the "design earthquake" for the study area.

DESCRIPTION OF THE DISSEMINATION OF RESEARCH

10. WHAT SPECIFIC DISSEMINATION EVENTS CONTRIBUTED TO THE EVENTUAL SUCCESS OF THE APPLICATION ? WHO PERFORMED THEM ?

The series of yearly workshops sponsored by the USGS/FEMA/DNR as well as the publication of the proceedings have played a major role in the dissemination of the research among local government officials and private sector such as insurance companies. The 1985 Mexican earthquake provided an excellent window of opportunity to disseminate the results of the vulnerability study throughout the newsmedia, especially newspapers, radio and television, as well as special interest groups such as insurance company representatives.

11. HOW COULD THE APPLICATION PROCESS HAVE BEEN IMPROVED ?

IF THE SPECIFIC PROCESS FOR A GIVEN APPLICATION COULD START OVER, WHAT FACTORS (PEOPLE, PROGRAMS, PROCEDURE, PLANS, ETC.,) WOULD YOU CHANGE ?

The insurance companies have greatly benefitted from this study without putting any money into it. They are presently using the earthquake induced geologic hazard maps to distribute the risk uniformly, not selling insurance in zones of greater risk. They have the economic resources to finance the research for the whole island of Puerto Rico. This source of funds could have been tapped initially so that federal and local governments monies could have been directed toward other needs.

RESEARCH APPLICATION:
EARTHQUAKE VULNERABILITY AND RISK ASSESSMENT IN THE U.S. VIRGIN ISLANDS

by Pamela Johnston-Fischer
(former Coordinator, Virgin Islands Disaster Programs Office)

Geoscience Services
Bernardsville, New Jersey

DESCRIPTION OF RESEARCH APPLICATION

The earthquake mitigation and preparedness efforts in the U.S. Virgin Islands began in 1979. At that time one of the objectives of the Territory's Disaster Programs Office (DPO), a division of Civil Defense and Emergency Services, was to prepare an introductory report on earthquakes that would alert the general public and local officials to the potential threat of earthquakesi, in or near the Territory, as well as to recommend some preliminary measures for mitigating their effects.

The Territory's overall disaster plan had been completed in 1978 and detailed the responses of various local government and private relief agencies to such frequently occurring disasters as hurricanes, droughts, plane crashes etc. By 1979, the Coordinator of the DPO felt that it was time to address those disasters which occurred less frequently but for which the public should still be prepared. Her concern was not what research process was necessary to define the earthquake threat, but rather a desire to educate and keep the public continually aware of earthquakes and their potential effects.

The Coordinator of the DPO also felt that if a few years passed without a major flood or drought occurring in the Territory, the public would probably begin to ask "what are you doing about other disasters, such as earthquakes?" And if an earthquake did occur in the Territory and a plan had not been developed or at least started, the DPO might possibly be liable for not having "done their homework."

The report was completed in 1979 and funded by the Federal Disaster Assistance Administration (FDAA). Since FDAA was abolished in late 1979 and replaced by the Federal Emergency Management Agency (FEMA), subsequent grants to the Territory, specifically for earthquake preparedness, did not resume until 1983. The FEMA grants from 1983 through 1987 were then utilized to prepare the hazard and vulnerability studies as well as the earthquake hazard reduction/emergency response plan. However, because the earthquake hazard and vulnerability studies generated so much new information for the territorial officials to utilize, the final earthquake mitigation/response plan published in 1987 became a far more comprehensive document than was originally anticipated.

Length of Time and Level of Effort Involved

A planner was hired by DPO in 1979 for a period of three months to complete the preliminary earthquake report. While the report was not a specific engineering or long range planning document, it was a beginning step in the earthquake awareness process.

Following publication of the report, a gap in local earthquake awareness efforts occurred because the Territory was preoccupied with relief efforts from various floods and hurricanes, and because of a lack of funding from FEMA, specifically for earthquake preparedness. By 1983 when funding for earthquake preparedness resumed, DPO and FEMA felt that the results of the 1979 document should be expanded to include determining the probability of an earthquake occurrence in the Territory, as well as the safety of specific key structures to a particular level of earthquake hazard.

As a result, DPO hired a consultant in 1983 to complete all subsequent reports as follows: hazard study - 1984, vulnerability studies - 1984 and 1985, and hazard reduction/emergency response plan - 1986.

Scope and Scale of the Application

The hazard study, completed in 1984, defined the tectonic setting of the three U.S. Virgin Islands - St. Thomas (28 square miles) - St. John - (20 square miles) and St. Croix (84 square miles), and developed the probable levels of earthquake hazard that allowed local officials to select the "design earthquake." The design earthquake was then used to estimate damage to some 200 key facilities in the islands. The results were described in the 1984 and 1985 vulnerability studies. Finally, the projected damages were utilized to develop a comprehensive mitigation plan in 1986 that was both an earthquake hazard reduction and emergency response plan.

Key Players

The Territory's interest in the earthquake threat, occurred as a result of the efforts of many key players. In 1979, the key players were the Region II office io FDAA, as well as the planner associated with, and the Coordinator of the DPO the Virgin Islands.

After the DPO published their preliminary earthquake report in 1979, it was sent to the U.S.G.S and Lamont-Doherty Geological Obervatory for comment. While neither agency officially commented on the report, it did lead to a dialogue between DPO, Lamont and U.S.G.S. The latter two agencies subsequently kept DPO advised of their various seismic activites in the Caribbean, including the U.S.G.S funded seismic network. While the network had been in operation since 1975, few territorial officials, including the DPO, were aware of its existence from 1975 through 1979.

Between 1980 and 1983, the U.S.G.S continued to provide DPO with many of their public information materials on earthquakes and the proceedings of the various earthquake conferences they had sponsored in other states. When FEMA awarded a grant to the Territory in 1983, specifically for earthquake preparedness, the dialogue between the above mentioned agencies and authorities was broadened to include FEMA. It was then a question of DPO, FEMA, and the U.S.G.S agreeing on "where do we go from here."

One of the suggested directions was to hire a consultant since the necessary geology/seismology expertise was not available in the Territory. Geoscience Associates was subsequently hired and completed all earthquake studies from 1983 to date.

Other key players in the Virgin Islands evolved as a result of FEMA's grant requirements. For instance, as part of their 1983 earthquake grant to the Territory, FEMA suggested that the Territory form a Natural Hazards Planning Council to oversee and provide input into the development of the Territory's proposed earthquake preparedness plans, as well as to review the final recommendations and products developed by the earthquake consultant. Comprised of representatives from local government and the private sector, the Council used the results of the 1984 hazard evaluation to select the design level earthquake that was the basis of the 1984 and 1985 vulnerability studies. This hazard level and the vulnerability studies then became the basis for the 1986 earthquake hazard reduction/emergency response plan.

Another key player in the Virgin Islands was local historian, Isadore Paiwonsky. In his weekly newspaper column he frequently covered historical accounts of various disasters in the Virgin Islands and surrounding area. As a result, the local population in the Islands gradually became aware of the potential effects of earthquakes.

Following the earthquake conference that U.S.G.S and FEMA sponsored in the Territory in 1984, the Virgin Islands Chapter of the American Society of Civil Engineers increased their efforts to draft legislation that would add seismic provisions to the Virgin Islands Building Code. While efforts by this organization had been underway prior to the conference, the technical assistance they requested at the conference, from the National Bureau of Standards, did not materialize after the conference ended.

The above individuals and organizations became key players because they provided either planning, educational, technical or funding expertise to the various earthquake studies and or the promotion of earthquakes in general.

Funding History of Research Application

In 1974, each state became eligible for a $250,000 grant from FDAA to develop disaster preparedness plans as a result of the Disaster Relief Act (PL 93-288). The grants were to be completed within two or three years. In 1975, the Territory was awarded $157,000 for this purpose and they completed their disaster plan in 1978.

In April of 1979 those states which had not spent or been awarded the full appropriation of $250,000, were given three months to spend the balance. Since the Territory had originally received only $157,000, the balance due was $93,000.

In order to spend the money, DPO proposed a variety of projects to FDAA. Since flooding and hurricanes were the most frequently occurring disasters in the Territory, most of the monies were utilized to complete related plans such as engineering surveys of shelters, flood damage mitigation plans, etc. The Coordinator of DPO suggested to FDAA that a small portion of these monies be used to explore the potential threat from earthquakes. A planner with a background in geology was living in the Territory at that time and her expertise along with the leftover money from FDAA enabled the DPO to complete the preliminary report on earthquakes within three months, at a cost of less than $5,000.

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As has been stated earlier in this report, a lack of funds was the primary reason for the gap in earthquake preparedness activity that occurred between 1979 and 1983. When the Territory received its first earthquake grant in 1983 from the newly formed FEMA, the interest in the earthquake program in the Territory was rekindled. Since 1983 the Territory has continued to receive funding for earthquake preparedness on an annual basis.

Internal and External Motivating Events

There were many internal and external events that motivated the earthquake program in the Virgin Islands. For instance, the local media frequently reported on various activites of Lamont Doherty and U.S.G.S as they related to the seismic network.

In 1983, the Coordinator of DPO attended the 1st International Earthquake Conference in Los Angeles and a U.S.G.S sponsored conference in Boston. The Los Angeles conference covered all facets of earthquakes in terms of preparedness, response and recovery. At the conference some very useful earthquake awareness materials were also distributed.

However, it was the 1983 grant from FEMA and the Boston conference that served as the catalysts to begin the earthquake hazard and vulnerability studies in the Virgin Islands. The Boston conference also served as a model for a similar earthquake conference that U.S.G.S and FEMA sponsored in the Territory, in 1984. The Virgin Islands' conference was the key event that opened the eyes of many local officials and the general public to the seriousness of the earthquake problem in the Territory.

DESCRIPTION OF SPECIFIC RESEARCH WHICH CONTRIBUTED TO THE APPLICATION

Input into the hazard and vulnerability studies was generated from the research of many individuals and agencies, particularly the U.S.G.S, Princeton University and Lamont-Doherty. The process used in the evaluation of the Islands' tectonic hazards was based upon procedures developed by the nuclear power industry. Engineering geology assessments drew upon liquefaction studies performed in the U.S. and China, amplification studies performed in the U.S. and Japan, and slope stability calculation procedures developed in the U.S. and Britain. Also, the evaluation and design concepts developed by the Veteran's Administration after the 1971 San Fernando earthquake, were invaluable in providing simple but accurate assessment of key structures.

Funded by

The various studies that were utilized were funded as follows:

1) Studies of Caribbean geology and tectonics were funded through government and oil company grants to universities.
2) Design earthquake selection was developed from power company needs during the building of nuclear power plants.
3) Structural design evaluation for seismic hazard was generated from both government and industry sponsored studies.

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4) Earthquake mitigation and emergency planning research was sponsored, primarily, by U.S. Government funds and others as follows: FEMA, U.S.G.S, National Science Foundation, Pan American Health Organization, Southern California Earthquake Preparedness Project (SCEPP), the California Earthquake Education Project (CALEEP), and the Bay Area Earthquake Preparedness Project (BAYREPP). The studies of the effects of actual earthquakes in other countries were particularly helpful in developing the emergency response portion of the Territory's final earthquake mitigation/emergency response plan.

Research or Needs Driven

The entire earthquake planning process in the Virgin Islands was driven by needs. In 1979, the need was to determine if indeed there was an earthquake threat in the Virgin Islands. By 1983, that earthquake threat needed to be evaluated and in some cases redefined. By 1986, the need was one of "what do we specifically do about the threat," hence the mitigation/emergency response plan published in 1987.

DECRIPTION OF ACTIVITIES THAT FACILITATED THE APPLICATION OF RESEARCH

The raw data concerning Caribbean tectonics and earthquake history was translated into earthquake damage probabilities by the consultant, Geoscience Associates. The Planning Council in the Virgin Islands considered the political and social implications of earthquake occurrence in their selection of a "design earthquake." The consultant then translated this design event into damage to critical Virgin Islands' facilities and finally into a mitigation/emergency response plan. Throughout these activities, the Planning Council was instrumental in assuring that the technical evaluations included local knowledge, thereby increasing the useability of the consultant's work products.

DESCRIPTION OF DISSEMINATION OF RESEARCH

In 1979, copies of the preliminary report on earthquakes were sent to each major government agency in the Virgin Islands, as well as to FEMA and the U.S.G.S.

The 1984 earthquake conference in the Territory enabled the DPO to distribute to the many attendess, a vast amount of educational material that had been gathered at the Ist International Earthquake Conference in Los Angeles; technical information from the U.S.G.S; and the hazard study that had been completed by the consultant earlier that year. All studies completed by Geoscience Associates between 1984 and 1987 were forwarded to members of the Planning Council as well.

A vast amount of material gathered at the 1987 earthquake conference in Los Angeles was disseminated as part of the final earthquake mitigation/response plan. The latter plan was also distributed to each territorial government agency. To date, comments have been received from the Fire, Health, and Police departments as well as from the local Water and Power Authority in the Virgin Islands. All have been favorable and each agency seems interested in implementing the recommendations that are suggested in the plan.

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Significant Events

The 1984 earthquake conference that was held in the Virgin Islands was probably the most significant event in terms of dissemination of research because it brought credability to the earthquake threat, via the endorsement of the many technical speakers, etc. The subsequent publicity that resulted also helped to convince the public and local officials about the seriousness of the earthquake threat.

HOW COULD THE APPLICATION PROCESS HAVE BEEN IMPROVED

One change that I would recommend is that more money be provided in the early stages. Because of the limited funding a lot of shortcuts had to be taken in the first phase of the program, particularly as they related to the hazard study, and this undoubtedly affected the input into the vulnerability studies and the final mitigation/emergency response plan. The end product might well have been the same, but both the DPO and the consultant would have felt more technically reassured, if time and money could have allowed them to utilize less of a judgemental process, and to check the initial research, before these early studies were used as input for the later work.

Secondly, I would recommend that in any earthquake prone community, an education or earthquake awareness program be started after the initial hazard study has been completed and before the vulnerability study is begun or at a a minimum, the two be conducted concurrently. In 1984 for example, the earthquake conference in the Virgin Islands as well as the results of the 1984 hazard study that were distributed to attendees, piqued the interest of many local officials and the general public. This interest could have been maintained if an education program in the schools and/or one for the general public had been started at that time, rather than wait until the vulnerability study was completed in 1985 or the final plan in 1987. As a result of this gap in interest between 1984 and 1987, the momentum for preparing for earthquakes in the Territory has diminished.

Finally, I question whether all of the information generated by the various technical studies on earthquakes is necessary, in order to get the emergency management official interested in developing a response plan for their community. In the quest or many federal agencies and others to develop more and more technical data on earthquakes, I wonder if we are not losing the interest of the state and local emergency management offcial, who for the most part is probably not technically oriented, but who is responsible for developing a plan to respond to the earthquake occurrence. Much of their interest may have been lost because they feel overwhelmed by the volume of technical data on earthquakes, data they don't totally understand, nor know how to relate to their everyday job and responsibilities.

Perhaps some time and money should be spent on developing more ways to assist the users at the grass roots level, with technical information on earthquakes that may have been developed at a much higher level, but which may or may not be relevant to the needs of the emergency management official, particularly at the local level.

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EARTHQUAKE HAZARDS RESEARCH APPLICATIONS--KENTUCKY

By
Corrine Whitehead
League of Women Voters of Kentucky
Benton, Kentucky

DESCRIPTION OF RESEARCH APPLICATION

The U.S. Geological Survey Open File studies of the New Madrid Earthquake Rift System have been distributed and used extensivly. The small phamplets on earthquake survival and explanation of earthquakes have been given out by the thousands to school children, civic clubs, news media, industrial facilities, engineering societies, college groups, churches, Scouts, and Home Makers Clubs through out all of the counties in the Purchase and Pennyrile sections of Western Kentucky.Each attendee was given a packet to take home and share with family members and neighbors.

The isoseismal maps have been copied by the thousands and shared with the public. Copies of the seismograph readings ,for one or two days ,have been used to show the small microearthquakes that are recorded on a daily basis ,to nearly all audiences. Slides of the Coalinga Earthquake in California and local slides that vividly show local land wave and liquifaction evidence has been used with all groups.

HAM RADIO OPERATORS AS VOLUNTEER TRAINERS AND EARTHQUAKE EDUCATORS

Ham radio operator Shemwell of Benton, Kentucky volunteered to train and organize a large group to act in an earthquake emergency. Operator Shemwell has trained and prepared scores of volunteers. Many have gone on for the examinations at Murray State University. Shemwell recruited and involved ham operators from as far away as Evansville, Indiana and Madisonville, Kentucky into a network. The Hams sought boom antennas and radios that are set up to withstand severe ground shaking. The group has met at the public library in Benton, Kentucky for about six years on a regular basis.

EARTHQUAKE INSURANCE

The purchase of earthquake insurance has followed presentations to civic, church and industrial groups and through advertising by insurance agencies and brokers. The most profound impetus for the purchase of earthquake insurance was generated when several banks required the insurance when customers sought loans for the purchase or construction of homes and business. The insurance industry estimates that 35% to more than 40% now have earthquake insurance for homes in extreme western Kentucky,among new insurance purchasers.

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RESUME' OF THE HISTORY OF THE EARTHQUAKE PROGRAM IN KENTUCKY

I read the Liu-Nuttli New Madrid Earthquake Preparedness Assessment report in 1980 and was shocked that Kentucky was totally omitted from the assessment. I called Dr. Ben Liu, who was then at the Argonne Labratories and Dr. Otto Nuttli, St. Louis University, research seismologist, to inquire if Kentucky is in such a totally hopeless position relative to the New Madrid earthquake threat, that the state was left out of the study? The information I was given prompted me to call the Kentucky Disaster and Emergency Services and inquire what preparations and plans they had made for a major earthquake. I was informed that no earthquake plans were in place and I felt there was a lack of real concern, or perhaps information and history of the subject.

A meeting of local officials, League members from Paducah, the Mayor of Paducah and concerned citizens met in January 1981 at Kentucky Dam to discuss the earthquake planning needs with the representatives of the Kentucky Disaster and Emergency Services, sponsored by the League.Plans were made for a regional conference to follow in July to be a public awareness effort, sponsored by the League of Women Voters of Kentucky and the DES. Dr. Otto Nuttli and Dr. Ron Street made the technical presentations and the Director of DES and personnel addressed the response and planning needs.A earthquake in Central Kentucky at Sharpsburg, earlier, had helped to add to the immediacy for earthquake planning. Since 1981, three regional conferences have been sponsored by the League in cooperation with the U.S. Geological Survey to involve and inform the public.

The Eastern United States Earthquake Conference in Knoxville, Tennessee gave an impetus and the inclusion of Paducah, Kentucky in the six cities earthquake hazards assessment was welcomed. The hope for some immediate action dwindled after the raw data was collected and left on the shelf by the Federal Emergency Management Agency for years before analysis. After analysis; the secrecy maintained by FEMA about the study did not set well. Most grassroots individuals believe in the "right to know", especially by those directly involved.

A major effort by the League of Women Voters of Kentucky to assure an independent Earthquake Safety Commission in Kentucky, by action of the General Assembly in 1983 was defeated due to lobbying against the legislation by the Kentucky Disaster and Emergency Services. States that have successful Earthquake Commissions have only been successful after an independent entity was voted by the state legislature to address earthquake related needs, on a full time and ongoing basis.

The failure to address earthquake survival and mitigation needs by the Federal Emergency Management Agency as a top priority in the Central United States and the resultant lack of priority assigned earthquake programs by their associate State agencies has placed the citizens in a position of almost a total loss of ten years of planning time in the Central U.S.The mixture of some earthquake related education techniques in with a list of other hazards has confused the issue in some schools which are using tornado life saving techniques during earthquake drills. General feeling is,that if there is a potential for a major earthquake why relegate the priority to the bottom of the list when it should be at the top? It is stupid, if the time frame is between now and the year 2000 to expect a major seismic event.

VOLUNTEER EARTHQUAKE HAZARDS EDUCATION

The well over 200 presentations, I have made to industry, churches, schools, various types of civic groups would have been impossible without the maps, pamphlets and materials furnished by the U.S.Geological Survey and Maryln McCabe of FEMA. The lack of a tribal memory generally found in Western Kentucky regarding the 1811-1812 great earthquake series made early presentations extremely difficult. Many audiences eyes just glazed over and an attempt to deny that earthquakes could or would happen in the Central U.S. That attitude has ceased to exist. Inquiries now are for specific information on how to survive and prepare for an earthquake. Each audience is very different and each presentation must be tailored to meet the needs of each group.One particularly rewarding aspect has been the response from school children, who after a presentation, designed seismographs and gadgets related to their ideas of earthquake measurement. I always urged each school group,including college classes to individually consider making a career of geology, seismology, and associated earth sciences. because of the intriguing nature of the New Madrid Rift System.

Particular credit should go to Fran Findley, a teacher in the Paducah school system, who took the earthquake planning needs seriously and set about to implement a policy for the Paducah schools. Fran has made more progress with a total school earthquake mitigation and survival plan. She is a champion who on her own time and initiative has succeeded as much as is possible in that location.

Bill Jackson, Administrator of the Regional Hospital , Madisonville, Kentucky is a champion who has worked tirelessly to bring his hospital forward with extra food, emergency response training and drills. Bill Jackson has spoken to scores of groups in the Madisonville and adjacent area on earthquake survival and preparation.He is a volunteer who has made great progress in educating the public and obtaining media attention.

Lourdes Hospital, Paducah, Kentucky has implemented earthquake resistant design in the construction of a new addition to the hospital. The cost was very substantially above what is normally expected; some $2 million additional dollars. If Lourdes Hospital does withstand the earthquake, it will possibly be the only medical facility in the region that has a chance of being operational or even surviving ground shaking,

The Fire Departments at Eddyville, Kuttawa and a far away town in Hart County, Kentucky asked for special earthquake programs. They have followed up with special training. I suggested to each that some of their personnel should attend the Emmitsburg, Md. FEMA facility for training. The Fire Department in Hart County is especially concerned because of the large amounts of natural gas stored by pipeline companies under ground in natural caves. The smell of gas greets one in the area and their concern is well merited since the Kentucky cave system is usually connected by hundreds of miles of underground passages.

Two new City Council members at Grand Rivers, Kentucky have declared that earthquake preparedness is their first priority when they take office January 1, 1988.

The many hours of work with local groups on a volunteer basis will never get the job done. The personal financing of such an effort while, there has been some degree of progress is unfair to every one concerned. The greatest need is for a GOVERNOR to act as a champion and get out front for earthquake safety and survival programs. Until earthquake safety programs with all segments of State Government involved in a dedicated and business like manner, the potential for an unnecessary disaster exists for the people of Kentucky.A study in future years may very well show the additional casualties due to the neglect by officialdom at the state and federal levels.

CURRENT NEEDS IN KENTUCKY

1) More seismographs located in the Western Kentucky area.
2) U.S.G.S. map the faults in the area west of the Tennessee River.
3) Open File publications for the high schools and colleges in Western Kentucky.
4)Fault mapping on the Wabash Arm of the New Madrid System and to the North East.

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6) Determine how to get emergency field hospitals into place in what will be isolated areas (West of the Tennessee River, Between the Lakes etc.).

7) Emphasis the clean up of toxic and hazardous waste below dams and in sensitive areas. Cut off the use of areas along rivers for disposal of hazardous and toxic substances.

8) Assure instrumentation at large reservoir dams such as Kentucky and Barkley dams to make evacuation of populations below the dams a possibility,prior to failure of the high dams, during earthquake activity.

9. Public emphasis on the liability factor involving, chemical industries, nuclear enrichment facilities, public officials, and school administrators, who have not taken timely action to prepare for survival of their personnel and public charges. One plant in Calvert City, Kentucky stores the largest amount of chlorine in the U.S. according to involved personnel, yet no action has taken place to train employees on how to escape or survive. (Most engineering personnel express the sentiment that they will "never get to the front gate when the earthquake happens".) These are real worries that burden workmen who have more knowledge than given credit for by management. All or most feel helpless and doomed under the present criteria in the work place.They seek information to try to make their families safe on a regular basis. Meanwhile representatives of engineering firms that are independent consultants, speak openly about the critical state of disrepair the chemical plants show. Rusted out piping, tanks that leak, valves that are in poor repair. One representative indicated some could "blow" at any time, without a ground shaking event.

SEISMIC MICROZONATION:
AN APPROACH TO SEISMIC LAND USE PLANNING

by

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1 Introduction

Microzonation is one of the most discussed and least applied methods with the potential for large scale reduction of earthquake risks. It has been before us as a promising mechanism for reducing earthquake hazards in a comprehensive manner for at least the past two decades. Microzonation's genesis can be attributed to the observation that different sites with comparable locations have different responses (that is, damage potential). It is well established that site conditions can influence observed ground motion in major ways. This is not a new notion, having been noted in virtually every historic technically recorded earthquake, [F1]. Medvedev [M1] assessed the then limited set of available California strong ground motion data and developed correction factors for the assignment of MMI values to observations of damage. His method (and those developed by others) reduces or increases the observed MMI value by a fixed number so that all reported values reference a common ground condition. The specific adjustment values are assigned based on measurable, quantitative aspects of the several soil and rock types. Everndon and Thompson [E1] have furthered this analysis and reported intensity correction values for rock and soil types commonly found in California. These adjustments range from decreases of 3 MMI units (for granitics) compared to saturated alluvium to increases of 1.5 for saturated alluviums with shallow water table. The MMI scale is a qualitative representation of the observed damage to a standard structure, and thereby a qualitative measure of the observed motion ground. A further observation in the Long Beach Earthquake [M6], where on saturated soils rick buildings were damaged less than similar buildings on stiffer soils, among others, indicates that when the period of the site and building are substantially different the damage to the building can be either increased or decreased compared to the damage for different structures located on the site, see also [T5]. Thus the relative vulnerability of a place depends on both the site's and building's characteristics.

This reproducible, if imprecise, observation begs that there be purposeful incorporation of these observations in policy and practice of earthquake hazards reduction, not-with-standing the deep and abiding difficulties in using intensity to represent ground motion as noted by

Steinbrugge [S2] and Thiel [T1]. The leaders in the development of this notion were the Soviets and eastern Europeans. The basis premise of their work focuses on identifying and predicting the relative hazard of sites. This focus on the relative hazard and risk of sites, in a planned economy, offers the means for influencing development decision, although more in theory than in actual practice. The ideas of microzonation were taken up and expanded in the U.S. to include a comprehensive, systematic approach to land use planning and development so that this development accommodates the relative site hazards and minimized some unstated functional risk exposure metric.

Land use planning and site selection are effective measures to mitigate the future impacts of earthquakes. Every major report, [O1], planning document, [F2], and policy statement, PL 95-124 [P1], of recent years has noted the potential benefits of land use as a method of accommodating earthquake hazards at low direct cost. The argument in its favor usually proceeds from the observation that areas where landslides, liquefaction and fault rupture are likely to occur can be identified through the fact that they have substantial damage potential to the point that avoidance is an effective strategy to render the hazard harmless to buildings. The observation that open space is needed in the community completes the argument by posing a benefit of leaving the land undeveloped. The other principal earthquake hazard, ground shaking, is accommodated through building codes and construction practices. Through this combined strategy mitigation of the physical impacts is presumed. (Preparedness planning and all the other adjustments are equally important but directed to limiting the consequences of the physical damage, [T4].)

The early development of microzonation in the U.S. might be best described as exclusionary (avoid fault traces) or investigative. Following the San Fernando Earthquake of 1971 the state of California enacted two land use related laws. The first required that all counties incorporate into their master plans (required under other state laws) a seismic element [C3]. Since these plans generally focus on land use and subdivision regulation, regulation of unusually hazardous sites during earthquakes was quite natural--particularly for sites of unacceptability high possibility of liquefaction, faulting and landsliding. The second, termed the Alquist-Priolo Act zones [C4], required that narrow zones around potentially active fault traces be identified and that any permits for construction in these zones have geotechnical investigations to determine if there is a potential rupture plane passing through the site. Coincident with these initiatives, there were efforts for state and Federal dams to determine possible flood plains from dam rupture, in part triggered by the seismically induced near collapse of the Lower Van Norman Dam in 1971. These flood plains are now incorporated as a matter of course in the FEMA flood plain maps that provide the basis for federally underwritten food insurance, a program that has used land use restrictions as a major element of its loss exposure control strategy. A review of recent California activities is contained in Wyner and Mann's assessment of local seismic safety policies [W1].

The observations of different site responses has become part and parcel

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of engineering practice and building code regulation of construction in the private sector. The code, particularly as recommended by the Structural Engineers Association of California [S1] has had a site condition parameter for many years. The most recent recommendations include specifications of conditions under which geotechnical site investigations must be performed. Without going into the specifics, the essence of current practices are that the differences of site response have been characterized by different spectra, base shear coefficients and the like that depend on both the site's and structure's characteristics.

To date in the United States, that is to say principally in California, microzonation's role in the public process has been principally one of exclusionary land regulation and very general planning guidance, while its role in the design and consulting professions has been one of proper characterization of the site's hazard for proper design and construction.

Microzonation has been the subject of three international conferences held in the past 15 years on the subject. Upon examination of the contents of these proceedings [M5] it is clear that there is relatively little agreement on what this word means. Most of the papers focus on general earthquake research problems, for all practical purposes comparable to the a World Conference. The operational definition of "microzonation" in these proceedings range from determining site spectra, to preparing uniform probabilistic hazard and risk maps, to general discussions of the urban planning process. For the purposes of this paper microzonation is taken to mean a comprehensive process of making land use development and utilization decisions, whether taken in the public or private sector or whether the process takes place in the post earthquake period or not.

An objective assessment of the microzonation related activity in the past decade would leads to the observation that:

- Site hazard assessment research has been driven by both the professional need and academic interests.
- Land use regulation research has been driven principally by a desire to understand the implications of specific public policies.
- The efforts to develop a real and regional risk maps has been driven by either academic interest or public agency desires to estimate the losses incurred in given earthquakes.
- Microzonation, as a systematic, comprehensive approach to management of earthquake vulnerability has received at best nominal research attention and even less applications attention.

Clearly research efforts have played a large role in supporting the development of currently used site hazard analysis and probabilistic hazard and risk assessments. Until Cornell's [C1] classic probabilistic risk analysis research paper, such assessments were not very scientifically satisfying. The observations of site failure in Niigata and Anchorage in the 1964 earthquakes and the relative building performance in Caracas in 1967 can be traced as progenitors of today's technology of site response analysis. William Spangle's and George Mader's research efforts on seismic land use planning and related efforts, particularly on pre-earthquake planning for post earthquake reconstruction, have been the seminal research efforts [S6].

Why is it that a possible earthquake risk management approach with such apparent positive benefit has been so scantly used? The easy answer is that there is a clear and apparent mismatch between the quality of what we know about earthquake hazards and the demands of the market place, with the latter wanting more precision than the former supplies. At a deeper level, as discussed in a companion paper by Thiel on utilization [T3] the public and professional community may have implicitly evaluated this research and found it to be professionally or politically naive, hard to find on specific issues, not responsive to the multiple hazard environment, and out of date. This is not unexpected since little systematic research has been performed.

The author's assessment is that broadly interpreted microzonation may be approaching the time when it warrants more intensive effort. There have been a few efforts in the international community to develop such applications, of which two are notable:

1. Microzonation of the Balkan region focusing on hazard and general mitigation approaches, conducted under the auspices of the UN [B1].
2. Microzonation of the Ech Cheliff region of Algeria following the El Asnam Earthquake in 1980 [A1], [H1].

The following sections explore the planning process, existing tools to support microzonation planning, a proposed approach to microzonation and the answers to a series of specific questions.

2 The Planning Process

One of the most important observation on the evolution of a communities earthquake hazards is that a hazardous site once occupied is likely to be occupied for a very long period of time, through several successions of buildings. As time progresses the development of one site puts pressure on adjacent site for harmonious or supporting development. In this way the development decision of one hazardous site can and will shape the earthquake vulnerability of the community in the long term (several centuries or more?). Thus, it is clear that current land use decisions have substantial influence on the communities present vulnerability and can have massive implications for future vulnerability.

Authority for land use planning within the public sector generally has been delegated to the local level. Usually the land use planning process has the general plan as its core. This is the long-range policy guide for the future development of a planning area, looking ahead for the next 20 or 30 years. This plan should be comprehensive and thus consider all types of land use and community functions. It should be general in nature since planning in detail for that time period is obvious impractical. Also, it should be capable of change from time to time as conditions and community values change. It should, however, present the best thoughts of the community at any one time of the type of future envisioned. It may govern some development that takes place in the near term as well as affect other development that will take place in the far term.

The general plan is of course useless unless there are tools for its implementation. For implementation the community usually relies heavily on several devices: zoning regulations, subdivision regulations, to some extent on grading and building codes, and on capital improvement programs (investments in transportation systems etc.). All of these devices are principally short-range, that is, they affect the immediate use and alteration of the land, and they should be based on the general plan. In California, state law requires that all cities and counties have officially adopted general plans and that zoning ordinances be consistent with these plans. Thus the general plan has taken on major importance. With regard to earthquake hazards, the state has further required that the general plan have a seismic safety element, and in this way has required communities to include earthquake hazards in their planning process (with varying degrees of success since the prescription does not say what the plans must entail or establish minimum quality standards).

Virtually all states have empowered local authorities to regulate the use of land. Table 1, from Petak and Atkisson [P2], gives a small indication of the actions that states have taken, while Table 2, taken from OSTP report on Issues for an Implementation Plan [O1], illustrates a few of the federal laws on the subject. Clearly land use regulation has become part of the fabric of governance. Unfortunately, when planning was adopted in the United States starting in ernest in the 1920's, another trend also was established: zoning would be more prevalent than planning. Early zoning laws divided cities into three exclusive-use districts: residential, commercial, and industrial, [M2]. Each district would be allowed only the designated type of development. The separation of zoning from a planning base removes the question of the values against which competing uses of land can be measured on a community basis. Clearly the delineation of zoning districts has major influence on the value of land, and thus provides a fertile ground for political interests.

Two important developments have occurred in land-use regulation at the local level. First, in increasing numbers, local governments have adopted growth management policies consisting of more than just zoning ordinances. In most instances considerable conflict has occurred over the adoption of these ordinances, no doubt because the impacts of such approaches are more difficult to predict than those of traditional exclusionary zoning. Of greater relevance to incorporation of earthquake hazards reduction policies has been the move by local governments to include more performance standards

Table 1 — Land use and building code authority in the United States, from Petak and Atkisson, [P2].

STATE	GENERAL AUTHORIZATION		HOME RULE POWERS		EXTRATERRITORIAL CONTROLS			PRIOR PLANNING REQUIREMENTS			ENABLING AUTHORITY FOR ADOPTION OF INTERIM REGULATIONS		SENSITIVE LAND USES INCLUDED IN REGULATIONS								COMPREHENSIVE PERMIT SYSTEM	COORDINATED INCREMENTAL PLANNING	MANDATORY LOCAL PLANNING	DIFFERENTIAL ASSESSMENT LAWS	STATUTES AUTHORIZING ADOPTION OF FLOOD PLAIN REGULATIONS BY STATE AGENCIES	LOCAL FLOOD HAZARD REGULATIONS SPECIFICALLY AUTHORIZED			STATE
													SUBDIVISION			ZONING													
	SUBDIVISION	BUILDING CODE	GENERAL	SPECIAL REFERENCE TO LAND USE	SUBDIVISION	ZONING	BUILDING CODE	COMPREHENSIVE PLAN FOR ZONING	COMPREHENSIVE PLAN FOR SUBDIVISION	FLOOD OR DRAINAGE LANGUAGE	ZONING	SUBDIVISION	PUBLIC UTILITIES	AGRICULTURE	LARGE LOTS	AGRICULTURE	NON-CONFORMING USES REGULATED	WETLANDS	POWER PLANT SITING	DESIGNATION OF CRITICAL AREAS						ZONING	SUBDIVISION	BUILDING CODE	
AL		●	●	●	●			●	●	●				●	●	●			●						●	●	●	●	AL
AK								●					●	●	●	●	●		●			●		●			●		AK
AZ	●		●		●	●				●			●						●			●		●	●	●	●	●	AZ
AR					●	●				●			●	●	●	●			●					●	●	●	●	●	AR
CA	●	●	●		●			●		●	●		●			●	●		●			●		●	●	●	●		CA
CO	●		●		●			●	●	●	●		●	●	●	●			●	●				●	●	●	●	●	CO
CT		●	●					●	●	●			●	●	●	●		●	●			●		●	●	●	●		CT
DE			●					●					●			●		●				●		●		●	●		DE
FL	●	●	●			●		●	●				●	●		●	●	●	●	●	●	●	●	●		●	●		FL
GA	●	●	●	●	●	●		●	●	●			●	●			●	●				●				●			GA
HI	●							●					●	●	●	●			●	●	●	●		●	●	●	●	●	HI
ID			●		●			●			●	●	●				●						●	●					ID
IL			●		●	●				●									●					●	●	●	●	●	IL
IN		●			●	●			●	●			●	●	●	●	●					●		●	●	●	●	●	IN
IA	●	●	●	●	●	●		●					●	●	●		●							●	●	●			IA
KS	●		●		●	●		●	●				●	●	●										●	●	●		KS
KY					●	●		●	●	●	●	●							●					●	●	●	●		KY
LA			●	●				●		●			●		●	●	●	●								●	●	●	LA
ME	●	●	●					●	●				●	●		●	●	●	●	●	●	●	●	●	●	●			ME
MD		●	●	●	●			●	●	●			●		●		●	●	●	●		●		●	●		●		MD
MA		●	●										●	●	●	●		●	●					●	●	●	●		MA
MI	●		●	●				●	●	●	●		●	●		●								●	●	●	●		MI
MN	●	●	●		●	●		●			●		●	●	●	●		●	●	●		●		●	●	●	●		MN
MS								●					●		●		●	●							●				MS
MO			●		●	●		●	●									●	●					●	●				MO
MT	●	●			●	●	●	●		●	●		●						●	●		●	●	●	●	●	●		MT
NE			●		●	●	●	●	●				●	●		●			●				●	●	●	●			NE
NV	●	●	●					●		●			●			●	●		●	●		●	●	●		●	●		NV
NH								●			●		●	●	●	●		●	●					●			●		NH
NJ			●		●	●		●		●			●			●		●	●					●	●	●	●		NJ
NM	●				●	●	●	●		●			●	●	●	●	●		●			●		●		●	●		NM
NY	●	●	●					●		●			●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	NY
NC		●			●	●	●	●					●	●			●	●				●		●	●	●			NC
ND	●				●	●		●	●				●	●	●				●					●		●			ND
OH		●	●		●			●	●				●	●					●					●					OH
OK			●					●	●	●			●		●									●	●				OK
OR	●	●	●		●	●		●			●		●	●		●			●	●		●	●	●			●		OR
PA			●					●		●			●			●	●	●	●	●				●	●	●	●		PA
RI		●	●					●					●	●	●	●		●	●			●		●		●			RI
SC		●			●			●	●	●			●	●		●	●		●					●		●	●		SC
SD					●	●		●	●	●	●		●	●	●	●	●			●				●					SD
TN		●	●		●	●			●				●	●	●				●							●	●		TN
TX			●	●	●			●					●		●	●	●	●						●		●	●	●	TX
UT			●					●	●	●	●		●		●	●	●					●		●		●	●	●	UT
VT	●							●		●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	VT
VA		●			●					●			●	●	●	●		●					●	●		●	●		VA
WA	●	●	●		●			●			●		●	●		●	●	●	●			●		●	●	●	●		WA
WV			●	●					●	●			●	●	●										●	●			WV
WI	●	●	●		●	●		●		●	●		●	●	●	●		●	●	●		●			●	●			WI
WY					●			●	●				●	●	●	●			●			●	●	●					WY

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Table 2 -- Federal programs or legislation affecting land use that could be amendment to encourage State and local governments to adopt earthquake hazard reduction measures include, taken from [01]:

Agricultural Land Protection (S-106, 1977)
Airport and Airway Development Act, as amended
Alaska Native Claims Settlement Act
Bankhead-Jones Farm Tenant Act of 1937
Bureau of Outdoor Recreation Act of 1962
Clean Air Act of 1970, as amended in June 1974
Coastal Zone Management Act of 1972, as amended
Concessions Policies Act of 1965
Disaster Relief Act of 1974
Estuarine Areas Act of 1968
Federal-Aid Highway Act, as amended
Federal-Aid in Wildlife Restoration Act of 1937
Federal Civil Defense Act of 1958
Federal Energy Administration Act of 1974
Federal Land Policy and Management Act of 1976
Federal Power Act of 1920
Federal Property and Administration Act of 1949
Federal Surplus Lands for Parks and Recreation Act
Federal Water Pollution Control Act Amendments of 1972
Federal Water Project Recreation Act of 1965
Fish and Wildlife Act of 1956
Fish and Wildlife Coordination Act of 1974
Flood Disaster Protection Act of 1973
Forest and Rangeland Renewable Resources Planning Act of 1974
Historic Preservation Acts
Housing and Community Development Act of 1974
Land and Water Conservation Fund Act of 1965
Multiple Use—Sustained Yield Act of 1960
National Environmental Policy Act of 1969, as amended
National Forest Management Act of 1976
National Trails System Act of 1968
National Wild and Scenic Rivers Act of 1968
National Wilderness Preservation Systems Act of 1964
Noise Control Act of 1972
Payments in Lieu of Taxes Act
Pickett Act of 1910
Public Works and Economic Development Act of 1965
Railroad Revitalization and Regulatory Reform Act of 1976
Solid Waste Disposal Act of 1965, as amended
Surface Mining Control and Reclamation Act of 1977
The Snyder Act of 1924 and Indian Reorganization Act of 1934
Trans Alaska Pipeline Authorization Act of 1973
Water Resources Planning Act of 1965

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in their zoning ordinances and the subsequent move away from the older zoning system based upon predefined development zones, [C2]. This appears to offer an opportunity for a more expansive interaction of earthquake hazards concerns to enter the planning and zoning process in more than a cursory way.

By and large earthquake hazards have entered the planning and zoning processes in two ways. First, and by far the most prevalent, through prohibitions that force development to avoid or render harmless the specific site ground failure hazards, e.g. liquefaction, landsliding or fault traces. This is sourced in the seismic safety element required in California to be part of the general plan. In this manner the identified and mapped hazards are avoided. In some cases, usually at the subdivision level or for large developments, there is a requirement that a geotechnical investigation identify the site's conditions so that hazards can be avoided in building placement. Second, through the conduct of land capability analyses that identify the hazard conditions, through a simple procedure (to be discussed below) that determines the relative preference for development based on the vulnerability of specific development options to the hazards of the site. Land capability analysis is the only approach known to the author to be currently used to assist the general planning process to accommodate earthquake hazards.

3 Current Planning Tools

There are several approaches currently used and discussed in the literature for the direct use of earthquake hazards information in the direct zoning and site development process. These are principally avoidance strategies and fall in the general realm of subdivision regulations, [M3]. Two methods incorporating seismic hazards issues are currently available that can assist the general physical planning process and the zoning regulations that may evolve from them. They are: land capability analysis and a locational approach to seismic risk mitigation.

3.1 Land Capability Analysis

Land Capability analysis is an approach that allows the incorporation of seismic conditions into the general planning process. It is a systematic method for collectively evaluating a number of environmental factors that affect the capability of specified land areas to support particular land uses. The seismic safety element of Santa Barbara County used this technique to rank areas in terms of their relative seismic or geologic hazards: ground shaking, tsunami, liquefaction, slope stability, expansive soils, soil creep, compressible/collapsible soils and high ground water. Fault rupture was separately treated. The county was broken up into 90-acre grid cells and each of the geological conditions rated on a scale of 1 to 3: 1 being no or low hazard, 2 a moderate hazard or condition and 3 a high hazard, [M3]. Each hazard is then given a weight representing its importance relative to the other hazards. The weight is a judgement based on three considerations: consequences, frequency of occurrence and difficulty of mitigation. The Geologic Problem Index (GPI) is obtained by summing the product of the weight and the rating for each of the hazards of the site. Based on the GPI, general categories of consistent land use are recommended in the element. Among the five categories used by Santa Barbara are: consider areas in Category V (severe) for natural areas, recreational or agricultural use, possibly low density use; consider areas in Category IV (moderate) for low density use or development, cost of development may be to high. The principal features of this application are that the hazards themselves are the only considerations in determining what development is preferred and that the heuristic for combining these hazards is very simple.

A variant of this technique is to vary the importance (weights) of the geological condition, with the type of development that could take place on the site. Mader and Thiel, [M4], applied this variant to develop recommendations for the reconstruction of El Asnam following the 1980 earthquake. In this application the weights associated with each geological condition vary for each type of land use, thus yielding an index that reflects both the hazard severity of the site and its importance in considering a particular type of development. A limited number of areas of comparable index values are formed to provide a planning basis for development. In this way the relative preference for different sites can be compared, first for the particular type of development and second among competing types of development, although the later is at some risk since the weights are not co-measurable. Figures 1 and 2 are illustrative of the results of such analyses.

Both the Santa Barbara and Algerian examples show how subjective the results can be: in both cases the assignment of the weights, based on professional judgement (often reached through a consensus discussion) determine the outcome of the process in ways that are not clear. Sensitivity analysis may help the user understand the consequences of these assignments. Common complaints about such approaches are that they give the technician full control of the process, the results are not very robust, it does not accommodate current usage patterns and that a flaw in the analysis is the need for different patterns of adjacent uses. While these criticisms are valid, they fail to note that land capability analysis is meant to be a tool, not a decision maker and that the heuristic used for combinations of hazards is presented as a simple, intuitive one.

3.2 Locational Approach to Seismic Risk Mitigation

Scawthorn, [S3,4], has used a regional economic modeling approach to regional segregation of community functions. He optimizes an objective function that takes into account land cost, capital costs, transportation costs and seismic damage with a series of production constraints on the amount of land available for different uses among others. The details of

Figure 1 — Microzonation map for part of Ech Cheliff, [M4].

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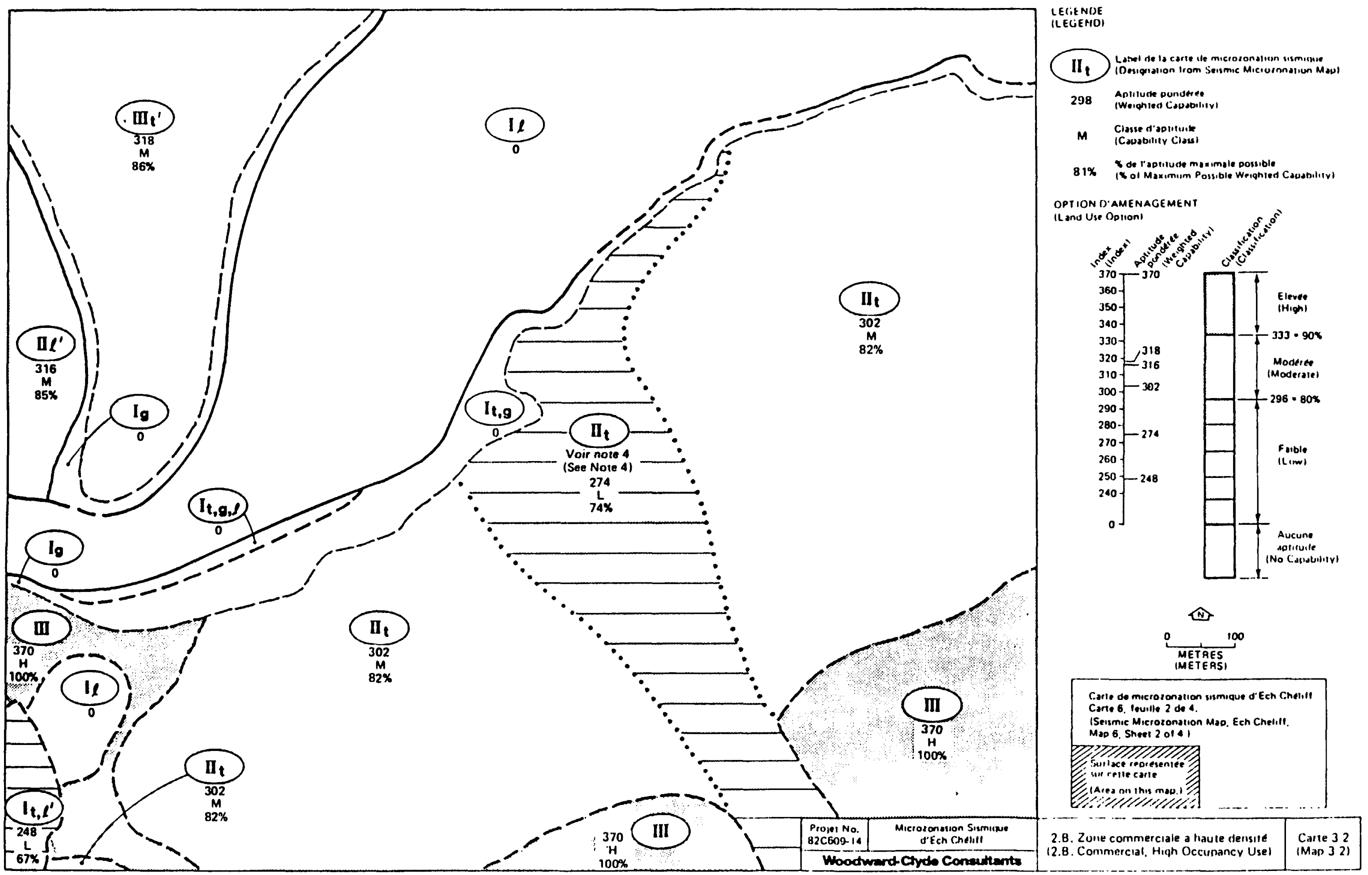

Figure 2 -- Land capability map for essential buildings or facilities for part of Ech Cheliff, [M4].

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this model are not discussed nor reported to date, thus it can not be evaluated fully. The power of this approach is that it allows the determination of a configuration of land uses that minimizes the net cost to the community of that development including the expected impacts of future earthquakes. In his particular application to San Francisco he notes that the current configuration of uses yield "operating costs" of $1.690 billion (private and some public costs associated with the configuration) plus a seismic component of $0.312 billion for a total of $2.002 billion imputed cost of the configuration. Optimizing structural and occupancy locations, but holding the central business district location, that is specifying a general plan, reduces the annual seismic damage by $76 million. By the relatively minor shift in land use policy a 4% reduction in seismic vulnerability accrues. Note that this is the present value return per year, not the total present value savings over the lifetime of the policy. As with all models, it is of course very sensitive to the myriad of constants, preferences and functional dependencies specified to formulate the model. Nonetheless, it yields interesting results that warrant further development. This analysis suggests that there is a substantial benefit to be gained if planning has available to it soundly developed tools to aid in the evaluation of different policies. One of the difficulties of potentially using this model in actual planning processes is that the specification of the models parameters is rather removed from knowing what the consequences of these actions are. Thus a user is likely to feel that this is a cold, theoretical method that yields results that are easily challenged.

4 A Microzonation Approach to Planning

The fact that seismic risk is but one of a community's concerns, usually a lesser one, places microzonation at a distinct disadvantage, since it is viewed as a single purpose approach to a multi-attribute problem. Thus if microzonation is to be successful it must become an element in an overall planning process. It is one of the purposes of this paper to propose another approach to microzonation that guides the formulation of a general plan to include seismic considerations through active user specifications of the performance characteristics specified by the policy maker in non-economic terms.

There is a clear need for development of microzonation as an orderly element of the planning process. The balance of this section suggests a series of criteria that microzonation techniques should meet and suggests an approach to meeting these criteria. For the purposes of this section, microzonation is taken to mean a comprehensive process of making land use development and utilization decisions.

We start with the premise that there is no absolute in the determination of the appropriateness of the development of a particular parcel of land. The following criteria are suggested to guide the selection of a microzonation approach.

1. Must be capable of accommodating the individual preferences of the community.

   Each community has different conditions and aspirations. Any system that does not accommodate this fact at the beginning is doomed to fail.

2. Focuses the making of value judgments by those that are professionally capable of rendering the judgement

   Each profession should be asked to exercise its skill and not to ask them to make judgments in areas and on topics for which they have little or no expertise: structural engineers should not specifying site conditions or development preferences and planners should not make structural capacity estimates. Unfortunately professions are often asked to cross the bounds of their expertise.

3. Should be non-mathematical, to the degree possible, to avoid the problems some people have in expressing themselves in such terms; that is there is a preference in collecting judgement and value data in qualitative statements and rankings, not by assignment of a number.

   Mathematics is not the natural language of most individuals, particularly those who are concerned with aesthetic values and planning. They tend to be put off by and leary of the results of mathematical process that they do not understand. Most land use and development processes are best stated in terms of linguistic statements that show the degree of relationship, not the specific mathematics of that relationship.

4. Must yield results that allow the comparison of different land uses for the same parcel and of different parcels for the same land use; that is, all measures must be comparable and consistent.

   The key to being able to use a land use capability tool is the ability to compare the results for different uses and parcels; without this ability, the tool is of limited practical use.

5. Should allow the interrelation of land uses preferences in adjacent and distant parcels to each other.

   The preference for a given land use for a parcel is clearly a function of the use of adjacent parcels. If the system results in the location of low density housing near hazardous industry, or far from a commercial area, these will be noted by the planner, and the results likely rejected as unrealistic.

A simple sequential process that meets these criteria is described in

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Table 3 -- Typical environmental properties of a parcel.

fault trace
intensity of earthquake ground motion
slope
land slide potential
liquefaction potential
bearing capacity
depth to ground water
degree of flood hazard (coastal, riverine, dam rupture)
contamination of the site by hazardous materials
tillability
soil percolation rates
historical significance
aesthetic qualities

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Table 4 — Possible land uses

- Residential
  - low density
  - moderate density
  - high density
- Commercial
  - moderate density
  - high density
- Industrial
  - light manufacturing
  - moderate manufacturing
  - heavy industry
  - hazardous process industry
- Agricultural
  - farm land
  - open space
- Recreational
  - park land
  - aesthetic view
  - historically significant
- Utility
  - water supply or treatment
  - electrical generation
  - waste disposal, benign materials
  - waste disposal, hazardous materials
  - transportation
  - port

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the following steps:

1. Specification of the geological and geotechnical properties of the site, with confidences in their specification. This should include all the conditions that the parcel has that might bear on its use, not just earthquake related conditions. A list of the environment conditions could include, but is not limited to those of Table 3. The properties of the site are sometimes very specific, but more often they are qualitative statements or judgments that are the result of professional opinion.

2. Development of the relationship of a given hazard condition or non-condition on the appropriateness of a particular land use by a panel of experts familiar with the hazards, engineering performance and local construction practices. Land use conditions include all the residential, commercial, industrial, recreational and agricultural uses the land may be used for. (Independent of the parcel but dependent on local construction practices.) Table 4 illustrates one possible universe of land uses. A particular parcel could support any of the variety of land uses which the community may require or desire. The universe of land uses might include any of those listed in Table 4. These have been organized into the six basic groupings residential, commercial, industrial, recreational, utility and agricultural. The list of Table 4 is by no means unique. It could have all the entries of the communities zoning classifications, or any other list of exclusive categories. The key point is that the systems framework for analysis should not depend on the set defined by the user, but only on the fact that the supplied list is an exhaustive set of uses that the community is interested in having or in regulating. It should be remembered that just because a land use category is listed does not mean that there will be sites for which it is an appropriate developmental use or that the community should commit land to that use. The relationships that expresses the appropriateness of a given land use for a given geological hazard circumstance should be value neutral. They should *not* express the preference for different types of development, but relate the capability of a site to support a land use *if* the parcel is developed with that use; it is a purely technical capability.

3. Determination of the capability of each parcel to support each of the candidate land uses based on the properties of the site and the appropriateness of such a land use. Given the array of relationships among possible land use categories and the physical attributes of a parcel, the capability of the parcel can be "ranked" based on its support for the particular land uses. The relationships need to be combined so that the preference, for a given land use is determined from the attributes of the parcel.

4. Specification of the preferred spacial (distance) relationship among different land uses from a panel of local officials and citizens, in essence an expression of community values. One of the key historical

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underpinnings of land use regulation is the desire to prescribe the physical interrelationship of different land uses. In its simplest form this is a kind of use segregation that expresses the preferences for the proximity of different land use categories. Such statements might take the form "Housing should be moderately far from heavy industry." This addition constitutes a weighting of the necessity of satisfying the stated constrain. These relationships express the primitive values of the community, for through them the preferences for separation of functions is expressed.

5. Specifications of the barriers, or micro-constraints between different parcels that effect the land uses of the respective parcels, for instance rivers that separate two land uses that prevent them being used for companion purposes. Among the barriers that may be important in determining optimal land use allocations are those that relate to topography (ridge lines, stream and river channels, wetlands, flood planes), utilities, particularly transportation (bridges, roadways, freeway on-off ramps) and environment (air quality, visual site lines, water quality). These barriers are physical constraints used in measuring the preference for distance between land uses and thus are deterministic.

6. Specification of the overall requirements (macro-constraints) on a given land use, that is minimum and/or maximum areas to be dedicated to each land use. There are three types of natural constraints for land uses: first, the requirement that a given parcel maintain its current land use; second, that a minimum, maximum or specified area in the community be in a given land use; and, third, that the land use for a given parcel can be selected from a reduced group of possible land uses.

7. Determination of alternative, possibly optimal, land use patterns based on capability of the site to support land use, the spacial relationships among land uses and the constraints. We are now ready to determine the preference for a given land use distribution among the several parcels using a particular model interrelating the various properties and desired relationships and interrelationships. The selection of the distribution that is most preferred is made by selecting the one with the highest consistent with the model and the constraints.

The approach proposed allows the determination of the preference for a given allocation of land uses among the parcels under consideration. The values of the preference function provides the preference measured in terms of the values of the community and professional opinion on the relative capacity of the physical land to support that use. It is natural to ask if there is an optimal allocation that meets all the constraints and, if so, what it is. This is a complex problem of linear (or possibly nonlinear, depending on the relationships assumed) programing problem over integers that is well posed and commonly solved using any of several simplex methods. It is expected that in most situations the solution will exist, particularly since the possibility of over specification is controllable. To review, we have started with a series of capability statements that represent professional opinion on the appropriateness of a parcel with a given set of physical characteristics to support a given land use. Using the values of the community expressed through a set of preferences for physical placement of parcels of different land use, and the constraints on specific parcels and the area of different land uses we have been able to determine a pattern of land use most consistent with both the physical capabilities of the land and the values of the community.

Such a microzonation system could be used to support a variety of circumstances: e.g. general planning, post disaster planning, zoning ordinances, capital investment planning, hazard mitigation, and subdivision planning. The products can be used at several different levels. First, the process of determining the capability of a parcel to support a given land use through the combination of expert opinion on suitability is useful in itself in the investment decision process, as well as the permitting process. Second, the preference for a given proposal for development can be easily compared to os. It should be noted that with minor modification (only in the specification that preferences and constraints are given in terms of cost) this entire process can become an investment or return on investment methodology. Third, optimal allocations can be found.

The development of this methodology focuses on the problems posed to a community when it must accommodate earthquake threats (ground motion, faulting, soil failure, etc.) and desires to use the communities physical configuration as a part of its mitigation strategy. Since earthquakes are but one of the physical conditions that effects building decisions, other conditions should be examined including floods. When choices are forced, they should be made to assure the ability of the methodology to accommodate earthquake issues. It is expected that this will not be a severe limitation.

5 Specific Questions

Several specific questions were contained in the call for papers. The previous sections have addressed these in a nonstructured way. The questions are difficult to respond to for microzonation when the term is taken in its broad context, ranging from site spectra determination to risk maps and to urban planning. The latter is the only area where these questions will be addressed. The best application of microzonation in the sense of a comprehensive planning approach to earthquake hazards reduction is the Algerian microzonation application, see Hays [H1] and Mader and Thiel [M4] for details. Special attention is called to the companion paper on enhancing utilization presented at this meeting [T3]. The questions will be addressed in order.

Question 1.

What were the planned and actual outcomes of the specific application? The problem posed in this application was to advise the CTC of the Algerian government on how the reconstruction of Ech Cheliff should proceed after the 1980 earthquake. They were particularly concerned with how the reconstruction and repair process might effect the regions vulnerability in future earthquake. (There had been a serious, damaging earthquake in 1954.) The original proposition as described in the RFP for the study involved the full range of issues from hazard identification through regional planning. The project actually performed focused on developing risk and hazard maps for the region and general guidelines for how to incorporate these results into codes, land use and planning efforts, [A1]. Individuals involved in the project included professors, government researchers, and consultants. All had a direct relation to US research activities pursued under the NEHRP. The performing team and individuals serving as advisors to CTC through UNESCO are believed to have been selected based on their state of the art knowledge. Thus the time delay is minimal, but not typical for other possible applications. This is probably typical of what would be expected for any area where there is no extensive history of successful applications. In assessing the genesis of why this project was pursued (and most post earthquake environments have not triggered such actions), there are two central factors. First, there was a key individual that had influence and knowledge who advocated for "doing the job right." Second, the government agency involved had previously supported a low level project to assess the seismic aspects of the national building code and had become familiar with the technical issues involved in earthquake hazards reduction. Thus he was able to act as an internal advocate who could assert the positive benefits of microzonation when the subject was raised.

Question 2.

What specific research studies contributed to the knowledge base required for the application? This was an integrative project, thus many project influenced the effort. Probably the most influential were those that were pursued by the investigators and their consultants directly. The individuals (engineers, seismologists, engineering seismologists, and planners) all had been supported by NEHRP; individually they were each committed to applications and consulting effort from the start of the research efforts; thus applications was to be expected. The application was user driven, while the research efforts on which it was based were probably equally divided between research and applications driven.

Question 3.

What specific translation activities helped contribute to the success of the applications? Most prominent were: 1) development of geologic methods to assess relative activity of faults; 2) probabilistic hazard assessment methodologies; 3) geotechnical site response assessment procedures; 4)

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building code development, particularly ATC-3, and the professional code development process of SEAOC, which is influenced in substantial ways by research and field investigations; and 5) problem focused research on land use planning.

Question 4.

What specific dissemination events contributed to the success of the applications? The most significant are probably three: 1) the ATC and BSSC based code development process and publications; 2) technical reports, papers and conference publications; and 3) post-earthquake reconnaissance reports and research findings.

Question 5.

If the applications process could start over, what factors (people, programs, process, plans, etc.) would you change? The most important single factor that would improve this and other potential applications efforts in microzonation would be:

1. Support more participation by influential individuals in the research and technical dissemination process.

2. Support of more projects, like the ATC-3 and BSSC programs, to evaluate, and translate technical research findings and observations into practice implementable procedures and findings.

3. Wider participation in international and bilateral workshops by influential public officials that are not directly involved in research efforts.

4. Support of problem focused research on microzonation and applications, as distinct from basic research on some components of the microzonation problem.

5. The availability of more and better conducted and prepared analyses of possible policy studies that develop results in the area of microzonation.

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SEISMIC SAFETY ELEMENTS IN CALIFORNIA:
AN EFFECTIVE USE OF RESEARCH?

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Adoption and Purpose of Seismic Safety Element Requirement

How do you account for the adoption of the seismic safety element requirement? The requirement that all cities and counties in California adopt seismic safety elements as a part of their general plans would probably not have been approved by the state legislature in 1971 had it not been for the San Fernando Earthquake. The idea for the element would not have been developed had it not been for the Joint Legislative Committee on Seismic Safety which was in existence at the time of the earthquake. The committee would not have been in existence had it not been for the leadership of Senator Alfred Alquist. Thus, the element owes its existence to leadership plus a fortuitous event, if one can call an earthquake fortuitous.

What was the purpose of the element? The purpose was simply to require that local governments consider earthquakes and their effects when preparing general plans. No one had a clear idea of how this should be done and hence the requirement was very general. Of course, the proponents thought the requirement should lead to modification of land use proposals plus implementation through zoning, subdivision and building regulations, as well as other then undefined processes.

Results

How good are the elements? Virtually all cities and counties in the California now have adopted seismic safety elements.* Seismic safety elements vary considerably as to focus, quality and recommendations. Many do not reflect recently prepared basic research, interpretive studies, vulnerability studies and other new information. Nonetheless, while many elements are lacking in one way or another, even this level of seismic information would not now be included in general plans had it not been for the act requiring seismic safety elements.

Have the elements resulted in fundamental changes in land use policy? Here, I don't think we know the complete answer. Based on the few studies that have been made of seismic safety elements, it would appear that only in rare instances have major changes in land use been made based solely on seismic

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* Note: In 1984, the state law was amended to require that safety elements and seismic safety elements be combined into a single safety element. The safety element addresses all geologic hazards as well as other hazards such as fire and flooding. However, the term seismic safety element will be used in the balance of this paper since most elements are still so labeled.

concerns. In most instances, seismic safety appears to be considered along with other factors in arriving at land use decisions. (See additional observations under the "Evaluation" section of this paper.)

What has been the impact on local staffs? City and regional planners throughout the state are now aware of seismic problems, if not always well-informed. In the process of preparing seismic safety elements, many planners also have become interested in non-seismic geologic hazards. This is in dramatic contrast to the pre-1971 situation where geologic hazards were often, if not usually, ignored. Furthermore, a number of counties and cities now have either staff or consultant geologists. This trend is at least partially the result of preparing the seismic safety element. Increased concern for liability and the need to implement the Alquist-Priolo Special Studies Zones act also help account for the hiring of geologists.

What has been the impact on "routine" regulations? A number of local jurisdictions have added provisions to zoning and subdivision regulations, a routine part of general plan implementation, which require geologic information to be submitted on a routine basis. Also, seismic safety elements have become an important source of information when reviewing development proposals under the California Environmental Quality Act to determine if seismic studies are needed.

Summary The element requirement has led to attention to seismic hazards in general plans, informing planners regarding seismic hazards, retention of geologists at the local level, and amending local regulations to include greater consideration of geologic hazards.

Research Bases

Where has all of the basic and interpretive information come from to support this statewide effort? The answer has to be: From many documents. By and large, city staffs or consultants have gathered already existing information and tried to relate it to the particular jurisdiction. Where detailed mapping was not available, the element tends to be very general, and in the better elements, defer detailed studies to a later phase of the development process. In other cases, elements may be quite detailed. I would judge that most of the information used was originally prepared by either USGS or the State Division of Mines and Geology. In some notable cases, USGS provided basic and interpretive maps, such as for the San Francisco Bay Area and San Mateo County. Even the studies done for the San Francisco Bay Region, however, are often too general to be highly useful to local government. They are certainly a significant help, but much is still left for local government to do.

Why don't local governments do more research? Virtually no original basic studies were conducted by cities or counties in preparing seismic safety elements because of the costs involved. A significant geologic study of a city or county would probably absorb a very large portion of a planning agency's budget, more than most jurisdictions would believe justified or possible. A survey in 1982 of 118 cities and counties in the state found the average amount spent by planning departments on seismic safety was under

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$10,000 in any year (French, 1982). In the same survey, 90% of the jurisdictions said they needed better information on surficial geology and 51% said they needed better information on estimated damages from seismic events.

Do interpretive studies eliminate the need for professional interaction? The interpretive studies are a major step in the right direction in that the information can be used by non-geologists. Still, the translation from geologic information to land use policy and decisions is greatly enhanced if there is a geologist on the staff or regularly available to the local jurisdiction. It is highly doubtful if a planner will not want to discuss an interpretive study with a scientist.

Dissemination of Information

What types of information are planners likely to receive? The distribution of general plan guidelines, which included guidelines for preparing a seismic safety element, by the state was of major significance in that they pointed the way for cities and counties which were for the first time dealing with seismic problems. These guidelines are widely available and highly used, although there is a need for greatly improved guidelines. Beyond this, the distribution of information appears to be more selective and particularly related to the area covered by mapping projects. Thus, the SFBRS materials were distributed primarily in the San Francisco Bay Area. Some products of that project, however, are suitable for wider distribution, such as Professional Paper 941-B Seismic Safety and Land-Use Planning, Selected Examples from the San Francisco Bay Region, California (Blair, 1979).

What are some obstacles to the use of research information? The Association of Bay Area Governments has developed interpretive materials funded by USGS. While this information has been made available to local governments it appears that as much use may not have been made of the information as would be hoped for. The reasons for this are not clear. Some explanations probably include the following. Most jurisdictions have already prepared their elements and figure the job is done. The interest that followed the San Fernando Earthquake has waned. There are many other matters of greater importance in the minds of local officials. Budgets and staff time available are not large and first attention is given to current and pressing problems. Also, the products may require a level of geotechnical understanding that many local jurisdictons do not possess.

Evaluation

There have been only a few studies of the effectiveness of the SSE requirement. The most notable studies have been by Wyner and Mann (Wyner, 1986), and the California Seismic Safety Commission (Calif.SSC, 1985). These studies indicate that while elements have been adopted, not many dramatic changes in land uses can be found as a result of the elements. The more subtle effects of the elements are more difficult to identify, such as routine consideration of geologic hazards in application review, the use of elements in EIR processing, more ready use of geologists, etc. The truth of the matter may be that seismic concerns in and of themselves often do not require a

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dramatic change in land use. In many cases there are engineering solutions to problems. In other cases the probabilities of losses may not warrant a high level of concern. Still, there are many cases where sufficient attention is not given in land use planning to seismic and non-seismic geologic problems.

How can research be used more effectively in seismic safety elements and their implementation to reduce seismic hazards?

1. Require that seismic safety elements use up-to-date information and meet some standards as to quality.

   Assembly Bill No. 1150 (Cortese) currently before the state legislature would require local governments to submit proposed safety elements or amendments to the elements to the Division of Mines and Geology (CDMG) at least 45 days prior to adoption for review and comments. CDMG would determine if known seismic and other geologic hazards information have been incorporated in the draft and report its findings to the planning agency. This would constitute at least a minimal level of review and might lead to local jurisdictions considering some problems not included in the elements.

   State law might go farther and require elements to contain certain components and follow some format. In the end, however, as long as the safety element, which is a policy document, is the focus for controlling land use with respect to seismic hazards at the local level, it will be impossible to ensure that actions to increase safety will be taken.

2. Require more specific standards by the state.

   The Alquist-Priolo Special Studies Zones act is an example of where the state has decided to actually regulate development at the local level. If local governments are going to recognize landslide areas, areas of liquefaction, etc., some approach similar to the special studies zones act will probably be needed. A general plan is a policy document and to a degree a "wish list." While in California zoning must be consistent with the general plan, if a city doesn't want to recognize seismic hazards in its zoning, it simply won't address the problems in a firm way in the general plan. Therefore, zoning, which is carried out strictly at the local level, will not address the problem in a forceful way.

   By and large there is little incentive for politicians to deal with hazards. They prefer to be involved in more positive programs. Thus, in the long run it may simply be necessary to require conformance to some state levied standards. Developing state standards with respect to geologic problems is not easy. Geologic problems by their nature are complex and highly variable. How problems can be adequately identified at the state level and local compliance be required in some reasonable way will require considerable thought.

   One example of the political problems inherent in adopting state legislation to deal with local geologic problems can be found in the

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history of Assembly Bill 101. AB 101 (1983-84) was originally drafted to require CDMG to map landslides in the state and for local jurisdictions to incorporate such provisions in plans and regulations. Pressure from the real estate lobby resulted in a much more restricted bill. The end result is essentially to enable CDMG to resume its early 1970's mapping work (Olshansky, 1987).

Aside from identifying areal problems and requiring local response, the state can establish procedural requirements. For instance, Senate Bill No 879 (Alquist) currently before the legislature would require geologic reports as a part of subdivision applications. Even this simple requirement, however, has not been passed in several previous attempts in the legislature. State requirements for geologists' involvement in the review of projects on behalf of local government might be another reasonable requirement.

3. Develop Incentive Programs.

Incentives are another way to encourage local implementation of a safety element. If there ever is national earthquake or natural hazard insurance, a prerequisite to obtaining such insurance might be an up-to-date and adequate safety element. Possibly other programs could be contingent on an adequate element.

4. Educate Decisionmakers and Professionals.

Education may ultimately be the best defense. Educating decisionmakers and professionals as to the nature of the risk and the liabilities a public agency can face might lead to reasonable protective measures. This is not a small job and would take a considerable period of time for payoff. Efforts of the American Institute of Architects, through NSF grants, and SCEPP and BAREPP, through FEMA grants, are significant attempts to reach professionals and decisionmakers. More such efforts are needed.

5. Provide Assistance to Local Government.

Funding is another obstacle to improved seismic safety elements. The fact remains that the topic of seismic safety is not popular and good work costs a considerable amount of money. Thus, the incentive to perform better at the local level is not high. A significant funding program, however, might well elicit interest. The experiment of USGS in Utah where it is funding county geologists, for instance, bears careful watching in this regard.

The other important form of assistance is through the provision of information. The mapping programs by USGS and CDMG are invaluable resources to the local communities.

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Summary

The seismic safety element in California has probably come close to doing what such an element can accomplish. Some improvements can be made in the quality of the elements through providing more education, information and guidance, but it will continue to remain a policy document. If major advances are going to be made in implementing the elements, it will probably be necessary to adopt state legislation that mandates local governments to recognize seismic hazards in regulations in at least a procedural way. Beyond that, the state may have to actually map hazards and require local governments to regulate development in those areas.

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APPLICATION OF A PROCESS FOR ASSESSING THE POTENTIAL EFFECTIVENESS OF LAND USE PLANNING MEASURES FOR EARTHQUAKE HAZARD MITIGATION: PROVO, UTAH AND BELLINGHAM, WASHINGTON

by
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DESCRIPTION OF THE APPLICATION

The research application reported here was funded by the National Science Foundation from 1982 to 1985.[1] The research and analysis was focused on the development of a process that local planners could use for assessing the potential effectiveness of specific land use planning approaches for earthquake hazard mitigation in their own community. This assessment process was to facilitate the selection from among many choices of land use planning measures that potentially can be used for applied to the goal of reducing losses from earthquakes. The central tasks of the project included: (1) a synthesis of existing information on implementation of mitigation measures, (2) the development of a concept of effectiveness, including implementation feasibility; (3) a test application of the assessment process, by its developers, in Provo, Utah, and Bellingham, Washington; and (4) the production of a handbook to introduce practicing planners to the assessment process (see Figure 1).

The assessment process (described as a decision-making framework in the project reports) was developed by research planners and social scientists. The assessment process was designed to be applied by planners and decision-makers at the local level. The project did not include a phase for studying the way in which actual practicing planners applied the assessment framework. However, a hypothetical application of the framework was undertaken as part of the development process. That is, an analysis was made of the expected comparative effectiveness of various planning options in the selected test communities, but no agreement had been made with any of the test communities that it would then attempt to implement any of the approaches.

During the initial development phase of the project, the elements in a framework for comparing the local appropriateness and effectiveness of land use measures were delineated. In the second phase of the project, the research planners tested the applicability of the framework for problems likely to be encountered in selecting among land use planning measures potentially useful for reducing future earthquake damage and loss of life in a particular community. To carry out this test, the research planners on the project acted as what might be referred to as "surrogates" for local practicing planners.

The research planners selected three communities (including Bellingham, Washington, and Provo, Utah) in which the local earthquake hazard would warrant the implementation of an earthquake hazard reduction strategy. A "field test" of the assessment framework was then conducted in the communities, utilizing locally

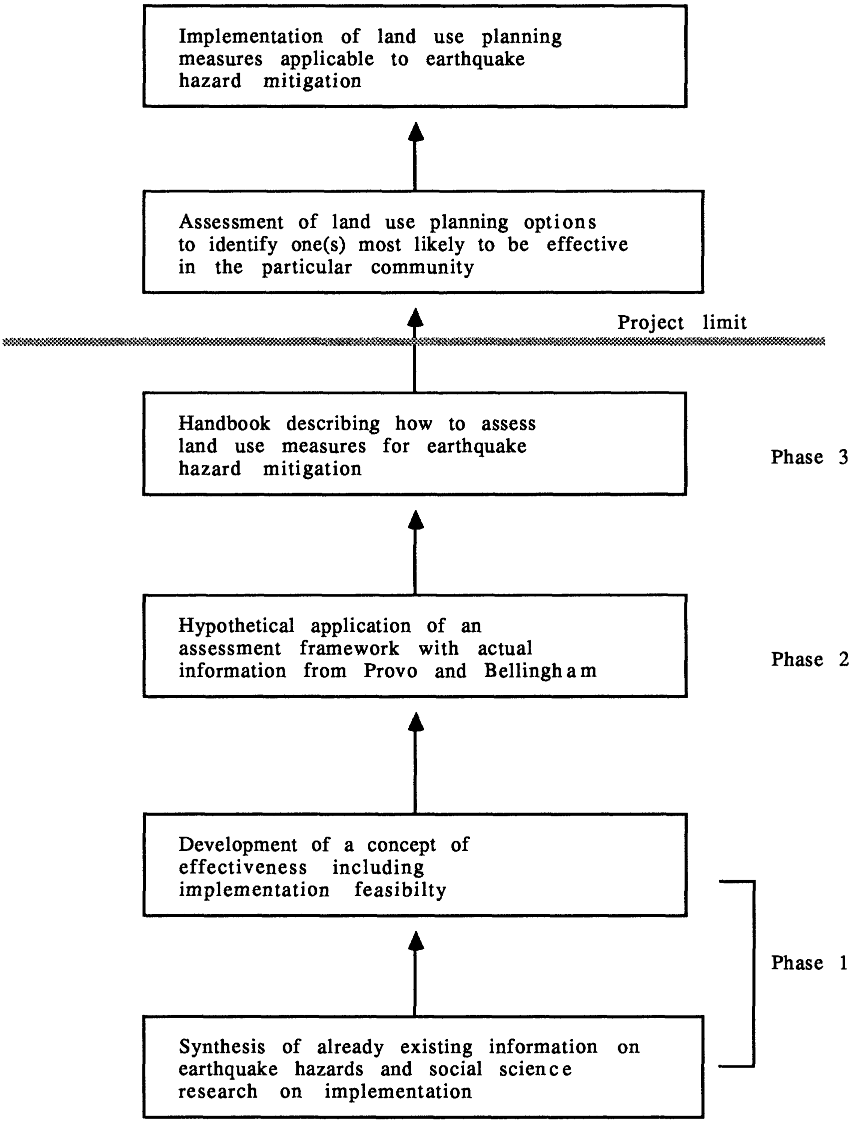

Figure 1. Relationship of Assessment Process Developed During Project to Application of Land Use Planning Measures

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available information on the hazard, and information and insights about the community gathered from interviews with local planners and experts.[2]

The scope of the "application" is indicated by the cells in the "summary work sheet" illustrated in Figure 2. Selected planning measures (represented by columns A, B, and C) are examined in terms of their effectiveness and the relative costs of adoption, compliance, and enforcement. The relative effectiveness of the measures is determined based on each planning measure's degree of coverage of hazardous areas, the impact the measure would have in reducing risk if the measure were fully implemented, and likely level of implementation success.[3]

The locally provided information was synthesized and analyzed by the research planners. Reports were prepared with the Bellingham and Provo data, presenting the analysis of the comparative suitability of selected land use planning measures. The reports of this field test were provided to the local planners and decision makers for their comments. For the most part the local reviewers did not dispute the plausibility of the outcome. Of course, they were not also faced with actually trying to implement the measure proposed as the one judged most likely to be effective in that community, which may have led them to be less critical.

Appendix A contains the completed summary worksheets produced from the test applications in Bellingham, Washington, and Provo, Utah. In each case, selected approaches were compared. As can be seen from the worksheets, all approaches had some drawbacks. It would be up to the local agency staff to decide on the trade-offs between potential for reducing losses versus difficulty in implementing.

For example, from the Bellingham test analysis it was observed that in Bellingham and Whatcom County specifically (and not necessarily in other communities), all three options selected for consideration would probably be appropriate to implement. However, the option for modifying the zoning ordinance would probably be the most costly and difficult to fully implement, the option for modifying the subdivision ordinance would be easier to implement but not have much effect on the hazard, and the sensitive area ordinance would meet multiple objectives of the community beyond the earthquake hazard alone, although there might be some difficulties with adoption and adequate staff expertise for oversight.

From the Provo, Utah, test analysis (and again, applicable only to Provo), it was observed that of the four options selected for consideration, the two with the best potential for reducing seismic risk would be a strengthened sensitive land development ordinance and an expanded site review process. The former was judged to be likely to have a slightly greater impact in reducing risk exposure, while the site plan review option was thought likely to be easier to adopt. It was observed that the adoption of a hazardous building abatement ordinance would probably be politically unacceptable in the community, and that the adoption of infrastructure design standards would be difficult because the city lacked direct control over independent utilities.

RESEARCH WHICH CONTRIBUTED TO THE DEVELOPMENT OF THE APPLICATION.

The development of the assessment framework involved synthesizing various kinds of information. The types of information used as background included:

	Potentially appropriate land use planning measures		
	A	B	C
Coverage: The amount of buildings located in all "sensitive" areas that will be affected by the ordinance (assuming it is fully implemented.)	Of Existing Development: Of Future Development:	Of Existing Development: Of Future Development:	Of Existing Development: Of Future Development:
Impact: A rating of how much change in risk exposure would result from the full implementation of specific planning measures. Implementation Success: The likelihood of adoption, compliance, and enforcement of the selected planning measures			
Cost: Relative cost to adopt, comply, and enforce: To government: To Private Sector:	Front-End Future	Front-End Future	Front-End Future

Figure 2. Work Sheet for Evaluation of Loss Reduction Potential and Costs of Selected Land Use Planning Measures

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- information on the nature of earthquake hazards
- research on the use of hazards information
- research on political agenda setting
- information on the design and application of land use planning mechanisms,
- research on the applicability or adoption of land use planning measures for hazards reduction.
- research on policy implementation;
- research on observed barriers to the implementation of earthquake mitigation policy and practices specifically

No systematic analysis has been done of the source of these various types of research. However, a check of the project's bibliography lists shows that many publications on the use of land use planning approaches for earthquake hazard mitigation that were reviewed for this project had been produced by the U.S.G.S. or sponsored by U.S.G.S, many prior to the passage of the NEHRP. Social science research on the success of attempts to adopt or implement various kinds of hazard reduction measures has for the most part been funded by the National Science Foundation, both before and since NEHRP.

IMPETUS FOR THE DEVELOPMENT OF THE ASSESSMENT PROCESS

There are frequent observations in the mitigation literature that this "non-structural" (sometimes referred to as locational) approach to earthquake hazard mitigation is not applied as often as are structural approaches such as building codes, despite researchers and "users" assertions that land use planning measures could be applied to earthquake hazard mitigation. The weight behind the development of this assessment approach for land use measures most probably lies with interest on the part of researchers as to why users (such as local level planners) do not use land use approaches. It was believed that introducing planners to what types of land use planning options are available, and enhancing their ability to judge the effectiveness of such measures in their community for reducing losses might increase the likelihood of their use.

At various U.S.G.S. workshops local planners often are observed to say that land use measures cannot be applied because local data is of inadequate detail for this type of application. "If only I had maps, I would proceed." With respect to this, one of the interesting findings from the field test sites was that there were more applicable sources of data available than most agency staff realized, but it had never been collected into one central place for the purpose of applying it to land use planning.for hazardous areas. The project staff testing the assessment approach ran across these various data sources because they were systematically combing the community for expert opinions and insights.

Of course, even where data do exist, or can be collected as part of the development process, there are many other potential barriers to the use of any earthquake hazard mitigation approach. Obtaining detailed data on the local hazard will not automatically ensure application of locational measures for hazard mitigation. However, local planners are likely to be familiar with these other types of barriers; most planning initiatives evoke opposition from some sector of the community. The assessment process in the handbook lays out a systematic way for a user to compare the potential barriers to adoption, enforcement and compliance across several land use planning options that may be appropriate for that community's type of hazard. Then the local officials can make a reasoned decision about what will probably be the course of least resistance weighed against the path that will lead to the greatest payoff in loss reduction, and decide what level of effort they can put into implementing a specific land use approach.

Information from past research that indicated that planners might benefit from being better informed about the nature of land use planning measures and their applicability for earthquake hazard mitigation included observations that:

- Land use-related planning measures can be used as an approach to reducing future damage and losses from earthquakes.
- Locational approaches often can be used in combination with structural approaches.
- Available locational approaches--land use planning measures--vary with respect to the hazard situations for which they are applicable; i.e., not all measures are appropriate to all types of earthquake hazards.
- Available land use planning measures vary with respect to their acceptability in different communities; .i.e., adoption of various types of land use measures is not equally likely across all communities due to community values and development contexts.
- Lack of information on the nature or scope of the earthquake hazard in a particular community is only one of several important barriers found to implementing land use measures for earthquake hazard mitigation.
- Acquisition of more information about the local earthquake hazard in a particular community will not automatically assure that land use planning measures the information permits will be implemented, since other reasons for non-adoption are likely to exist as well.

In particular, it was believed that planners would find it instructive to have a systematic approach for assessing implementation <u>feasibility.</u> of specific measures. Land use planning measures that might appear applicable to the hazard, may be too problematic with respect to implementation. A particular land use option will only be effective to the degree that it is fully implemented. If an analysis indicates that a particular measure will probably be plagued with many gaps in implementation, then it may not be worth the expenditure of time and money to try to implement it. Also, it was believed that consideration of implementation feasibility could help planners both to foresee and better negotiate potential barriers before they began the implementation of a particular measure that they felt it was important to implement because of its potential for reducing losses.

TRANSLATION ACTIVITIES

The research planners had a translation role themselves. Social science findings about implementation barriers were translated into steps for making a prospective assessment of implementation barriers. The preparation of the handbook was an attempt to make this easily accessible to local planners.

Also, the assessment approach, as designed, would entail that local earthquake hazard experts take an active role in translating and interpreting technical information on the hazard for the local planners when they set out to make an assessment. The nature of the hazard, and the specific locations which are hazardous are important types of information for planners. This type of information needed to be translated into statements about the likely locations where damage will occur, and the relationship between particular seismic events and extent and type of damage in various locations.

DISSEMINATION OF THE ASSESSMENT APPROACH

The major product to be disseminated from the project was the handbook. Beyond that, the most direct introduction of the approach to the type of person for whom it was designed was to the local agency personnel in Bellingham and Provo (and another California city) who were interviewed during the field test phase. However, this was only a fortuitous aspect of the project design. These planners and others had been requested by the project staff to participate in the test; they had not initially solicited help or advice from the project's research planners (nor did any of them subsequently solicit any further advice or guidance that I know of). Further follow-up would be needed with them to ascertain if their participation in the field test influenced any later actions they took with respect to implementing an earthquake hazard reduction strategy in their community.

The field test indicated that the assessment framework was applicable to the problem of comparing the potential effectiveness of planning measures, and provided insights for some refinement of the assessment process. As the final stage of the project, the handbook was prepared, describing how to apply the assessment approach.[4] The handbook's intended audience is local agency personnel and the staff of elected officials who will design policy and the means for implementing it. The handbook has been published by a major hazard information clearing house. A synopsis of it was provided in at least one newsletter that is distributed for free to what is probably the bulk of researchers interested in natural hazards, and to many federal, state, and local agency persons. The handbook's existence also is publicized by the publishing organization, through inclusion on the organization's list of available publications. However, there probably is a major gap in this distribution route, which is the large number of local level planners who do not read beyond regional or national professional newsletters for planners. This route of publicizing the handbook has not been fully tried.

An inquiry to the distributing organization revealed that less than 50 of the handbooks have been purchased. The authors also have distributed about 40 of the handbooks, but many of those have gone to other researchers/academics. No handbook owners have been been queried as to whether or not they have tried to apply any of the analysis steps described in the handbook, and whether or not the assessment approach actually helped them arrive at the selection planning measures for implementation.

As a further potential dissemination channel, there is some possibility that the handbook, or other published sources that describe the concepts behind the assessment process, were provided to persons who teach in schools of planning or public administration. This can be an important source of dissemination of ideas and approaches.

One major factor in the use of the handbook is that it assumes that the community has decided to establish an earthquake hazard mitigation strategy and just needs help in deciding what will work for that community. The handbook is not designed to try to persuade communities that they should engage in earthquake hazard mitigation.

IMPROVEMENT OF THE APPLICATION PROCESS

The project was carried out because of the belief that the process for selecting and applying land use planning approaches for earthquake hazard reduction could be better informed. It was observed that when various kinds of measures are described as useful for earthquake hazard reduction, the assumption usually is being made that the measure can be fully implemented (i.e. fully complied with). However, studies of implementation typically demonstrated that mitigation measures may be adopted, but often are not actually implemented to the fullest extent. Thus their potential effectiveness for reducing future earthquake damage and loss is not achieved.

This project had as its ultimate goal the better application of land use planning approaches. It addressed how to assess ahead of time which planning measure have the greatest likelihood of being effective if selected for implementation. One implication of making such an assessment is that some of the potential barriers for implementing a planning measure are detected prior to beginning the implementation process, making it possible to develop strategies for reducing or removing such barriers.

The closest project staff got to working with users was when they made their own hypothetical application of the assessment framework using data and assessing barriers specific to the communities they selected for the application. The field test was conducted by the research planners on the project and the "process" aspects of this application are not documented. Certainly the short time allotted to data collection in each of the field sites resulted in the final analysis not being as refined as it could be made by local planners with much more information and intimacy with the community. The time allotted was considered adequate to find out what was useful for the project.

The project did involve the use of an advisory group, and the use of reviewers for the handbook. These two groups included a mix of experts who either trained professionals such as planners or engineers, or persons who were trained as planners but were working as consultants or agency specialists of some sort. However, none were currently working as "hands-on" planners at the community level.

The project design could have included a phase in which communities were found that would agree to use the assessment process. This application then could have been monitored and the usefulness of the approach to practicing planners, and how the handbook represented it, been evaluated. As another option, the project could have emphasized dissemination more, by providing workshops in the use of the approach.

Finally, it can be asked whether or not it is advisable to disseminate an approach that has only been validated in three communities, and then through use by its own developers. However, the workshops could have served in this capacity to some extent, by being designed so that participants--e.g. practicing planners--both learned about the approach, and provided further insights to the research planners based on their experience and knowledge of their own communities.

NOTES

1. Financial support for this research was provided through National Science Foundation grant number CEE-8118450. The judgements contained herein are solely attributable to the author and not to others participating in the research project or to the National Science Foundation.

2. These field test applications were conducted by Marjorie Greene and Susan Heikkala, research planners, and co-principal investigators for the project. The results of the field test analysis were presented in unpublished reports on each of the field test communities.

3. For a fuller description of this concept of effectiveness, see Peter J. May and Patricia A. Bolton, "Reassessing Earthquake Hazard Reduction Measures," Journal of the American Planning Association, 1986, Vol. 52, No. 4, pp. 443-451.

4. Patricia A. Bolton, Susan G. Heikkala, Marjorie M. Greene, and Peter J. May, Land Use Planning for Earthquake Hazard Mitigation: A Handbook for Planners. Special Publication 14, Natural Hazards Research and Applications Center, Institute of Behavioral Science, University of Colorado, Boulder, 1986.

APPENDIX A

Example of summary notations from assessment of the effectiveness of selected land use planning measures for Bellingham, Washington and Provo, Utah. These two worksheets summarize the outcome of the analysis made during the hypothetical application of the assessment process described in this paper.

SUMMARY WORKSHEET: BELLINGHAM, WA EXAMPLE

PLANNING TOOL

	Modification to Zoning Ordinance (hazard overlay map with performance standards).		Modification to Subdivision Ordinance (site-specific geologic reports in areas of particular seismic hazard sensitivity.		Development of a Sensitive Area Ordinance with Performance Standards.	
COVERAGE - the amount of buildings located in all sensitive areas which will be affected by the ordinance (assuming it is fully implemented).	Existing Development: NA Future Development: Low - only small and well-documented hazard areas are likely to be included in the ordinance.		Existing Development: NA Future Development: Moderate - tool would apply on a site-specific basis. Likely that developers would steer away from hazardous area development anyway.		Existing Development: NA Future Development: extensive - an SAO will only "miss" those areas too small to be picked up by other mapping procedures.	
MAXIMUM IMPACT - a rating of how much change in risk exposure would result from the full implementation of planning tools.	High - a well-enforced zoning ordinance can significantly restrict or condition development.		Low-moderate - a subdivision regulation does not affect the type of use or structural characteristics. Instead, it can only regulate the location of development on the site and some site preparation and foundation characteristics.		High - effectively used performance standards would emphasize end result and control land use.	
IMPLEMENTATION SUCCESS - the likelihood of adoption, compliance, and enforcement of the planning tools.	Low - adoption likely to be a stumbling block because of map preparation and standards.		High - city & county have subdivision ordinance in place. Might require additional expertise to enforce. Similar requirements to existing procedures.		Moderate - burden of developing criteria for sensitive areas on city/county. Indication that political mood not right.	
COST - to adopt, comply, and enforce	Front-End	Future	Front-End	Future	Front-End	Future
To Government:	High-info gathering, map preparation.	High-could require hiring of additional expertise, updating of information.	High-some new information required to determine areas of particular seismic sensitivity.	Moderate to high-might need additional expertise to review/interpret studies. Large number of permits to be reviewed.	Moderate.	Moderate-could require hiring additional expertise.
To Private Sector:	Low.	Moderate-could require site and engineering changes.	High for residential developers--must provide information.	Moderate-could require design changes.	None.	Moderate-requires site studies and may necessitate development modifications.

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SUMMARY WORKSHEET: PROVO, UTAH EXAMPLE

	PLANNING TOOL			
	Hazardous Building Abatement Ordinance	Strengthened Sensitive Land Development Ordinance	Expanded Site Plan Review Process	Infrastructure Design and Development Standards
COVERAGE - the amount of buildings located in all sensitive areas which will be affected by the ordinance (assuming it is fully implemented).	Existing Development: Low-Moderate. The tool specifies that all buildings constructed prior to a certain date or any unreinforced masonry building is subject to the program. Newer buildings will not be affected, yet may be exposed to the hazard. Future Development: NA	Existing Development: NA Future Development: Moderate. The ordinance will cover some of the more severe hazards--faults, slide areas, flood plains--but areas subject to ground shaking and liquefaction are not likely to be included because it is difficult to define their location.	Existing Development: NA Future Development: Moderate. Because the review applies to all major developments regardless of location, there is the opportunity to address hazardous conditions for each. Assuming subdivisions are included, only single-family dwellings remain "uncovered."	Existing Development: NA Future Development: Low. This will not affect the exposure of existing or new developments/buildings, but it will affect how quickly areas can respond or recover in the event of an earthquake. This tool can be used in conjunction with others for more comprehensive coverage.
MAXIMUM IMPACT - a rating of how much change in risk exposure would result from the full implementation of the planning tools.	Low-Moderate. The retrofitting standards will not bring a building up to current standards. It will significantly reduce hazards to human lives, but structural damage is still likely.	High. The case-by-case application of development standards will substantially reduce the risks for new developments. It will not completely eliminate risk since development will still be permitted in identified sensitive areas.	Moderate-High. With careful consideration of the hazard potential at each site, the case-by-case application of development standards can substantially reduce the risk to new developments. It will not completely eliminate it, since development will still take place (and single-family homes are not covered).	Low. Lifeline design standards will increase infrastructure resiliency but will not likely have a significant affect on development.
IMPLEMENTATION SUCCESS - an assessment of the likelihood of adoption, compliance and enforcement of the planning tool.	Low. Adoption is unlikely due to the difficulty of applying retroactive regulations to structures. If adopted, compliance will be difficult because of the owner's unwillingness to incur high retrofitting costs. The local and national economic slowdown will exacerbate the compliance problem.	Moderate. Although the city has a simiar ordinance in effect, a stronger version was politically rejected. Thus adoption may still face some opposition. However, recent experience with flood disasters may improve adoption chances. If adopted, developers are likely to comply with the study requirements and development conditions, with some successful attempts at negotiating reduced standards. Once standards are specified, enforcement should be effective.	Moderate. Little change is required of the existing ordinance so adoption should not face major obstacles. Compliance will be low-moderate since the city is relying on the developer to identify the hazard. Enforcement will be low-moderate--the Site Plan Review Committee has not used their authority to actively condition development in the past. Standard enforcement will be effective.	Low. Services are provided by individual companies. There is little coordination between them and the city has little authority over them. Adoption of a memorandum of understanding relating to development standards is likely to be difficult; compliance will be uncertain. The city has little recourse for enforcement.

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Proyo Example (continued)

	Hazardous Building Abatement Ordinance		Strengthened Sensitive Land Development Ordinance		Expanded Site Plan Review Process		Infrastructure Design and Development Standards	
COST - to adopt, comply, and enforce.	Front End	Future	Front End	Future	Front End	Future	Front End	Future
To Government:	Low. Little initial research is required.	Moderate. Will require additional professional staff to do the building inventory, plan review, and inspection.	Moderate. No new field information is required. Existing staff can compile a draft sensitive area map. A professional is needed to review and evaluate the map. Other costs include staff time to draft ordinance changes; take it through the political process.	Moderate. Compliance will require ongoing expenditure for an engineering geologist or structural engineer--as staff or consultant. With increased development volume over time, more building inspectors may be needed.	Low. Small amount of staff time is needed to prepare administrative or legislative changes for program adoption.	Moderate. Compliance and enforcement require geologic and engineering expertise to be available to or on the review committee. The building inspector's work load may also increase, requiring additional inspectors.	Moderate. Primarily relates to negotiating memorandums of understanding with each respective utility.	Moderate. Requires the use of more flexible materials and/or the provision of duplicative back-up service lines.
To Private Sector:	Low	High. Individual building owners must pay to retrofit buildings. Per building costs will be high.	None	Moderate. Costs will be associated with on-site hazard investigations and related site or structural mitigation measures. Costs will vary.	None	Moderate. Costs will be associated with on-site hazard investigations and related site or structural mitigation measures. Costs will vary.	None	Low. Higher costs of providing services will be passed to customers in the form of higher user charges.

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UTILIZATION OF HAZARD MAPS IN SALT LAKE COUNTY

By
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INTRODUCTION

Salt Lake County is subject to a variety of natural hazards which must be addressed in land use planning. Among these hazards are flood, avalanche, slope failure, earthquake, unstable soils, high water table etc. For the past 20 years there has been a growing awareness of the seriousness of the threat to life and property caused by natural hazards. The floods experienced by Salt Lake County in 1983-1985 with the resultant landslides and millions dollars of damage brought attention of the public officials as well as the general public to the necessity of mitigation planning.

This paper briefly outlines the development of regulations and hazards mapping in Salt Lake County. First the legal framework will be reviewed then a brief history of regulation development and present efforts to adopt a Natural Hazards Ordinance will be discussed.

LEGAL FRAMEWORK

In 1978 The Utah State Seismic Safety Council established a land use planning task committee to address planning issues. One of the first questions raised was whether the State Planning Enabling Legislation permitted planners to consider geologic hazards in the development of plans and enforcement ordinances. After review of the statute, the State Attorney General's Office concluded that planning for earthquake safety is within the intent of the planning statute although the language is not explicit. Planners throughout the state would prefer more explicit language but amendments proposed by the Seismic Safety Council have not been adopted. Many local jurisdictions have, however, adopted various hazards ordinances under the existing statute.

A recent decision of the United States Supreme Court concerning property rights versus public rights may hinder land use regulations (First English Evangelical Lutheran Church of Glendale v.County of Los Angeles). A forest fire denuded a large tract of mountain woodland. The next year rains triggered a flood that killed 10 people and destroyed the church's campground and buildings. The County declared the area a floodplain and banned at least temporarily any new construction. The Church went to court charging denial of use of its land and demanding monetary damages. The State Court said no. The U. S. Supreme Court based its decision on the fifth amendment to the

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Constitution which prohibits government taking of property "without just compensation," and held that the government is liable for damages even if a landowner is only temporarily banned from use of the property. Previously the courts have invalidated the subject regulations, now it seems that government will be forced to pay compensation. The fallout from this decision likely will take years to resolve and could likely affect regulations aimed at earthquake hazard mitigation particularly if those regulations deny landowners "all reasonable use" of their property. According to recent advise from our Attorney, the court left open the question as to whether the community could avoid the conclusion that a denial of all use constituted a taking when done under the power to enact safety regulations. This is the question that must be answered. In the interim, officials must make sure that the regulations are reasonable, fair and supported by scientific information. If not, the community runs the risk of the takings clause, and if it does, the court seems to say the community will pay.

SALT LAKE COUNTY - HISTORY OF REGULATIONS

Since early in the 1970s Salt Lake County officials have been increasingly aware of opportunities to mitigate natural hazards by land use and planning techniques. Following is a brief summary of the major ordinances and actions that have taken place:

1965 - The County Commission approved a new zoning ordinance which divided uses allowed in a zoning classification into a permitted or a conditional use category. Most uses of higher intensity than single family dwellings were listed as conditional uses requiring planning commission approval. As the planning commission reviewed conditional uses it began to require hazards reports where the hazards were known. Conditions were placed on approvals to mitigate the hazards as was reasonably feasible.

1972 - After two years of study, Zoning of the canyons east of Salt Lake City was accomplished. The canyon zones specified that construction is not permitted on slopes over 40% and also contained the stipulation that "construction of permanent structures is not permitted in areas . . . . . subject to hazards such as floods, landslides and avalanches. Grading plans and revegetation plans are also required.

1973 - A master plan for the upper reaches of Little Cottonwood Canyon (Alta and Snowbird) was adopted. This plan was the first in Salt Lake County to use a land suitability rating system where analysis of hydrology, geologic hazards, avalanche hazard, soils erosion hazard, etc., was used to determine areas suitable for construction. Since that time all master plans have utilized hazards data, when available, as a basic consideration for land use decisions.

1980 - After six years of study and negotiation with special interest groups, the Hillside Protection Ordinance was adopted. The regulations of this ordinance covered the mountain foothills on the east side of the valley. The regulation provides that construction is not permitted on slopes greater than 40%. In addition, the planning commission may require a soil report, geology report, grading and drainage plan, vegetation plan and other reports. The ordinance provided that persons preparing the reports must be qualified by training and experience to have expert knowledge of the subject and outlined in a general way the minimum requirements of the content of the reports including conclusions and recommendations for mitigation.

1982 - A new zone was approved for the foothill-agriculture area in the southwest portion of the valley. This zone provided that permanent structures may not be built in areas subject to hazards such as floods, avalanche, unstable soils, landslides or other geologic hazards. The ordinance further provided that slopes greater than 40% shall not be disturbed.

1985 - Flood regulations based upon FEMA requirements were adopted.

1986 - All ordinances relating to slope requirements were amended to prohibit development on property over 30% slope rather than the previous requirement of 40%.

OBJECTIVES OF THE NATURAL HAZARDS ORDINANCE

Because of the complexity of the ordinances, lack of expertise of staff members, and lack of definitive information relating to various hazards and appropriate mitigation techniques, permits were often issued without proper attention to hazards. The planning staff decided to draft a natural hazards ordinance along with maps clearly showing the hazards, in order that all property owners would be treated fairly and insofar as possible all applicable hazards would be considered prior to issuance of building permits.

There were three main goals:

1. Inform citizens of natural hazards.
2. Protect life and property from the effects of natural hazards.
3. Insure that critical facilities will survive hazards events.

GEOLOGIC HAZARDS MAPS

The USGS funded a geologist as a planning staff position for three years starting July 1, 1985. The second year work program for the geologist was to prepare hazards maps for Salt Lake County which would be utilized to implement hazards reduction policies and ordinances. This program has been extremely useful to accomplish the task. The geologist has been available on a daily basis to prepare and interpret maps, assist planners and county officials in identifying hazards as permit applications have been proposed, review hazards reports and assist local government officials with siting of critical facilities.

Previously, many studies of hazards affecting Salt Lake Valley have been completed, most of which have not had much impact on local officials because (1) the information has not been communicated effectively to decision makers, (2) Studies are very complex, and are not easily understood by layman (3) Scientists were more interested in the research than in applications (4) Studies did not go far enough to suggest practical and implementable solutions to the identified problems.

LIQUEFACTION

The first group of scientists to approach Salt Lake County officials with a real desire to apply their work to the planning process was Lorin Anderson and Jeff Keaton et.al. Meetings were held with planning officials to explain the work in progress on liquefaction potential. A good attempt was made to translate the mapping to fit a planning need. During the discussions it was determined that an additional step was needed to answer the planners questions "So what", "What does this all mean to the person who must decide whether to issue a building permit for a particular use at a particular location",and What kinds of uses or Construction types are vulnerable?" etc..

Scientists went one step further by preparing a matrix of the effects of liquefaction on various uses. With a great deal of effort of the county geologist, planners, and building code specialists, we were able to prepare a map and legend which can be made a part of the proposed geologic hazards ordinance. While the research that went into the liquefaction potential study is important we believe the process where planners were brought into the study to discuss the application of the data to planning was perhaps equally important.

SURFACE FAULT RUPTURE MAP

The County Geologist detailed the map based on previous studies. There were lengthy discussions on the width of the study zone and appropriate map scale. (Planners, with their computer technology, and the general public often desire much more detailed information than the original research supports).

SLOPE STABILITY MAP

This map is presently being prepared under the direction of the county geologist. It will show areas prone to instability and areas subject to debris flows and debris floods.

AVALANCHE HAZARD MAP

This map will be prepared based upon information from the U. S. Forest Service. At the present time, we anticipate that construction for human occupancy will not be permitted in a known avalanche path as our ordinances now state.

GROUND SHAKING MAP

We have not concluded the approach to take regarding the ground shaking hazard, There needs to be much more discussion on the map itself as well as the appropriate ordinance provisions to best mitigate this hazard.

OTHER MAPS

Other maps (dam failure inundation, tectonic subsidence, problem soils, etc.) must be reviewed to determine the extent of the hazards and appropriate mitigation measures needed. We expect we will adopt a hazards ordinance before these decisions are made. Amendments would come later as the information becomes available.

USE OF MAPS

The planning and building permit staff are now using the liquefaction, surface fault rupture and avalanche hazard maps. The map legend is attached as Appendix 1. The maps are general and are to be used only as "red flags" indicating where more information is needed. It should be noted that the language "should" and "recommended" will be changed to "shall" and "required" when the ordinance is adopted. The maps are on display in the county offices and are being referred to regularly by property owners, developers and lending institutions. The building inspector has agreed to use the maps to insure that the provisions of the building code relating to seismic design are followed. The Planning Commission will also use the maps in review of site plans for conditional uses and in the master plan process. An application flow processing chart prepared by the county geologist is attached as Appendix 2.

THE NATURAL HAZARDS ORDINANCE

The third draft of the Natural Hazards Ordinance is attached as Appendix 3. Because of the lack of very specific hazards information, the ordinance identifies areas and uses which need site specific studies prior to issuance of building permits. The ordinance provides:

1. Adoption of natural hazards maps, including a means to resolve disputes relating to hazard boundaries as well as a means to amend the maps should additional scientific information become available.

2. A matrix of uses and hazards requiring site specific studies and reports.

3. A general outline of the report requirements.

4. A method of independent review of the reports.

5. A requirement that uses for human occupancy not requiring a site specific report not be built astride an active fault.

6. Requirement for disclosure of natural hazards on deed covenants.

ADOPTION OF THE ORDINANCE

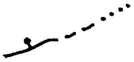
We will submit the ordinance and maps to the Planning Commission and the County Commission within the next 6-12 months depending upon completion of the maps. It remains to be seen whether the public will support the proposal or whether special interest groups will lobby against adoption. The experience in Salt Lake County on similar ordinances has been that the process will become controversial and take a great deal of time to accomplish. As an example, the Foothill Protection Ordinance took six years to adopt because of the controversy over regulating private property rights. We need support from agencies, scientists, and the general public to gain adoption.

SURFACE FAULT RUPTURE and LIQUEFACTION HAZARD AREAS

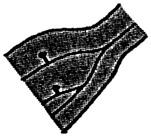
Compiled by
Craig V. Nelson, County Geologist
Salt Lake County Planning Division
August 1987
For more information call: 468-2061

This map is a compilation of the most recent geologic information available. It is for public information and general planning purposes only. This map does not substitute for site specific data obtained from special studies, and is subject to revision as new information becomes available.

EXPLANATION



FAULTS: Solid line where location is known from scarps or trenching; dashed where approximately located or inferred; dotted where concealed. Bar and ball symbol indicates downthrown side.



SURFACE FAULT RUPTURE SPECIAL STUDY AREA: Indicates areas where site specific studies addressing fault rupture should be performed prior to construction.

LIQUEFACTION POTENTIAL:

HIGH	> 50 %
MODERATE	50 - 10 %
LOW	10 - 5 %
VERY LOW	< 5 %

Approximate probabilities that the critical ground acceleration needed to induce liquefaction will be exceeded in 100 years.

Special Study Guidelines

Should a Site Specific Hazard Study Be Performed Prior to Construction?

Land Use (Facility)	Fault Study Area	Liquefaction Area			
		High	Mod	Low	V. Low
Essential Facilities (UBC 2312(k)) & High Occupancy Buildings (UBC A-1, A-2, A-2.1)	YES	YES	YES	YES	YES
Industrial & Commercial Buildings (over 2 stories or >5,000ft²)	YES	YES	YES	NO	NO
Multi-family Residential (4 or more units/acre) Other Ind. & Commercial	YES	YES	YES	NO	NO
Residential Subdivisions	YES	NO ✗	NO ✗	NO	NO
Residential-Single Lots & Multi-family developments (less than 4 units/acre)	NO ✗	NO ✗	NO ✗	NO	NO

✗ recommended disclosure to buyers/residents

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ANDERSON, L.R., KEATON, J.R., SPITZLEY, J.E., and ALLEN, A.C., 1985, Liquefaction potential map for Salt Lake County, Utah: Utah State University and Dames & Moore, Final Report for U.S. Geological Survey Earthquake Hazards Reduction Program, Contract #14-08-0001-19910, map 1:48,000.

CLUFF, L.S., BROGAN, G.E., and GLASS, C.E., 1970, Wasatch Fault, northern portion, earthquake fault investigation and evaluation: Woodward - Clyde & Associates, Oakland, CA, map 1:24,000.

KEATON, J.R., CURREY, D.R., and OLIG, S.J., 1987, Paleoseismicity and earthquake hazards evaluation of the West Valley Fault Zone, Salt Lake urban area: in press, map 1:24,000.

SCOTT, W.E., and SHROBA, R.R., 1985, Surficial geologic map of an area along the Wasatch Fault zone in the Salt Lake Valley, Utah: U.S. Geological Survey Open- File Report 85-448, map 1:24,000.

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The Review Process and Adequacy of Engineering Geologic Reports Wasatch Front, Utah

By C.V. Nelson, G.E. Christenson, M. Lowe, and R.M. Robison

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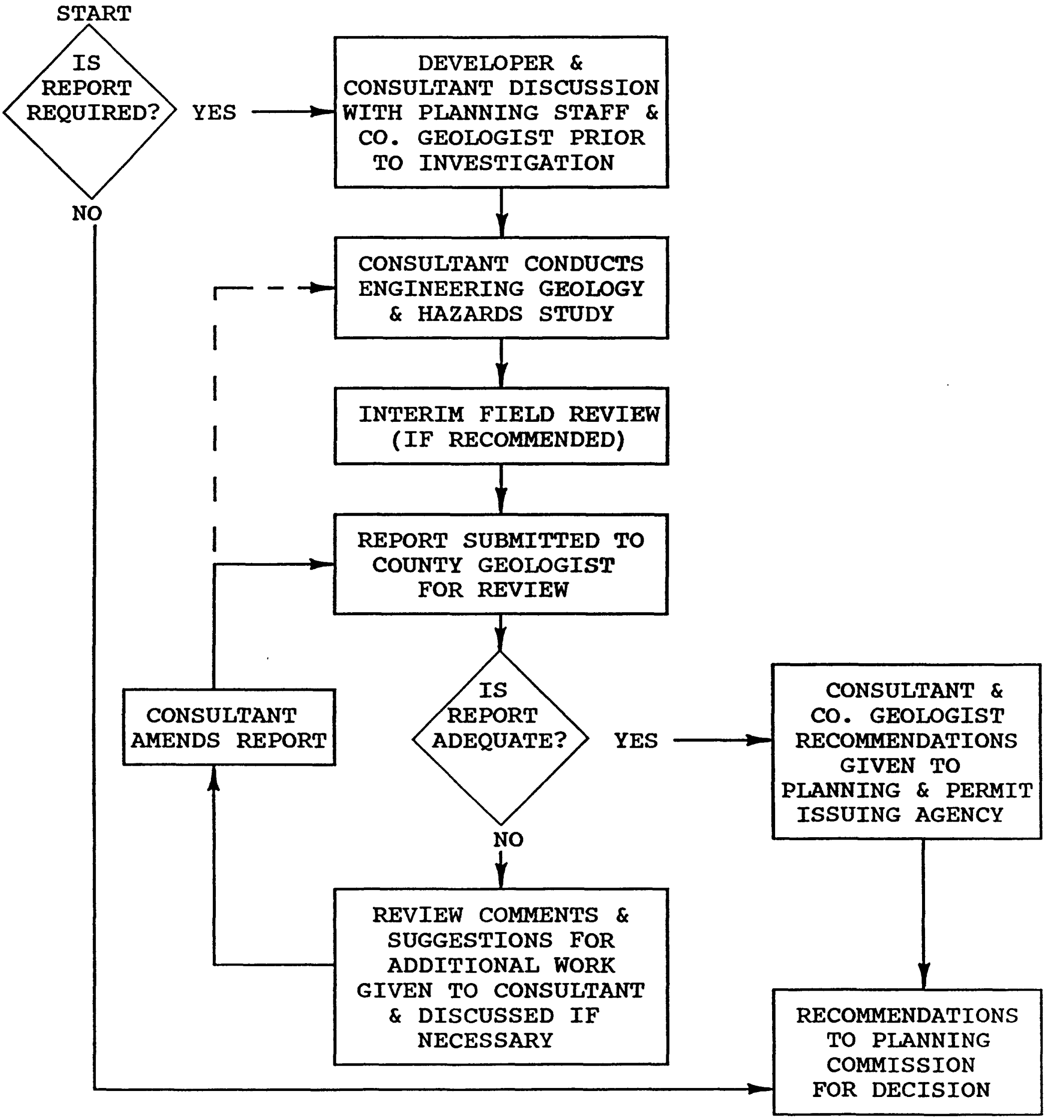
FIGURE 1:

THE COUNTY GEOLOGIST REPORT REVIEW PROCESS



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APPENDIX 3

Chapter 19.75

NATURAL HAZARDS ORDINANCE

Sections:

19.75.010 Purpose of provisions.

The purpose of the natural hazards ordinance is to promote the health, safety and general welfare of the citizens of Salt Lake County and minimize the potential effects of natural hazards to public health, safety and property by encouraging wise use of hazardous areas.

19.75.020 Definitions.

As used in this chapter:

A. "Active fault" means a fault displaying evidence of surface displacement along one or more of its traces during the Holocene time (about 11,000 years).

B. "Critical facilities" means:

1. Lifelines, such as major communication, utility and transportation facilities and their connection to emergency facilities; or

2. Unique or large structures whose failure might be catastrophic, such as dams or buildings where explosive, toxic or radioactive materials are stored or handled; or

3. High occupancy buildings as defined in the Uniform Building Code (UBC R-1, R-2, & R-2.1) such as schools, hotels and offices; or

4. Essential facilities as defined in the Uniform Building Code Section 2312 (k) such as police and fire stations, hospitals, communication centers and disaster response facilities.

C. "Engineering geologist" means a geologist who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and for the protection of the public. This person should have at least a four-year degree in geology, engineering geology, or a related field from an accredited university and at

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least three full years of experience in a responsible position in the field of engineering geology.

D. "Engineering geology" means the application of geological data and principles to engineering problems dealing with naturally occurring rock and soil for the purposes of assuring that geological factors are recognized and adequately interpreted in engineering practice.

E. "Fault" means a fracture in the earth's crust forming a boundary between rock or soil masses that have moved relative to each other.

F. "Fault trace" means the intersection of the fault plane with the ground surface.

G. "Fault zone" means a corridor of variable width along one or more fault traces.

H. "Landslide" means a general term for the downslope movement of a mass of soil, surficial deposits or bedrock.

I. "Liquefaction" means a process by which certain water saturated soils lose bearing strength because of ground shaking and increase of groundwater pore pressure.

J. "Natural hazards maps" means the maps adopted by the county commission showing natural hazards in unincorporated Salt Lake County.

K. "Natural hazard area" means a potentially hazardous area within which hazard investigations are generally required prior to development.

19.75.030 Applicability.

These regulations are applicable to all lands within the natural hazard areas in unincorporated Salt Lake County. The boundaries of the natural hazard areas shall be as they appear on the official Natural Hazards Maps which are dated 198 , which are attached hereto and are on file with the Salt Lake County Planning Division. Such maps and all amendments thereto are a part of this ordinance as if fully described and detailed herein. Each change in the official Natural Hazards Maps shall be subject to the amendment procedure in Chapter 19.90.

19.75.040 Disputes--Boundaries or severity of conditions.

The boundary lines on the Natural Hazards Overlay Maps shall be determined by use of the scale appearing on the map. Where there is a conflict between the boundary lines illustrated on the map and actual field conditions, or where detailed investigations show that hazardous conditions are not significant throughout the entire designated area, the dispute shall be settled as follows:

A. The person contesting the hazard area boundary or the severity of conditions at a specific location shall submit technical and geologic evidence to support such contest to the planning commission.

B. The planning commission may seek review by the county geologist, the Utah Geological and Mineral Survey, or the U. S. Forest Service prior to making a decision concerning the dispute.

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C. The cost of the review shall be paid by the person contesting the maps. The planning commission may allow deviations from the boundary line or severity of the hazard only if technical and geological evidence clearly and conclusively establishes that the map boundary location is incorrect, or that the designated hazard conditions do not present a significant hazard to public health and safety or to property at the specific location for the particular proposed land use.

D. Any decision of the planning commission may be appealed to the board of county commissioners through procedures set forth in Section 19.76.270.

19.75.050 Studies and reports required.

To determine if land is suited to a particular use, site specific natural hazard studies and reports are required to be submitted to the planning commission for particular uses in natural hazardous areas according to the following chart.

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MATRIX CHART SHOWING REQUIRED NATURAL HAZARDS REPORTS

Facility	Natural Hazard (as shown on the Natural Hazard Maps)												
	Ground Shaking			Surface Fault Rupture	Liquefaction		Debris Flow		Landslide/ Rockfall		Shallow Gr.Wtr. (<10')	Problem Soils	Avalanche
	High	Medium	Low		High & Mod	Low & V Low	High & Mod	Low	High & Mod	Low			
Critical Facilities, & High Occupancy Buildings	X	X	X	X	X	X	X	X	X	X	X	X	X
Industrial & Commercial Buildings other than high occupancy	X	X		X	X		X		X		X	X	X
Multi-family Residential development 4 or more units/acre	X	X		X	X		X		X		X	X	X
Residential Subdivisions	X			X			X		X				X
Residential Single Lots & Multi-Family Residential Development less than 4 units/acre							X		X				X

X = Report Required

19.75.060 Natural hazards report.

The natural hazards report shall be prepared by an experienced engineering geologist. In the case of snow avalanche hazard the report shall be prepared by an experienced avalanche expert. The report shall identify all known or suspected natural hazards, originating on site or off site, affecting the particular property and present an assessment of the hazards as they relate to the intended land use. Recommendations and conclusions shall be presented to insure that the hazards are avoided or mitigated so that the purposes in Section 19.75.010 are met.

19.75.070 Review of reports--Prior to approvals.

A. Prior to any development services division or planning commission actions, the natural hazards report shall be submitted for review and recommendation to the county geologist, the Utah Geological and Mineral Survey and/or the U. S. Forest Service. Any cost of the review shall be paid by the applicant prior to planning commission or development services division action. In all cases, a copy of the natural hazards report and review shall be filed in the county natural hazards library in the planning division and another copy shall be filed with the Utah Geological and Mineral Survey.

B. In order to fulfill the purpose of the natural hazards overlay zone the planning commission for conditional uses or the development services division for permitted uses shall determine whether the proposed development meets the requirements of this ordinance based on the required reports, recommendations and other data available to it. Any area which is determined to contain significant natural hazards shall not be approved for development unless the applicant demonstrates that such identified hazards can be overcome in such a manner as to reduce to an acceptable level;

1. Hazards to life, limb, or property;
2. Adverse effects on the safety, use or stability of a public way; and
3. Any other adverse impact on the natural environment.

C. The planning commission or development services division may set requirements necessary to overcome any natural hazards and to ensure that the purposes of this chapter are met.

19.75.080 Active fault considerations.

For uses that do not require a natural hazards study, no structure designed for human occupancy shall be built astride an active fault.

19.75.090 Disclosure required.

Where the natural hazards report shows a natural hazard affects a particular parcel the type and severity of the hazard shall be recorded as a deed covenant running with the land.

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19.74.100 Warning and disclaimer.

The natural hazards overlay ordinance and maps represent only those hazardous areas known to the county or mappable at the present time, and should not be construed to include all possible potential hazard areas. The provisions of this ordinance do not in any way assure or imply that areas outside its boundaries will be free from the possible adverse effects of natural hazards. This ordinance shall not create liability on the part of the county, any officer or employee thereof for any damages from natural hazards that result from reliance on this ordinance or any administrative requirement or decision lawfully made thereunder.

19.75.110 Conflicting regulations.

In cases of conflict between the provisions of the existing zoning classifications, building code, subdivision ordinance, or any other ordinance of Salt Lake County and the natural hazards ordinance, the most restrictive provision shall apply.

UTILIZATION OF TSUNAMI HAZARD MAPS IN ALASKA

BY

JANE PREUSS

URBAN REGIONAL RESEARCH
SEATTLE, WASHINGTON

PROBLEM ADDRESSED BY RESEARCH

Tsunami hazard maps have been prepared for Alaska and the State of Washington which are generalized projections of inundation zones for portions of each coastal region. These inundation areas have been used for two purposes. One is to define evacuation zones. The other is to establish a basis for flood insurance. Numerical models used for the projections have generally been calibrated at a large grid size which are useful to forecast the wave direction and general indication of wave elevation. They have not been useful for small area/community level planning because they have not taken into consideration land based variables which either may retard or exacerbate the hazard. For example, friction creating features such as large groves of trees or massive structures can slow the wave while fuel tanks and stored materials can create secondary hazards such as the fires which occurred in Valdez, Whittier, Seward and Crescent City.

Analysis of the 1964 tsunami reveals that damage is caused by discrete but interrelated aspects of the tsunami event. In order to develop policy which responds to the tsunami threat, it is, therefore, first necessary to conduct a thorough risk analysis for the individual community. Through this analysis, it is possible to translate implications of generalized inundation maps into a series of microzones reflecting the geographic dimensions of the risks and the appropriate administrative/jurisdictional structures for responding to the defined risk. The project described in this paper developed a prototype methodology to 1) identify the various characteristics of tsunami risk within the generalized hazard area and 2) to mitigate those risks. Kodiak, Alaska is used as the case study. Figure 1 defines the aspects of tsunami risk which are subsequently translated into an implementation/risk mitigation framework.

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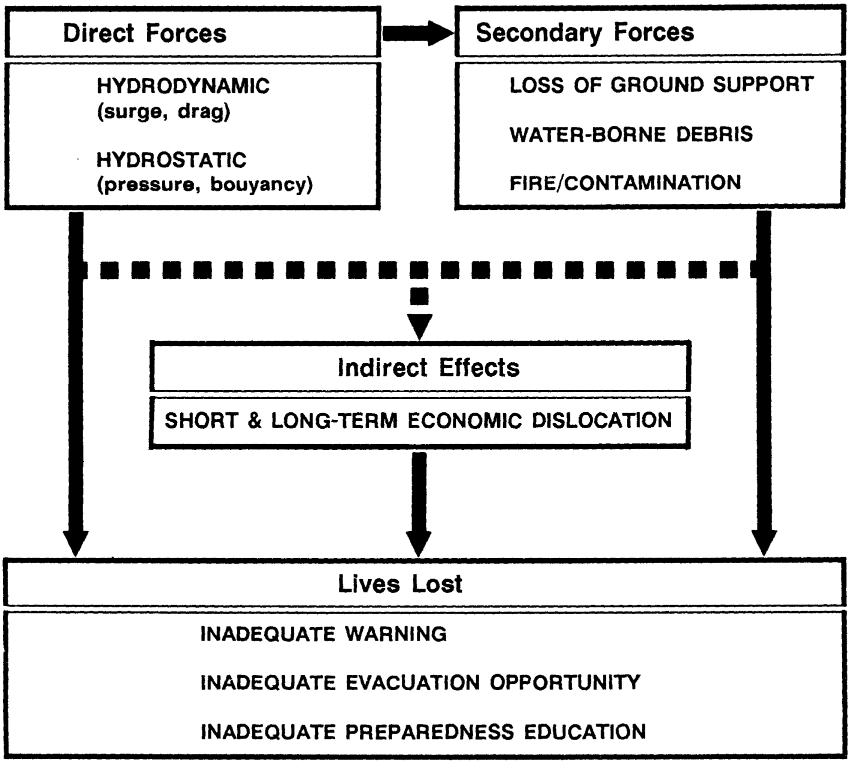

Figure 1
Components of Tsunami Risk

RESEARCH WHICH CONTRIBUTED TO APPLICATION

The research consists of three phases. Phase I is a numerical simulation to define the physical parameters for a "design" tsunami event. Phase II is analysis of the risks associated with that event. Phase III develops urban planning/policy responses to the risk.

During Phase I, a numerical model of the tsunami experience simulates the inundation area, depth of flooding and velocity throughout the case study which has been defined as downtown Kodiak. The region is 1.5 by 1 kilometer. Grid size for the numerical model is 33 meters. Inland extent of flood is approximately 400 meters (433 yards). In addition, arrival time of the tsunami from the source to Kodiak City was projected. Computed tsunami reoccurrence elevation in Kodiak has been projected at the 30 foot (10 meter) ground elevation. Maximum flooding ranges from four meters to less than one meter.

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During Phase II, the risk implications of the Phase I physical parameters are defined in terms of primary and secondary impacts. Primary impacts are the hydrodynamic and buoyant forces exerted by the water. Secondary impacts are from loss of ground support, debris, fire and contamination.

In 1964, "floating debris" consisting of boats, vehicles and buildings dislodged from their foundations were a major source of damage. Figure 2 identifies potential sources of floating "debris" under present conditions.

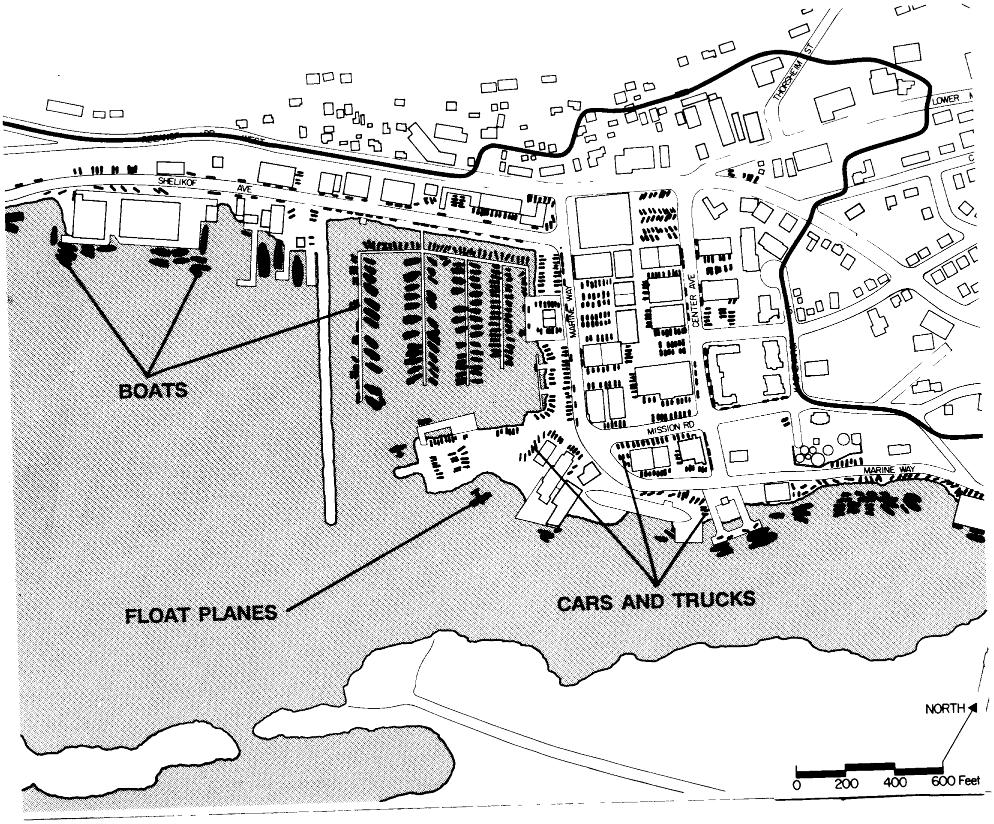

Figure 2
Inventory of Floating Debris Potential

Many communities experienced major fires during the tsunami of 1964. The fires were from such causes as fuel tank rupture, explosion of railroad storage cars, and a fuel truck being tossed against an electrical vault. In each case, flaming oil was carried inland on the surface of subsequent

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waves. The towns, built primarily of wood, burned for several days. Although Kodiak experienced no fires in 1964, many susceptible conditions are represented in the study area. Figure 3 illustrates potential fire risks for Kodiak.

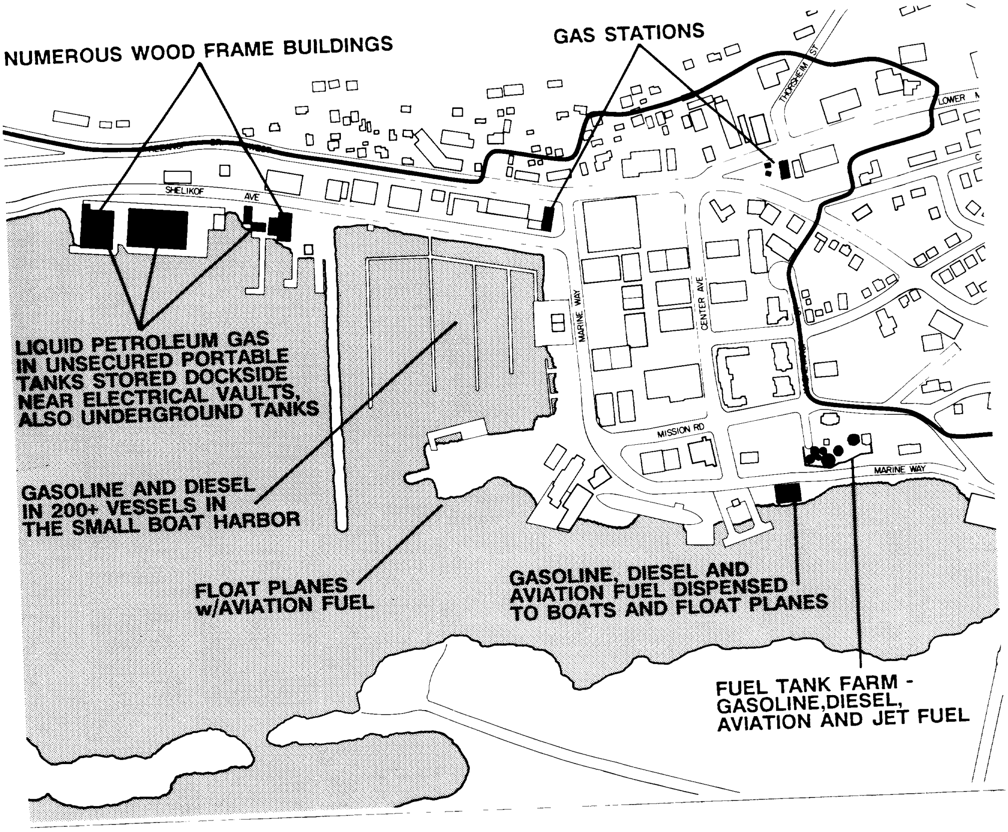

Figure 3
Inventory of Risk from Fire

Once the risk locations are clearly defined it becomes possible to develop a risk reduction program responding to their specific characteristics organized according to sub-areas. Analysis of risks indicate that they are primarily a function of use. Accordingly, the four sub-areas identified in Figure 4 were defined. These districts and the primary/secondary risks to which they are exposed are listed in Table 1.

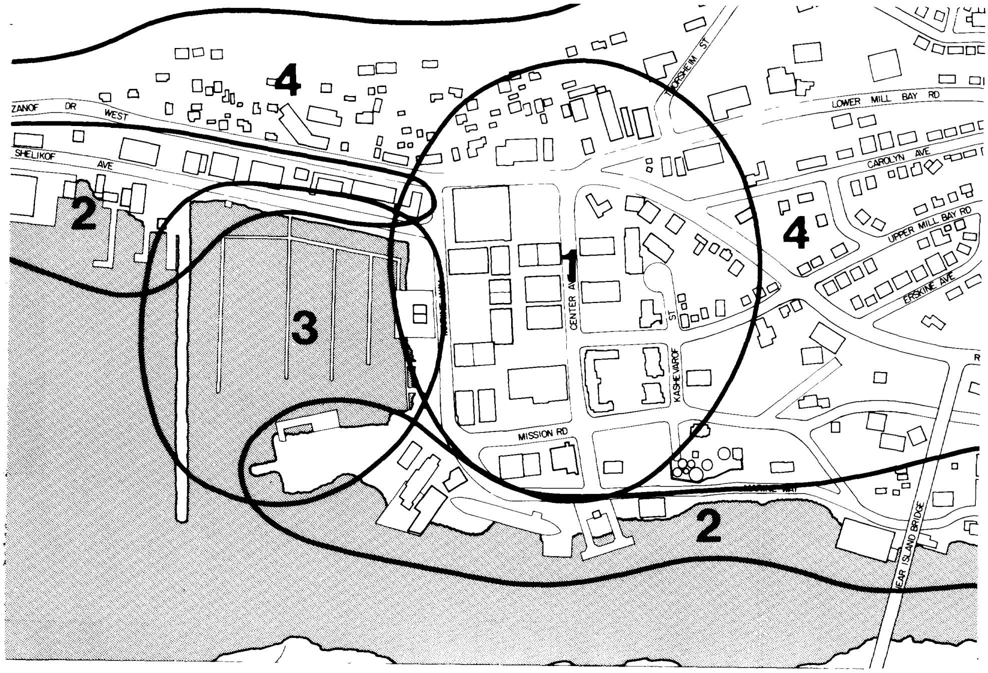

Figure 4
Tsunami Based Planning Zones

TABLE 1

Use Correlated with Tsunami Risk

Zone	Dominant Use	Risk
1	Commercial/Mixed Use	Water Volume and Wave Velocity Ground Failure
2	Marine and Industrial	Debris Impact Ground Failure
3	Industrial Uses	Fire and Contamination Ground Failure
4	Residential	Water Volume Fire

TRANSLATION TO FACILITATE APPLICATION

Translation of risk analysis into an effective risk reduction program is dependent on an integrated administrative process involving many agencies and jurisdictions. Since public responsibilites tend to be based primarily on use, tsunami risk mitigation measures are organized according to special overlay districts which can be administered in conjunction with the on-going planning process.

These special districts create a range of administrative options the provisions of which can be defined in relation to risk characteristics for each community. Depending on the types of risk, different communities would implement only those provisions which address the greatest threat. Examples of special concerns for each district are outlined below for the Kodiak case study.

Sub-area 1: Commercial/ Mixed Use:

Objectives of mitigation are to protect property from direct effects of water forces and to keep structures from becoming a secondary hazard. Two micro zones are proposed within the commercial/mixed used area based on the amount of flooding. One is the area of maximum flooding/velocity which is projected to be more than three meters. The other is less than three meters.

The area for which three meters or more of water is projected will be subject to stringent criteria for redevelopment in the event of another tsunami. Figure 5 illustrates a proposed redevelopment concept for the high impact area which also includes driveway and parking relocation.

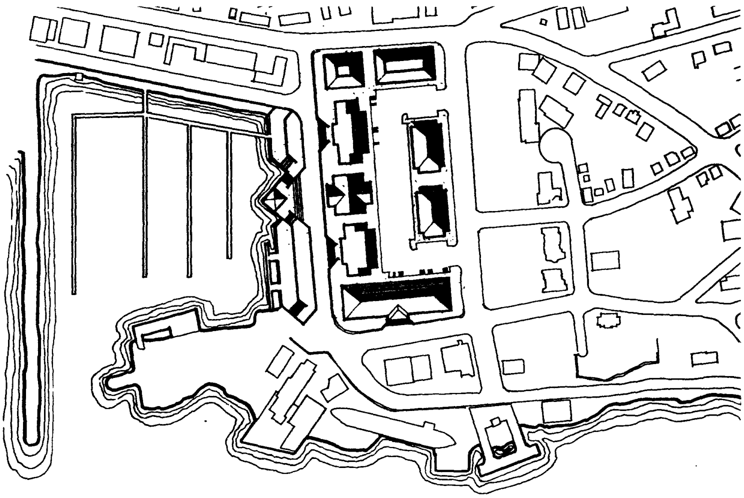

Figure 5
Commercial Redevelopment Concept

During reconstruction after the 1964 event, the downtown area was filled to a constant twenty foot elevation. Kodiak's commercial core consisting of commercial use and a retail mall with office and retail on second stories are located on the fill. Virtually all structures have slab on grade foundations. None of these buildings are expected to withstand a repeat tsunami event. Interim measures would be, therefore, designed to minimize debris impacts and improve evacuation by relocating parking areas and driveways to reduce traffic at critical intersections. Once parking access and access patterns are changed it will be possible to shift primary traffic from Marine Way onto Center Street. This shift will also be designed to minimize commercial use of the already congested intersection at Marine Way and Rezanof Drive.

In portions of the inundation area for which the projected inundation is less than two meters, it is possible to develop buffers. Experience has shown that dense groves of planting are effective means of catching debris. In Japan, low (fence level) walls are also used to buffer selected structures such as existing high occupancy buildings from impact. Within this district, new critical facilities (hospitals, schools, fire and police stations) should not be built. Other high occupancy structures such as auditoriums and theaters because of high potential for life loss are inappropriate throughout the entire inundation zone. Historic buildings in both high and low velocity zones should be protected.

In the low velocity zone, special care should be taken to ensure optimum drainage conditions. For example, ground should slope away from buildings for two feet while drainage swales and other non-structural measures can be utilized to reduce vulnerability.

Responsible agencies for these measures would be Zoning and Building Departments.

Sub-area 2: Industrial Uses

Inventory of port-related industrial uses reveals a heavy concentration of potentially flammable materials within the hazard area. For example, fuel tanks are loosely anchored and unprotected electrical vaults are located adjacent to highly combustible materials. An additional danger is that in many instances water reactive materials such as sodium hydrosulfite, chlorine or cyanide compounds are transported or stored within the industrial areas. These uses are subject to two types of hazards: 1) being impacted by boats and other debris borne inland, and 2) breaking loose and hitting nearby buildings. Both types of hazards can result in fire.

The objective of this sub-area is to minimize sources of ignition and fire spread to nearby wood structures.

Special attention must be given to storage of fuel and other combustible materials. All uses such as oil tanks and storage areas would be evaluated in terms of siting and construction of protective measures. Discretionary uses such as gas stations which have high damage potential could be restricted to outside of the high impact zone. Other recommendations include:

- Anchor all flammable uses in order that they not become debris.
- Buffer electrical vaults.
- Create fire breaks to buffer fire sources from flammable sources. These breaks could either be structural (concrete) to create enclosed protection or open/planted space.

Many of the measures to reduce fire risk are procedural. For example, there should be precise monitoring programs for the storage and transport of hazardous materials. In addition, special inspections should be conducted of fuel lines to ensure good repair. Operational preparedness would also define the stationary positions and dispersion procedures for fire fighting teams and equipment. Materials such as sufficient foam/fire chemicals within close proximity to fire sources would be specified as part of the operational plan.

Responsible agencies would include the Fire, Building, Police and Public Works Departments.

Sub-area 3: Marine Uses

A major cause of damage from the 1964 Alaska tsunami was from boats and piers which broke loose and struck buildings when they were carried inland. The primary objective of this sub-area would, therefore, be to reduce the risk from uses in this district becoming debris.

The seaward boundary of the tsunami hazard area encompasses the breakwater and all water-borne uses in the near shore which could be swept inland, including boats, float planes, docks and piers. Landward boundaries would include erosion-prone banks of exposed fill.

Special attention should be given to securing the moorages of boats berthed in the small boat harbor. For example, steel cables can be used to secure the boats. Piers and docks should be designed to be 1) flexible enough to withstand impacts and 2) provide maximum resistance to avoid becoming debris (pilings anchored to bedrock/sufficient bracing).

Tsunami resistant berths can be constructed for selected high intensive loading docks such as in major port areas. In smaller boat harbors, such as Kodiak, piers and wharves are unfortunately not expected to withstand a major event. It should, however, be noted that in 1964 along the Near Island Channel some docks did withstand the tsunami.

Bank areas, especially where there has been fill should be reinforced to minimize erosion and to contain debris which is created by failure of the boat moorages and piers. This stabilization is especially important for areas accomodating underground storage tanks. Revetments would be constructed to withstand a "design" specified velocity event. This revetment can be designed to also create some protective buffers to keep debris such as boats from impacting structures such as potentially hazardous uses.

Responsible agencies would be the Harbormaster, Port Authority and/or state transportation agencies.

Sub-area 4: Life Safety District

Sub-area 4 is primarily concerned with life, as opposed to property, safety. The boundaries of the life safety district include the harbor, all of the inundation area from which people will be evacuated plus the upland areas to which evacuees will be directed. The objective of this district is to facilitate evacuation out of the hazard area. Primary considerations are therefore associated with facilitating vehicular and pedestrian traffic flow.

Evacuation planning consists of two components. One is route design. The other is traffic control. Evacuation plans must be adopted which address requirements of vehicles, pedestrians, and boats. All traffic routes should be established prior to the event. These routes should be an integral part of the traffic network which means a) clearly identified and b) year round accessible/maintained.

The second component of the evacuation plan is traffic control. The Kodiak Police Department has prepared an evacuation plan which assigns people to specified intersections. For larger communities, it will be necessary to ensure that the signals can be controlled to optimize traffic flow. Traffic control signals must have an override provision so they respond to volumes and turning movement requirements.

Figure 6 illustrates the evacuation plan prepared by the Kodiak Police **Department**.

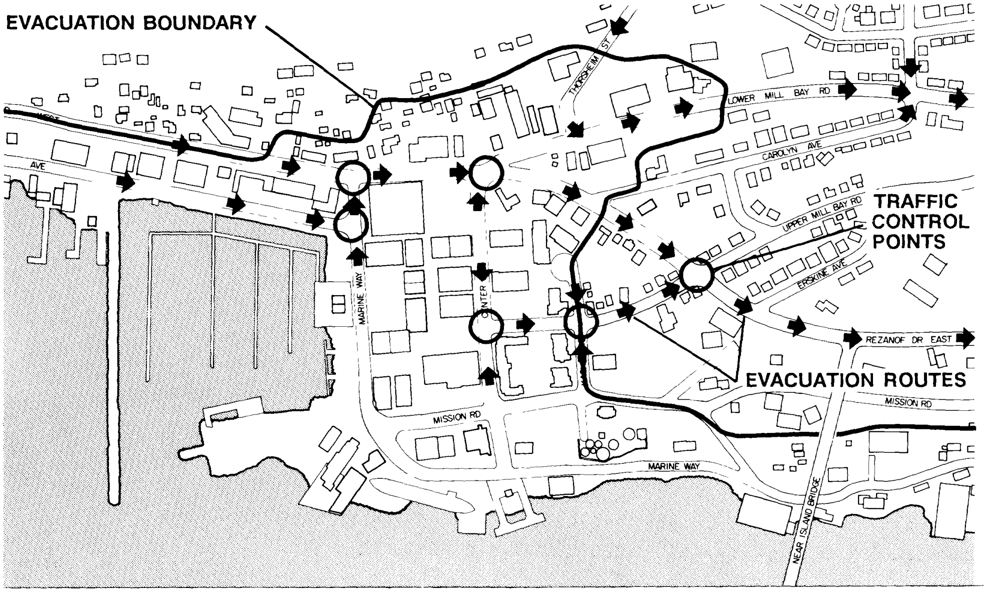

Figure 6
Evacuation Plan for Kodiak

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Marine radio operators must be trained to give proper advice to ships.

Responsible agencies would include Fire and Public Works Departments and the Harbormaster.

DEMAND FOR RESEARCH AND DISSEMINATION

During the 1970's, I worked as a land use planner on several comprehensive development plans for the Island of Hawaii. Hilo suffered major tsunami inflicted damage in 1949 and 1960. The Ka'u District experienced a damaging local event in 1975. Because of continuing volcanic activity communities were more aware of vulnerability to future tsunami events. A major uncertainty from the standpoint of land use decision making was, however, definition of the tsunami hazard area. For example, in Hilo, underlying issues were to decide whether to base planning policies on the maximum forecast event, on the 1949 event, the 1960 event or on a middle point. Unfortunately, there were no guidelines for land use planners to integrate tsunami susceptibility related criteria into the planning process.

In 1982, Urban Regional Research completed a National Science Foundation funded project which analyzed and defined land management practices for tsunami hazard areas. This study which used case studies in Alaska and Hawaii found that all uses are represented in the hazard zone. Land management guidelines proposed by the project were designed to mitigate tsunami inflicted damage. Follow-up interest in the 1982 report was from a wide variety of implementing interests including harbormasters, police, emergency services and public works departments. Special projects responsible for public facility location on the west coast and coastal zone management staff also expressed interest. Departments with land use planning authority did not, however, express as high an interest in the findings. Interviews with representatives of the latter departments indicated the reason for the lack of follow-through was that they require more precise understanding of the risk before complex (and generally controversial) land use and construction related decisions can be made. Their comments have been integrated into the scope of investigations for the present project.

Two events have contributed to dissemination of interim research results from the project described in this paper. One was the May 1986 tsunami alert on the West Coast. The other is the recent geological evidence that great earthquakes in the Puget Sound Region have been accompanied by tsunamis. Interest has been most intense in communities which experienced damage in 1964. Dissemination of the results has been through word of mouth, primarily through informal channels such as emergency services, public works, and police departments. Preliminary findings were also transmitted in Alaska through a radio interview conducted in Kodiak. Comments on the program have subsequently been expressed from several sources throughout the state.

The most difficult problem in disseminating the results is essentially that funding was allocated only to conduct the research. Aside from publication of the report, funding has not included dissemination activities. The ideal dissemination format would be to have formal follow-up contact with users.

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Funding for this type of follow-up would come from agencies with responsibility for preparedness such as FEMA or for development of construction guidelines such as the National Bureau of Standards. No clearly defined channels of responsibility however exist for utilizing/disseminating the research.

Dissemination of the research findings must overcome additional obstacles. One pertains to a generally low level of interest because of the infrequency with which tsunami events occur. In Alaska, because of the 1964 experience and because scientists have projected that tsunamis could accompany an earthquake generated in either the Shumagin gap or the Yakataga gap, there is considerable interest in the tsunami problem. There is less interest on the remainder of the west coast despite recent discoveries in the Puget Sound region which indicate that historically large earthquakes in the area have been accompanied by tsunamis. The second obstacle is the limited understanding of the discrete causes of damage which results in a stereotypical attitude that "there is nothing which can be done". Policy makers must be educated to address the various aspects of tsunami risks which can be uniquely tailored to the characteristics of the community. The application process for this type of research would be improved if a process for education and dissemination could be established at the onset of research efforts.

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THE PROCESS OF INTRODUCING NEW OR IMPROVED SEISMIC DESIGN PROVISIONS IN THE WESTERN UNITED STATES

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It is possible to argue that the only earthquake hazard mitigation activities that save lives and reduce property damage are strengthening existing buildings, improving the construction of new buildings, or land-use planning that prevents the construction of buildings in hazardous geologic sites. All other hazard reduction activities - such as geophysical studies, building instrumentation, structural analysis and testing, public awareness programs, etc - are only effective to the extent that they contribute to improvement in building or its location.

If we pursue the thread that binds research to construction improvement, it is generally assumed to lead to improved building codes. Research in the laboratory or the field leads to discoveries about building performance that are then translated into code directives that all designers and contractors must follow. Concerns, for example, about the performance of nonductile concrete frame structures, culminating in failures in the San Fernando earthquake of 1971, resulted in increased laboratory and analytical research, which was translated into building codes around 1975.

This sequence accomplishes the engineering objectives, but the hazard mitigation objectives are only accomplished if the improved seismic building code is adopted, and if it is enforced. This is not a technical process, but a social, political, economic and even cultural one. Moreover, code adoption is primarily a local activity, in which cities and counties decide to adopt a model code, or a later version of the model code they currently use. Larger jurisdictions may sometimes add their own modifications to the model codes. So, significant code change and improvement is reflected in the model codes, which then must be adopted by the local jurisdiction.

Federal Government buildings are exempt from local codes, and often State buildings are also exempt. A typical community may thus erect buildings under three different code situations - local, state and federal. And different state or federal jurisdictions may have different codes: thus in the same location a Veterans Hospital is designed to a different code than an Air Force Hospital; and a State hospital may be designed to a different code than the Federal hospitals or a private hospital.

This background is sketched to indicate that an assessment of the process of the introduction of new or improved provisions in a range of Western States is necessarily uncertain. It would require a major research effort to establish the present code situation - both adoption and enforcement - for hundreds of jurisdictions, and to establish the status of change and improvement. Moreover, since codes establish only a minimum standard of seismic resistance, the actual quality of seismic resistance is determined by practice. It is possible to maintain a good standard of seismic resistance without a code - as was often done before the introduction of building codes.

This paper can do no more than make a few personal observations; about the process and present a few "snapshots" that represent opinions rather than established fact.

In the effort to make our built environment safer against earthquakes, the use of new or improved seismic codes is rightfully seen as an important measure. However, codes dealing with new building affect approximately 2% of our building stock each year. So the building code approach is very long-term, but nonetheless important. Indeed, for less seismic areas, introduction of a seismic code now may ensure that if, in fifty years time, a moderate earthquake finally strikes, by then a majority of buildings will be seismically resistant, and many of those that are not will have been pulled down or improved by market forces. So the introduction of improved codes is perhaps best seen as a long-term improvement in building quality, or an aspect of building maintenance, rather than as an immediate and urgent response to an immediate earthquake threat.

This issue can be put into better perspective by the realization that for many areas the issue is not whether to introduce a seismic code, but whether to introduce a building code of any sort.

Thus for example, in Idaho, 17 jurisdictions have not adopted a building code, including two that were hard-hit by the Borah Peak earthquake of 1987. Use of a building code is not mandated by the State, but is optional. There is presently a move afoot to reinstate a state requirement for use of the Uniform Building Code, but the motivation is not public safety, but to normalize building procedures so that the better designers and contractors can compete more fairly with those operating at a lower level.

In the two earthquake hit communities that have no code, it is argued that the damaged buildings were very old and poorly built, the communities are small, and their economics are very depressed, so that only simple structures, if any, are being built. So perhaps these are not places in which the lack of a code is surprising: the use of codes goes hand-in-hand with extensive development.

In the State of Wyoming, the 24 county jurisdictions range in the NEHRP Seismic Index from 1 to 4, and from 1 to 7 in the acceleration coefficients - in other words from minimum to maximum seismicity in one state. At the same time, many of these jurisdictions have no building codes - they are sparsely populated by people who do not expect the "government" to tell them how to build their homestead. This is an anti-regulatory "culture," and in many cases construction is associated with marginal resources.

Building codes express a minimum standard, agreed on by the community, to provide (but not guarantee) health and safety. They protect the community against the developer, designer or builder who is either dishonest, ignorant, or both. Sophisticated owners may require a building to be built above a prevailing seismic code standard, or to be built to a seismically resistant standard even if such a code does not exist. Thus the leadership role of major corporate builders and mortgage bankers or designers is important.

In Memphis, which currently has no seismic code provisions, major buildings in the city are built to seismic standards because mortgage bankers from California require them, and major industries also require them. And in Salt Lake City, two buildings are currently under construction using a sophisticated base isolation system (of which California currently has only one example). In this case, this innovation is due to effort and pursuasion on the part of architects and engineers, and also owners who are willing to listen and understand.

This action is dependent on a public perception of the earthquake threat such that public officials feel justified in making an issue of the technical merits of alternative seismic design approaches. So the issue has moved from debating the issue of seismic design and its cost, to accepting seismic design and debating its merits - and cost. This represents implementation rather than awareness.

Of great significance is the fact that the two leading structural engineers in Salt Lake City, who are responsible for some 80% of the major buildings, are both strong proponents of seismic design, and have spent much of their own time becoming proficient in seismic techniques.

Moreover, the level of awareness in Utah is such that measures dealing with the hazard to existing buildings become possible, and studies to assess the seismic resistance of fire stations and schools are in progress.

At the same time, a hazardous building ordinance in Ogden, Utah - to date the only such ordinance outside the State of California - appears to have found local political interest too strong to resist. Such problems are to be expected as a few activists attempt to persuade a general - or a special - population to take measures which demand a level of sophistication and long-term concern which is not typical of our present social and political culture.

The interpretation of seismic hazard reduction in buildings as best represented by the adoption of seismic codes is a very simplistic vision of a very complex process. As noted, code adoption is only one part of the process that includes code enforcement and the variety of levels of design and construction practice.

The City of Seattle, Washington, has adopted the 1979 Uniform Building Code, including the seismic provisions. Opinions in design circles vary as to the effectiveness with which seismic design is actually pursued. The extensive rehabilitation projects in Seattle - for marketing and historic preservation reasons - have also focused attention on the seismic strengthening of existing buildings.

Simultaneously, a long-term effort has been underway by a few activists to institute seismic hazard mitigation measures in the State, particularly directed towards school buildings. After many years of effort, a statewide vote in November this year (1987) will determine whether some $504 million for school construction needs in the next 15 years. If it does, then 10 unreinforced masonry schools may finally be replaced or repaired within the next 5 or 10 years, as part of a general capital improvement program.

At the same time a bill relating to gathering and disseminating information on earthquake dangers recently was killed by the State Ways and Means Committee. This bill arose out of a Washington State Seismic Safety Council, formed in 1985 as an advisory group to the Department of Emergency Management (a bill to authorize a Seismic Safety Commission was vetoed by the Governor, on the grounds that these tasks should be done by the Department of Emergency Management).

The advisory Seismic Safety Council existed for a year, and the recent bill proposed inventorying public buildings (including schools), disseminating information about the earthquake problem, and reinstituting a State Seismic Safety Council under the Department of Community Development.

As the bill progressed through committees, the earthquake information dissemination activities and the seismic safety council proposal were struck out, leaving only the inventory. Though the bill was ultimately killed, $250,000 was appropriated for an inventory of school facilities to be conducted by the Office of Financial Management. This inventory is intended to provide date to a management information system and includes, but is not limited to, seismic information.

The detailed history of these political activities include many reversals and misunderstandings and, only now, the hope of action. This action will come long after the children of those investigating the activity have passed through the school system: political activism of this sort is a service for the future, not the present.

From these 'snapshots' one can draw certain conclusions:

1. Adoption of seismic codes must also be accompanied by enforcement, if the code approach to hazard reduction is to be effective.

2. Beyond and not necessarily related to code adoption and enforcement, improvement in standards of practice of design and construction are critical to improving safety.

3. The leadership role, whether by design professionals or building owners, is important.

4. In the larger picture of improving the present or future building stock there are innumerable activities being pursued by a still relatively small number of activists.

5. Seismic hazard reduction in buildings is often accomplished through other motivations, and, in less seismic areas, this may be the most effective approach to encourage.

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PERSPECTIVES ON FOSTERING THE BUILDING CODE PROCESS

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ABSTRACT

Historically, it has taken seven years or more for new developments to move from research to implementation in construction using normal channels of building code development. In an attempt to shorten this time period, the Applied Technology Council, developed a new design procedure for seismic resistant buildings and published it in a document entitled, "Tentative Provisions for The Development of Seismic Regulations for Buildings," (ATC 3-06). When published in 1978, this document represented a significant change in design procedures.

Although the Applied Technology Council effort did not reduce the time between inception and utilization of the design procedure, it did lay the foundation for the successful efforts of the Building Seismic Safety Council (BSSC). The BSSC was formed with the intent of developing a "consensus" organization. Whereas the ATC had avoided having participants who were formally representing specific portions of the construction industry, BSSC solicited full participation from all portions of the industry.

The Building Seismic Safety Council used a procedure that first "calibrated" the original provisions to make them viable. They then developed a consensus of the member organizations to achieve an acceptable version of the provisions. The Council's efforts also spurred other organizations to adopt a similar approach to code development. As a result, basic concepts of the BSSC-developed provisions are now being widely adopted by code writing agencies.

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BACKGROUND

In the early 1970's, one of the most ambitious efforts to develop and implement a state-of-the-art design procedure for earthquake resistant buildings was started by the Applied Technology Council (ATC). Using funding supplied by the National Science Foundation, the Applied Technology Council established the ambitious goal of shortening the time from research to implementation for design concepts related to earthquake resistant buildings. To accomplish this task, they assembled a group of the most knowledgeable and respected academic researchers and practioners in the United States. However, they intentionally avoided having representatives of specific commercial interests among the participants.

With input and support from the National Bureau of Standards, work of the Applied Technology Council went forward and resulted in publication of, "Tentative Provisions for the Development of Seismic Regulations for Buildings," in 1978. Ultimately known as ATC 3-06, this effort involved approximately 100 people and several years of tough work. The resulting document was a state-of-the-art effort that included many innovations.

As publication of ATC 3-06 drew near, many industries which would be directly affected by its implementation became concerned that results of ATC 3-06 had not been assessed and that some segments of the construction industry might be unfairly penalized in the market place. These fears were brought to the attention of the National Bureau of Standards. As a result, the Bureau of Standards chose to print the following statement at the beginning of the report:

> "Because of the many new concepts and procedures included in these tentative provisions, they should not be considered for code adoption until their workability, practicability, enforceability, and impact on costs are evaluated by producing and comparing building designs for the various design categories included in this document."

When published in 1978, the ATC 3-06 document entitled, "Tentative Seismic Provisions," provided a real breakthrough in the approach to seismic-resistant design. However, there was great resistance to adopting this into building codes.

In 1979, the Building Seismic Safety Council was established through the efforts of the National Institute of Building Sciences. The Council was a "consensus" group charged with expediting the widespread acceptance of seismic design procedures. As their first effort, BSSC undertook to "calibrate" and gain acceptance for the ATC 3-06 design approach. The approach the BSSC used for gaining widespread acceptance for the recommended provisions was to first do trial designs to calibrate the provisions and then provide back-up material to help get the document accepted by code-writing groups.

Although it was well recognized that the effects of ATC 3-06 needed to be evaluated, no suitable mechanism for this effort was available. Many organizations were capable of doing the work, but few could meet the test of "independence". Among

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those considered as "independent" was the American Society of Civil Engineers. However, ASCE did not have an established method for taking on contracts of the type required.

Another organization, the National Institute of Building Sciences (NIBS), had both the "independence" and mechanism for doing the contract work. Consequently, NIBS elected to take on the job by creating an independent subsidiary called the Building Seismic Safety Council. The scope of the Council was established to allow participation by all groups interested in building seismic safety. Although all interest groups were to be represented, the Council was established so that no single "special interest" could dominate.

Directed by a 16 member Board of Direction and with a membership of more than 50 organizations either involved with or impacted by the building process, BSSC provides a forum for elements of federal, state, and local governments; standards and model code bodies; professional societies; building industry and trade organizations; the research community; and consumer groups to participate equally in the development of a consensus on improving building seismic safety provisions. The purpose of BSSC is to, "enhance the public's safety by providing a national forum to foster and improve seismic safety provisions for use by the building community."

In its purpose, the Council recognized that it should work through existing organizations and institutions rather than attempt to force seismic provisions as separate and additional requirements. In addition, BSSC recognized that regional and local differences in the nature and magnitude of potentially hazardous earthquake events would require a flexible approach. Not only should the relative risk be included but it was recognized that resources and capabilities should also be considered.

After publication of the 1985, "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," continuing efforts have been established to update the provisions. Activities of the BSSC are on schedule. Codes based on the general approach described in the recommended provisions are becoming accepted in jurisdictions scattered throughout the United States.

RECOGNIZING THE NEED

After formation of the Building Seismic Safety Council, its Board of Direction began these efforts to "enhance the public's safety." It began these efforts by first defining what should be done.

The BSSC Board of Direction recognized that the most widely used seismic provisions were those of the Uniform Building Code (UBC) (2). Seismic provisions of the UBC are based on a document prepared by the Structural Engineers Association of California. This document, commonly called the "Blue Book" (3), has been widely used both on the west coast and in foreign countries, as a basis for modern seismic design. However, the eastern United States has generally

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perceived the Blue Book and the Uniform Building Code as "California documents not suitable for use in the eastern United States."

Based on this perception, the Building Seismic Safety Council set out to develop a document that could be used nationally and accepted nationally. It was decided that this document should be based on ATC 3-06 (1). The Board further decided that, to develop the document, it would be necessary to do trial designs and to "calibrate" ATC 3-06. Once the calibration had been completed, it was the intent of BSSC to get a "consensus" of its membership to accept the document. Thereafter, it was planned that efforts should be started to gain wide acceptance of this new up-to-date document. A time frame of about five years was established for the trial designs and development of the first consensus document.

The BSSC Board of Direction recognized that, for the trial design results to be meaningful, design firms would have to be hired to do the work. Money to pay for these designs was solicited from the Federal Emergency Management Agency.

To gain the widest possible acceptance of the results, the entire membership of BSSC was involved in the effort. Key players included representatives of the Applied Technology Council, the Structural Engineers Association of California, the American Society of Civil Engineers, the National Bureau of Standards, and many of the individual industries that are directly affected by seismic design requirements. Funding for manpower supplied by the National Bureau of Standards was within the NBS budget. All other effort, by far the greatest contribution, was volunteer.

As originally written, the design procedure in ATC 3-06 greatly changed the relative economics of different types of construction. Because of the significance of the change, many segments of the construction industry ran the risk of being put out of business. This provided a great external motivating force that assured industry would, if given the chance, participate in the process. In addition, money provided by BSSC through the FEMA contract permitted participation of individuals and organizations that did not have their own financial support.

TRIAL DESIGNS

Soon after the Building Seismic Safety Council was started, a joint BSSC-NBS committee was formed to develop the trial design procedures. To start this activity, the ATC 3-06 tentative provisions were reviewed. The result of this review effort was to produce 198 recommendations for changes prior to doing the trial designs. To facilitate development of criteria by which the trial designs could be carried out, a small committee of about 14 people was formed. In addition, a BSSC-NBS Trial Design Overview Committee was established to determine the clarity and completeness of the modified document used in the trial designs.

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The trial design activities, the most significant "research studies" that contributed to development of the BSSC document, were done in two phases. A total of 17 professional design organizations from nine cities were retained to prepare designs of the following building types:

1) Low-, mid-, and high-rise residential buildings
2) Mid- and high-rise office buildings
3) One-story industrial buildings
4) Two-story commercial buildings

During the trial design phase, each building was designed twice. One design was done according to the tentative provisions and the other according to the prevailing local code for the particular location of the design. Basic structural designs, partial structural designs, and partial non-structural designs were done so that design costs and construction costs could be estimated. The BSSC-NBS overview committee, assisted by a technical consultant, reviewed the design concepts at each stage. When the designs were completed, the firms were asked to certify the accuracy of their calculations and to report their findings.

In Phase I of the program, ten design firms were retained to prepare trial designs for 26 new buildings in four cities. The cities included Los Angeles, Seattle, Memphis, and Phoenix. During Phase II, seven firms were retained to prepare trial designs for 20 buildings in five cities. The cities included Charleston, South Carolina; Chicago; Ft. Worth; New York; and St. Louis.

Upon completion of Phase II, additional changes were made and a draft version of the recommended design provisions was published. The document was in three parts, including the draft provisions, draft commentary to the provisions, and an appendix presenting three chapters related to existing buildings. In addition to the draft provisions, a summary report on the trial designs along with complete reports of each design were published. Funding for all of these efforts came primarily from FEMA.

NEHRP RECOMMENDED PROVISIONS

Soon after completion of the trial designs, the first draft of the, "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings" was sent for ballot by the membership of BSSC. This draft contained revisions made prior to conduct of trial designs and further refinements made by the Overview Committee after reviewing results of the trial designs. The first ballot by the BSSC member organizations, completed in July 1985, showed that many disagreements still remained. After revisions had been made, a second draft was sent to the membership for ballot in August 1985.

The second ballot on the provisions showed that virtually the entire document received consensus approval. A special BSSC council meeting was then held in November 1985 to attempt to resolve the remaining differences. Where differences could not be resolved, the items were referred to BSSC technical

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committees for consideration during updating after 1985. The updating effort is also being funded by FEMA. In early 1986, the approved copy of, "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," was published (4). Publication of the document was on time and within the original scheme of completing the effort within five years.

FACILITATING APPLICATION OF THE NEHRP RECOMMENDED PROVISIONS

Publication of the, "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," was a significant step toward the objectives of the Building Seismic Safety Council. However, the process of getting the provisions adopted was only beginning. At the time the provisions were published, the BSSC Board of Direction adopted the position that significant efforts were still needed to obtain acceptance and utilization of the provisions. An effort was undertaken to develop a document that would identify for those that wished to utilize the provisions, potential impacts, issues, or problems that might be expected during the introduction process. Also, this document, "Guide to Application of the NEHRP Recommended Provisions in Earthquake-Resistant Design," is designed to provide sufficient background information to deal with those impacts, issues, and problems (5).

Several other documents have also been prepared to help with the implementation. These include handbooks on "Societal

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Implications" (6,7), an action plan (8), a non-technical explanation of the provisions (9), and guidelines for preparing code changes (10). Recently, a "hot-line" to answer questions about implementation and training sessions have been developed to encourage further dissemination of the information.

Work to help facilitate application of the provisions has been financed almost entirely by FEMA. The BSSC has acted as the contracting agency and has hired consultants to write the documents, man the hot-line, and teach the courses.

ANALYSIS

Although the direct efforts to gain acceptance of the NEHRP recommended provisions have been useful, perhaps the indirect effect has been even more successful to date. During the time when the BSSC efforts were underway, a parallel effort by the Structural Engineers Association of California was started to adopt the ATC 3-06 provisions into their "Blue Book." The SEAOC activities were spurred on by the "competing" BSSC activities. Without the BSSC effort, it seems likely that the SEAOC activities would have gone at a much slower pace.

In the end, the BSSC and the SEAOC documents ended up being similar in many respects. The most important difference is that the SEAOC document is still based on "working stress" design procedures, while the BSSC document uses "strength design."

With publication of the 1989 Uniform Building Code, the first widespread use of design provisions based on the approach used by the BSSC will go into effect. Calibration of the UBC provisions was based heavily on the BSSC trial designs and follow-up studies. Although the "competition" for writing the new provisions may have been the catalyst, the BSSC activities were significant and helped to more quickly obtain implementation.

SUMMARY

The Applied Technology Council effort in writing a new document for seismic-resistant design of buildings is one of the most significant events to occur in this area. Although the technical results were nothing short of a breakthrough, the ATC effort did not result in a document that was accepted by the construction industry. The main reason this did not occur was that portions of the affected industry were not involved in the process, therefore depriving the document of a "consensus" of acceptance.

Recognizing the reasons that ATC 3-06 had not been readily accepted, the Building Seismic Safety Council was formed with the intent of developing a "consensus." Through the financial assistance of FEMA, technical efforts to "calibrate" the original provisions and make them viable were carried out. Through the use of volunteer committee members and paid consultants, a thorough study and resulting recommendations were developed.

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Although the BSSC may be judged to have accomplished their original goals, the "update" procedure has fallen somewhat short. After completion of the 1985 version of the recommended provisions, a period of more than a year elapsed before "update" efforts began. This loss of momentum has meant that the first revisions will be more superficial than they might have been otherwise. On any document such as the NEHRP Recommended Provisions, continual updating by a standing committee is needed. Now that this committee has been formed and is beginning to function, the success of BSSC may further improve in the future. Finally, one of the most important lessons from the entire exercise is that any new document will be accepted much faster if it has a thorough technical review and "calibration" by a "consensus" organization. Exclusion of any portion of the affected industry will only delay acceptance of a new document.

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PERSPECTIVES ON SEISMIC RISK MAPS AND THE BUILDING CODE PROCESS IN THE EASTERN UNITED STATES

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INTRODUCTION

The design and construction of buildings, or for that matter any type of facility, in the eastern United States (EUS) for earthquake loads has been virtually nonexistent. The EUS is defined herein as that area east of the Rocky Mountains and is an area where only nuclear power plants have been consistently required to be designed for earthquake loads (seismic design), even though the threat is real to all facilities.

The largest series of earthquakes known to have occurred on the North American continent occurred in the EUS near New Madrid, Missouri during the winter of 1811 and 1812. These earthquakes are known as the "New Madrid" earthquakes, three of which would have measured 8.4, 8.6 and 8.8 on the Richter scale (1).[1] These "great"[2] earthquakes rang church bells in Boston, Massachusetts, one thousand miles away. A total of 22 destructive or

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[1] Numbers in parenthesis refer to references.

[2] The term "great" earthquake has been coined by the scientific community for earthquakes having a Richter magnitude equal to or greater than 8.0.

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potentially destructive earthquakes are known to have occurred in the EUS (2 & 3), 10 of which would have measured greater than 7.0 on the Richter scale. These earthquakes have occurred from northern Maine, to South Carolina, to the Midwest and as far west as western Texas.

Today, 80% (194 million) of the U.S. population (242 million) live in the EUS and 60% (145 million) live east of the Mississippi River (3). In 1811 and 1812 the center of population in the U.S. was just northeast of Washington, D.C. Ironically, today it is just a few miles northwest of the New Madrid seismic zone within the area that has been projected as being capable of producing a magnitude 7.7 earthquake (3). To support this heavily populated area of the EUS, there exists approximately 70 million housing units, 3 million commercial buildings and 300 thousand manufacturing establishments (4). In addition, over 25% of the total U.S. energy consumption is transported interstate by pipeline or water throughout the East and 80% of the electrical energy consumed in the U.S. is being transported in the East (3). Regardless of these facts, today only three areas of the EUS are known to have adopted some recognized form of mandatory seismic design into the governing building codes for new buildings or facilities. These areas are the states of Kentucky (5) and Massachusetts (6) and the city of Charleston, South Carolina (7).

Fortunately, for the EUS, the twentieth century has been relatively quiescent from earthquake disturbances, a time when the U.S. population has grown from 75 million in 1900 to its 242 million today. During the early part of the nineteenth century when the New Madrid earthquakes occurred the population of the U.S. was only seven million. The largest populated area near the New Madrid earthquake epicenters is Shelby County and its county seat Memphis, Tennessee, about 30 miles to the southeast. In 1820, eight years after the earthquakes, Shelby County had a population of only 354 (8). Based on the growth rate from 1820 to 1830 (354 to 5,652) the resident population of Shelby County in 1811 and 1812 was probably only a few, if any. Other counties in West Tennessee, such as Obion County to the north where Reelfoot Lake was formed as a result of the earthquakes, had no recorded population in 1820. Today Shelby County alone has a population of nearly 800 thousand and West Tennessee, west of the Tennessee River, has a population of over 1.3 million (9). If an 8.8 magnitude earthquake were to occur today in the New Madrid area, the affected population within the expected damage zone of a Modified Mercalli Intensity (MMI) of VII or greater would most likely exceed 40 million, over 15% of the U.S. population. The population that would, as a minimum, feel the shaking from such an earthquake would far exceed 100 million, probably somewhere between 50% and 60% of the total U.S. population. In addition, the total estimated damage from such an event within a regional six city area of the epicenter would be in excess of $50 million (10). If the earthquake occurred during the day over 4,500 deaths would result, of which over 1,000 would be school children.

As a result of the past destructive earthquakes in the West and the East and the current population density in the U.S., it is important that some form of seismic design requirements be adopted by all code governing bodies throughout the U.S. It is stated (11): "All 50 states are vulnerable to the hazards of earthquakes, and at least 39 of them are subject to major or moderate seismic risk...." In addition, the U.S. has over 15 thousand school districts housing over 40 million K1 through 12 grade school students (12). To date California is the only state that has had a strong program for seismic design of its schools. Unfortunately schools across the rest of the U.S. are for the most part constructed with unreinforced masonry walls without regard for seismic resistant design.

There are no technological reasons why the governing code bodies of every municipality or county in the U.S. have not adopted seismic design provisions because the technology does exist (13). Today, reasons for not doing so can be attributed to three basic areas: 1) lack of awareness or education, 2) politics or self-interest and 3) indifference or lack of concern.

EARLY SEISMIC CODE DEVELOPMENT

The first form of a recognized seismic design code in the U.S. occurred in California following the 1925 Santa Barbara earthquake measuring 6.25 on the Richter scale (14). These seismic design procedures were included in an appendix of the first edition (1927) of the Uniform Building Code (UBC) (15), but were not mandatory at the time. Although some California municipalities did make seismic provisions mandatory, this approach was not widely accepted until after 1933 when on March 10, 1933 an earthquake measuring 6.3 on the Richter scale occurred in Long Beach, California. Seventy-five percent of the schools throughout the area were heavily damaged, with many being reduced to rubble. Fortunately, this earthquake did not result in any deaths of school children because it happened at 5:54 p.m. after most had gone home. However, three teachers were killed at one collapsed high school. The event caused such public concern about poor construction that the California Legislature passed the Field Act of April 10, 1933 to control design and construction of new schools thereafter (16) and (17).

As a result of the Field Act of 1933 and the additional efforts that were being put forth by a group of California engineers, now known as the "Structural Engineers' Association of California" (SEAOC), by the early 1950's most all buildings in the state of California were required to have seismic design provisions and by 1960 the state of California seismic design requirements became more or less uniform (18).

During the 1950's and 1960's the UBC was the only code that addressed the earthquake design issue. It was not until 1976 that the Standard Building Code (SBC) (19), previously known as the Southern Standard Building Code, published by the Southern Building Code Congress International, Inc., incorporated seismic design provisions. However, these provisions were not required unless the local authorities required seismic design. As has been noted (18), the basic development of seismic design provisions into the code process has occurred as a result of the code bodies following the developments and adoptions that were occurring within the SEAOC group, first being adopted into the UBC and then later adoptions of these same, or similar, requirements into other code bodies.

The inclusion of the seismic design provisions in the UBC as an appendix in 1927 remained so until 1961 (20) when the Pacific Coast Building Officials Conference, now known as the International Conference of Building Officials

(ICBO), adopted them into the main body and they became mandatory. Originally these seismic requirements were primarily developed for the state of California and, except for some coefficient revisions following the work of SEAOC, remained the same until the 1949 edition when ICBO adopted a national seismic hazard map (21) that defined relative seismic hazards throughout the U.S. The UBC seismic design provisions adopted in 1949 basically remained unchanged, except for some minor changes in the hazard map, until 1970 when the ICBO adopted a new seismic hazard map (22) that was believed to be more representative of the seismic hazards in the U.S., as discussed below.

The only other major change in the UBC occurred following the 1971 San Fernando earthquake that resulted in 60 deaths and had a magnitude of 6.4. In the 1976 edition of the UBC (23), although the seismic hazard map did not change significantly, the lateral force formula was changed considerably when coefficients were introduced based on the importance of facilities to the public's well being and on the effect of site conditions. Again, these changes were a result of developments by SEAOC. These seismic requirements have basically remained the same through today's 1985 edition (24).

Today there are basically three major model building codes used in the U.S. The UBC and the SBC, mentioned above, and the BOCA National Building Code, previously known as the BOCA/Basic Building Code, issued by the Building Officials and Code Administrators International (25). A fourth code had been in use known as the National Building Code of the American Insurance Association (26), however, this code has not been published since 1976. All three of today's codes now include some form of seismic design requirements and the UBC/ICBO still remains the leader in seismic design development and adoption following the work of SEAOC.

CODES AND SEISMIC RISK MAPS - A NATIONAL CONCERN

As eluded to earlier, the first seismic risk map was published in 1948 by the U.S. Coast and Geodetic Survey based on the work of F.P. Ulrich (21). Ulrich developed his map on the premise that similar earthquakes will occur in the future where they have occurred in the past. Areas of historical seismic activity were shown as bounded regions called seismic zones that were identified with assigned numbers (0, 1, 2, 3) indicating relative seismic hazard, Seismic Zone 3 being the area of highest seismic hazard. Because this map did not fully reflect tectonic principals or differences in attenuation the map was withdrawn by the Survey in 1952. However, by that time the ICBO had already adopted the map into its building code as noted above. Although other risk maps were developed (27) it was not until the 1970 edition of the UBC (22) that the 1948 map was replaced, although some minor changes had occurred.

Before the 1960's little attention was being paid by the design professionals in the EUS to seismic risk maps or to the seismic code developments in California. In the East the threat of earthquakes was perceived as a threat only to California until, what this author considers, two major events occurred. The first event was the development of commercially available nuclear power. Although commercializing nuclear power actually began in the 1940's, it was not until the 1960's that serious issues began to be raised about the seismic design adequacy of nuclear power plants. These issues first began in California but rapidly spread to the EUS where the majority of the U.S. nuclear power capacity was projected to be needed and was being planned. Although the predecessors (U.S. Coast and Geodetic Survey) of the United States Geological Survey (U.S.G.S.) had been researching the earthquake hazards problems in the East, a renewed emphasis began being placed upon these hazards and design engineers were beginning to ask hard questions about what level of ground shaking might be expected at a power plant's site during its life.

The second event that occurred, although not totally independent of the first, resulted in 1970 when the 1970 edition of the UBC was published (22). In the previous additions of the UBC using the modified 1948 U.S. Coast & Geodetic Survey risk map, most of the EUS was identified as being in either Seismic Zone 0 or Seismic Zone 1 defined as areas of no or minor damage. However, in the 1970 edition of the UBC most of the EUS was identified as being in Seismic Zone 1, minor damage, or Seismic Zone 2, moderate damage, as a result of the work completed during the 1960's by Algermissen (28). In addition, some areas previously identified as Seismic Zone 3, major damage, were expanded and some Seismic Zone 2 areas were upgraded to Seismic Zone 3. Thus the design professionals in the East suddenly became more interested in: 1) the seismic code developments occurring in California, 2) what the seismic hazard in the EUS was and 3) how to design structures in the EUS to resist earthquake forces. Since the 1970 edition of the UBC the seismic risk map for the EUS has basically remained unchanged (24) except for 1976 when a

Seismic Zone 4 was added to California, although major revisions are now occurring as discussed below.

ACCELERATION RISK MAPS

The first development of seismic design criteria resulted in requirements that a building or structure be designed for a lateral force equivalent to a certain ratio, or percentage of its weight. Although seismic code provisions have improved significantly and expanded over the years the code concept is still the same today, buildings or structures are still designed for a certain percentage of their total weight although some modifying coefficients are now incorporated. As it turns out, utilizing the laws of physics, the percentage value used is almost the same as the peak ground acceleration (PGA) that would be experienced by a light rigid one story building at the location of interest as a result of the earthquake of interest. These accelerations are those measured by today's strong motion instruments.

Throughout the many editions of the UBC the seismic risk map[3] has been shown in the form of a hazard map identifying the various seismic zones related to the largest MMI earthquake that had occurred within areas of similar geology and seismic activity as noted earlier. Using the relative coefficients representing the various seismic zones on the hazard map with the simplified formulas in the code, the design engineer basically ended up designing his/her facility using a cookbook approach that resulted in very

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[3] From the 1927 edition until the 1949 edition, there was no national seismic risk map published in the UBC.

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little, if any, understanding of the real meaning of the code approach and the corresponding expected seismic performance of the facility being designed. During the 1960's, with the advent of nuclear power, a more direct and more meaningful approach was needed so that the design engineer would have a better understanding of the design concepts and how the designed facility would perform in an earthquake. As a result those engineers designing nuclear power plants began talking about seismic hazard more specifically in the terms of PGA. The engineer needed to know at exactly what PGA certain stress levels occurred in the structures, systems and components of nuclear power plants. Thus, seismic design began to move away from the "cookbook" approach of coefficients to the more direct use of ground acceleration as the design load input.

During the same time frame, recognizing that the occurrence of earthquakes appeared to be somewhat stochastic, questions began to arise such as the chances of an earthquake occurring during a facility's lifetime or the likelihood that a facility designed to a certain level of acceleration would experience an earthquake causing accelerations larger than for what it was designed. As a result, the seismic risk map began to move away from the hazard maps based on experience MMI events to maps that actually displayed contour lines denoting certain acceleration levels based on some probability of being exceeded, usually 10%, during a certain time frame, usually 50 years, which has been considered the life span of most buildings. Today this approach to seismic design for building codes is just now beginning to be seriously considered by the code bodies.

TODAY'S SEISMIC RISK MAPS

In response to the advent of nuclear power, the development of the computer as a design tool, the Alaskan earthquake of 1964, the San Fernando earthquake of 1971 and the Earthquake Hazards Reduction Act of 1977, continued emphasis has been placed upon more precisely defining the seismic hazard of the contiguous U.S. in terms of a risk map represented by PGA or "effective" PGA contour lines having some probability of exceedance. To reflect upon the many studies which have addressed this issue over the past twenty years is beyond the scope of this paper. However, two recent works are worthy of mention at this point as discussed below.

Following his work in the 1960's, Algermissen (28) has continued to expand upon and refine his seismic risk map working with Perkins (29). Following their publication of the first national seismic risk map in terms of PGA and probability of exceedance, the Applied Technology Council used it as a foundation for the development of new provisions for seismic design of buildings (30). More recently, Thenhaus, Algermissen and others have continued to access the earthquake risk in the East to include what has been learned during the last decade (31).

In addition to Algermissen's work, the Electric Power Research Institute (EPRI), in support of the nuclear power industry, set about to develop a risk analysis procedure for seismic hazard/risk assessment that would represent the state-of-the-art as viewed by a number of seismic professionals. This work has been completed and is available from EPRI (32).

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If one compares the work by EPRI, the work by Algermissen, or the work by others such as Bernreuter (33) a distinct difference is likely to be noticed in the resulting estimates of the PGA values for a certain area and the likelihood that such PGA's will be exceeded. This characteristic has been a major source of concern to the design engineer over the years but has been something that he/she has had to live with. For example, estimated PGA values at one particular site near Paducah Kentucky (34) varied by as much as a factor of four (0.08g's - 0.35g's) for an estimated return period of 500 years. These estimated PGA values were primarily based on ten different independent studies of the area over a ten year period. Although these differences can be somewhat troublesome for a particular site, their occurrence is a result of the lack of historical data, different assumptions made during the assessments, differences in expert opinion and our lack of fully understanding the earthquake phenomena, especially in the East. Since facilities can't be effectively designed to a range of PGA's sound judgement must be used, and is, to select the appropriate PGA level for the seismic design load input. For the Paducah, Kentucky site the PGA chosen for design purposes at a 500 year return period was 0.25g's. At this time it is difficult to expect the scientific and engineering professions to develop a greatly improved seismic risk map because no new data or discoveries will likely appear in the near future. For all practical purposes the original Algermissen and Perkins seismic risk map (29) or modifications of it are still as good as any to use.

EASTERN CODE EXAMPLES

As mentioned earlier, the three areas in the EUS known to have adopted and enforced seismic design requirements are the states of Kentucky and Massachusetts and the city of Charleston, South Carolina. In each case it is a mandatory requirement throughout each state and Charleston that all new buildings be designed and constructed to meet specified seismic design requirements. The first to adopt such requirements in the East was the state of Massachusetts. In 1973 a state commission was formed to examine the adoption of a statewide building code as a result of the building industry's push for code uniformity throughout the state (35 & 36). During its deliberation the commission decided to adopt the BOCA National Building Code as a framework for the state code. However, the commission wanting to improve upon the area related to structural and foundation loads formed three advisory committees. Since, at that time, the BOCA code had no seismic design requirements, one committee became a seismic advisory committee. Following the seismic advisory committee's work, the Massachusetts code officials adopted the seismic requirements developed for Boston and the state by the committee in 1974. Although these requirements do address new construction, no serious consideration has been given to develop retrofit or upgrade requirements for the large stock of existing structures in the state of Massachusetts, many of which are very old and may be extremely vulnerable to ground shaking.

The state of Kentucky adopted its mandatory state wide seismic design requirements in 1983 (37). This was simply done by adopting the 1981 BOCA code in its entirety, which contained the seismic design standards recommended in the 1972 ANSI A58.1 (38). Thus specifically adopting mandatory seismic design requirements throughout a state in the EUS never became an issue, in itself, as has occurred in some areas of the East.

In 1982 the new ANSI A58.1 seismic design guidelines (39) were published based on the 1979 UBC requirements with modifications. One major modification was to replace the 1979 UBC seismic hazard map with a new map based on the ATC 3-06 map "Effective Peak Velocity-Related Acceleration Coefficient" (30). In 1986 the BOCA code officials adopted the 1982 ANSI A58.1 seismic design guidelines and these guidelines became a requirement in the 1987 edition of the BOCA code.

Following the 1987 edition of the BOCA code, the Kentucky building officials adopted it in its entirety for the 1988 edition of the Kentucky building code (37). In addition to the requirements identified in the BOCA code the Kentucky building officials have modified those requirements in two areas. First, all counties of the state have been assigned which seismic zone (1, 2, or 3) on the map they are located. This avoids disputes over the interpretation of which side of a zone boundary line a particular county may be located. As has been assigned by the Kentucky building officials only eight counties in Kentucky have been identified as being in Seismic Zone 3. The second additional requirement is that Kentucky now requires single and two family dwellings to include seismic design requirements. This resulted when the Kentucky Building Code officials adopted the model code for single and two family dwellings of the Council of American Building Officials (37). Although this later requirement caused some concern to local building officials, they soon accepted it when it was shown to not significantly increase the cost of housing.

The city of Charleston, South Carolina, the location of the 1886 Charleston earthquake that would have measured 7.7 on the Richter scale and resulted in great destruction and loss of life, adopted the 1976 SBC seismic requirements (1972 ANSI A58.1 guidelines) on June 23, 1981 (7). These requirements were mandatory for all new construction and for any existing building work in excess of fifty percent of its value, except for dwellings as defined in the SBC. Although the city of Charleston adopted these requirements, it exempted such requirements in the case of historical buildings. If seismic design and construction were to be included in the case of modification to a historical building such requirements would be judged on a case by case basis.

NEW INITIATIVES

Today there are a number of initiatives that are taking, or have taken, place toward mitigating the effects of an earthquake occurrence on the population of the U.S., especially the EUS. These initiatives are basically taking place because of several key reasons mentioned or eluded to earlier and are summarized as follows.

1) Although the West Coast is well known for its earthquake activity, 22 destructive or potentially destructive earthquakes have occurred in the EUS and 10 of them had measured greater than 7.0 on the Richter scale.

2) The 1811-1812 New Madrid earthquakes are the largest known to have occurred on the North American Continent and they occurred in the EUS.

3) The Charleston, South Carolina earthquake of 1886 occurred on the East Coast causing great destruction and resulted in over 60 deaths.

4) Other areas of the EUS known to have experienced considerable seismic activity are the Northeast area where the February 5, 1663 St. Lawrence Valley earthquake occurred that would have measured greater than 7.0 on the Richter scale and the November 18, 1755 Cape Ann earthquake occurred that would have measured greater than 6.0; and the West Texas area where the August 16, 1931 earthquake occurred that would have measured greater than 6.0 on the Richter scale.

5) The tremendous destruction and loss of life of the April 18, 1906 magnitude 8.3 San Francisco earthquake, the March 27, 1964 magnitude 8.4 Alaskan earthquake, and the February 6, 1971 magnitude 6.4 San Fernando earthquake are still remembered by many.

6) The recent September 19, 1985, magnitude 8.1 Mexico earthquake that resulted in relatively low acceleration levels with long duration

in Mexico City which resulted in over 400 collapsed buildings and ten thousand deaths.

7) The continued commercialization of nuclear power, albeit not as great as originally projected in the 1960s and 1970s, in the U.S. and the continued concern, by many, over the seismic design issues.

8) The passage by Congress of the Earthquake Hazards Reduction Act of 1977 to mitigate the effects of earthquakes in the U.S.

9) The continued education of the public, especially in the EUS, on the potential hazards and risk of earthquake occurrences.

10) The concern by the insurance industries and even the engineering profession about the liability responsibilities in the event of a destructive earthquake.

11) The concern for the ability to maintain viability of the industrial and financial base of the U.S. following a destructive earthquake and to mitigate the effects on the populace.

Just recently, as one initiative, the Southern Building Code Congress adopted the 1982 ANSI Standard A58.1 in a manner in which the seismic design provisions are now mandatory in the code. As has been noted (40) several states have adopted the previous versions of the SBC as mandatory. Thus, there is a reasonable chance that when these states adopt the 1988 SBC revisions, they will be adopting the 1982 ANSI Standard for seismic design.

In the state of South Carolina, where only the city of Charleston currently has seismic design requirements, an effort is now in progress to adopt the 1988 SBC in its entirety throughout the state. Since there is legislative support to introduce this into the 1988 South Carolina legislative agenda (41) there is a reasonably chance that seismic design requirements for new construction will become mandatory throughout the state. However, only time will tell.

Another area where an initiative is taking place is in the city of Memphis, Tennessee. If a magnitude 8.8 earthquake were to occur during the day in the southern tip of the New Madrid seismic zone, in the Memphis area over 35 hundred deaths would occur with over one thousand being school children, over 350 thousand would most likely require shelter and over $30 million in damage would result (10). Until recently the city of Memphis has been stymied at adopting any form of seismic design requirements. However, in 1986 a committee headed by Warner Howe was formed to evaluate the type of code requirements needed for the city of Memphis (42). This committee has completed its work and has basically settled on the seismic design requirements to be specified in the new 1988 SBC. The commitee is now in the process of preparing its recommendations for presentation to the City and County Administrators. In addition, on October 29, 1987 the Memphis City Council passed a resolution that stated (43): "Be it further resolved that the Memphis City Council commends Mayor Hackett for his public statement that he will propose revisions to the Building Code to require seismic design for new construction and urges him to move on this as speedily as possible." Again, as in the case of South Carolina, only time will tell.

As eluded to earlier, the ICBO has been in the process of revising the UBC to be published as the 1988 edition (44). This edition of the UBC will represent a significant departure from past requirements in seismic design and is heavily based on the work done by SEAOC. The new UBC requirements will be more in line with the approach identified in 1978 (30) by the Applied Technology Council and represents the increased knowledge base over the past ten years and lessons learned from previous earthquakes such as the September 19, 1985 Mexico earthquake. A new seismic risk map has also been included based on modifications to the previous works mentioned herein. This edition of the UBC can be heralded as a major step toward designing facilities using a more realistic approach rather than the previous simplified approach referred to earlier. Now when engineers use the UBC they should have a better understanding of what it is they are designing for and how it will perform in an earthquake.

Other initiatives have been occurring as a result of the efforts being put forth by the Building Seismic Safety Council (BSSC). The BSSC has been working with the Federal Emergency Management Agency (FEMA), and under FEMA's guidance and funding, toward improvement and understanding of the seismic design process. As a result, BSSC and FEMA have published a series of documents (45, 46, 47, and 48 for example) to aid practitioners, code officials, planners and engineers in their efforts to mitigate the effects of earthquakes. In addition the BSSC and FEMA are working toward developing procedures/guidelines for the assessment and upgrading of existing facilities that do not meet today's seismic requirements.

CONCLUSIONS

One of the major goals of this paper was to briefly examine the historical development of seismic risk maps and the building code process in the EUS. In addition, another goal was to examine what events, be they research, funding or perceived national need, result in certain actions being taken toward the improvement of seismic risk maps and building codes and the adoption of seismic design requirements. From reading this paper the events that cause certain actions to happen toward mitigating the effects of earthquakes vary greatly. Obviously the event that most often causes rapid action by all is the occurrence of a destructive earthquake that results in serious damage and loss of life. In some cases, the desire to do something after the fact is so strong that actions can occur that are not really in the long term best interest of the public. In other areas the events which have resulted in mitigating actions have been the growing public fear of the potential consequences that might result from damaged facilities (e.g. a nuclear power plant) and of course, availability of funds to commit the person power to develop and implement mitigating actions.

In the western states, particularly California, it is the opinion of this author that the most significant events that have resulted in mitigating

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actions have been the continued occurrence of moderate to major destructive earthquakes. Without such earthquake occurrences, even though the threat still could be significant, the western U.S. would not be any further along in preparedness than the EUS.

In the EUS, the most significant event that has resulted in a much better understanding of the earthquake threat, greater public awareness, increased research and increased monies for research and study has been the commercialization of nuclear power. A better understanding of the earthquake threat in the EUS may be the number one indirect benefit of nuclear power. If one were to plot the growth and decline of activity in the nuclear power industry over the past thirty years along with the activity that has occurred in the "earthquake industry", this author would expect the "earthquake industry" activity to be lagging behind but steadily tracking the nuclear power activity. If the "earthquake industry" in the 1990's tends to level off, or even increase, rather than continue to decline as is now occurring in the nuclear power industry, it will be because of continued funding of the Earthquake Hazards Reduction Act of 1977, or because of new funds made available following a major destructive earthquake in the U.S.

In summary, the major events that have occurred in the U.S. that have and are resulting in mitigating actions to reduce the effects of destructive earthquakes have been the 1906 San Francisco, 1925 Santa Barbara, 1933 Long Beach and the 1971 San Fernando earthquakes of California, the 1964 Alaskan earthquake, the commercialization of nuclear power, the Earthquake Hazards Reduction Act of 1977 and possibly, the 1985 Mexico earthquake. The public is becoming more aware of the earthquake threat and is no longer "sticking its head in the sand". Positive mitigating actions are occurring outside the state of California. States in the EUS have made seismic code provisions mandatory and other EUS states are in the process of doing so. In addition, all national model code bodies now have seismic design requirements as a mandatory part of their code. As was stated at the beginning of this paper, "the technology exists" all that needs to be done is implementation through continued education of the public and its leaders, be they the federal government or the local politician. Progress has been made and momentum exists. It is up to the scientist and engineer to assure that this progress and momentum continues and, in the end, when the next "big one" comes the effects that would occur today will be greatly reduced.

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DESIGN GUIDELINES FOR LOW-RISE BUILDINGS

by

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INTRODUCTION

A document tentatively called "Guidelines for Design of Low-Rise Buildings Subjected to Lateral Forces" has been actively under preparation since June 1985. A new professional organization, the Council on Low-Rise Buildings was created. The membership of the Council consists of more than one hundred engineers and architects. The present headquarters of the Council are at North Carolina State University. The University has a grant from the National Science Foundation to support the Guidelines - activity of the Council. The writer is the principal investigator. The grant covers the out-of-pocket expenses incurred by various participants, but does not include any reimbursement for the professional effort. It is expected that the Guidelines will be completed by the summer of 1988.

OUTLINE

The Guidelines are being written in a text book format. The book has been divided into the following eight chapters.

Chapter 1 - Introduction, Scope and Performance Criteria

Chapter 2 - Definition of Natural Hazards

Chapter 3 - Design for Wind Loading

Chapter 4 - Earthquake Loading and Modeling of Buildings

Chapter 5 - Design of Structural Systems

Chapter 6 - Design of Connections Between Building Elements

Chapter 7 - Non-Structural Elements

Chapter 8 - Summary and Recommendations

The writing of these chapters is being carried out by eight Task Groups. Each Task Group has a Chairman and one to five members. Various Task Groups, their responsibilities and the name of their respective Chairmen are summarized below.

Task Group A - Chapter 1, Robert D. Ewing, Ewing and Associates, Rancho Palos Verdes, California.

Task Group B - Chapter 2, Yi-Kwei Wen, University of Illinois, Urbana, Illinois.

Task Group C - Chapter 4, Sigmund A. Freeman, Wiss, Janney, Elstner and Associates, Emeryville, California.

Task Group D - Chapter 3, James R. McDonald, Texas Tech. University, Lubbock, Texas.

Task Group E - Part of Chapter 5, Edwin Zacher, H.J. Brunnier Associates, San Francisco, California.

Task Group F - Part of Chapter 5, Melvyn Green, Melvyn Green and Associates, Manhattan Beach, California.

Task Group G - Chapter 7, Satwant S. Rihal, California Polytechnic State University, San Luis Obispo, California.

Task Group H - Chapter 6, Richard N. White, Cornell University, Ithaca, New York.

ORGANIZATION

The only activity of the Council is the writing of the Guidelines. This effort is being directed by an Executive Committee with the writer (the principal investigator of the NSF grant) as the Chairman. The membership of the Executive Committee is given below.

1. Duane S. Ellifortt, University of Florida, Gainsville, Florida

2. Robert D. Ewing, Ewing and Associates, Rancho Palos Verdes, California

3. John Kariotis, Kariotis and Associates, South Pasadena, California

4. Earl W. Kennett, Gaithersburg, Maryland

5. Lawrence A. Soltis, U.S. Forest Products Laboratory, Madison, Wisconsin

Ex Officio

1. Michael P. Gaus, National Science Foundation, Washington, DC

2. Andrew J. Eggenberger, National Science Foundation, Washington, DC

The members of the Executive Committee and the Chairman of various Task Groups, together, constitute the Steering Committee of the Council.

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PROBLEMS SPECIFIC TO LOW-RISE BUILDINGS

The following seismic problems are specific to low-rise buildings, and are often not addressed by the present codes which are written with high-rise buildings in mind.

1. In the case of heavy concrete walls, the diaphragm picks up the mass of the side walls and oscillates like a nonrigid member. This is especially important in large span buildings. This action increases demand on connections.

2. In many cases walls designed for the vertical load carrying system are much too strong for seismic stresses. When the walls behave elastically, the roof diaphragm experiences a much higher than calculated motion.

3. Low-rise buildings are often made of several materials which have dissimilar properties.

4. Rather than the whole building responding in one frequency, various components respond in their own frequencies. The same is true for ductility.

5. In low-rise buildings damage to ceilings and partitions is much higher than that in high-rise buildings.

6. Low-rise buildings are more likely to have irregular plans, elevations and structural systems.

7. Reinforced concrete walls framed into concrete frames often receive disproportionate damage.

8. Low-rise buildings have shallow foundations, and show a tendency to respond in the rocking mode. Structure-foundation-soil interaction is important.

9. Diaphragm-wall-frame interaction is important.

10. Dynamic analysis of low-rise buildings is different from that of high-rise buildings.

11. The low-rise building model does not fit the current fixed base model.

12. Base shear approach may not be applicable. The C_p factors are important.

The following are the wind design related problems specific to low-rise buildings.

1. Attachment of cladding needs specific attention.

2. Internal pressure plays an important role.

3. Size of openings (open or closed) affect the pressure distribution and design.

4. Missiles (Roof gravel, 2 x 4 planks) pose a hazard.
5. Local wind effects due to irregularities should be accounted for.
6. Lateral load distribution--load paths should be clearly defined.
7. Overlaps and canopies, architectural ornamentation, and balconies require special attention.
8. The design and construction cost are sensitive to roof loading.
9. Overturning is not a factor.
10. Low-rise buildings have cranes, unlike high rise buildings.

BACKGROUND

A workshop on "Seismic Performance of Low-Rise Buildings" was held in Chicago during May 1980 under NSF sponsorship. One of the important recommendations of the workshop was to prepare a Design Manual for low-rise buildings. Although the workshop primarily addressed the topic of seismic hazard, many groups, in particular the group on Implementation Strategies emphasized a multi-hazard approach.

In view of the momentum created by the workshop, a special panel session on Seismic Design of Low-Rise Buildings was organized during the ASCE Convention in Las Vegas in April 29, 1982. The objective of the session was to discuss the desirability and feasibility of writing a Design Manual. The session was followed by a planning meeting. A summary of the Las Vegas session and the Planning Committee meeting, and a list of attendees is given in Appendix I. It was unaminously agreed that the effort is worthwhile and should be undertaken. It was felt that the profession would be better served if a "Guideline" was prepared rather than a "Manual." It was also decided to include wind effects in the document. Two Ad hoc Committees were formed, one on "Principles and Concepts" and another one on "Contents," which were chaired by John Kariotis and Robert Ewing, respectively.

The recommendations of the two Ad hoc Committees were discussed in a meeting of the Planning Committee on October 26, 1982 in New Orleans, during the ASCE's fall convention. A list of people in attendance is given in Appendix II. After much discussion, the two reports were adopted in the New Orleans meeting with one exception. The exception to the report of the Ad hoc Committee on Contents was regarding the proposed topical report on retrofitting. It was felt that the topic of retrofitting is in many ways very special, and should be treated subsequently. It was later decided to form a Council on Low-Rise Buildings independent of the ASCE to prepare the Guidelines.

ACKNOWLEDGMENT

The present effort is supported by the NSF Grant No. ECE-8414478 to North Carolina State University. Many ideas presented in this paper are based on the contributions of the membership of the Council on Low-Rise Buildings. However, this paper has neither been reviewed nor endorsed by the NSF or the Council.

APPENDIX I

SUMMARY OF THE SPECIAL PANEL SESSION AND PLANNING COMMITTEE MEETING ON SEISMIC DESIGN OF LOW RISE BUILDINGS

ASCE Spring Convention, Las Vegas
April 29, 1982

A special panel session on the Seismic Design of Low-Rise Buildings was held on April 29, 1982 in Las Vegas. A list of attendees is enclosed. The objective of the special session was to discuss the role ASCE should play in the area of the seismic design of low-rise buildings. Particularly, should a task committee be formed under the auspices of the Dynamic Effects Committee of the Structural Division to write a Design Manual or some such document? Panel members and the participants were required to express their views on this topic.

The following made formal presentations at the session:

1. James W. Axley, University of California, Berkeley
2. Michael P. Gaus, National Science Foundation
3. Ajaya K. Gupta, North Carolina State University, Raleigh, NC
4. William J. Hall, University of Illinois at Urbana-Champaign
5. John Kariotis, South Pasadena, CA
6. Anton Polensek, Oregon State University, Corvallis, OR
7. Satwant S. Rihal, California Polytechnic State University, San Louis Obispo, CA
8. Vahid Schricker, Structural Software Development, Berkeley, CA

Written position papers were made available by almost all the speakers.

Roland Sharpe of EDAC, Palo Alto, California, could not attend the session. He provided a written position paper. The paper was received after the session and could not be presented. Marvin Criswell of Colorado State University sent written comments, which were summarized at the session by A.K. Gupta. Criswell's comments are enclosed.

The morning panel session was followed by a Planning Committee meeting in the afternoon. The meeting was open to anyone interested. The following people participated in the meeting:

1. Christopher Arnold, Building Systems Development, Inc., San Mateo, CA
2. James W. Axley, University of California, Berkeley
3. John E. Brown, Brown & Lindsey, Santa Rosa, CA

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4. Duane S. Ellifritt, Metal Building Manufacturers Association, Cleveland, OH
5. Robert D. Ewing, Agbabian Associates, El Segundo, CA
6. Sigmund A. Freeman, Wiss, Janney, Elstner & Associates, Emeryville, CA
7. Michael P. Gaus, National Science Foundation, Washington, DC
8. Ajaya K. Gupta, North Carolina State University, Raleigh, North Carolina
9. Timothy K. Hasselman, J.H. Wiggins Company, Redondo Beach, CA
10. John Kariotis, Kariotis & Associates, South Pasadena, CA
11. James J. Noland, Atkinson-Noland & Associates, Boulder, CO
12. Anton Polensek, Oregon State University, Corvallis, OR
13. Satwant S. Rihal, California Polytechnic State University, San Louis Obispo, CA
14. Charles Schawthorn, Dames & Moore, San Francisco, CA
15. James T.P. Yao, Purdue University, West Lafayette, IN

In the planning committee meeting, it was unaminously agreed that a task committee be formed. The following decisions were taken:

1. Tentatively, the document would be called "Guidelines" and not "Design Manual."
2. It should include design for both the Earthquake and Wind forces.
3. The majority agreed that the task committee should address low-rise buildings defined by their characteristics, as opposed to limiting to one or two story buildings.
4. The tentative title is "Guidelines for Wind and Seismic Design of Low-Rise Buildings."
5. Two ad hoc committees were formed.
    (i) "Ad hoc Committee on Principles and Concepts" to be chaired by John Kariotis.
    (ii) "Ad hoc Committee on Contents" to be chaired by Robert Ewing.

The respective chairmen would co-opt other members. The reports of the ad hoc committees are due by the end of September 1982 so that they can be discussed during ASCE's New Orleans convention in October.

6. A.K. Gupta would take up the matter of officially forming the task committee with ASCE. Also, he should try to find financial support from NSF and other agencies.

List of Attendees

1. Shuaib H. Ahmad, North Carolina State University, Raleigh, North Carolina
2. Christopher Arnold, Building System Development, Inc., San Mateo, California
3. Ersin Arioglu, YAPI MERKEZI-CAMLICA, Istanbul, Turkey
4. James W. Axley, University of California, Berkeley, California
5. Thomas M. Breen, Inryco, Inc., Milwaukee, Wisconsin
6. John E. Brown, Brown & Lindsey, Santa Rosa, California
7. Franklin Y. Cheng, University of Missouri-Rolla, Rolla, Missouri
8. Edward F. Diekmann, GFDS Engineers, San Francisco, California
9. G. Day Ding, University of Illinois at Urbana Champaign, Champaign, Illinois
10. Duane S. Ellifritt, Metal Bldg. Manufacturers Association, Cleveland, Ohio
11. Robert D. Ewing, Agbabian Associates, El Segundo, California
12. Mark Fintel, Portland Cement Association, Skokie, Illinois
13. Sigmund A. Freeman, Wiss, Janney, Elstner & Associates, Emeryville, California
14. Michael P. Gaus, National Science Foundation, Washington, DC
15. Ralph W. Goers, Van Nuys, California
16. John E. Goldberg, National Science Foundation, Washington, DC
17. Barry J. Goodno, Georgia Institute of Technology, Atlanta, Georgia
18. Ajaya K. Gupta, North Carolina State University, Raleigh, North Carolina
19. William J. Hall, University of Illinois, Urbana, Illinois
20. Gilbert A. Hegemier, University of California, Lo Jolla, California
21. Arthur A. Huckelbridge, Case Western Reserve University, Cleveland, Ohio
22. Rafik Y. Itani, Washington State University, Pullman, Washington
23. John Kariotis, Kariotis and Associates, South Pasadena, California
24. James J. Noland, Atkinson-Noland & Associates, Boulder, Colorado
25. Anton Polensek, Oregon State University, Corvallis, Oregon

26. Satwant S. Rihal, California Polytechnic State University, San Louis Obispo, California

27. Charles Schawthorn, Dames and Moore, San Francisco, California

28. Vahid Schricker, Structural Software Development, Inc., Berkeley, California

29. Fernando Sesma, United States Gypsum Company, Torrens, California

30. Thomas G. Williamson, Laminated Fabrications, Inc., Indianapolis, Indiana

31. James T.P. Yao, Purdue University, West Lafayette, Indiana

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APPENDIX II

DESIGN OF LOW-RISE BUILDINGS SUBJECTED TO LATERAL FORCES
PLANNING COMMITTEE MEETING, NEW ORLEANS
OCTOBER 26, 1982
LIST OF ATTENDEES

1. Russell H. Brown, Clemson University, Clemson, South Carolina
2. Marvin E. Criswell, Colorado State University, Fort Collins, Colorado
3. G. Day Ding, University of Illinois, Champaign, Illinois
4. Eric Elsesser, Forell/Elsesser, San Francisco, California
5. Robert D. Ewing, Agbabian Associates, El Segundo, California
6. Mark Fintel, Portland Cement Association, Skokie, Illinois
7. Sigmund A. Freeman, Wiss, Janney, Elstner & Associates, Emeryville, California
8. G. Robert Fuller, U.S. Dept. of Housing and Urban Development, Washington, DC
9. Michael P. Gaus, National Science Foundation, Washington, DC
10. John E. Goldberg, National Science Foundation, Washington, DC
11. Barry J. Goodno, Georgia Institute of Technology, Atlanta, Georgia
12. Melvyn Green, El Segundo, California
13. Ajaya K. Gupta, North Carolina State University, Raleigh, North Carolina
14. Arthur A. Hucklebridge, Case Western Reserve University, Cleveland, Ohio
15. Rafik Y. Itani, Washington State University, Pullman, Washington
16. John Kariotis, Kariotis & Associates, South Pasadena, California
17. Frederick Kimgold, National Science Foundation, Washington, DC
18. James Pendergast, Construction Engineering Research Laboratory, Champaigns, Illinois
19. Roland Sharpe, EDAC, Palo Alto, California
20. Christopher G. Tyson, American Iron and Steel Institute, Washington, DC
21. Thomas G. Williamson, Laminated Fabricators, Indianapolis, Indiana
22. James T.P. Yao, Purdue University, West Lafayette, Indiana

HAZARDOUS BUILDING ORDINANCE IN LOS ANGELES

John Kariotis, President, Kariotis & Associates, Structural Engineers
South Pasadena, California

SECTION 1
PLANNED AND ACTUAL OUTCOME OF THE SPECIFIC APPLICATION

1.1 Length of Time and Level of Effort

The impetus for the writing of a hazardous building ordinance was a request made in 1974 by the Los Angeles City Council to the Department of Building and Safety to formulate a retroactive ordinance for the abatement of earthquake hazards in high occupancy buildings, specifically movie theaters. After many public hearings the proposed ordinance was made applicable to all pre-1934 unreinforced masonry bearing wall buildings. One and two family residences were exempt from the ordinance.

Action was delayed on the development of the ordinance until 1977. At this time, the Council approved the following actions:

A city-wide survey for identifying and categorizing the bearing wall buildings.

Establishment of a special study committee to develop a comprehensive ordinance.

Preparation of an environmental impact report by the Planning Department.

Request to the Council Congressional Delegation to seek financial assistance prior to a disaster rather than after.

The involvement of technically oriented engineers and researchers in the 1974-1977 period was small and sporadic. Academics representing the research community and structural engineers with a personal interest in earthquake hazard reduction made presentations to the Building and Safety Committee of the Los Angeles City Council and to the Council itself. In 1977, under the general umbrella of the Los Angeles Chamber of Commerce, a large technically-oriented subcommittee was formed for the development of the ordinance. About 30 active committee members participated in the early stages. The number of active members diminished to about 10 after the ordinance was generally outlined.

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The Technical Code Development Committee formed by the Los Angeles Chamber of Commerce became the Ad Hoc Hazardous Building Committee of the Structural Engineers Association of Southern California (SEAOSC). The beginning membership of this committee was about 12-15 active members from the previous technical committee. The Ad Hoc Committee has continued its activities to the present day. Its activities have included introduction of the results of National Science Foundation sponsored research into the ordinance on a continuous basis, the presentation of continuing education seminars for engineers and familiarization with the ordinance seminars for owners, contractors, and non-technical persons. The seminars were presented immediately after adoption of the ordinance in 1981 and in 1986 after major revisions to the ordinance. These revisions to the ordinance were based on the completed NSF-funded research. The seminars were generally six hours and were attended by up to 450 people. Seminar and proceeding costs were financed by the SEAOSC and recovered by registration fees.

The Ad Hoc Committee meets monthly and has an active membership of six to twelve. The committee also functions as an advisory group for building officials.

1.2 Scope and Scale of the Research Application

The earthquake hazard reduction research data has been written into two parallel applications. The Methodology, published by ABK upon completion of the research, follows the format of the NEHRP Provisions in that earthquake loading is expressed at realistic levels and the required material strength is specified as factored yield strength. The Los Angeles City ordinance has been written as a working stress code with earthquake loading given as comparable values to current code values. The SEAOSC Committee has factored the materials strength side to values that are comparable to the reduced load values. Both documents use the Effective Peak Acceleration of 0.4 g as given in the NEHRP Provisions as the earthquake risk zoning for the Los Angeles area.

The ordinance is now in effect in Los Angeles, and the cities of Santa Ana, Monterey Park, Culver City, and South Pasadena have adopted the technical content of the Los Angeles City Ordinance. The cities of Pasadena and Burbank are considering adoption of a similar ordinance. The County of Los Angeles has conducted public hearings as a preliminary adoption procedure. The Los Angeles ordinance is generally accepted in the Southern California area as an acceptable and adequate document for earthquake hazard reduction. Kariotis & Associates has prepared an ordinance for the City of Ventura based on the ABK Methodology. A draft ordinance, factored for seismic zone 3, has been reviewed for the City of San Diego.

The ABK Methodology is used as an alternative procedure for historic buildings throughout the western United States. The Division of Parks and Recreation of the State of California and the National Park Service provided ABK a grant to rewrite the Methodology as a guideline with commentary for earthquake hazard reduction for historic brick buildings. This document

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adds another factor for risk and damage consideration. The impact of the proposed damage reduction reconstruction is weighed against loss of historic fabric. Life-safety threats that may be posed by earthquake damage are considered separately from general building damage and the risk may be adjusted to minimize three events. These factors are:

- Annual probability of life-safety threats.
- Annual probability of possible future earthquake damage.
- Loss of historic fabric caused by proposed strengthening.

The use of alternative analyses and strengthening schemes for historic buildings is acceptable to the City of Los Angeles and other jurisdictions in the Southern California area.

The ordinances and methodologies are applicable to unreinforced <u>bearing wall</u> masonry buildings. The analytical techniques are <u>not</u> generally applicable to infilled framed buildings. Research indicates that the structural response of this class of buildings that may have unreinforced masonry as part of the building system is substantially different from the bearing wall type building.

1.3 The Key Players

The principal key players that carried through the development of the ordinance in the political and technical fields were Ben Schmid, Earl Schwartz, and John Kariotis. The principal researchers were Albin Johnson of S.B. Barnes and Associates, Bob Ewing of Agbabian and Associates, and John Kariotis of Kariotis & Associates. The key technical contributors include the aforementioned and many structural engineers and building officials. Ray Steinberg has chaired the Ad Hoc SEAOSC Committee for many years. Dick Jasper has served as secretary for the same number of years. Al Asakura, John Moore, Art Devine, and others from the City of Los Angeles have participated in writing and revising the current ordinance and in the education seminars. The total effort has been supported continually by the Board of Directors of SEAOSC.

Ben Schmid, as a member of the Board of Directors and President of SEAOSC, had a major role in development and adoption of the ordinance as a representative of the engineering profession. Earl Schwartz provided continuous pressure in the City of Los Angeles for adoption and updating of the ordinance. John Kariotis provided technical leadership for development of code provisions. Committee meetings were held during and after usual working hours. The professional time contributed to the effort has been volunteered.

The time contributed to convert earthquake hazard reduction research into application was volunteered as a part of professional practice. The motivation was concern about possible life-safety threats and earthquake damage to the inventory of existing buildings.

1.4 Funding History

The 1978 draft of the ordinance was based on a research program conducted in existing buildings scheduled to be demolished. This preliminary research was unfunded and conducted by volunteer engineering personnel. The static testing of masonry, masonry embedments, and in-plane piers provided data that assisted in the planning of the NSF-funded research.

The pre-1977 attempts to develop an effective earthquake hazard reduction ordinance recognized that the known data was totally inadequate. Four small business firms responded to an SBIR solicitation for research proposals. Three firms were given contracts for Phase I studies for the preparation of a methodology for the mitigation of earthquake hazards in URM buildings. The three firms formed the joint venture, ABK, at the conclusion of the Phase I studies and jointly presented a proposal for a Phase II research plan. A contract for $924,748 was awarded to the joint venture in October 1978. Supplemental grants of $421,577 and $20,110 were funded in February 1981 and December 1984 for continuing research and dissemination.

1.5 Internal and External Motivating Events

The internal motivating events for the persons involved in the development of earthquake hazard reduction programs was the completion of earthquake design codes and requirements for new buildings. The Uniform Building Code had major revisions in the earthquake design requirements in the 1976 Edition. The ATC-3 Requirements (basis for the NEHRP Provisions) were completed in 1978. The engineers previously mentioned as key players recognized that the effort expended in changing the earthquake design requirements for new buildings would have minimal immediate effect on national earthquake hazard reduction goals. They recognized that existing buildings comprised the majority of the earthquake hazard of the United States. The external motivating events were the requirements of the State mandated Seismic Safety Plans and the decision of the Los Angeles City Council to address the existing building problem.

SECTION 2
SPECIFIC RESEARCH STUDIES THAT PROVIDED THE KNOWLEDGE BASE

2.1 Funding for the Research

The research studies that provided the technical basis for the earthquake hazard reduction ordinances applicable to URM bearing wall buildings were funded by the National Science Foundation. The Phase I and II contracts were supplemented by a grant to complete the research. The research included large scale experimental testing of materials in a dynamic mode.

The structural test laboratory of North American Rockwell at El Segundo was utilized for the static and dynamic testing. The dynamic testing of full size elements utilized scaled time-histories of recorded earthquake motions as input motions for the shaking of test specimens that weighed up to 65,000 pounds. The experimental research solved the control problems of real-time kinematic experimental testing and obtained data that could not be acquired by static testing.

2.2 Driving Force for the Application

The need for the application of the research was the principal reason for the immediate acceptance of the research. The research was oriented directly to the problem needs. The research addressed complete buildings. Structural elements tested and analyzed represented real construction and conditions that exist throughout the United States. A part of the research was a nationwide survey to categorize this class of buildings into the analytical problem areas.

SECTION 3
TRANSLATION ACTIVITIES TO FACILITATE THE APPLICATIONS

The results of the research were disseminated to engineers, architects, and building officials by a series of full-day seminars. These seminars were conducted by the ABK researchers. The seminars were held in Boston, Massachusetts; Charleston, South Carolina; St. Louis, Missouri; Salt Lake City, Utah; Seattle, Washington; Sacramento, California; and Los Angeles, California. The seminars' content was technical and oriented to engineers and building officials. The presentation included 16 mm movie clips of the dynamic testing as well as the results of the research, the methodology, and its applications.

SECTION 4
DISSEMINATION EVENTS THAT CONTRIBUTED TO USE OF THE APPLICATION

4.1 Significant Dissemination Events

The evening seminars presented to the professional engineers were very effective to provide training. The retrofit or strengthening of existing buildings is generally viewed as very costly in proportion to the building value or replacement cost. The main purpose of the research was to address the critical issues needed for strengthening. This application of the research gave very significant cost reductions over strengthening programs previously used. These cost reductions depended on the knowledgeable use of the ordinance. The ordinance incorporates very significantly different concepts than used for design of new buildings. Education of the engineering profession is very important to assure that the strengthening costs are appropriately spent. Strengthening an existing material that is

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adequate has no cost benefit whatsoever. The engineer's training generally leads him to believe that only the materials he designs have structural value. This concept must be changed to make the application cost effective and therefore acceptable politically.

Seminars addressed to the building owners and public officials were designed to educate them to the risk posed by a do-nothing program and to assure them of the economic feasibility of an earthquake hazard reduction program.

4.2 Non-Productive Dissemination Events

Engineers and building officials were invited to the testing facilities to view the research in progress. These invited persons were in addition to an advisory panel that met regularly with the researchers. These presentations had minimal value because the persons that would visit were those already committed to support the application.

SECTION 5

RECOMMENDED REVISIONS TO THE PROCESS OF TRANSFER OF RESEARCH TO THE APPLICATION

5.1 Transfer Procedures

The weaknesses of the procedure used for the development and application of an earthquake hazard reduction program were the large demand on volunteer work, the difficulty of re-education of the users (the engineers), and the education of elected officials as to the need for the application.

Each of these is viewed as a problem area. There may not be a solution for or an alternative to these problem areas. The demands on the time of the people that can assist in the transfer of research cannot be limited. The transfer process needs their awareness and interest. The demand for volunteer time can be diminished for persons other than public officials by partial compensation.

5.2 Suggested Improvements in the Transfer Process

The transfer process must be highly visible to all affected by the application. The benefits of the application must be clearly stated without exaggeration. The engineering profession must be re-educated to utilize the application. This is of highest importance. The cost benefits to the building owner will be lost if the application of the procedures is not effective. This is the most significant single issue in the observed use of the Los Angeles City Ordinance. The engineer must recognize that analysis of existing buildings is extremely sensitive to the quality of the engineering assumptions and to the utilization of the research. The re-education process of the user of the application must be of high priority and engineering specialists for the use of the application must be encouraged.

GUIDELINES FOR EVALUATING THE NEEDS FOR STRENGTHENING AND REPAIR OF EXISTING BUILDINGS IN THE UNIVERSITY OF CALIFORNIA SYSTEM

BY

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INTRODUCTION

The need to strengthen and repair the existing buildings in the University of California system developed from the concerns of The Regents of the University of California about the seismic safety of University facilities. The 1971 San Fernando, California, earthquake caused minor damage to several buildings on the University of California, Los Angeles campus which were located 22 miles from the epicenter. This minor damage caused The Regents to order preliminary investigations concerning the seismic safety of their facilities on all nine campuses. By mid-1970, 170 buildings had been investigated and reconstruction costs for those buildings needing strengthening were approximately $100.0 million.

The Regents adopted a Seismic Safety Policy, dated January 20, 1975. This policy stated that to the maximum extent feasible by present earthquake engineering practice, it was University policy to acquire, build, and maintain buildings and other facilities which provide an acceptable level of earthquake safety as defined in the policy for students, employees, and the public, who occupy these buildings and other facilities, at all locations where University operations and activities occur. At the recommendation of the General Counsel to The Regents, the following wording was included in the policy. "Feasibility is to be determined by weighing the practicability and cost of protective measures against the gravity and probability of injury resulting from a seismic occurrence."

Since the State Legislature had funded over $50.0 million to strengthen the State Capitol for seismic forces, it was expected that if The Regents adopted a reasonable seismic safety policy similar to their fire safety policy, the State Legislature would look favorably on funding the seismic reconstruction of State-owned University buildings which did not conform to this policy. The funding from the State Legislature was not forthcoming quickly enough or in amounts sufficient to address the "clear and present danger" which many of the University buildings represented.

The bids for the first major seismic reconstruction project (South Hall built in 1873 on the

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Berkeley campus) will be opened in May 1987, sixteen years after the 1971 San Fernando earthquake which precipitated the University Seismic Safety Policy.

The following questions will be addressed: what happened, why did it happen, how long did it take, and what problems were or were not overcome. Answers to these questions will provide insight into evaluating the needs and implementation of a seismic reconstruction program for University buildings.

1. WHAT WERE THE PLANNED AND ACTUAL OUTCOMES OF THE SPECIFIC APPLICATIONS?

The planned outcome of the application of a rational public policy to provide an acceptable level of earthquake safety for University students, employees, and the public, was to obtain a source of funding from the State Legislature to abate the hazardous University buildings through a prioritized reconstruction program.

In 1974, preliminary studies by the University indicated that abatement of 170 buildings rated Poor and Very Poor would cost in excess of $100.0 million. As a result, the Department of Finance and the Legislative Analyst recognized that the seismic and life-safety correction problem was much larger than first anticipated and recommended that the remainder of the first $10.0 million authorization not be released until these problems had been more carefully studied. In 1976, the Legislative Analyst recommended that the Seismic Safety Commission determine the need for a statewide seismic safety rehabilitation program. The Commission developed a priority system for the abatement of seismically hazardous buildings based on a "Benefit-Cost Methodology" developed by consulting earthquake engineers who were both consultants to the University and the Seismic Safety Commission.

The actual outcome of following the guidance of the Legislative Analyst, the Department of Finance, and the Seismic Safety Commission, was that by 1981 an additional $500,000 was released by the Department of Finance. Most of this money was allocated for additional studies of the first eight buildings on the University's "Benefit-Cost" priority list. By 1984, State funding for seismic correction work included only two of the highest priority buildings: South Hall and Wheeler Hall on the Berkeley campus with reconstruction costs of $2.7 million and $1.4 million respectively.

A. What length of time and level of effort were involved?

Length of time was from 1975 when the University Seismic Safety Policy was adopted by The Regents to date.

Level of effort was approximately $2.0 million in State funds for seismic reconstruction studies and reconstruction of two State owned University buildings. Approximately $.500 million in Regents' funds were used for seismic studies of non-state owned University buildings.

B. What was the scope and scale of the applications?

The scope included over 800 buildings, representing over 44 million gross square feet of 1978 buildings, which were evaluated for their seismic performance and assigned a rating of Good, Fair, Poor, or Very Poor, in accordance with the University Seismic Safety Policy.

The scale of the applications was: 80% of the total building gross area was rated as Good or Fair, a low life hazard; 20% of the building gross area or 9 million square feet was rated Poor or Very Poor, representing a high life hazard. In 1978 the reconstruction costs for the Poor or Very Poor buildings were estimated in excess of $300 million dollars or $500 million dollars in 1987.

C. Who were the key players? Why?

1. The Regents recognized the seismic hazard and the risk to the University students, employees and the public. They also recognized the potential liability to their endowment and their investment reserves that could result from litigation developing from the deaths and injuries to the occupants of the facilities in the event of major earthquakes.
2. The State Public Works Board, Legislative Analyst and Director of the Department of Finance were concerned about funding any University reconstruction projects without getting "a handle" on the total cost of seismic corrections not only for the University of California buildings, but for the State of California's own buildings and the State College and University buildings requiring seismic reconstruction. They were reluctant to open up the State treasury to the University of California seismic program which they saw as a possible attempt to modernize the older University buildings under the disguise of seismic rehabilitation.
3. The State Legislature gave mixed messages to the University by funding the approximately $50.0 million seismic reconstruction of the State Capitol but would not fund seismic correction work on other State owned buildings used by the University.
4. The General Counsel, attorneys for The Regents, did not attempt to prevent or express any opposition to having seismic investigations performed or making the results of these investigations made public. In fact, they strongly recommended that the occupants of all University buildings be advised of the seismic risk in their buildings. University Hall in Berkeley, which is the headquarters for University Systemwide Administration and has the Offices of the General Counsel, has been given a seismic performance rating of "Very Poor" and all the occupants have been notified in writing of this evaluation.
5. Some of the University Chancellors were not strong advocates for seismic correction work because of the loss of much needed space during the reconstruction period. They also faced what they believed to be more serious problems than seismic safety with low faculty salaries, crowded facilities and scarce state funds for educational needs.
6. The current President of the University Systemwide Administration is well respected by The Regents, the Legislature and the University community. After a year of careful consideration and opposition from some of the Chancellors, he issued a letter, dated September 30, 1986, requiring a third party

structural (seismic) review of all new University buildings, major structural additions and reconstruction designs. Previous to this letter, because the University building designs were exempt from the local building department permit and plan review process, structural design calculations, drawings, and specifications were not reviewed for compliance with State of California building code requirements.

7. The University of California at Los Angeles' (UCLA) Ad Hoc Joint Senate Administration Earthquake Committee prepared a report, "A Campus At Risk", dated September 1985, and it was released to the public soon after the September 19, 1985 Mexico earthquake. The Committee stated in the report that if UCLA were in session and a major earthquake occurred on the San Andreas Fault or on one of the other faults in the vicinity of UCLA, that the number of deaths could approach 2,000 and serious injuries could exceed 4,000 on the UCLA campus. The tenured professors on the Committee had nothing to lose by "calling a spade a spade" and projecting the number of deaths and injuries at UCLA. The large number of casualties in Mexico City had an impact on The Regents. Several UCLA residence halls that had been rated Very Poor looked like buildings that had collapsed in Mexico City. Additional detailed studies of these residence halls were undertaken.
8. Two investigative reporters from the Los Angeles Times who were looking into the seismic safety of University buildings picked up the "Campus at Risk" story and kept it alive for several weeks. This brought the facts about the seismic safety problems with many of the UCLA buildings to the public's attention.

D. What was the funding history?

In 1974-75 only approximately $1.5 million of the $10.0 million, which had been included in the 1974-75 State Budget for seismic and other life-safety hazard corrections, was released by the State Public Works Board. Approximately $1.5 million was utilized to complete two seismic correction projects at the Santa Barbara campus. It should be noted that until 1981 only about $.500 million of the remaining $8.5 million was released for planning studies of University seismic safety projects. Since 1971, The Regents have allocated approximately $1.0 million for seismic studies of non-state University owned facilities, such as residence halls, parking structures and other non-classroom buildings.

E. What were the internal and external motivating events (if any)?

The 1971 San Fernando, 1978 Santa Barbara, 1980 Livermore, and 1985 Mexico earthquakes were motivating events. The Regents were first confronted with the problem of unsafe buildings following the 1971 San Fernando earthquake. This conclusion was confirmed by the $3.5 million damage to University buildings caused by the 1978 Santa Barbara earthquake. The 1985 Mexico earthquake was important in bringing home the real possibility of deaths and injuries on the UCLA campus because of the fortuitous timing in the release of the "Campus At Risk" report soon after the Mexico earthquake.

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2. WHAT SPECIFIC RESEARCH STUDIES CONTRIBUTED TO THE KNOWLEDGE BASE REQUIRED FOR THE APPLICATIONS?

The National Science Foundation's funded "Learning from Earthquakes" research studies and field investigation of earthquakes provided the background for the evaluation the seismic performance of buildings.

The United States Geological Survey and the former NOAA earthquake studies of earthquake loss estimation, seismicity, faulting, causes of earthquakes, and earthquake hazard reduction contributed to the knowledge base for the identification of potential seismic hazards.

The Federal Emergency Management Agency funded research studies on earthquake loss estimation, response to earthquake predictions, and other socioeconomic public policy issues were important to understand how the decision makers and the public view the seismic hazard represented by unsafe buildings.

A. Was the applications research driven or needs driven?

Both.

3. WHAT SPECIFIC TRANSLATION ACTIVITIES HELPED TO FACILITATE THE APPLICATIONS?

The press and television coverage of the 1971 San Fernando, 1978 Santa Barbara, 1980 Livermore and 1985 Mexico earthquakes helped facilitate the development and implementation of the University Seismic Safety Policy and funding. Another factor was the concern of the University General Counsel about the potential liability to The Regents if the information about the seismic safety of University buildings was suppressed, an earthquake occurred and injured people.

4. WHAT SPECIFIC DISSEMINATION EVENTS CONTRIBUTED TO THE SUCCESS OF THE APPLICATIONS?

The adoption of the University Seismic Safety Policy by The Regents on January 20, 1975 established the basis for the University Seismic Safety Program.

The release of "Campus at Risk", September 1985, soon after the Mexico earthquake, that projected the number of dead and injured, and was authored by respected professors and administrators on the UCLA campus, added a much needed credibility to the previous University seismic reports which had basically been ignored.

The Los Angeles Times articles about the report "Campus At Risk" provided the needed publicity to get that report out into the public domain rather than have it filed away as just another report in the UCLA library which no one reads or remembers.

A. Which of these events was most significant to the eventual successful application?

All three.

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B. Which were not significant?

None.

5. IF THE APPLICATIONS PROCESS COULD START OVER, WHAT FACTORS (PEOPLE, PROGRAMS, PROCESSES, PLANS, ETC.) WOULD YOU CHANGE?

In retrospect, one of the most important programs which could have been implemented to preclude the construction of many of the buildings that were seismically rated Poor and Very Poor, would have been a quality assurance program including the peer review of structural (seismic) design calculations, drawings, and specifications for all University buildings starting in 1933 when the Field Act was implemented. It is important to note that the Field Act applies to elementary through junior college public schools in California and not to the State Colleges and University System or the University of California buildings.

A. What would you do differently now because of your "perfect" hindsight to ensure success?

Appoint on each campus an Ad Hoc Joint Senate-Administrator Earthquake Safety Committee with tenured professors who have the necessary engineering background to understand and explain the seismic risks in their buildings and the courage to call "a spade a spade" and report their best judgment as to the number of deaths and injuries which might occur in the event of a major earthquake.

Develop a better early-on working relationship with the news media and television reporters in order to get the information out to the public about the seismic risks represented by many of the University buildings and operations.

Have a pre-earthquake public relations program with draft legislation and funding program developed and ready for adoption in the event of future earthquakes.

B. Why?

A successful earthquake hazard reduction program must have the support of the public based on realistic estimates of the hazards and stated in simple terms that the public can understand. The time to implement an earthquake hazard reduction program is immediately after an earthquake when people see the possibility that property losses and personal injuries could happen to them.

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EXPERIENCES WITH STRENGTHENING AND REPAIR OF EXISTING BUILDINGS IN THE LOS ANGELES AREA

By

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The City of Los Angeles has been implementing its Earthquake Hazard reduction program since the enactment of its ordinance on February 13, 1981. The program applies to the structural upgrading of 8,000± unreinforced masonry bearing wall buildings. The development leading up to the eventual passage of the Ordinance involved a complex array of events, key people, political atmosphere and technical readiness. Each were important and necessary players in the passage of the Ordinance. In this paper, I would like to focus on "technical readiness" and the important role that it has played in the Los Angeles City Ordinance.

The 1971 San Fernando earthquake provided the impetus that finally led to the adoption of the hazard reduction ordinance in Los Angeles. Six (6) years after the earthquake, in 1977, the Los Angeles City Council passed a most progressive action that led to the adoption of the Earthquake Hazard Reduction Ordinance in 1981. That action established a "technical" committee working together with an "impact evaluation" committee (that addressed financial, social and political needs) to develop a workable earthquake mitigation ordinance. The research work, accomplished under a National Science Foundation grant by a joint venture of Agababian, Barnes and Kariotis (ABK), was utilized in part, to develop the basic technical standards of the Ordinance that was finally adopted in 1981. The research work gave sound creditable background from which reasonable structural standards could be developed that also mitigated the financial, and social problems that were anticipated with the passage of the Ordinance. In essence it established reasonable cost figures for the necessary structural upgrading work. It balanced out the largest concern of those that opposed the passage of the ordinance whose contention was that the cost of upgrading would lead to a demolition derby and result in the elimination of available low income housing stock. The Los Angeles City experience to date has shown that buildings are being structurally upgraded, that demolition and loss of housing stock has not increased beyond the normal attrition rate.

This technical committee, (ad-hoc committee of the Structural Engineers Association of Southern California) continued to meet on a monthly basis, from 1981 to the present, with the

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objective to review/study the research work done by ABK and to improve upon the technical standards established in the 1981 Ordinance. The result was improved enforcement (including changes) of the new Ordinance and the development of an alternate design methodology that more closely takes into account the actual response of a building to an earthquake. This new design methodology, in many instances, further reduced the cost of the work necessary for structural compliance to the Ordinance.

In the latter part of 1986, the Apartment House Owners Association thru the legislative process, proposed as part of a rent control package, a restudy of earthquake standards with the intent of reducing the earthquake standards for residential buildings. The basis for this proposal was simply to reduce the cost. The Department of Building & Safety was successful in lobbying against the reduction in seismic standards simply because the technical research work and the follow-up application/study of the research had been diligently and extensively performed.

The experience in the City of Los Angeles hazard reduction program highlights the importance of "technical readiness". In most instances, research applications include information that would allow good decisions to be reached on the relevance of the subject matter that is to be researched and the competence of the researchers. Our experience with the Los Angeles City Ordinance shows the important role that a researcher can play in the implementation of the research work.

The principal(s) responsible for the research work on unreinforced masonry buildings continued to be active in the legislative process and in professional organizations to develop technical standards consistent with the results of the research work. The dissemination/explanations of the results of the research work through the professional organizations led to a better understanding and subsequent acceptance by the technical profession and governmental agency. The process did not stop with the publication of the research work but continued until the important results of the research work had been incorporated into law.

CONCLUSION

The experience in Los Angeles City emphasizes the importance of "technical readiness". The results of the research work recognized that existing materials in hazardous buildings have structural strength and stability and could be used (with limitations) to help resist earthquake forces. It provided creditable structural standards to be established that allowed for the structural upgrading work to be done in buildings at a reasonable cost. Cost was a key factor in the passage of the hazard reduction ordinance and it is the research work that allowed for the cost factor to be within the limits that made it politically acceptable and developed standards that simulate the action of buildings in earthquakes.

The Los Angeles City experience points out the importance of having the research team members participate beyond publication/dissemination. Where the results of research work is important enough to be incorporated into practice or law, the means to accomplish such must be incorporated in the total process such that the research program can achieve its full potential.

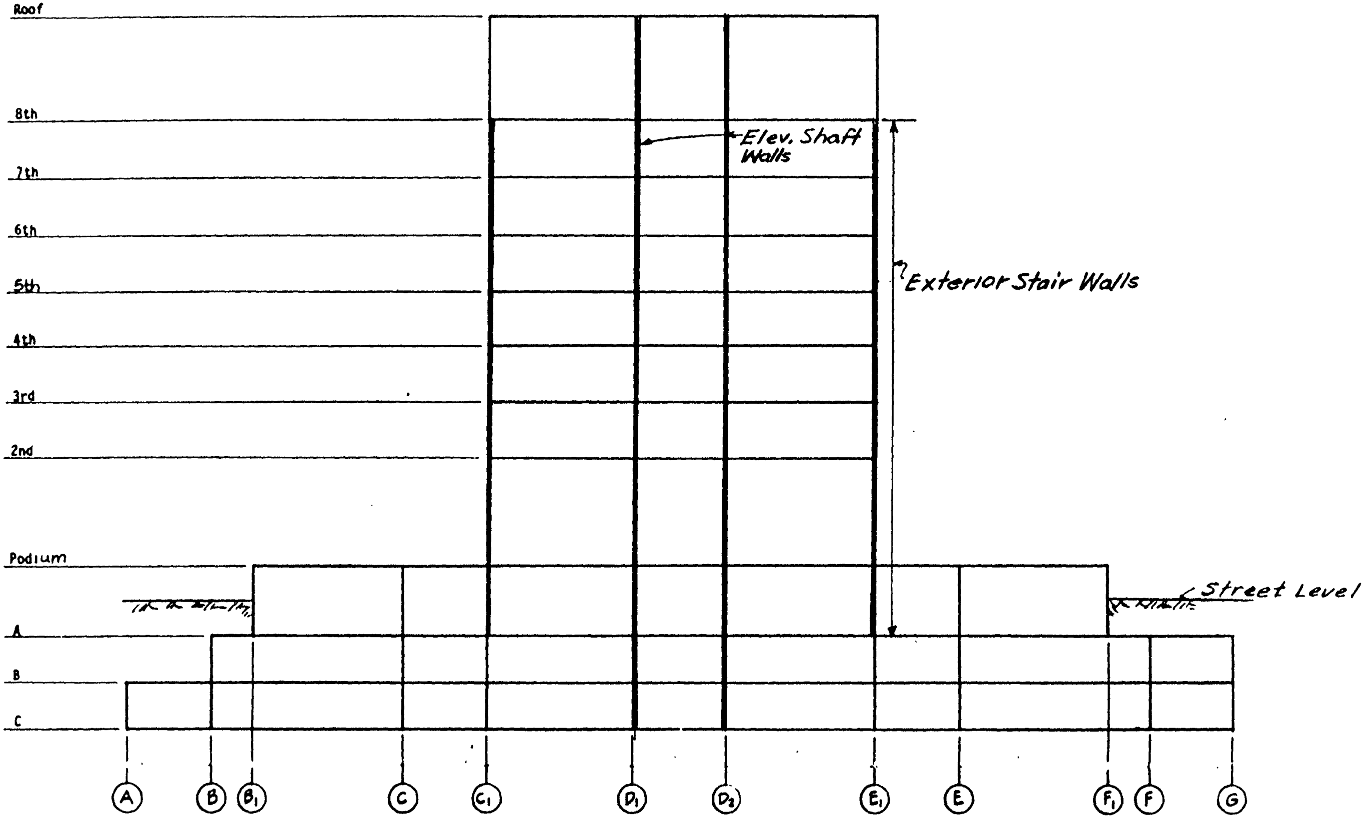

FIGURE 4. SCHEMATIC SECTION LOOKING NORTH

SEISMIC STRENGTHENING OF PALO ALTO CIVIC CENTER

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INTRODUCTION

The City of Palo Alto Civic Center (PACC) was constructed in 1968 -1970. Palo Alto is located about five miles east of the San Andreas fault, see Figure 1. City operations are housed in PACC; the exceptions are public libraries and city maintenance yard. About 250 people work in the building.

Indications of potential structural problems first appeared in 1975; from 1975 to 1982 additional weaknesses were observed. After a detailed seismic risk study and structural evaluation the City authorized schematic designs in 1982 and design documents in 1983. Construction bids were received in early 1984, construction activities started in June 1984, and work was completed in August 1986. All work was performed while the building was occupied and in full operation.

BUILDING DESCRIPTION

The initial design and construction of the building was in general accordance with the 1961 Uniform Building Code. The building consists of an 85 ft square eight story tower supported on a three story below-grade parking garage 242ft by 272ft in plan, see Figures 2 and 3. The garage is constructed with reinforced concrete columns and exterior walls with poststressed concrete slabs and girders. An expansion/contraction joint divides the garage into two parts.

An eight story office tower is supported on the garage with elevators serving the lowest level to the eighth floor. The tower is constructed with reinforced cast in place concrete columns and walls, and poststressed slabs and girders. The exterior cladding is precast concrete facade columns with window walls between. Tower story heights are 12ft except for 23ft high first and eighth stories, see Figure 4. The parking structure story heights vary from 10ft to 13.75ft. Lateral force resistance was provided by the walls of the elevator shaft and the exit stairways, and the rear wall of the restroom areas.

SCHEDULE OF EVENTS

The first structural concerns arose in 1975 when cracking and some spalling of the precast concrete facade columns were observed. EDAC assessed the problems and recommended repairs plus a seismic analysis of the tower because the lateral force resisting system did not appear complete. The exterior facade columns were caulked and painted in 1978.

An independent study of water leakage in the garage was commissioned by the City in 1978; the study raised new concerns about the building. In 1980, EDAC was retained to make a preliminary investigation and assessment of the structure; a program of repair for badly cracked floor slabs and walls was recommended. The work was completed in 1981 and then portions of the floor slab was load tested. The floor slabs withstood the load testing satisfactorily.

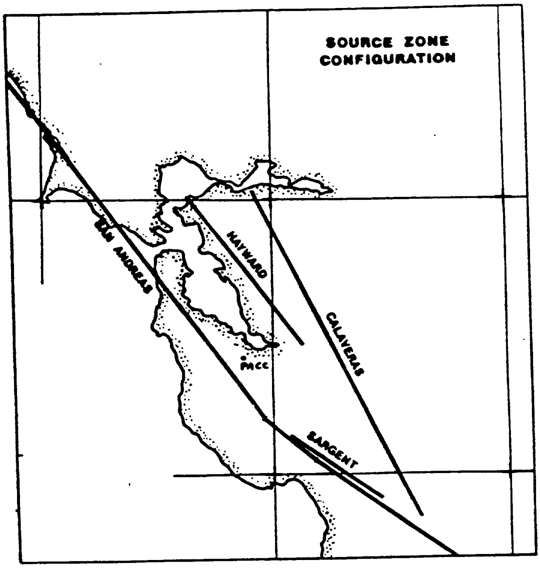

FIGURE 1. FAULT SOURCES

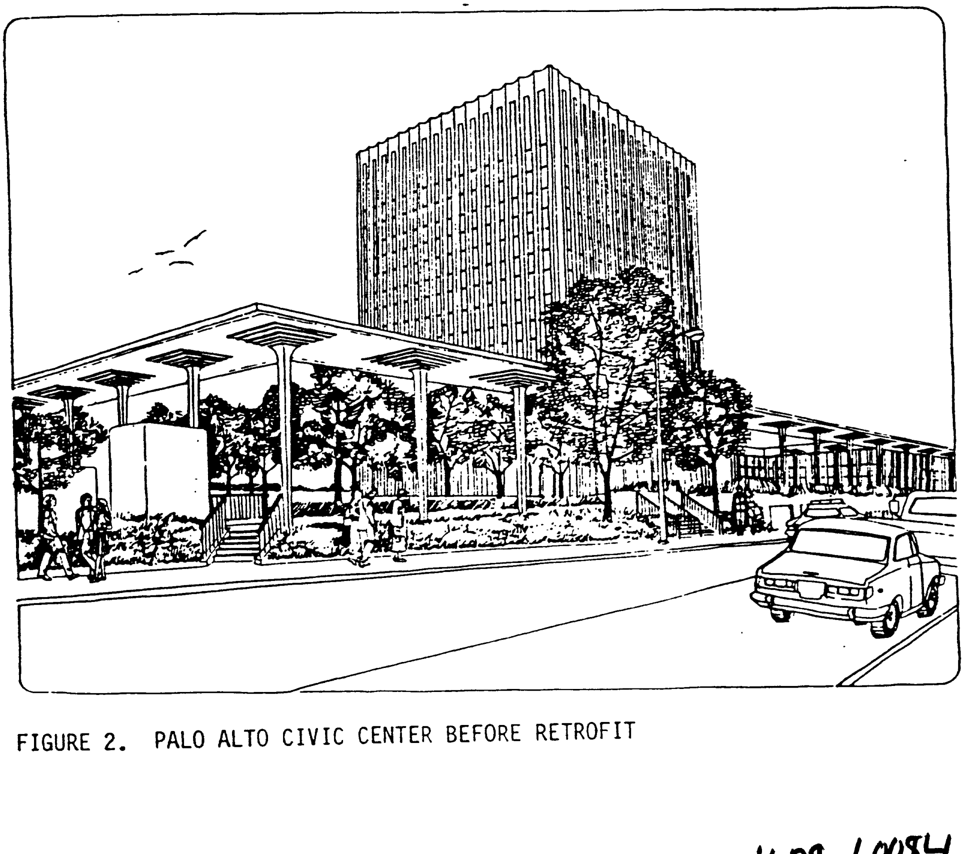

FIGURE 2. PALO ALTO CIVIC CENTER BEFORE RETROFIT

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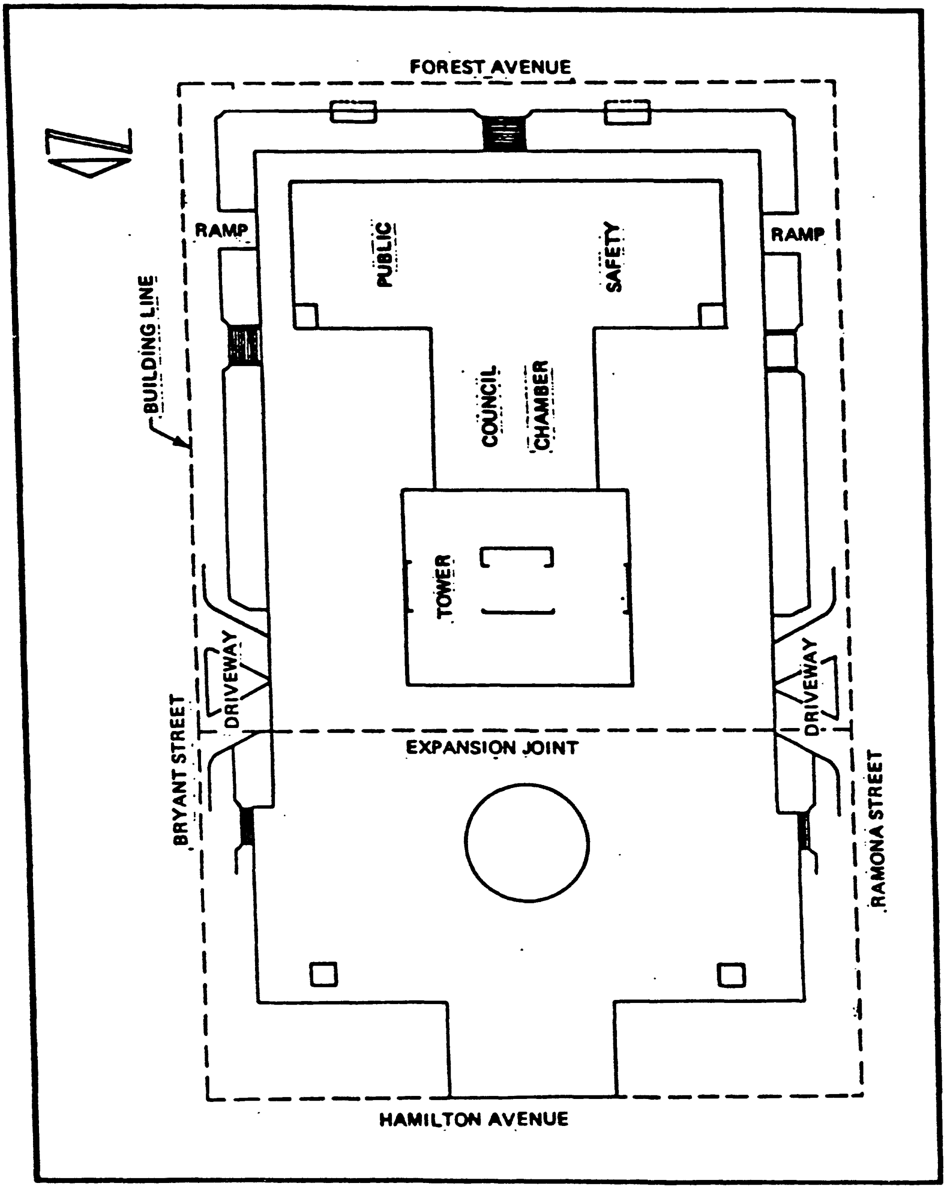

FIGURE 3. PALO ALTO CIVIC CENTER PODIUM LEVEL

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In 1982 the City authorized EDAC to make a seismic risk study of the facility. Strengthening of the lateral force resisting system was recommended plus reinforcement of the lower three stories of the concrete columns supporting the tower. These columns had exhibited cracking patterns indicating potential overstress.

After completion of the risk study, the City approved development of schematic designs for the required strengthening. Design documents were started in 1983 and completed in early 1984. Bids were taken and construction started in June 1984, and completed in August 1986.

PROBLEMS ENCOUNTERED

There were many problems and delays encountered during the ten-year period from initial concern to construction completion.

The building was five years old when the first cracking and spalling appeared; thus it was difficult for the City Council to understand why there were problems. Concern over the potential injury to the public from falling spalled concrete led to the first repairs. Recommendations to make a careful review of the structure and reanalysis for seismic forces were resisted because the building was relatively new.

1980-81 When extensive cracking appeared in the garage floor slabs and walls because of differential creep and shrinkage between the poststressed slab floors and the normally-reinforced exterior walls, the City was motivated to make repairs because of safety concerns. The stressed tendons were were subject to corrosion from the environment unless the cracks were repaired. The repairs were completed in 1981.

About this time unsightly water leaks started occurring at the expansion/contraction joints. Evaluation of the limited data available indicated that differential displacements during a major earthquake could cause loss of vertcal support because concrete shrinkage and creep had narrowed the bearing surfaces.

1982-83 EDAC conducted a detailed seismic risk study of the PACC including a structural assessment and made the following recommendations:

1. Strengthen elevator shaft walls with steel plates plus required architectural, mechanical and electrical work.
2. Strengthen the eighth story by adding two north-south shear walls and steel bracing in the east-west direction.
3. Add new reinforced concrete shear walls at garage levels B and C.
4. Strengthen tower perimeter columns on lines 10 and 14 at levels B and C.
5. Strengthen connections of precast facade columns to tower structure.
6. Strengthen 34 columns supporting umbrella walkway at Podium level.
7. Provide support extension at expansion joints for Podium, and garage levels A and B.
8. Provide seismic restraints for mechanical equipment at Level A and eighth floor.
9. Add wire bracing and hangers for the suspended ceiling and light fixtures on all levels.
10. Upgrade tower restrooms and access to meet California Handicapped Requirements.

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Major problems arose because of the cost and potential impact on City operations. EDAC was directed to prepare schematic design documents, a construction plan and cost estimate.

Meanwhile the City announced plans to float a bond issue. Objections from some residents about the legality of a bond issue made the City Council change its mind. Finally a solution was developed whereby the City transferred the PACC to a non-profit corporation for twenty years and agreed to pay rent to the corporation. The corporation in turn issued Certificates of Participation bearing interest for twenty years. The funds were deposited in a local bank with authority for the City to request periodic reimbursement for design and construction expenses. EDAC was directed to prepare design and construction documents.

The question of whether to evacuate the PACC during construction was studied at length. Inconvenience to the public, lack of adequate close-by office space, expense of moving the staff, and difficulty of moving the Emergency Communications Center which served Palo Alto, Mountain View and Stanford University precluded moving. The fourth floor had been left unfinished when originally constructed. It was decided to finish this space including restrooms and then move occupants from a floor to the new floor while construction was completed on their floor.

Another problem was construction noise, dust and debris. Accoustical studies were made to assess the impact of core drilling versus rotary impact drilling. Because the poststressed construction of the tower created a sound chamber, the intensity of noise was a serious concern. The Emergency Communications Center operates on a 24 hour basis and thus special acoustical sealing, insulation and procedures were adopted. A bell was installed where the drillers were working which EMC could ring when an emergency call was received. Many emergency callers are difficulat to understand because of their panic or injuries, thus low ambient noise levels are essential when the operator is receiving a call.

The coordnation of construction activities with daytime City operations and night time Council and Committee meetings was also critical. Noisy work during the day and during evening meetings was prohibited. However, to minimize impact on City operations, wherever feasible, noisy work was conducted from 5:00 pm to 7:00 am.

It was decided to employ a construction manager and bid the work in three packages; architectural-type including cast-in-place concrete, structural steel, and demolition and concrete drilling. The three contract packages were used so close control of scheduling, access to construction areas, use of elevators during normal working hours, noisy operations, etc. could be maintained.

1984 Bids were taken during the spring and work started in June 1984. Initially only two elevators had been installed, so steel plate could be installed in the empty shaft. Meanwhile the fourth floor was completed with restrooms, ceilings, HVAC, telephone system, and partial height movable partitions. Work was also started on construction of new concrete shear walls in the garage.

In general construction activities progressed quite well. However, changed conditions were encountered such as electrical conduit in the ceiling slab rather than in the floor slab; the conduit was inadvertently severed during work on a Saturday. Unbeknown to the workman, this cut power to a sump pump draining a lower portion of the garage and caused flooding which severely damaged control equipment for an exit elevator. A member of the public was isolated for a time in the elevator. Fortunately no cars were in the flooded area. In other areas reinforcing steel was not in locations as shown on the building drawings.

Despite careful precautions and detailed procedures, numerous fire alarms were caused by smoke from welders. Each alarm caused complete evacuation of the building with about forty five minutes lost time for each City employee.

The City project manager worked closely with the city employee unions before and during construction to help them understand the need for the strengthening and to answer their complaints. This planning materially reduced complaints. The City staff endured the inconveniences remarkably well.

<u>1986</u> Construction work on all floors was completed in the fall of 1985. The installation of steel plates in the elevator shafts and steel plate bracing of the exterior concrete walls in the stairways were not completed until August 1986 because of labor and access problems.

STRENGTHENING DESIGN

The 1982 seismic risk study showed that the lateral force resisting system for the tower was inadequate. Shear walls were missing from the eighth story and in the garage levels below the tower, shear resistance of walls on other floors was inadequate, concrete columns supporting the perimeter walls of the tower were overstressed in the lower levels, and connections of the precast facade columns to the structure were overstressed.

Initially it was planned to thicken the concrete walls of the elevator shaft on the exterior. However, careful inspection of running clearances in the shaft revealed that there was enough clear space (2.5") to install steel plates against the concrete walls. It was ecided to strengthen the walls with 0.5" and 0.63" thick steel plates anchored with bolts through the walls and epoxy injected between the plates and the wall, see Figure 5. This solution minimized impact on adjacent office spaces and did not reduce usable office space which was at apremium.

New concrete shear walls were added in the two lower garage levels to resist torsional forces from the tower and transmit shear to the foundations, see Figure 6. Shear walls were also added at the eighth floor.

The precast facade columns were anchored to the floor slab with steel angles. Where this could not be done, bolts were installed from the exterior by drilling through the precast prestressed columns into the poststressed perimeter floor beams. Careful measurements and good workmanship avoided cutting any tendons although over 400 bolts were installed in this manner.

When the strengthening of the umbrella columns supporting the exterior canopy was started by stripping some of the concrete cover, it was found that the

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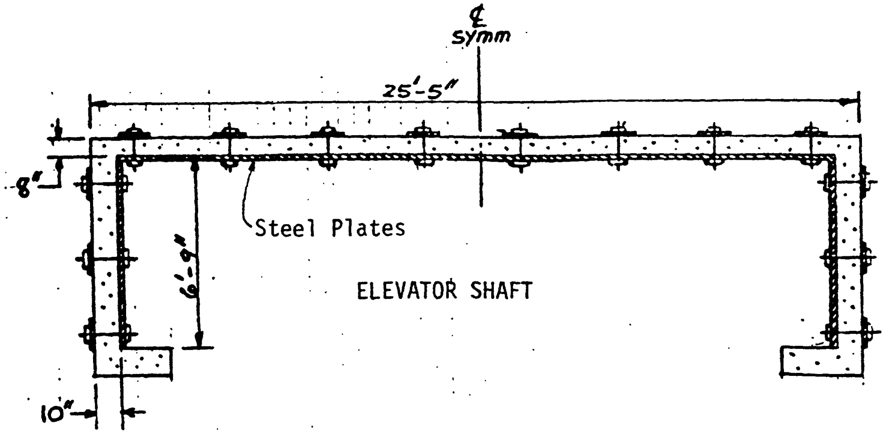

FIGURE 5. ELEVATOR SHAFT REINFORCEMENT

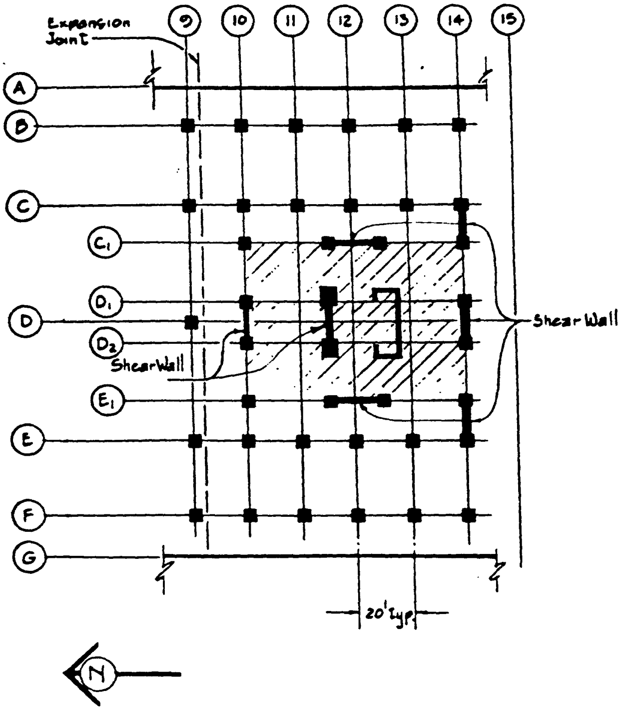

FIGURE 6. NEW SHEAR WALLS AT GARAGE LEVELS

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structural steel and reinforcing were so misplaced that the required reinforcing would be architecturally unacceptable. After careful study and consideration the City decided to remove the canopy and columns. The work was accomplished in January 1985 without incident.

CRITIQUE

A number of questions were posed for each author to answer. Following are the writer's comments:

1. Planned and actual outcome.
   The result is a strengthened building capable of withstanding major earthquake motions. This was planned.

   a. Length of time and level of effort, scope and scale.
   The total process encompassed ten years. The level of effort was extensive; total cost of the work including early slab repairs and facade patching was about five million dollars plus considerable City staff time.
   b. The key players were concerned City Council members over the ten year period, the City Manager, three different City Project Managers, and EDAC staff; the author was the responsible principal and A-E Project Manager during the seismic risk study, design and construction stages.
   c. The funding history involved City funds for all studies and certificates of participation/non-profit corporation (payable by City funds) for the the design and construction phases. It is of interest that the City filed suit against the initial building contractor and structural engineer for faulty construction and design. The suit was settled out of court in the City's favor in March 1985.
   d. The internal and external motivating events stimulating the process were evidence of structural weaknesses, concern for staff and public safety, and proximity to the San Andreas fault system.

2. Specific research that contributed to the application. Stanford University Civil Engineering Department developed the probabilistic response spectra for the site. The dynamic analysis programs used were initially developed at the University of California, Berkeley.

   a. Presumably the research effort to develop each of the above was funded by the National Science Foundation.
   b. The probabilistic spectra and the computer programs were used because they were available and were applicable to the project.

3. There were no specific translation activities.

4. The specific dissemination events helpful to the project were research reports and papers published on probabilistic spectra and on dynamic analysis.

5. If the process were to start over again, the only major changes would be in more detailed planning for the coordination of construction with building occupants and realignment of responsibilities during construction. Specifically, inspection and testing should be reportable to the

A-E rather than the Construction Manager. The CM does not fully understand the intent and needs of the design and thus inspection/testing may not be timely or effective.

SUMMARY

The use of probabilistic response spectra was helpful in demonstrating the need for seismic design levels greater than building code. The dynamic analysis programs clearly pointed out the weak areas in the lateral force resisting system.

Research is needed in the area of strengthening concrete walls with steel plates and/or bracing. During the design the literature was surveyed in detail to find applicable research; little was available. Thus experienced engineering judgement based on detailed calculations was relied upon for the design.

THE PROCESS OF DEALING WITH HAZARDOUS BUILDINGS IN LONG BEACH, CALIFORNIA

By
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Description of Research Application:

The Building and Safety Director for the City of Long Beach in 1970 condemned 928 buildings that were built of unreinforced masonry prior to 1934, the time at which new building codes addressed specifically to earthquakes were introduced. He condemned the structures because of the California State Supreme Court's decision regarding the rehabilitation of structures in the City of Bakersfield regarding the fire hazard.

In that State Supreme Court decision rendered February 4, 1966, the City of Bakersfield's application of the City's Uniform Building Code against a hotel owner regarding fire safety was upheld. The case involved a lengthy dispute between the City Council and the owner of the Hotel Padre, which was built in downtown Bakersfield before fire hazards were clearly recognized and incorporated into building codes. The case started in 1955 when the owner was advised that his building was a fire hazard.

> "It is undisputed that conditions within the Hotel Padre violated provisions of the Unified Building Code which has been adopted by the City of Bakersfield", the court said in an unanimous opinion by Justice Stanley Mosk. "The Uniform Building Code drafted by the International Conference of Building Officials was included as part of the City Ordinance enacted in May 1959 and has been enacted by many cities throughout the State", the court noted.

The court said that sections of the government code gives local agencies the authority "to adopt such uniform codes by reference" and "the practice of adoption by reference had been judicially approved".

The City filed suit against the hotel owner in September of 1961, charging him with code infractions. He countered that the City had exceeded its legislative powers and had erred in not granting a public hearing before notice was posted that his building was unsafe. The Superior Court ruled in favor of the City. But the hotel owner won a reversal before the District Court of Appeals. The City appealed to the Supreme Court for a final ruling. The Supreme Court said that, "It is clearly within the statutory powers of the City to declare buildings violating the ordinance in ways which directly affect the health and safety of the public as nuisances."

So far, as a public hearing is concerned, the court said, "The trial itself constituted a public hearing on the matter."

The main thrust of the decision revolved around the definition of the word "nuisance". The court noted that, "The semantics of Civil Code Section 3479 provide little guidance in ascertaining the degree of danger which must be present for a condition or activity to be considered a nuisance. Almost all human activities involve some risk and in circumstances in which Civil Code Section 3479 is the only applicable statute, considerable judicial discretion has been allowed in determining whether an alleged danger is sufficiently serious to justify abatement."

In concluding its decision, the court noted the following points:

a. "City legislative bodies are empowered by Government Code Section 38771 to declare what constitutes a nuisance.

b. Health and Safety Code Section 17951 specifically provides that a city or county may impose standards which equal or exceed the state regulations.

c. The fact that a building was constructed in accordance with all existing statutes does not immunize it from subsequent abatement as a public nuisance.

d. It would be an unreasonable limitation on the powers of the city to require that this danger be tolerated ad infinitum merely because the hotel did not violate the statutes in effect when it was constructed 36 years ago.

e. It has been recognized that a building code may constitutionally impose stricter standards for newly constructed buildings than for those which existed at the time the code was enacted. The Uniform Building Code makes such a distinction, however the Constitutional criteria to be applied in either case are whether the expenses necessarily incurred in compliance with this statute and the sanctions imposed for non-compliance are reasonable in relation to the public health or safety interests being protected.

f. In this case, compliance with the ordinance would in all probability result in increased value of the hotel rather than diminution or destruction."

This legal precedent was used by Mr. Edward O'Connor, the then Director of Building and Safety in the City of Long Beach, to condemn the 928 buildings that did not comply with earthquake standards then in existence within the City of Long Beach, namely the provisions of the 1967 Uniform Building Code.

Mr. O'Connor reasoned that if he did not condemn these known earthquake hazardous structures in the event of severe earthquake in which persons were killed in such structures he would be professionally and personally liable for the health and safety considerations violated. This opinion resulted not only from the Hotel Padre decision, which has been discussed above, but also because in 1933 similar structures suffered great destruction when a 6.3 magnitude earthquake hit the city. He also reasoned, as did Judge Mosk in the Hotel Padre decision concerning the fire hazard, that, "In this case, compliance with the ordinance would in all probability result in increased value of the hotel rather than diminution or destruction." He, therefore, required all the structures to be demolished or repaired and brought up to existing code. Repairs were required to conform with the criteria developed by the State Division of Architecture for public school buildings as set forth in Section 414, Title 21 of the California Administrative Code. This was the only approved repair technique at the time.

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When the notices went out to the building owners in question, a cry of alarm was expressed. The Los Angeles Times was full of reports of the destruction required by the building official in Long Beach and Town Hall meetings were called. Finally, a group of about 300 owners hired an attorney who in turn sued the building official and the city.

At that time, the author was called in to the Long Beach City Manager's office to discuss the problem and to develop a solution that would satisfy both the perceived and real requirements of the Director of Building and Safety regarding his liability and his perceived need to protect the citizenry under his charge and to satisfy the building owners with their otherwise useful property and the tremendous expenses which they would bear should they comply with the Building Director's request. Accordingly, we set out to develop a compromise solution to the problem -- to tear them down was not the answer, to let them stay in place forever was also not the answer.

As a result of the foregoing situations, the author was engaged to find a middle ground that would answer the public's needs and balance them with the public's safety. The following tasks were completed in developing our recommendations:

1. The latest knowledge concerning earthquake action was surveyed, along with the various parameters affecting it.

2. The performance of various structural types during past earthquakes was researched and analyzed.

3. New code criteria based on equating involuntary earthquake risk with other voluntary risk situations, such as auto accidents, were developed. This original research conducted during this program introduced the new concept of <u>Balanced Risk</u> design.

4. A means by which representatives of the lay citizenry can establish or modify code limits was provided.

5. Procedures for assessing the earthquake hazard in existing structures so that rating of existing structures could take place was developed.

6. General remedial standards for repairing existing buildings were developed from the standpoint of <u>performance</u> recommendations as opposed to using a specific technique.

7. Potential problems with regard to legal ramifications were discussed prior to the formulation of the final recommendations prepared for City Council consideration. Some of the legal considerations revolved around the question of retired persons living in existing, non-conforming structures who did not have the wherewithal either to move or to increase the seismic resistance of their structure.

The total time for balanced risk design research, review of existing research literature and preparation of recommendations for City Council action was six months. The effort involved, in current 1987 dollars, approximately $45,000.

the Building and Safety Director, the courageous City Manager who stood up to the City Council and, of course, the February 9, 1971 San Fernando earthquake. Had any one of these factors not been present, an ordinance for rehabilitation purposes would not have been developed. Had not imagination been used to balance all of the many and varied positions, the ordinance would not have been passed. This was truly the situation of the right time, place and people for action to be taken. Unfortunately, it takes crises to generate mitigating actions. In this case, the opportunity did not depend upon lost lives in the City of Long Beach. However, lost lives in the City of Los Angeles were required as one of the ingredients for action.

What has happened since 1971 when the ordinance was first adopted?:

Although a major improvement over previous regulations, the enacted ordinance had certain deficiencies that became evident in subsequent implementation. Of particular concern to owners of affected buildings was the uncertainty as to when the Building Department would evaluate their respective buildings plus failure of the regulations to establish prescriptive budgets to pay for inspection. Without such information, many owners argued that property sales were being affected, long-term leases could not be executed, and sound investment decisions could not be made.

A series of meetings were held with local engineers which culminated with an ordinance amendment adopted in 1976 refining the regulations into its present format.

The City Council, in passing the regulations, recognized that the engineering attendant to evaluating the many buildings in the City could easily bankrupt the resources of the Building Official. Therefore, as a compromise, the adopted ordinance requires that owners of buildings over 3 stories in height provide and pay for the necessary engineering data to the Building Official so that the grading can be determined. Failure to do so results in a prescriptive rating of Grade I - Excessive Hazard.

At this time, 16 years later, virtually all of the regulated buildings have been graded and the owners notified. In addition, certificates of hazard grades have been recorded with the County Recorder to ensure that future buyers are aware of earthquake hazardous condition of the buildings.

The scope of the Long Beach program is significant. It involves all structures built before 1934. Unreinforced masonry construction above accounts for a total of 928 building containing 3,053 dwelling units and 2,023 hotel guest rooms. In the last decade, 161 buildings have been demolished and 37 repaired. Currently, there are a total of 42 buildings with dangerous parapets (Immediate Hazards) and 55 buildings are Grade I - Excessive Hazards. Another 215 buildings are Grade II - High Hazards and the remaining 455 buildings are Grade III - Intermediate Hazards. The remaining structural types are yet to be evaluated.

It is to be voted that the Long Beach Ordinance prescribes an enforcement process along established Municipal Code procedures for dealing with substandard buildings. When an owner fails to repair or demolish a building after notice, the Building Official is required to apply to the Board of Examiners, Appeals, and Condemnation for an order to abate a nuisance. The

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The key players involved in the project included the Building and Safety Director who generated the situation, the building owners who provided the necessary stimulation for action, the City Manager who wisely saw the need for middle ground action, and the City Council itself who made the final decisions.

Description of Research which Contributed to Application:

Research studies published principally by the California Institute of Technology researchers dealing with the seismicity of the Southern California area was used to develop seismic intensity risk situations. Research conducted at the University of Illinois under Nathan M. Newmark in the area of earthquake engineering developed the analytical base for structural considerations. The author's prior work on the effect of site conditions on earthquake intensity provided input as well.

Description of Dissemination of Research:

The results of this research were published in Civil Engineering magazine. The major document was also published by the author's firm and over 1,000 copies distributed. The research was also published in the First National Academy of Engineering's symposium dealing with Benefit Risk analyses. This took place in 1971 at Dulles International Airport, Washington, D.C.

The results of the Long Beach study were read and considered by the State Geologist's office of California and used as the primary blueprint for formulating the guidelines for implementing the Seismic Safety element law that passed in 1972. Finally, it was the Long Beach study that prompted the introduction of hazardous building relief for the City of Los Angeles which eventually adopted an ordinance in 1981, nine years after an ordinance was adopted in the City of Long Beach. The Long Beach experience influenced the 1974 Seismic Safety Study which included a model Hazardous Building Ordinance for the City of Los Angeles.

How could the application process have been improved?:

It must be emphasized at this point that the ordinance would not have been passed in 1971 even though the recommendations had been approved by all of the administrative persons within the City of Long Beach, had it not been for the occurrence of the February 9, 1971 earthquake. At the final hearing in May of 1971, the City Manager simply told the City Council members that if they did not approve the model ordinance that we had drafted, he would simply allow the Building and Safety Director to condemn the 928 buildings since he deemed it his legal obligation to do so. At this point, the City Council adjourned to the City Manager's office for private deliberations and asked the author which of the risk tables presented for adoption most closely corresponded to the de facto risk that the City of Los Angeles was taking, and then went back to Council chambers and approved the ordinance.

No people, programs, processed plans or any other consideration would be changed. All of the ingredients for action were at hand, namely the stimulating action of the Building and Safety Director who saw his duty to warn, the response of the building owners who saw their businesses threatened, the law suit of the building owners against the City of Long Beach and

Board is comprised of seven private citizens generally having a background in engineering, architecture, construction or real estate. A public hearing is conducted before this Board and, if they concur with the findings of the Building Official, the owner is ordered to repair or demolish the structure. The findings and order can be appealed to the City Council. Failure to comply with the order results in the revocation of the Certificate of Occupancy by the Building Official. Continued occupancy after that point results in prosecution through the courts. If necessary and feasible, the City can also raze the building at the expense of the owner.

The regulations offer flexibility to owners of affected buildings to deal with the problem. For example, intermediate repairs may be undertaken to reduce the degree of hazard, thereby placing it into a less restrictive hazard grade and thus buying some more economic life for the structure. This can be accomplished by changing the occupancy use, or by vacating a portion of the building, or by making certain repairs to the critical structural deficiencies of the building. The recomputed Hazard Index arising from such changes can result in placing a building into a lessor hazard grade and thereby gaining the owner another three to ten years of economic life.

THE PROCESS OF DEALING WITH EXISTING HAZARDOUS BUILDINGS IN UTAH

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INTRODUCTION

Utah has a large inventory of buildings that are vulnerable to the ground motions that would be generated by earthquakes. The bulk of the population, and therefore the associated buildings, are located along a narrow corridor that parallels the Wasatch Mountain Range. The Wasatch Fault also runs along the same general line.

During the last thirty years, the general awareness of the public and officials for earthquake safety has grown from being virtually non-existent to a state of recognition and mild general concern. This increased awareness and concern has created an environment in which responsible individuals and organizations are beginning to deal with the problems of the existing hazardous buildings. This paper briefly outlines the reasons why there is a large inventory of hazardous buildings and what has been done, and is being done, to reduce the problem.

HAZARDOUS BUILDING INVENTORY

The Mormon pioneers entered Utah in the year 1847. Out of the ensuing 140 years only during the last decade has there been any significant awareness and acceptance of the earthquake problem. It is convenient to group the building inventory into the age categories shown in Table 1. This table is a generalization of the predominant building types constructed during a given period along with a subjective seismic rating. The table data displays the fact that the majority of the buildings constructed during the history of Utah are vulnerable to seismic forces. It is most important to note that it is the authors opinion that most of the new buildings constructed during the last five years have good seismic resistance. There are exceptions, but the exceptions are in general not the most significant of the newly created inventory.

REASONS FOR PROGRESS

Included as part of Table 2 is a list of eleven reasons why the building inventory in Utah is so seismically deficient. This list is not complete and other factors may well have contributed. To understand why the most recent buildings are more seismically resistant, it is constructive to review the eleven reasons for seismic deficiency and to try to identify what type buildings are in place. Table 2 includes a brief statement as to what has been effective in modifying the Utah picture. Many influences have been brought to bear on the issues. The authors strong opinion is that the series of trenches that have been dug across the fault at different locations is the single most important activity that has been conducted. From these trenches has come irreputable data that the Wasatch Fault repeatedly moves as individual segments each with its own recurrence interval. Vertical offsets have been measured from two to five meters. With this "hard" data, all other

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TABLE 1

EXISTING BUILDING SUMMARY WASATCH FRONT COMMUNITIES

PREDOMINANT BUILDING TYPES

YEAR BUILT	HOUSING (SINGLE FAMILY)		COMMERCIAL, INSTITUTIONAL & INDUSTRIAL	
	MATERIAL TYPE	SEISMIC RATING	MATERIAL TYPE	SEISMIC RATING
1847 to 1900	———	———	URM & WOOD	POOR
1900 to 1945	URM & WOOD WOOD FRAME	POOR FAIR	URM & WOOD URM & CONC. URM & STEEL CONC. FRAME STEEL FRAME	POOR POOR POOR POOR FAIR
1946 to 1959	URM WOOD FRAME	POOR FAIR	URM & WOOD URM & CONC. URM & STEEL CONC. FRAME STEEL FRAME	POOR POOR POOR POOR FAIR
1960 to 1973	WOOD FRAME REINF. MASONRY	FAIR GOOD	CONC. FRAME STEEL FRAME REINF. MASONRY & OTHER MAT'L PRECAST CONC. FRAME URM & OTHER MAT'L CONC. TILT UP	POOR FAIR TO GOOD FAIR POOR POOR POOR
1974 to 1981	WOOD FRAME REINF. MASONRY	GOOD GOOD TO EXCELLENT	CONC. FRAME STEEL FRAME REINF. MASONRY & OTHER MAT'L PRECAST CONC. FRAME URM & OTHER MAT'L CONC. TILT UP	FAIR GOOD GOOD POOR POOR FAIR
1982 to 1987	WOOD FRAME REINF. MASONRY	GOOD TO EXCELLENT EXCELLENT	CONC. FRAME STEEL FRAME REINF. MASONRY & OTHER MAT'L PRECAST CONC. FRAME CONC. TILT UP	GOOD TO EXCELLENT EXCELLENT GOOD TO EXCELLENT POOR TO FAIR FAIR TO GOOD

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TABLE 2

REASONS FOR SEISMICALLY INADEQUATE BUILDINGS IN UTAH

REASON	PAST INFLUENCE FOR CHANGE
1. LACK OF KNOWLEDGE OF THE EARTHQUAKE PROBLEM. INFREQUENT LARGE SEISMIC EVENTS	USGS, UGMS, UNIVERSITY OF UTAH RESEARCH PROJECTS. TRENCHING PROGRAM OF UPMOST VALUE. BORAH PEAK EARTHQUAKE HELPFULL
2. INADEQUATE BUILING CODES	UNIFORM BUILDING CODE HAS IMPROVED WITH EACH NEW VERSION OF THE CODE SINCE 1958. ACT-3 AND NEHRP PROVISIONS HAVE INFLUENCED 1988 VERSION OF UBC.
3. INADEQUATE TRAINING OF ARCHITECTS, ENGINEERS & BUILDING OFFICIALS	IMPROVED UNIVERSITY LEVEL TRAINING. NEW RESEARCH FINDINGS. BUILDING OFFICIAL TRAINING SEMINARS.CONTINUING EDUCATION. HAZARDS MAPS
4. INITIAL SEIMIC ZONING THAT UNDERSTATED THE REAL HAZARD	CONTINUED RESEARCH EFFORTS BY VARIOUS ORGANIZATIONS. CURRENTLY A PROBLEM FOR THE WASATCH FAULT. UNDERSTATING GROUND SHAKING INTENSITY LEADS TO LONG TERM DEFICIENCIES.
5. PUBLIC APATHY	NEWSPAPER, RADIO, TELEVISION COVERAGE, CLASSROOM EDUCATION SEMINARS, USGS LOSS ESTIMATION STUDY
6. PERECEIVED ECONOMIC HARDSHIP	REALIZATION OF COST/BENEFIT OF WELL DESIGNED STRUCTURES
7. NOT RECOGNIZING THE LIABILITY OF FAILURE OT ACT	ARCHITECT/ENGINEER INSURANCE PREMIUMS. CITY AND COUNTY RESPONSIBILITY DETERMINED IN COURTS. GENERAL LIABILITY OF THOSE WHO HAVE KNOWLEGE AND DONT ACT.
8. RESISTANCE TO GOVERNMENTAL DIRECTIVES	EDUCATION
9. RESISTANCE TO CHANGE	EDUCATION. REPEATED STATEMENTS OF HAZARD
10. INADEQUATE PLAN REVIEW AND CONSTRUCTION INSPECTION	BUILDING OFFICIALS ARE MAKING STRONGER EFFORTS. STRONGER LANGUAGE IN CODES. LIABILITY ISSUES
11. GREED AND LAZINESS	EVER PRESENT PROBLEM

influences have followed in a logical manner. Without specific scientific data, the people of Utah would tend to use most of the reasons listed in Table 2 to make no change in their activities.

The issue of the proper level of ground shaking intensity is not resolved for the Wasatch Fault Zone. The 50 year probabilistic approach tends to overlook the infrequent, large magnitude seismic events that occur in this area. As a result the codes have prescribed design force levels that are probably going to lead to the collapse of many structures; new as well as old. The Uniform Building Code force level for California is set at a level that the expected actual forces from an earthquake will exceed the design value. This means that structures are required to deform inelastically and absorb the excess forces. The code is somewhat calibrated by the California experience. The current UBC, and the "NEW" NEHRP (Recommended Provisions for the Development of Seismic Regulations for New Buildings) provisions both set the design forces for the Wasatch Fault zone below that of equivalent California zones. The current UBC has the Wasatch Fault Zone at three-fourths of (Zone 4) California, whereas the NEHRP provisions have the Wasatch Fault Zone at one-half the California (Zone 4). This is in spite of the fact that when the Wasatch Fault does rupture, it produces ground shaking intensities equivalent to the expected in the Los Angeles Region (USGS Open File Report 82-1033).

Because the code "minimum" force levels are in practice the code "maximum" values, the buildings that are now being designed and constructed along the Wasatch Fault may not have sufficient ductility to absorb the eventual seismic forces. If the force levels are not adjusted, the ductility factors must be. Currently there are no provisions in any U.S. code for this type of adjustment on the basis of different seismic zones. No one knows when the next segment of the Wasatch Fault will rupture. It could be tomorrow. The need to have consistent ductility demands in code designs far outweighs the need to have consistent probabilistic seismic zoning. Until this problem is resolved, the architects and engineers in Utah will continue to produce new buildings that will someday be recognized as needing seismic upgrade. The most important thing in addressing the seismic retrofit problem is to make sure that all new structures are designed and built to a rational standard.

THE FACTORS INFLUENCING SEISMIC RETROFIT DECISIONS

As discussed in previous sections, the attitude of those in responsible charge of buildings in Utah has changed. During the last ten years, many different buildings have been analyzed to determine their earthquake resistance. Many of these structures have been strengthened or retrofitted to increase their ability to resist lateral forces. The questions arises as to what constitutes a seismically retrofitted structure, or, how far does one go in trying to make an "old" building "new", or in making a "bad" building "good"; therein lies the problem of determining what constitutes a retrofitted structure.

There have been many reasons that buildings have been seismically retrofitted in Utah. Some of these reasons are:

- Fear for safety of occupants or pedestrians
- Need to have building operational in the event of an emergency
- Desire to mitigate economic loss because of damage to structure

- Desire to mitigate economic loss because of damage to building contents

- Desire to mitigate economic loss because of loss of function and loss of business

- To reduce liability for a hazardous structure

- Claims against a previous owner for deficiencies

- Plan check review after construction disclosed deficiencies

- Desire to preserve the historic structure in the event of an earthquake. (Some loss of historic fabric required).

- Local ordnances requiring upgrades when structure has a change of use or is added to.

- The simplicity of retrofit in conjunction with major remodel

For each of the reasons given there is at least one example in the Utah area of a building that has been retrofitted.

Every building is unique. Each one is different, even if the difference lies only in the fact that they were constructed at different times. Because of this uniqueness, each structure should be examined individually to determine the seismic deficiencies that it has. Through careful review of the construction documents, examination of the existing structure, and by completing brief calculations, it is possible to list the various deficiencies that a structure has. Listing the most significant or serious deficiencies in a ranked order is beneficial. Or to put it another way, listing the items that appear to be the most important to correct first, second, third, etc., allows the engineer and owner to decide just how far they want to go in retrofitting a structure. The Uniform Building Code does not cover this aspect of building design. It is, therefore, a subjective matter in deciding where to stop. Table 3 is an example of the listing of the various deficiencies that a building might have. It is taken from a feasibility study of the City and County Building in Salt Lake City. After defining this list of deficiencies, costs were estimated to correct the deficiency. By carefully ranking and by running a cumulative total of the estimated costs, it is possible to create a graph of the form shown in Figure 1. The ordinate is a subjective assessment of the relative benefit of each successive corrective measure. Generally , it would be imprudent to choose a level of retrofit that would leave the structure below the collapse level of resistance associated with the expected earthquake. This highlights the need for the accurate assessment of the ground shaking intensity. Figure 1 is from a study of a complex of buildings at the same approximate location but of a distinctly different structural character. In this instance the owner has decided to demolish certain buildings, to upgrade others, and to do nothing to the balance of the inventory. For most types of buildings, this type of analysis leads to strengthening techniques that focus on the prevention of collapse.

One very important use for the cost/benefit analysis has been to help school officials decide whether or not to remodel or replace older facilities. At

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TABLE 3

CITY AND COUNTY BUILDING COST ESTIMATES FOR STRUCURAL REPAIRS

	DESCRIPTION	COST	ACCM TOTAL
1.	COMPLETE PHASE TWO OF TOWER STABIZATION	$583700.00	$583700.00
2.	COMPLETE SHEAR WALL BASE FOR TOWER SUPPORT	1427300.00	2011000.00
3.	REPLACE CORRIDOR WALLS WITH CONCRETE	400000.00	2711000.00
4.	REPLACE Ea-We MASONRY WALLS WITH CONCRETE	514200.00	3225200.00
5.	NEW SEISMIC CHORD BEHIND STONE AT FLOOR LINES	72000.00	3297200.00
6.	CONTINUE FLOOR DIAPHRAGMS TO EXTERIOR WALLS	827400.00	4124600.00
7.	REINFORCE SMALL MASONRY PIERS AT EXTERIOR	400000.00	4524600.00
[illegible]	ANCHOR REMAINING BEAMS AND JOISTS TO WALLS	37800.00	4562400.00
9.	REINFORCE EXTERIOR MASONRY WALLS	1155000.00	5717400.00
10.	STABILIZE ROOF FRAMING	400000.00	6117400.00
11.	REINFORCE STONE ARCH ENTRIES	259000.00	6376400.00
12.	REPLACE STAIR LANDING	28000.00	6404400.00
13.	ANCHOR PHANTOM FLOORS ON COUNTY SIDE	19000.00	6423400.00
14.	REINFORCE REMAINING MASONRY BEARING WALLS	820000.00	7243400.00
15.	STABILIZE STAIR FRAMING OR REPLACE	83800.00	7326200.00
16.	ANCHOR INDIVIDUAL STONE VENEER TO NEW WALLS Done with Task 9	2275000.00	9601200.00
17.	REINFORCE AND ANCHOR STONE CHIMNEYS	96000.00	9697200.00
18.	BRACE AND ANCHOR CLOCKWORKS	24000.00	9721200.00
19.	BRACE AND ANCHOR STATUES, CUPOLAS ETC.	150000.00	9871200.00
20.	BRACE MECHANICAL AND ELECTRICAL SYSTEMS	500000.00	9921200.00
21.	ANCHOR REMAINING ORNAMENTATION	252000.00	10173200.00

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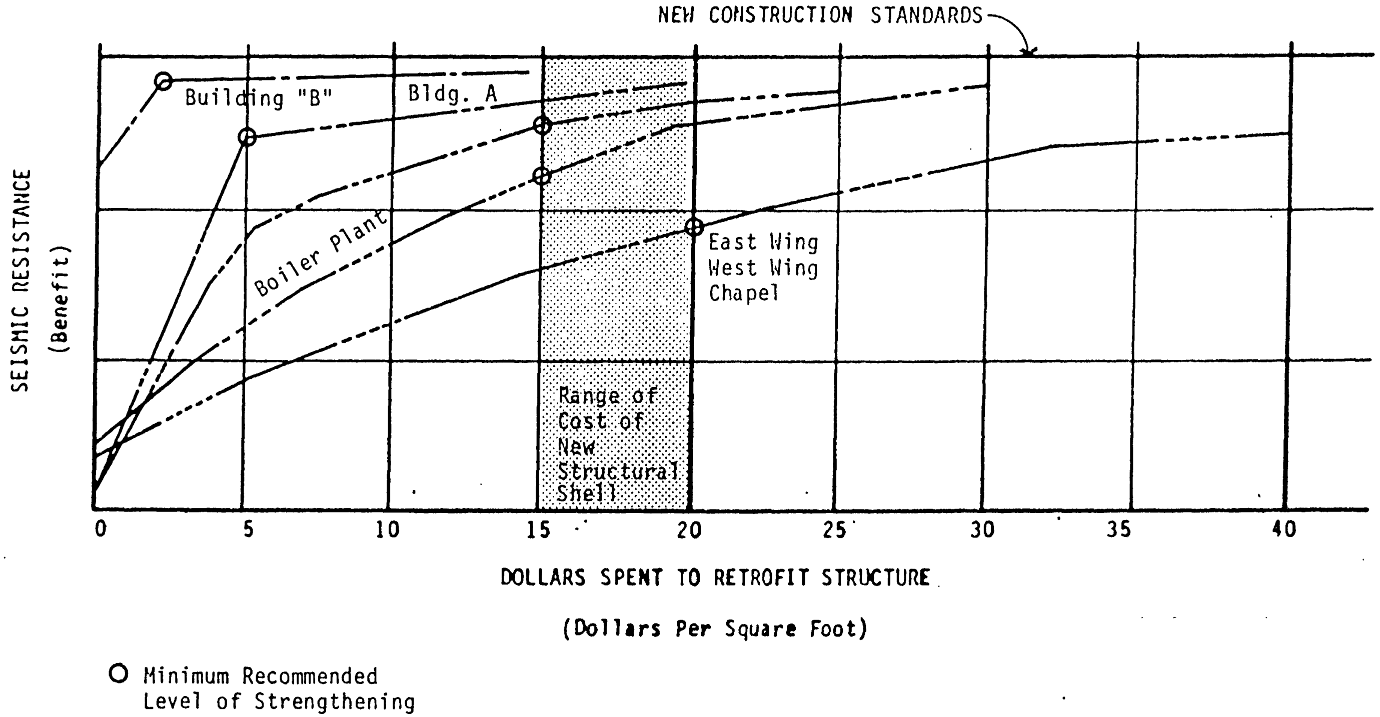
NEW CONSTRUCTION STANDARDS
SEISMIC RESISTANCE
(Benefit)
Building "B"
Bldg. A
Boiler Plant
East Wing
West Wing
Chapel
Range of
Cost of
New
Structural
Shell
0
5
10
15
20
25
30
35
40
DOLLARS SPENT TO RETROFIT STRUCTURE
(Dollars Per Square Foot)
○ Minimum Recommended
Level of Strengthening

FIGURE 1

least six different school districts in Utah have utilized this kind of engineering analysis along with other operational studies to make these determinations.

GENERALIZED RETROFIT APPROACHES

In general, seismic retrofit measures are intended to increase the capacity of the structure to resist ground motions. This done by:

- Connecting building elements together
- Eliminating vertical discontinuities
- Eliminating horizontal stiffness variations (torsion)
- Adding strength to system
- Adding redundancy to system
- Adding ductility to system
- Bracing non-structural components and parapets
- Utilizing ground improvement techniques

These techniques are discussed in the growing body of literature on this subject. There exists differences of opinion of the specifics of techniques but in general they all lend themselves to rational engineering analysis.

A new and exciting approach to building retrofit does not try to increase the buildings resistance capacity, but rather tries to decrease the force level that the building will be subjected to. This approach is termed "base isolation." By placing energy dissipating shock absorbers between the ground and a structure, the level of acceleration that the base isolated structure is exposed to is decreased. Figure 2 is taken from a specific vendors literature and displays the concept of the reduction of ground motion through the use of an isolation device. This technique is now being implemented on the historic City and Count Building in Salt Lake City. As part of the initial feasibility study for the seismic retrofit of the facility, it was suggested that base isolation be investigated before any final decision was made on approaches to take. The design team, for the actual retrofitting of the building, has determined that the installation of base isolators will protect the structure. The design required that the tower section be strengthened by conventional methods. One fourth of the approximately 480 isolators have been installed at this time. The use of base isolators was facilitated by the fact that the building had an existing "crawl" space below it.

For those interested in base isolation, Salt Lake City will be the place to see retrofit techniques as well as the application of the technique to new construction. The author has designed a new base isolated building that is under construction at the University of Utah Research Park

One other approach to the problem of retrofitting buildings has been advanced by Chris Arnold, Building Systems Development, Inc. This approach utilizes the concept of providing "Safe Zones" within a building shell. This approach

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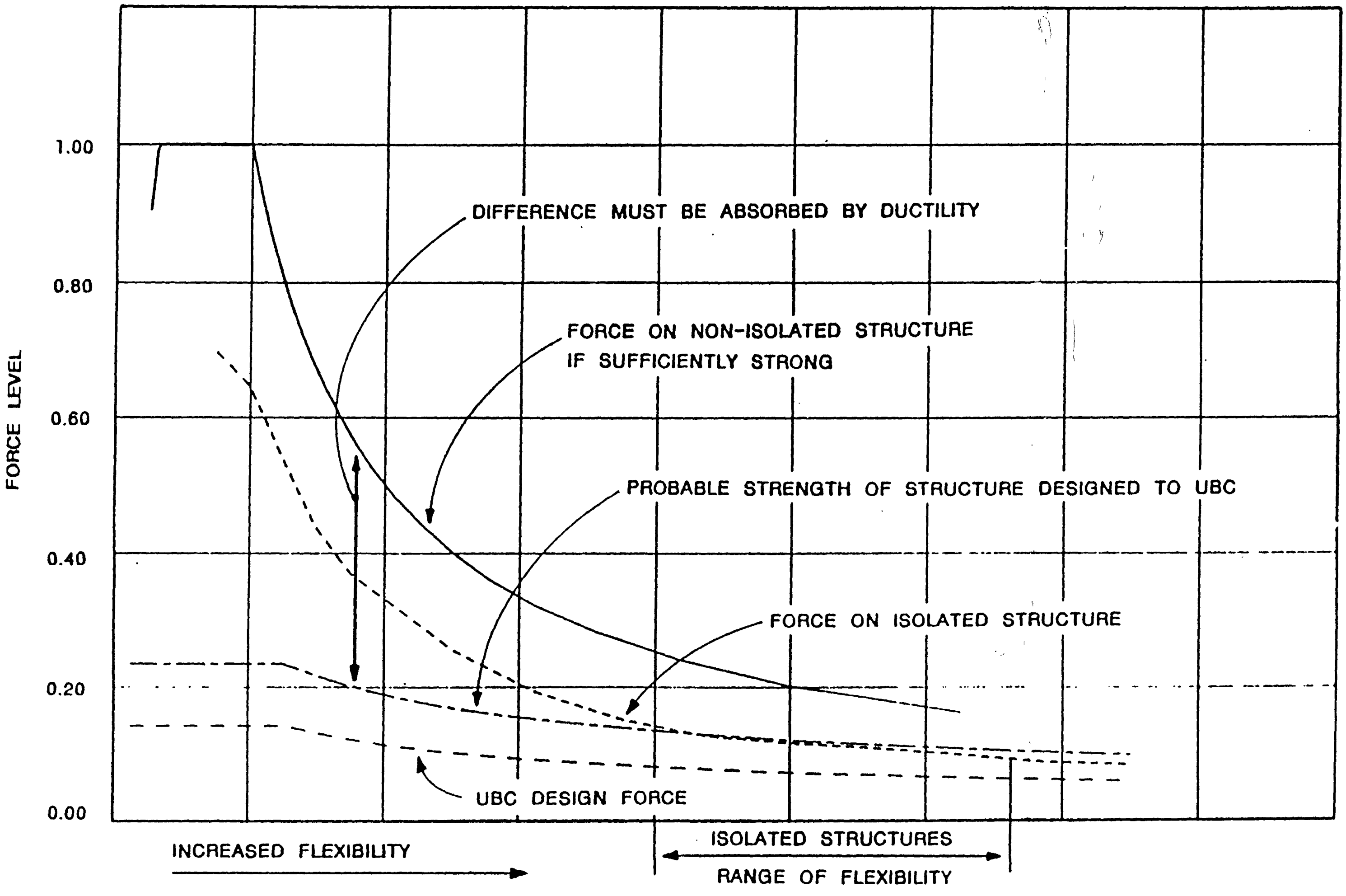

FIGURE 2 : EARTHQUAKE FORCES

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utilizes the philosophy that for many facilities it would be entirely acceptable to strengthen only a portion of a structure. This would create a safe zone within the overall envelope. Included within this "safe zone" would be protected and strengthened exits. For certain types of structures and for some historic buildings where little disruption of the historic fabric was desired, this approach may prove to be entirely feasible. Specific occupant training for earthquakes would have to be an integral part of this approach.

SUMMARY

The Wasatch Fault Zone, in Utah, has recently been studied in detail by various researchers. These researchers have compiled a very comprehensive set of data that strongly suggests that the fault is active and with some regularity does rupture. The emergence of this data has changed the attitude of the public at large as well as the concerned building community. Architects, engineers, building officials, and owners have become aware of their responsibilities and liability with respect to seismic safety.

The inventory of buildings along the Wasatch Fault is, in general, deficient with respect to seismic resistance. There are many reasons that this is the case, but the main ones are that the seismic hazard has only recently been quantified and that the public did not believe there was a real problem. Through the recent research efforts of the various organizations the seismic hazard has been quantified and exposed.

Design professionals, building owners, code officials and lending institutions are working to improve the seismic resistance of new facilities. The last five years has seen great improvement in new construction. This awareness has lead to an interest and desire to improve the inventory of existing buildings. Seismic analysis of existing buildings and the design of building retrofits is starting to be a regular occurrence. The desire to safeguard life, property, and to protect business income are the primary reasons that buildings are being retrofitted. Also, the desire to avoid liability for inadequate buildings following an earthquake is behind many of the decisions to retrofit.

The fundamental approach in building retrofit is to increase the capacity of a structure to resist potential seismic forces. This capacity increase is gained by strengthening techniques as well as by enlarging the internal strain absorption capabilities of the system.

A new approach to the retrofit problem is to reduce the force level that the building will be subjected to by placing base isolation devices between the structure and the ground.

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SEISMIC UPGRADING OF EXISTING STRUCTURES IN THE EASTERN UNITED STATES

by

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Description of Research Application

As stated in a FEMA-sponsored ABE report [1],

> "The problem of reducing the earthquake hazards posed by existing buildings is the most pervasive - and perhaps the most complex and controversial - issue to be found in contemporary earthquake hazard reduction. Yet, more than any other hazard abatement strategy, a coordinated program for confronting the hazardous building problem has the greatest potential for saving lives and limiting serious injuries."

The same topic is addressed in the 1982 NRC Report on Earthquake Engineering Research [2]:

> "In future earthquakes the major causes of injury and loss of life will almost certainly be the collapse of older structures that were designed and built before modern building codes were developed."

This report goes on to state:

> "The situation is truly staggering when considered on a national scale. Damaging earthquakes have occurred in 37 states, yet in reality few communities outside the western United States have even modest earthquake design requirements in their building codes. An all-out program of building reinforcement (as well as equipment upgrading) would take decades to accomplish, and when completed, might prolong the use of obsolete buildings in an effort to obtain some return for the enormous resources spend in reinforcing them. This illustrates that in

> addition to engineering and economic barriers, there are important governmental and social questions. At present, the existence of the problem is recognized, but no one knows how to solve it. As a beginning there is a need for selective research on the identification and assessment of hazardous existing buildings, followed by development of effective means of strengthening such buildings."

The pervasiveness and complexity of this situation has largely been responsible for a lack of success in a systematic application of research in the area of seismic upgrading of existing structures, and this is particularly true in the eastern United States.

Research efforts in identifying and evaluating hazardous buildings, and in retrofit strategies, were reviewed by Bresler [3] in 1985. While his review covers some Japanese literature, it is primarily directed to U.S. efforts. His detailed bibliography begins with a single 1967 paper by J. Blume. The listing totals only 7 papers and reports for the six year period 1967-1972. The entries gradually become more numerous in the mid-1970s, and grow to about 8 per year by 1980. The last year covered in Bresler's review, 1984, has 24 citations, indicating the greatly increased interest in the seismic threat to existing buildings.

Early papers were written mainly by West Coast engineers; academic researchers became involved in building assessment and evaluation only in the mid-1970s. Early financial support came from Western municipalities and from such governmental agencies as HUD, USAEC (later NRC), the VA, the U.S. Navy, NBS, GSA,and NSF (initially through ATC and later to universities). More recently, both NSF and FEMA have played major roles in supporting research. It is apparent that organized research efforts in this important area of structural engineering are a very recent development when viewed from the perspective of research on structures for new construction. In addition, the overall level of funding dedicated to building evaluation has been relatively modest. Research aimed strictly at Eastern U.S. structures has not been reported, although there are now efforts underway with the support of the National Center for Earthquake Engineering Research.

International research efforts in seismic performance of existing buildings should be mentioned here, even though many of the results may have no special significance to Eastern U.S. structures. The U.S/Japan Cooperative Earthquake Engineering Research Program has produced many volumes of papers and reports, most of which were presented at workshops held in the U.S. and Japan. The workshop references will be cited in the next section of this paper.

Because the discussion below concerns building codes, a comment or two about the lag time from research to application is in order. As pointed out in Ref. [2], the time needed for research results to find their way into building codes normally ranges from 5 to 10 years after completion of the research; this is substantially longer than the 1 to 3 years lag time cited for application of specific research to critical facility design.

One of the major difficulties met in achieving an improved climate for building evaluation and strengthening in the Eastern U.S. is the lack of codification of suitable approaches, along with a general lack of appreciation of the seismic threat and a hesitancy of building owners to even think about the costs involved in strengthening strategies. An overriding factor motivating a building owner to perform seismic evaluation and, if necessary, upgrading of an existing structure has to do with code enforcement by state and municipal agencies. In the West, a number of jurisdictions have passed ordinances requiring seismic upgrading of certain classes of existing structures, such as unreinforced masonry. Los Angeles, for example, has in place an ordinance requiring rehabilitation to some specified standards [4]. In Long Beach, seismic upgrading of some unreinforced buildings to the 1971 Uniform Building Code is required at the time of sale or change of occupancy. Other cities in California have followed the lead and are considering or have adopted similar ordinances. Examples of existing structures in California that have been upgraded include the California State Capitol Building [5], buildings in Long Beach [6], in San Francisco [7], and in Los Angeles [8].

In the East, primarily due to the low frequency of damaging, but nevertheless devastating earthquake occurrences, municipalities have not kept pace with the developments in the West. In cities such as Buffalo, New York, no seismic provisions are prescribed for the construction of privately-owned structures. Unreinforced or lightly reinforced structures are routinely built, even though there exists a real seismic hazard. In Boston, seismic provisions for building codes apply to new buildings and, in cases involving public attendance, to existing buildings upon a significant change of use [9]. These codes, in general, do not require the seismic upgrading of the some 5,000 unreinforced or poorly reinforced masonry or concrete buildings in the Boston area, even though the structures are susceptible to possibly severe damage during an earthquake similar to the Cape Ann event in 1755 [10].

In spite of the lack of code enforcement, some studies of seismic upgrading have been carried out for existing structures in the eastern United States. Examples of possible evaluation and upgrading procedures for two old masonry buildings in Boston are given in [10]. More recently, an NSF-sponsored cost-benefit study was made on possible seismic upgrading of some unreinforced masonry warehouses and reinforced concrete buildings in the Boston area at the time of remodeling [11]. Three possible levels of reinforcement were investigated which the Massachusetts Seismic Advisory Committee could recommend as a part of the Boston Building codes. Table 1 shows the policy for each level of upgrading together with its cost for the two classes of structures. It was concluded that only the first level of upgrading could be considered for adoption as a regulation and, because of higher cost per life, higher level standards could be left to the choice of buildings' owners.

The second example involves strengthening of the Veterans Administration Medical Center in Charleston, South Carolina [12]. The Veterans Administration, with hospitals throughout the United States, has been one of a few governmental agencies requiring seismic analysis and, if necessary, upgrading of its facilities [13]. The Charleston Medical Center, built in 1963, is a reinforced concrete flat-slab structure. The original design considered only 3% of the building weight as base shear; the base shear was increased to 20-50% of the weight based on the new design requirements. Two types of shear walls (interior and exterior) were used. The interior transverse shear walls were steel-ribbed panels built outside the existing partitions and the exterior shear walls were made of shotcrete and were built outside the existing frame. While the cost of strengthening at $22.23/sq. ft. (1981 dollars) was considered high, it would have been considerably more expensive to correct this situation if the Veterans Administration had elected to demolish the structure and rebuild an equivalent code-conforming facility.

Knowledge Base in Research Application

Without an effective seismic upgrading program in place, most masonry and lightly reinforced concrete structures are at risk in the eastern United States. Steps must be taken in order to develop rational seismic upgrading regulations at the state or local level.

The development of a seismic upgrading program for existing structures is a complicated task. The knowledge base needed for such a development consists of the important elements indicated in Fig. 1. Research over the last decade has provided an expanding technological base for seismic upgrading of existing structures. For example, various methods now exist for strengthening existing masonry and concrete structures for seismic resistance (e.g., [14,15]), while taking into account functional usage, aesthetics, continued usage during renovation, economic impact, etc. Other ongoing research studies, such as the study at the University of Texas on strengthening schemes for concrete buildings, will add significant new information to the knowledge base.

Cost-benefit studies have also been performed at various levels. In addition to [11], other studies have included political, social and behavioral considerations [16,17].

Different schemes of structural categorization have been used for the purpose of strengthening and repair of existing structures. This can be done at a somewhat coarse level, e.g., unreinforced masonry, precast concrete, steel frame, etc. It can also be done using a finer classification. In [18], for example, unreinforced masonry buildings are categorized according to design characteristics, materials used, and methods of construction, focusing on those parameters that are perceived to be influencing seismic response of the structure.

Our utilization of the extensive Japanese literature on building evaluation and strengthening has been facilitated by the many activities coordinated by the U.S.-Japan Panel on Wind and Seismic Effects (UJNR). Eight volumes of proceedings have been published since 1980. The first seminar series (1980-1982) was on Repair and Retrofit of Structures [19]. A second workshop series was held in 1982-83 on Seismic Performance of Existing Buildings [20]. The most recent volume was on Repair and Retrofit and had some 30 papers on all aspects of repair and strengthening [21]. The table of contents of the last volume is reproduced in Appendix A to portray the type of developments that have taken place recently in Japan. Direct application of Japanese techniques to U.S. buildings (and particularly to those in the East) is usually not possible, of course, because of the substantial differences in Japan and U.S. building design philosophies and practices, but the basic ideas and approaches used in Japan certainly merit closer attention by U.S. engineers and public officials.

Returning to the more specific topic of the eastern United States, it appears that the critical incomplete building blocks of the knowledge base are in the areas of seismic risk mapping, in producing inventories of existing hazardous structures, and in predicting the response of certain classes of buildings that have not been designed for any substantial lateral force level.

In [22], questions are posed regarding the possible recurrence in the southeastern United States of an earthquake similar to the 1886 Charleston earthquake. It is pointed out that an adequate knowledge base on seismicity is lacking due to a lack of data of all kinds - geological, geophysical, technical, and seismological.

A thorough inventory of hazardous existing structures in the East is also necessary. Development of such an inventory can be a monumental task due to differences in types and methods of construction, in age, in materials, and in levels of conformity of the buildings to present building codes. However, this inventory process, as difficult as it is, must be completed before a rational basis can be reached for establishing a seismic upgrading program for existing structures in the eastern United States.

An increased knowledge base is also required for more accurate prediction of structural response of typical Eastern U.S. buildings to seismic events. Structural types needing additional attention include lightly reinforced concrete and masonry structures, and the broad class of "composite" buildings built from several different materials such as masonry walls, steel columns, and timber floor and roof diaphragms. The interconnection of components in the latter type of construction is of particular concern in assessing integrity against lateral loads. Current and planned research effort's will add substantially to this knowledge base.

Research Translation Activities

Translation of research results into a format acceptable for dissemination and use in practice will be discussed here from two perspectives: recent FEMA publications, and the new document from the Applied Technology Council that has just been published. Discussion of other important government agency publications is beyond the scope of this paper.

One of the FEMA reports [1] has been cited earlier -- this action plan is a general treatment of needs to reduce seismic hazards. More specific FEMA publications contain important distillation and translation of research results. The 1985 workshop proceedings [23] is written from a very broad viewpoint and should be on the required reading list for structural engineers interested in earthquake hazard reduction. Part 3 of Ref. [24] utilizes material from ATC 3-06 to provide engineers with methodologies for evaluation and for repair and strengthening of existing building.

The ATC-14 Report [25] on methods for evaluating the seismic strength of existing buildings is certainly one of the most comprehensive distillations of research results and advanced practice yet to be published. It is intended to be used across the U.S. for the evaluation of many different types of individual buildings. There is a strong emphasis on identification of life-safety issues. Evaluation will be implemented for three basic seismicity zones: low, moderate, and high. Analysis approaches are multi-level, and include a method for calculating member capacities, rapid analysis procedures for determining overall building strength and interstory drift, an equivalent lateral force procedure, a procedure for using dynamic analysis, and a special analysis procedure for buildings with wood diaphragms.

Procedures for specific building types include a description of each type, performance characteristics peculiar to the particular type, examples of performance of similar buildings in previous earthquakes, descriptions of expected loads and load paths, procedures for low seismicity regions, and procedures for high seismicity regions.

The evaluation format in ATC-14 will be in terms of a set of statements and concerns; a "true" response means adequacy and a "false" response means that evaluation is required. An allowable capacity/demand ratio is listed

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for each statement, based on anticipated excess capacity available and the level of overall system ductility assumed in the demand criteria. Considerable emphasis will be placed on structural connections, on structural details, on foundations, and on nonstructural items.

The complex relationships between the many parameters involved in ATC-14 illustrate an important point in this discussion of research applications -- a good share of structural evaluation is an art rather than a science, and development of successful practical techniques requires much more than typical structural engineering research. The implications of this fact will be explored again near the end of this paper.

As a follow-up to ATC-14, FEMA is funding ATC to develop a handbook (ATC-22) to implement the provisions of ATC-14 for numerous case study buildings, resulting in a thorough review, testing, and calibration of the techniques in the real world environment. Looking ahead to another related project based on ATC-14, a critical review directed specifically at Eastern U.S. buildings is now underway. This project, sponsored by NCEER, will be conducted by a team that includes engineers who helped prepare ATC-14 and several engineers from eastern and central U.S. Upon the conclusion of this project (October 1988), a significant translation of research will occur on the safety of Eastern U.S. buildings subjected to earthquake effects.

Research Dissemination Events

Dissemination of pertinent research results on seismic evaluation and strengthening has been through conventional means - published papers and reports, presentations at technical conferences, and by workshops and seminars. Unfortunately, the impact of these events on most Eastern U.S. engineers, building officials, and public officials has been rather light. Workshops and seminars are excellent for those participating but, by their very nature, consist primarily of experts talking with experts. Those who should become more knowledgeable are not only absent from the workshops, but do not take the time to read the proceedings nor to study the other papers and reports that come out in the literature. As engineers, we are part of an intensely busy profession, driven by current work assignments that are being paid for by clients. Until we have substantial numbers of clients interested in improving building safety against seismic effects, we simply will not have a very large group of engineers skilled in the art of building evaluation and the devising of strengthening strategies.

How Would We Do It Differently?

In light of general public apathy about the earthquake threat in the Eastern U.S., and the hesitancy of owners to spend the necessary funds to strengthen buildings and other facilities, it appears that the most critical problems encountered in trying to "improve the system" are more in the realm of socio-economics than in engineering. Some of these problems have been discussed in the preceding section of this paper. There is a wealth of research results that are waiting to be applied in the Eastern U.S. (and in the West, as well). Nevertheless, some suggestions may be made on how we might improve the overall process of research and research application to the evaluation and strengthening problem:

(a) More attention needs to be given to developing easy-to-implement approaches for building inventories and for preliminary building evaluation.

(b) Additional input from East Coast engineers is needed in national efforts on development of methodologies for individual building evaluation and strengthening; at least some of this will occur in the near future through a new NCEER project designed to extend the ATC-14 document to particular problems in Eastern U.S. structures.

(c) The usefulness and immediacy of research could be enhanced through more cooperative programs involving both academics and consulting engineers.

(d) Involvement by the U.S. construction industry in research and development activities would also enhance developments, as has been shown in Japan, where construction companies support research institutes and are actively involved in such activities as perfecting new strengthening schemes. Constructability is a key issue here.

(e) Another area has to do with education efforts that could be undertaken by engineering researchers in parallel with their research. We need to be more aggressive in explaining the earthquake threat--to students in elementary and secondary schools, to the public, and to public officials. We also need to play a stronger role in continuing education efforts for engineers, and in promoting instruction in seismic effects in engineering programs at colleges and universities. In particular, we should be teaching more on ductility, load paths, connectivity of components, and overall structural systems behavior. With member design being increasingly done with computers, we have the opportunity to make rather major changes in

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teaching of structural engineering at the undergraduate and graduate levels.

(f) We need, in Eastern communities that have significant seismic risk, activities such as the Southern California Earthquake Preparedness Project (SCEPP).

(g) We should be pushing ahead more rapidly on the current vulnerability studies and related activities underway in South Carolina, Massachusetts, and New York.

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	Costs of Reinforcement ($/Horizontal SF)	
	With Major Reinforcement*	Without Major Reinforcement*
UNREINFORCED MASONRY WAREHOUSES		
Policy 1 Provide new floor and roof diaphragms; tie new roof and floor diaphragm to framing and existing masonry walls.	$1	$5.5
Policy 2 Tie the building together; add a sufficient number of internal walls to get some ductility, and provide foundations for those new walls.	$1.5	$6.5
Policy 3 Tie the building together; reinforce the existing masonry walls to get some ductility, and reinforce the parapets.	$2	$7.4
REINFORCED CONCRETE BUILDINGS		
Policy 1 Add reinforced concrete or reinforced masonry in some of the bays; increase the existing shear wall sizes.	$1	$5.7
Policy 2 Add reinforced concrete or reinforced masonry in some of the bays; add a sufficient number of new interior shear walls to get some ductility; provide foundations for those new walls, and tie the new walls to the floor diaphragms.	$1.5	$6.1
Policy 3 Add reinforced concrete or reinforced masonry in some of the bays; increase the size of the columns; tie the columns to the floor diaphragms, and reinforce the parapets.	$1.5	$5.6

*costs in 1980 $ per square foot

TABLE 1. Different Policy Levels of Seismic Upgrading

(Taken from [11])

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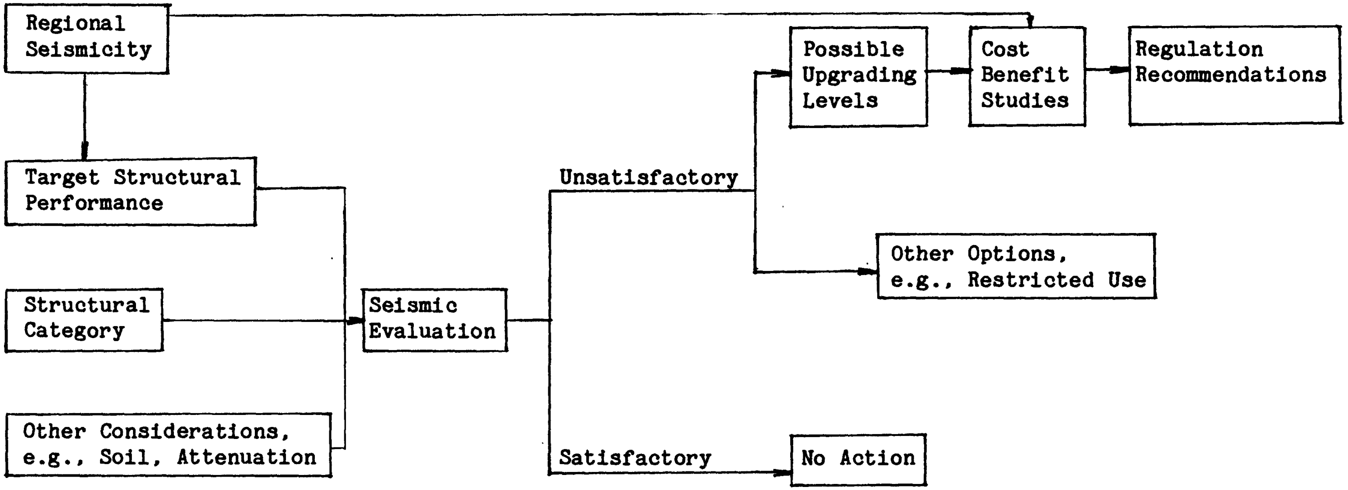

FIG. 1. Elements of Seismic Upgrading Program

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APPENDIX A

Workshop on Repair and Retrofit of Existing Structures
U.S.- Japan Panel on Wind and Seismic Effects, UJNR

Tsukuba, Ibaraki, JAPAN
May, 8-9, 1987

(Presentations from U.S. Side)

1. RESEARCH NEEDS FOR REPAIR AND STRENGTHENING OF REINFORCED CONCRETE FLOOR SLAB SYSTEMS
   J.P.Moehle

2. DESIGN AND CONSTRUCTION SCHEMES FOR BUILDINGS
   L.A.Wyllie

3. REPAIR AND STRENGTHENING OF INDUSTRIAL FACILITIES (Oral Presentation)
   N.F.Forell

4. EXPERIMENTAL STUDIES ON REPAIR AND STRENGTHENING OF R.C FRAMES (Oral Presentation)
   J.O.Jirsa

(Presentations from Japanese Side)

5. COMPARISON OF BUILDING SEISMIC DESIGN IN U.S. AND JAPAN (REPORT ON THE SECOND U.S.-JAPAN WORKSHOP ON THE IMPROVEMENT OF BUILDNG SEISMIC DESIGN AND CONSTRUCTIN PRACTICES)
   Y.Ishiyama

6. EVALUATION ON POSITIONS OF DYNAMIC RESPONSE ANALYSES IN SEISMIC DESIGN BY A FULL-SCALE SIX-STORY STEEL BUILDING STRUCTURE
   H.Yamanouchi, A.Hori and T.Yomo

7. OVERALL DESIGN STANDARD FOR EARTHQUAKE RESISTANT CAPACITY OF GOVERNMENTAL BUILDINGS
   K.Onisawa and K.Shimizu

8. RECENT FIVE YEARS SOURCE LIST ON REPAIR & RETROFIT FOR RC BUILDINGS DUE TO EARTHQUAKES
   S.Nakata

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(R.C.Building)

9. POST-EARTHQUAKE INSPECTION AND EVALUATION OF EARTHQUAKE DAMAGED IN REINFORCED CONCRETE BUILDINGS
H.Hiraishi, M.Murakami, T.Okada, M.Ohkubo, S.Otani and K.Takiguchi

10. METHODS OF TEMPORARY AND PERMANENT RESTORATION APPLIED TO REINFORCED CONCRETE BUILDINGS DAMAGED BY EARTHQUAKE
M.Yoshimura, T.Okada, T.Endo and M.Ohkubo

11. SEISMIC CAPACITY OF REINFORCED CONCRETE BUILDINGS WHICH SUFFERED 1985.9.19-20 MEXICO EARTHQUAKE
T.Okada, M.Murakami, T.Minami and N.Ishikawa

12. SEISMIC INSPECTION AND RETROFIT OF NINE-STORY RC BUILDING DAMAGED BY THE MEXICO EARTHQUAKE, 1985
M.Hirosawa, Y.Endo, T.Noji, H.Yoshida, H.Yamanaka and T.Akiyama

13. SEISMIC CAPACITY OF REINFORCED CONCRETE 4-STORY SCHOOL BUILDINGS WHICH SUFFERED 1985 MEXICO EARTHQUAKE IN MEXICO CITY
S.Sugano, H.Eto,T.Noji and K.Tamura

14. INESLASTIC ANALYSIS OF THE NAMIOKA TOWN HOSPITAL BUILDING DAMAGED DURING THE 1983 NIHONKAI-CHUBU EARTHQUAKE
Y.Yamazaki, M.Hirosawa, Y.Kitagawa and M.Teshigawara

15. BEHAVIOR OF EXPANSION ANCHOR BOLTS
T.Endo and Y.Shimizu

16. EXPERIMENTAL STUDY OF STRENGTHENING EFFECT ON REINFORCED CONCRETE SHEAR WALL THICKENED WITH RETROFIT (MASHIUCHI) WALL
T.Goto and H.Adachi

17. PERFRMANCE OF REINFORCED CONCRETE COMPONENTS REPAIRED WITH EPOXY RESIN
A.Tasai, H.Aoyama and S.Otani

18. A STUDY ON THE STRENGTHENING WITH CARBON FIBER FOR EARTHQUAKE RESISTANT CAPACITY OF EXISTING REINFORCED CONCRETE COLUMUS
H.Katumata, Y.Kobatake and T.Takeda

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19. STUDY ON RETROFIT METHOD OF EXISTING STRUCTURES BY STEEL BRACES WITH DAMPERS
M.Seki, H.Katsumata and T.Takeda

20. SEISMIC BEHABIOURS OF EXISTING R/C FRAME STRENGTHENED WITH RETROFITING STEEL ELEMENTS
Y.Yamamoto and H.Aoyama

21. SEISMIC STRENGTHENING OF EXISTING REINFORCED CONCRETE BUILDINGS BY BRACES AND PANELS OF STRUCTURAL STEEL
S.Sugano and M.Fujimura

22. SEISMIC INSPECTION AND STRENGTHENING OF PUBLIC REINFOECED CONCRETE BUILDINGS, CHIEFLY IN CASE OF SCHOOL BUILDINGS
M.Hirosawa and T.Akiyama

28. DAMAGE ASPECTS AND HYSTERESIS PROPERTIES AHTER REPAIR AND INSTALLATION OF NON STRUCTURAL ELEMENTS
S.Nakata, A.Baba and H.Itoh

(Steel Structure)

23. STRENGTHENING OF STEEL BUILDINGS AGAINST STRONG EARTHQUAKES
K.Takanashi, B.Kato and A.Tanaka

24. AN OUTLINE OF THE MANUAL FOR REHABILITATION OF EARTHQUAKE DAMAGED STEEL BUILDING
K.Takanashi, T.Murota, H.Yamanouchi and I.Nishiyama

25. EVALUATION OF SEISMIC RESISTANCE CAPACITY OF DAMAGED STEEL BUILDING STRUCTURE
S.Morino, K.Takanashi and I.Nishiyama

26. AN EXPERIMENTAL STUDY ON THE REPAIR OF STEEL STRUCTURES SEVERELY DAMAGED DUE TO EARTHQUAKE
H.Narihara, A.Tanaka and M.Izumi

27. ULTIMETE STRENGTH AND REPAIR METHOD OF BEAM-COLUMN CONNECTIONS FABLICATED BY FILLET WELDING
K.Morita, K.Takanashi and T.Murota

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(Others)

29. SEISMIC STRENGTHENING OF REINFORCED BUILDINGS IN JAPAN
S.Sugano and T.Endo

30. ACTUAL EXAMPLES OF SEISMIC JUDGEMENT FOR EXISTING BUILDINGS WITH OR WITHOUT RETROFITTING
H.Aoyama and M.Hirosawa

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BUSINESS AND INDUSTRY COUNCIL FOR EMERGENCY PLANNING AND PREPAREDNESS (BICEPP)

By
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EARTHQUAKE: THE CONSTANT DANGER AND GREATEST THREAT

Two great tectonic plates underlie almost all of California. Each of them moves fractions of inches a year, one gradually pushing over the other generating unimaginable stress on the earth's underlying structure. A topographic map of California reveals a network of faults, fractures in the earth's surface, marking this geologic process. Periodically the stresses become too great and the result is an earthquake. California experiences many small earthquakes a year, many so minor that they go undetected except by delicate seismic equipment. Others simply are passing events in the daily lives of millions of people. From time to time, however, these seismic events take on the proportion of a major disaster. The 1906 earthquake in San Francisco, which set off fires that burned large parts of the city, is perhaps the most famous. But others have been serious disasters with loss of life and damage to property running into the millions. In 1933, the city of Long Beach was virtually destroyed by a serious earthquake which effected all of Southern California, collapsing buildings and weakening others beyond repair. For over a decade, many children, 20 or more miles from the devastated Long Beach, went to school in tents while their school buildings were being repaired. In 1971, a major quake struck the northern portion of Los Angeles killing 65 people, collapsing a freeway overpass, and destroying or damaging numerous homes, businesses and public buildings.

In the early 1980s, near the town of Palmdale in the Antelope Valley north of Los Angeles, the earth began to bulge. Seismologists monitored the ominous swelling and worried inhabitants of Southern California watched nightly reports for the latest news of what became to be known as the "Palmdale Bulge." Scientists and a great many non-scientists were predicting a major earthquake as imminent. The activity in Palmdale stopped as suddenly as it had begun leaving a low hill in the desert, but seismologists tended to consider it a warning of things to come. Experts now predict that Southern California can expect a major earthquake to occur at any time. The force of the quake, they estimate, could be as great as 8.3 on the Richter scale. This is a magnitude as great or greater than the destructive San Francisco quake. The tremendous forces released in 1906, except for the urbanized San Francisco, expended themselves in rural areas. A major quake in Southern California today would effect an area occupied by millions of people, housing thousands of industries linked by freeways that in many instances might not withstand such forces. As in 1906, an earthquake poses the danger of secondary disasters: fires caused by broken gas lines and fallen electric lines; hazardous materials spills and fires; broken water mains which would hamper fire fighting and contaminate potable water; damage to hospitals and other medical facilities. The nuclear reactor at San Onofre could be damaged releasing radioactivity into the atmosphere. In short, an earthquake of this magnitude in Southern California would be a disaster of unprecedented dimensions.

THE WARNING

It was against this threat background that Los Angeles Mayor Tom Bradley called a breakfast meeting of the Chief Executive Officers of 80 major Los Angeles corporations in 1983. His message was simple, but somber. In the event of a major disaster, business and industry could not depend on the normal government emergency response services. A major earthquake, for example, would disrupt water supplies for fire fighting; streets and freeways would be damaged, blocked or congested impeding movement; casualties would be high and medical facilities overloaded; and telephone service would in all probability be interrupted. Government personnel and equipment would, he said, be almost totally involved in restoring basic governmental and public service functions before they could be diverted to deal with the disaster's consequences in detail. Individuals and businesses would in fact be "on their own" for from 48 to 72 hours. He urged the business leaders of the region to begin to think about how their companies would respond to various major emergencies and to begin to prepare themselves and their employees for emergency reaction. He pledged the city's support and assistance in such preparedness efforts and pointed out that business and industry faced the need to resume operations as soon as possible after an emergency. They needed plans not only for meeting immediate emergency situations, but for cleanup, repair, and recovery in order that their businesses' loss of productivity would be as limited as possible and to restore the economic viability of the region.

THE RESPONSE: BUSINESS AND INDUSTRY COUNCIL FOR EMERGENCY PLANNING AND PREPAREDNESS (BICEPP)

The Mayor's message posed a challenged for Los Angeles business and industry and pointed up certain problems in the structure of emergency response preparedness. The members of groups interested in emergency response tended to be government employees or member of volunteer organizations. Their backgrounds were very often military or related to emergency response -- firemen, policemen, medical emergency specialists, etc. Very few business men or business women took part in such groups. Clearly, beyond basic planning to respond to -- let us say, a fire on the business premises -- business leaders and not incorporated emergency planning into their corporate structures. There was an often unspoken assumption that disaster response was a matter for the government emergency services. There was in short a general lack of awareness of the issue of preparedness and emergency response in the business community. Only a few corporations had given the problems any consideration. Even fewer had created positions for emergency response coordinators. The Mayor's message was not delivered to deaf ears, however. The leaders of the Los Angeles business community began to consider emergency planning as a part of their corporate responsibilities. The major problem was to disseminate the message and generate awareness throughout the business and industrial community. To accomplish this, to make Los Angeles business and industry more aware of the threat disasters posed and to encourage planning to respond to emergencies, they initiated the development of BICEPP, Business and Industry Council on Emergency Planning and Preparedness. The mission of the council was to disseminate information, encourage emergency preparedness and planning in the non-governmental commercial sector of Los Angeles county.

Initial support was provided by several major concerns in the Los Angeles area, ARCO (Atlantic Richfield), Bullocks Department Stores, Security Pacific and The Los Angeles Times joined hands to sponsor BICEPP. The corporations provided support and administrative services, assigned staff members to part-time work with BICEPP and made nominal annual contributions to sponsor the group's activities.

Since that beginning in 1983, BICEPP corporate membership has risen to over 50 companies each paying annual dues of $250 and over 600 individual members who receive mailings and attend BICEPP educational and informational programs. Although the group is supported by the Los Angeles City government, it receives no funds from that source and remains independent and self-sustaining, paying most of its expenses by charging fees for attendance at its workshops and seminars. And, in keeping with the business orientation, BICEPP has shown a "profit" sufficient to keep regular publication of a newsletter devoted to emergency preparedness in the private sector.

The Problem

Encouraging emergency response planning in the business and industrial communities requires a number of steps to be taken. This is complicated by the fact that the steps must be taken with each individual firm rather than with a single government agency, is so often the case in the public sector.

Developing Awareness

Before a company initiates emergency response planning, the corporate leaders must be aware of and concerned about the threat various environmental and technical disasters pose for their firm. These must be presented in both human terms, protection of life and safety of employees, but also in corporate terms, the impact of a disaster on company operations.

BICEPP takes advantage of a growing public concern with potential hazards. The "Palmdale Bulge," for example, captured the attention of virtually everyone living in Southern California and made the public more conscious of the possibility and the consequences of a

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major earthquake. Building on this increased public awareness, BICEPP members make contact with individual business leaders by a number of means. Contacts made through professional and service associations, articles in industry or business magazines, invitations to "Timely Topics," dinners and BICEPP workshops and seminars all serve as vehicles of communication with potential supporters of emergency planning.

Other recruits are often identified as a result of business or social contacts between business leaders, one learning from another about their company's emergency response planning efforts. Before businesses undertake emergency planning, the general awareness of potential disaster must be translated into specific business problems. Corporate leaders must be asked a number of questions:

- If a disaster strikes when you are away from the office, who is in charge?
- Is your office prepared to minimize the danger of non-structural damage, falling objects, filing cabinets, office machines?
- Is your machinery and equipment secured to minimize damage and the danger it might pose if it fell or tipped over?
- Do your employees know what to do to protect themselves and protect company records and equipment?
- Do you have any alternate means of communicating with your headquarters if you are away and telephone service is cut off?
- What if your employees could not leave the premises for a day or longer? How would they be fed? Is there potable water available?
- How would your staff handle medical emergencies if medical services were not immediately available?
- Do you have alternate sites identified from which you could continue to conduct business during or immediately after a disaster?
- Do you have cleanup and recovery plans?
- If a fire started in your headquarters and firefighters could not respond, what could your staff do?
- How rapidly can your business resume partial or full operations?

Business leaders who begin to ask -- and try to answer -- these questions about their own operations become potential advocates of emergency planning within their own companies. But few businesses make corporate decisions without consultation. The emergency preparedness advocate may not be in the highest echelons of the corporation structure and may need assistance in selling the idea.

Selling the Planning Idea

BICEPP provides these enthusiasts with the information and the skills needed to convince corporate leaders that a company emergency response plan is needed. BICEPP members are active in the collection of data on disasters and their costs which provides ammunition for arguments for developing a company's response capability. BICEPP maintains a library in space donated by the Los Angeles American Red Cross which contains data on disasters and examples of individual corporate emergency plans as well as presentation materials used in BICEPP educational activities. An example of a corporate emergency plan is provided in Appendix B. Appendix C is an example of a corporate effort to prepare employees for emergency response.

BICEPP members also provide assistance to people wishing to develop emergency plans for presentation to corporate executives. Several of the sponsoring corporations permit members of their own emergency management staff to assist other businesses in the development of plans. To support these "sales" and "development" efforts, BICEPP has sponsored workshops on "Selling your Plan" and the emergency planning process.

Implementation and Support

The implementation of a corporate emergency response plan is of course a matter internal to the company. BICEPP, however, provides the educational and informational support necessary for effective implementation. BICEPP workshops cover a wide range of subjects essential to effective emergency response. The BICEPP library provides information on planning, emergency response equipment, training, government and other resources available to business. One of BICEPP's functions has been to assist companies in locating training resources for their employees. Through the network of connections developed as a result of BICEPP, the organization collects information on disasters throughout the world seeking to identify lessons which might be useful to the Los Angeles business and industrial communities.

BICEPP ORGANIZATION AND PROGRAMS

Membership and participation in BICEPP is entirely voluntary and is drawn from two sources, corporations and individuals interested in emergency preparedness.

As noted earlier, sponsoring corporations contribute $250 annually in return for which their employees are invited to attend BICEPP educational workshops and seminars at a reduced fee. Individual members pay no dues and their only benefit of membership is to receive mailings announcing BICEPP activities for which they pay full fees. There are 50 corporate sponsors and approximately 600 individual members.

General direction of BICEPP activities is provided by the elected steering committee, many of whom are full- or part-time emergency managers in their home corporations. The function of the board is to establish policy for the organization, but the vitality of BICEPP is maintained by encouraging the widest possible participation of the membership on various committees.

BICEPP committees are too large to encourage maximum member participation and to minimize the burden on any single individual of carrying on committee assignments. An important standing committee is the TOPICs Committee which explores the question of what subject areas are most timely and most needed. When a subject for a seminar or workshop has been decided upon, a subcommittee is formed to plan and implement the event. Among the subjects chosen for presentation have been:

Bringing a Plan to Life

This seminar was designed for corporate training managers and demonstrated a five-step process of planning emergency preparedness training which included:

- Identification of subject matter
- Selection of teaching methods
- Design of the teaching program
- Implementation of the training program
- Evaluation of the training program for improvement.

The second phase of the seminar dealt with Instruction Development:

- Writing Behavioral Objectives
- Conducting Task Analysis
- Developing Lesson Plans.

In addition, the seminar provided "bonus workshops" for trainers in different industries; Manufacturing, Large Business, Small Business, Retail and Distribution, Non-profit and Public Agencies.

There is No Doctor in the House

This workshop was an experience designed to provide individuals with the basic tools and know how to formulate a company-wide Emergency Medical Plan. The subjects included:

- EMS in Los Angeles County; Capabilities and Earthquake or other Disaster Response
- Components of Emergency Planning for Business
- The Multi-Casualty Incident
- Discussion of EMT, CPR and First Aid Training
- What to do until the Coroner arrives.

In addition, participants were given special presentations by the American Red Cross and several commercial organizations involved in emergency response training.

Recovery Planning, Business Survival

This presentation dealt with the post-disaster issues of business recovery and included subjects such as:

- Broader Issues of Recovery Planning
- Hazard Evaluation
- Mitigation
- Response and Recovery
- Case History: "PCB and Me;" Recovery with no prior plan; Components of a Recovery Plan
- Recovery Planning and National Defense Experience and Perspectives for the Private Sector
- Psychological Stamina
- Contractor Services
- Insurance and Recovery
- Case Histories: Fire, Flood and Tornado Government Assistance and Regulation.

Seismic Risk and Emergency Preparedness

This seminar focused on the problems which businesses of all types may encounter during and after an earthquake and how to plan for emergencies. Subjects covered included:

- Los Angeles Fire Department Earthquake Training Program
- Corporate Planning Strategies
- Overcoming the Psychological Impact of Earthquakes
- Preventive Measures for Mitigating Earthquake Structural Damage
- Seismic Bracing -- Key to Reducing Non-Structural Earthquake Damage.

Mission Possible

An experience designed to provide individuals with the basic tools and know-how necessary to formulate a company-wide emergency preparedness plan. This "seminar" presented material in the form of "playlets" performed by the "BICEPP Players" who demonstrated the problems inherent in developing an emergency plan and the solutions to those problems. The "dramatic" form mimicked the format of the former Mission Impossible television series and provided a basis for holding audience interest with humor as well as information.

Earthquake Planning for your Data Processing Center

This was an all day seminar designed for contingency planners, data processors, and corporate risk managers. Three sessions discussed:

- Key resources in the battle to Recover Your Operational Capability
- Responsibilities in Contingency Planning; Planning is a Corporate Task -- Executive Involvement is a Must
- Structure of a plan for Data Processing; How to Start and Build a Plan your Center can Use Right Away.

In addition to these workshops and seminars, BICEPP sponsored a vendors fair in which companies which sell or manufacture emergency equipment or provide training for emergency services could display and demonstrate their products.

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Future plans in the spring of 1986 called for a seminar on Mitigating Non-Structural Hazards in the Workplace, and presentation of Fire Extinguisher Training Program.

With a single exception of all the participants in these events were volunteers, government employees and emergency responders, emergency planning consultants, physicians, consulting engineers, corporate emergency planners, and vendors of emergency equipment and services.

Other Activities

In addition to workshops and seminars, BICEPP sponsors periodic "Timely Topics" dinners at which speakers discuss a single issue of interest to emergency response personnel in business and industry. The success of the workshops and seminars has generated sufficient "profit" to support a BICEPP newsletter to be distributed to sponsor corporations, individual members, and other interested persons.

Continuing activities include assisting companies in developing emergency response plans and in obtaining employee training, discussions with property owners and managers hopefully leading to building wide emergency plans and assisting in the development of various cooperative agreements.

SUPPORT AND ASSISTANCE

BICEPP efforts are greatly enhanced by continuous and concrete demonstrations of support on the part of the Los Angeles City government. While no direct funding comes from this source, the city regularly assists by providing video tape copying services for BICEPP. Most important, however, is the direct and personal support of Tom Bradley, the Mayor of Los Angeles. His original meeting of CEOs which inspired the BICEPP program has been followed by other efforts, notably a second breakfast meeting for business and industry leaders. Although the planning was done by BICEPP members, the city government and sponsoring corporations provided the support and assistance necessary to implement a successful program.

Emergency Simulation

Using an invitation list prepared by BICEPP, the Mayor's office issues, over his signature, personal invitations to attend the breakfast meeting. The meeting was held in space donated by ARCO at its ARCO Tower downtown headquarters. The breakfast was catered by ARCO which also provided parking. The meeting was called to order and the Mayor delivered the introductory remarks. As he ended his comments, the unique BICEPP approach to developing awareness took over.

As the guests were digesting the Mayor's final words, a Los Angeles city policeman burst into the room to inform the Mayor that a "disaster" had occurred and that his presence was required immediately at City Hall. In keeping with the BICEPP dramatic approach, the policeman was gasping for breath and said that there was no power and that he had climbed the 51 stories of the ARCO Tower to carry this message. The Mayor, playing his role as instructed, motioned to his aides, gathered up his brief case, and turned to the assembled businessmen to say; "Like I said gentlemen, you are on your own."

His "departure" was immediately followed by a spotlight being turned on a simulated television news desk occupied by a BICEPP "anchorman" who told in breathless detail of a series of disasters throughout the Los Angeles area. As the "screen" went dark, a speaker at the main podium made a presentation which was followed by a switch back to the "television" studio and from there to various "remote and live" reports from BICEPP "reporters" who interviewed aptly named "businessmen" about their company's preparedness for and response to the disaster. The interviewees ranged from the executive officers of companies which had no plan to those who were prepared. Between each "remote," speakers presented serious discussions about emergency response. The Mayor, who was in fact scheduled to leave (via the elevator rather than walking down 51 floors) after his remarks, became so fascinated with the production and the reaction of the guests that he cancelled several appointments to remain and play a continuing role in the event. BICEPP will supply video tapes of the "dramatic" portions of the event if the requester will provide blank tape and cover mailing costs.

This meeting reveals one of the most important elements of BICEPP's success in 3 short years. The visible support of the Los Angeles government and of major business concerns.

Other Examples

Sunkist Growers, Inc. maintains and updates BICEPP mailing lists as well as providing facilities for events like the one just described. General Telephone Company does the printing for BICEPP mailers and brochures. Sunkist Growers, the University of California, and the American Red Cross provide rooms for meetings. The Red Cross has dedicated a room in its headquarters for the BICEPP Library. The City of Los Angeles and the University of Southern California provide equipment and personnel for videotaping of BICEPP educational presentations. A number of other companies and organizations including General Telephone, Standard Brands Paints, Security Pacific, First Interstate Services, the University of Southern California, and the American Red Cross contribute employee time for BICEPP activities. This support permits BICEPP to operate on an almost 100 percent volunteer basis. The organization has only one paid employee who works 40 hours a month to collect and answer mail.

Interaction, Networking and Cooperation

An important element of BICEPP activities is the relationships the organization and its members form by participating in other emergency oriented activities and developing cooperative relationships with other emergency response agencies.

BICEPP members regularly attend meetings of the Governor's Task Force on Earthquake Preparedness, The Los Angeles City and County Emergency Preparedness Commission, and the Southern California Emergency Services Association. Other members have attended national conferences on emergency and earthquake preparedness. At the same time, various emergency service organizations are represented by membership on the BICEPP Steering Committee, specifically the City of Los Angeles Office of Emergency Services, The California Office of Emergency Services, the Southern California Emergency Preparedness Program, and the American Red Cross. The interactions generated by the multiple memberships and participations is one of the principle sources of new sponsors and members and also the avenue through which much of BICEPP's impact is manifested.

In addition to the firms noted in early sections and the support and assistance given by the City of Los Angeles, BICEPP has received assistance largely in the form of presenters and trainers for its various seminars and workshops, from the Los Angeles County Sheriff's Department, Los Angeles County Coroner, Office of the Secretary of Defense, Los Angeles City Police and Fire Departments, Los Angeles Department of Building and Safety, Los Angeles Planning Department, and all of the major corporations. One presenter was a member of the staff of the National Emergency Training Center, Emergency Management Institute of Emmitsburg, Maryland, an element of the Federal Emergency Management Agency. A number of BICEPP members have attended EMI emergency management courses and are to apply new skills and knowledge to Los Angeles County activities.

IMPACT

BICEPP has basically limited the scope of its activities to Los Angeles County although it responds to requests for assistance from firms in neighboring Southern California counties.

Major evidence of the impact of BICEPP is the growth of the organization itself. Starting with five sponsoring corporations and a handful of members in 1983, BICEPP now has over 50 corporate sponsors and 600 individual members. Its educational activities have reached literally hundreds of individual businesses. Although at this time there are no statistics available as to how many have initiated emergency plans, there is a strong indication that emergency planning is increasingly becoming part of the business culture of Los Angeles. Through its various networking activities, BICEPP has encouraged other areas to initiate similar organizations. The City of Upland, east of Los Angeles, has begun a similar endeavor and inquiries have been received from as far away as the United Kingdom. BICEPP has provided assistance to the (San Francisco) Bay Area Earthquake Preparedness Program and the Central United States Earthquake Preparedness Consortium. Locally, the cooperative self-help message of BICEPP has inspired a number of concerns to form emergency response cooperation groups. The area's public utilities have signed mutual aid agreements to pool equipment and personnel resources to respond to major disasters. Several leading financial institutions have entered into similar agreements to share facilities and personnel in the event of disaster. Several major corporations in the area, notably Hughes, TRW, XEROX, and Chevron have joined in a multi-business disaster plan.

At Northridge Hospital, located in the San Fernando Valley, a 24-hour toxic materials information and response center has been established to provide immediate and accurate information and guidance by telephone or to dispatch knowledgeable professional personnel to assist in a toxic materials incident.

BICEPP is currently in contact with the Property Owners and Managers Association to encourage the development of emergency plans for buildings occupied by many tenants -- a major concern in the high-rise areas of the county.

BICEPP has also become the source of information about emergency planning which is being included in the newsletter published by many companies for their employees.

DEVELOPING A PROGRAM FOR BUSINESS AND INDUSTRY

The essential element in the successful development of an emergency response program for business and industry is the support of local government and key leaders in the business community.

BICEPP has built its current success on a foundation laid by the Mayor of Los Angeles who was aware of the threat posed to his city and to the commercial enterprises located there. In situations where this awareness has not developed in local government, proponents of emergency preparedness have the additional burden of stimulating such awareness. An analysis of the development of BICEPP reveals a number of steps which were taken to set the stage and muster support for an organization of this nature. Although BICEPP's founders did not consciously follow a particular model, their activities parallel in many ways, the steps outlined by the Integrated Emergency Management System (IEMS) process developed by FEMA. The goal of BICEPP was not to develop a single plan or system, but rather to encourage emergency

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response planning in a multitude of business and industrial organizations. The first step was to identify the hazards faced by the Los Angeles business and industrial community.

Hazard Identification

An accurate and objective assessment of the threats faced by a specific community is the first essential step in the emergency preparedness process. The classification of emergencies and disasters used by BICEPP is a useful one. Potential threats are categorized as either natural or technological.

Natural Disasters

Include hurricane, blizzard, extreme heat, floods, mudslides, earthquake, volcanic eruption, lightening and fires caused by lightening, drought to name some but not all of the possibilities. An assessment of the possibility of this type of event can be drawn from historical sources, the statistical and other information collected by the National Weather Service, records of local emergency responders, old newspaper files, etc. Information should include the type of incident, when it occurred, frequency of occurrence, an estimate of the damage and loss of life it caused, and some assessment of the potential of such an incident to disrupt business and industrial activities.

Technological Disasters

Include fires, hazardous materials spills, airplane and rail crashes, multiple vehicle highway accidents, arson fires, nuclear reactor accidents, natural gas leaks, electrical power failures, non-nuclear explosions, potable water supply pollutions, terrorism, structural collapse, etc. Once again, historical material can be of assistance in identifying hazards, but in the case of technological incidents, one must remember the threat exists even if no disaster has occurred. Determination of possible threats requires a reasonably complete survey of industrial activities in an area, the rate of movement of hazardous materials through an area, the kinds of chemical or other industrial processes being used in local manufacturing, the kinds of materials stored in commercial inventories. Once a reasonably complete Hazard Identification picture has been developed, it is necessary to undertake the second step of the IEMS process.

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Response Capability

Put simply, this is an assessment of the resources available in a community to respond to the various hazards identified in step one. Such capabilities should include governmental resources and resources available in the private and volunteer sectors of the community. Although public sector response systems in Los Angeles are among the best in the nation, their ability to provide assistance in a major disaster is limited. In the private sector, BICEPP pointed out a very limited response capability due to lack of awareness in most business organization.

The third step of the IEMS process is:

Shortfall identification

By comparing the threat profile of an area with its response capability and degree to which emergency plans exist, it is possible to pinpoint the areas of weakness in planning, personnel, knowledge, and equipment available for emergency response. Major weaknesses in the Los Angeles business and industrial community's ability to respond to emergencies were: lack of corporate plans; failure to assign emergency response responsibilities; lack of knowledge of the possible consequences of various types of disasters; lack of training or emergency equipment or supplies.

Marshalling Forces

At any point in the three-stage process outlined above, advocates of improved emergency response planning can publicize their work and seek support: service organizations, professional groups, business and industry groups, official and quasi-official agencies, neighborhood associations, and such groups as Boy Scouts, Girl Scouts, and PTA are potential audiences for the emergency planning message and potential sources of recruits to gather and evaluate information. The goal of such an effort is to elicit the interest of government and business leaders and the local media and to encourage their support of the effort.

As a volunteer group, a business and industry program must depend on the enthusiasm of individuals and their willingness to contribute time and effort to the process.

Obtaining Assistance

Communities or individuals seeking to develop a business and industry program can turn to BICEPP for advice by contacting BICEPP, Post Office Box 57930, Los Angeles, California 90057.

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ADDED DAMPING AND STIFFNESS ELEMENTS FOR EARTHQUAKE DAMAGE AND LOSS CONTROL

by

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Introduction

Following is a review of the research - applications process in connection with Added Damping and Stiffness (ADAS) elements for earthquake damage and loss control that has transpired thus far. The application of ADAS elements is presently just beginning. Accordingly, much of the discussion provided in the following pages addresses the need, research, and translation activities that have led to the development of ADAS elements.

Applications of ADAS elements for improving the earthquake performance of structures are presently being made both in nuclear power plant facilities and in non-nuclear structures. Specific applications made thus far in the nuclear and non-nuclear areas of practice are quite distinct. However, the technological developments that have been made in the two areas of practice have significant translational value and therefore both applications are addressed here.

Need for ADAS Elements

Non-nuclear Facilities. The design of structures to resist earthquakes depends on a number of factors. Certainly one of the more important factors is the rigidity of the structural system chosen for the building or structure. Structural systems in common use are classified in many ways; for this discussion they will be distinguished only as being either flexible or stiff.

There now is extensive literature that describes the merits of stiff structural systems in reducing both structural and nonstructural damage, and conversely the extensive damage commonly observed in connection with flexible construction. Naito (1927) was among the first to chronicle the benefits of stiff construction for resisting earthquakes. His reasoning involved designing buildings to have a fundamental period of vibration smaller than the dominant ground motion period of any conceivable great earthquake in order to preclude harmonic vibration amplification. The concept of stiff earthquake-resistant design was adopted many decades ago by Chilean engineers who use the reinforced concrete shear wall structural system extensively. The generally good performance of buildings observed following the March 1985 magnitude 7.9 earthquake in Chile is attributed to the extensive use of stiff shear wall construction (Wyllie, et. al., 1986).

Ground motion recordings in Mexico City from the September 19, 1985 magnitude 8.1 Mexico earthquake clearly show that the shaking severity far surpassed that which was contemplated in building codes for the Federal District (Rosenblueth and Meli, 1986). While the majority of the multi-story engi-

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neered buildings there performed well, 210 buildings collapsed and thousands of buildings were damaged. A variety of factors contributed to these structural failures, but detailed postearthquake evaluations have shown that the severely damaged buildings were mostly in the range of 5 to 15 stories high, and building flexibility was cited as a common characteristic (Meli, 1986).

Perhaps one of the most dramatic comparisons of the relative performance of stiff and flexible building construction revealed thus far is from the 1972 magnitude 6.2 earthquake in Managua, Nicaragua. Two multi-story engineered buildings, the Banco Central and the Banco de America stood in close proximity to each other and presumably experienced similar ground shaking. Both are relatively modern buildings and were built in the mid-1960's (see Figure 1).

The Banco de America (Selna and Cho 1973, and Sozen and Shibata, 1973) is a 17-story shear-wall building and was relatively stiff. Although there was minor structural and non-structural damage, a close-up view of the building exterior (Figure 2) does not reveal any distress. The offices remained in good condition (Figure 3), and although the building required structural repair, it could have been re-occupied in short order and remained in use while structural repairs were being made.

The Banco Central (Wyllie, 1973) was a relatively flexible, 15-story, moment-resisting reinforced concrete frame building with a few shear walls around the elevator enclosure at the west end. A close-up view of the exterior of the building (Figure 2) reveals extensive concrete spalling at the beam-column connections caused by excessive inter-story drifts. Moderate to severe structural damage occurred to the columns, elevator core walls, and floor slabs. The building also sustained serious nonstructural damage: brittle clay tile infill walls shattered, lay-in ceilings fell, poorly anchored interior partitions toppled, and contents were strewn about (see Figure 3). Although the building remained structurally sound, the non-structural components were a shambles and rehabilitation would have been very slow and expensive. The combination of a flexible structure and brittle nonstructural components was disastrous.

Repairs on the Banco de America building were made using the epoxy injection technique. Engineers proposed repairing the Banco Central building, but the appearance of extensive damage caused the owners to decide to remove the upper 12 stories of the building. The two-level basement containing the national vault was not damaged by the earthquake, so it was deemed desirable to preserve the vault and an aboveground structure sufficient to service it.

Arnold (1986) gives a detailed description of the occupant response, contents disruption, nonstructural damage, and structural damage that occurred in the Santa Clara County Government Center building in San Jose located about 12 miles from the epicenter of the 1984 magnitude 6.2 Morgan Hill, California earthquake. The building is a 13-story flexible steel moment-resisting frame structure which, because of the overall disruption, was evacuated following the earthquake. The overall level of damage to the building and its contents was modest, but this must be contrasted with the fact that no other high-rise building in San Jose suffered any significant damage at all - structural, nonstructural, or contents.

Figure 1

View of downtown Managua after the 1972 earthquake showing the 15 – story Banco Central building on the left and the 17 – story Banco de America building on the right. The Banco Central , a reinforced – concrete , moment – resisting – frame structure , experienced severe structural damage , but large interstory drift caused severe nonstructural damage. The Banco de America , a shear – wall structure , experienced minor structural damage , and only minimal non – structural damage.

(Photo by H. Degenkolb)

a. Banco Central building. Note the extensive concrete spalling at the beam—column joints. (Photo by L. Wyllie)

b. Banco de America building. (Photo by L. Selna)

Figure 2

Exterior views of the Banco Central and Banco de America Buildings following the 1972 Managua , Nicaragua Earthquake.

a. Typical office in the Banco Central showing the extensive nonstructural and contents damage. (Photo by L. Wyllie)

b. Typical Office in the Banco de America showing negligible nonstructural and contents damage. (Photo by H. Degenkolb)

Figure 3

Photos of Offices in the Banco Central and Banco de America Buildings following the 1972 Managua Nicaragua Earthquake.

In light of the above observations, it is clear that stiff structures have generally produced less structural, nonstructural, and contents damage during moderate and severe earthquake shaking than that revealed in flexible buildings. Of course, stiff buildings designed using conventional concentric-braced frames or moment-resisting frames must also be strong. Added Damping and Stiffness (ADAS) elements, used in modern frame construction, are an alternative structural system for economically achieving a moderately stiff and highly damped structure that minimizes dynamic amplification in buildings, interstory drifts, and damage, without having to add significant strength.

Nuclear Facilities. In the late 1970's a strong need arose for developing more reliable nuclear power plant pipe support elements than the hydraulic and mechanical snubbers in use at the time. As of December 1, 1977, it was reported that about 8,000 snubbers were in use in some 30 U.S. nuclear power plants and that these snubbers were generating significant and costly maintenance requirements. Hydraulic snubbers were observed to be inoperative frequently because of fluid leakage, while mechanical snubbers are susceptible to binding caused by corrosion (Spencer, et.al., 1979). This observation has substantially affected the development of ADAS elements, and it is expected that it will have significant impact on future applications as well.

Added Damping and Stiffness Structural Elements

Added Damping and Stiffness (ADAS) structural elements are mechanical devices that can be practically installed in structures in order to 1) substantially increase the overall damping in a structure, and 2) to increase the overall stiffness of a structure. ADAS elements are ideally installed in flexible moment-frame structural systems, either for new construction or for retrofitting existing buildings, to economically achieve a moderately stiff and highly damped building system.

More generally, an ADAS element can be described as a moderately stiff and energy dissipating link between sets of pairs of points that experience relative motion during vibration of a building. ADAS structural elements consist basically of two major components arranged in geometric series as follows: 1) a stiff component consisting of conventional structural engineering materials having high shear, compression, and tension moduli (e.g. steel or concrete) for transferring forces from one point in the structure to another point, and 2) a moderately stiff component consisting of polymers, rubber, or steel material having lower compression, tension, and shear moduli than the stiff component and also having high energy dissipation properties that absorb the majority of the relative displacement that occurs between the two points of the structure.

The moderately stiff and energy dissipative component is the major engineering innovation involved in ADAS elements. One concept that has been proposed in this regard is steel plates, which are uniquely configured and deformed plastically in flexure to achieve the objectives desired. Figure 4 schematically illustrates three different steel plate configurations that might be considered in this regard. Note that only the triangle-shaped plate and the x-shaped plate configurations will produce a substantial volume of steel that yields plastically - thus dissipates substantial energy when deformed.

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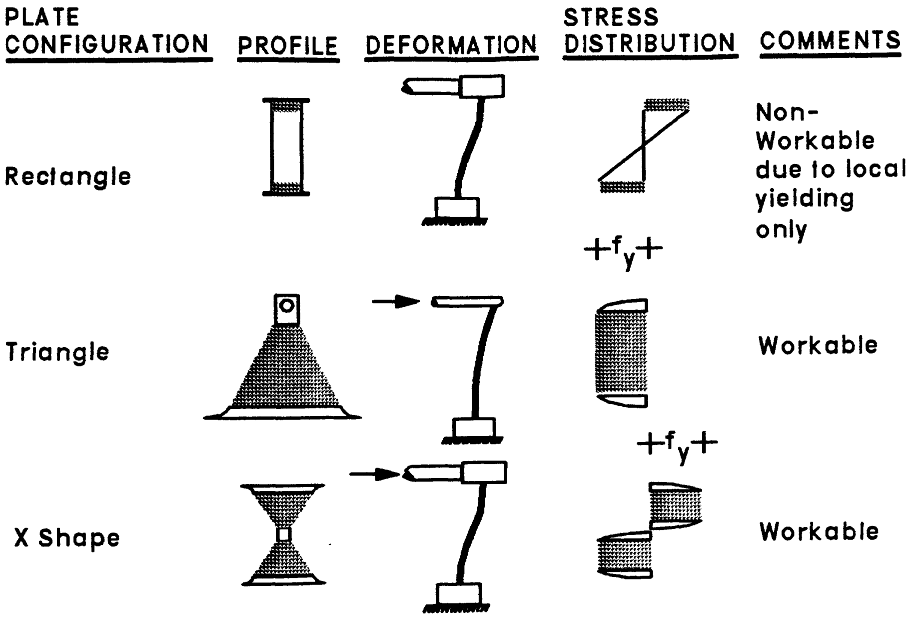


FIGURE 4
CONCEPTS OF STEEL PLATE ENERGY ABSORBERS

Two critical features that determine the utility of steel plates for improving the earthquake performance of structures are: 1) the amount of energy that can be absorbed, and 2) the fatigue failure characteristics of constructable plates. Figure 5 shows the hysteresis loops determined experimentally for two 4 inch high x 1/4 inch thick plates acting in parallel for the first cycles and for the 100th cycle. Note the substantial similarity of the hysteresis loops for the first cycles to that of the 100th cycle indicating overall toughness of this system. More extensive cyclic testing, reported by Khalafallah, et.al. (1987), has resulted in the production of the fatigue results shown in Figure 6.

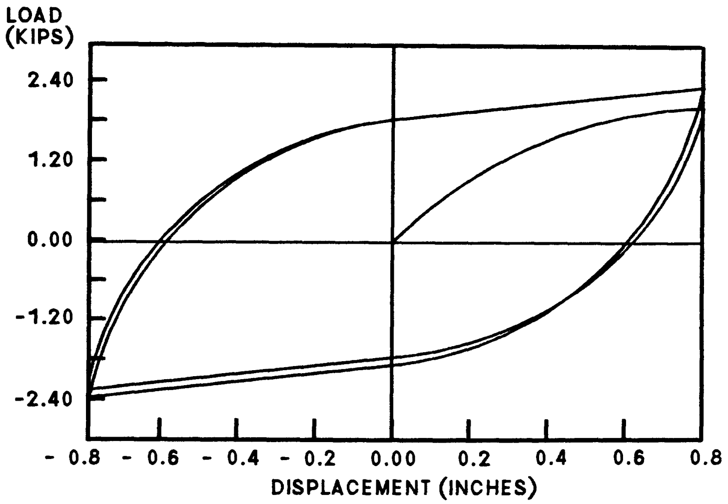
Several devices have thus far been proposed that serve the purposes of adding damping and stiffness to structures. Figure 7 schematically illustrates how an assemblage of steel plates can be attached to chevron bracing, thus forming a complete ADAS element for installation in a typical building framing system. The Energy Absorber (Khalafallah, et.al., 1987) that has been developed for use in nuclear power plant piping systems to serve both as a restrainer and a damper is illustrated schematically in Figure 8. The Energy Absorber incorporates x-shaped plates that are deformed flexurally, and therefore it is characteristically and functionally similar to the ADAS element shown in Figure 7. A similar embodiment to that shown in Figure 7, which incorporates viscoelastic material in lieu of steel plates, is proposed by Scholl (1986).

Although the Friction Damped Braced Frame (FDBF) proposed by Pall (1986) is characteristically different from the devices discussed thus far, functionally it serves to add damping and stiffness. Therefore this device is included in this discussion. Figure 9 is a schematic illustration of the FDBF, which contains friction brake lining pads at the intersection of the diagonal braces. During lateral motion of the frame, the device slips at a predetermined force, and energy is dissipated.

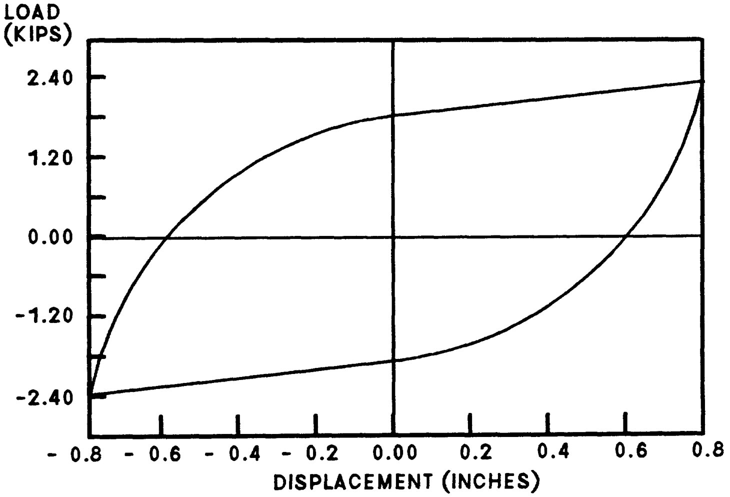
Research that Contributed to ADAS Element Development

Hysteretic damping in structures has long been recognized as an effective means for reducing interstory deflections in structures. Substantial research effort, both analytical and experimental, has been devoted to evaluating response reductions that result from hysteretic damping in major structural components of buildings (beams, columns, and shear walls). These efforts are excluded from this discussion because structural component damage must occur to mobilize this type of hysteretic damping. In addition, base isolation as a means of reducing interstory drifts in structures is also excluded from this discussion because the mechanism involved is totally different from that under consideration here.

Research conducted for the explicit purpose of developing viable ADAS-type devices to reduce the earthquake response of structures appears to have commenced in the early 1970's. Kelly, et. al. (1972) and Skinner, et al. (1973) describe the results of early testing of beams deformed plastically in various combinations of torsional, flexural, and shear deformation. While this work was probably research motivated, Kelly and Skinner clearly recognized the value of these devices in connection with reducing interstory drifts in buildings. The work was conducted at two research facilities - the Earthquake Engineering Research Center at the University of California, Berkeley, and the Physics and Engineering Laboratory, Department of Scientific and Industrial



1st Cycles



100th Cycle

FIGURE 5
EXAMPLE EXPERIMENTALLY OBTAINED HYSTERESIS CURVES

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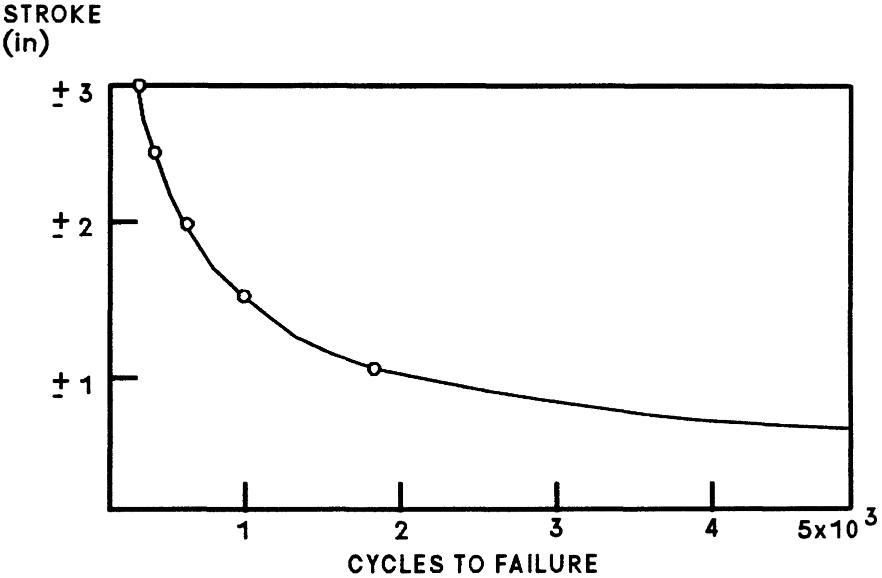

FIGURE 6

FATIGUE TEST RESULTS FROM 6 INCH LONG, 1/8 INCH THICK X–SHAPED PLATE

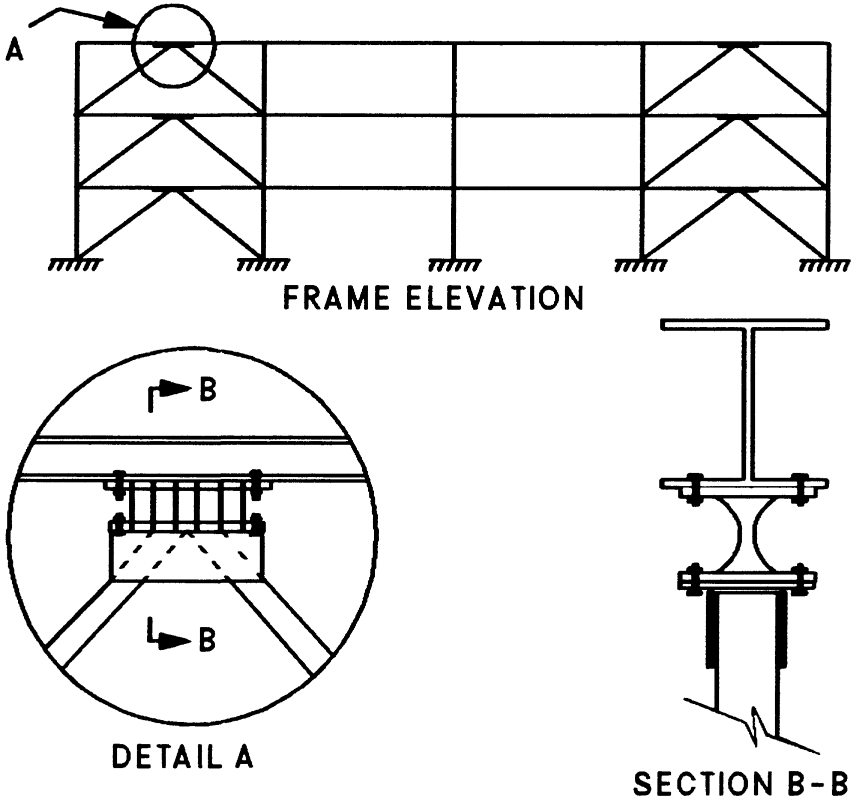

FIGURE 7

CONFIGURATION OF ADDED DAMPING AND STIFFNESS STRUCTURAL ELEMENTS EXAMPLE APPLICATION IN A 3-STORY BUILDING

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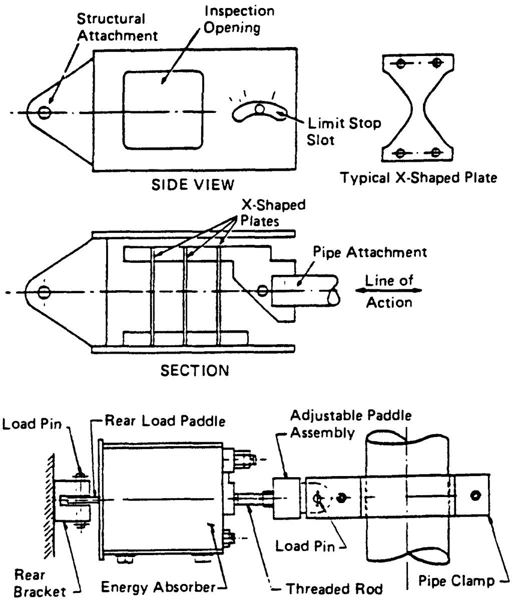

FIGURE 8

SCHEMATIC OF BECHTEL ENERGY ABSORBER

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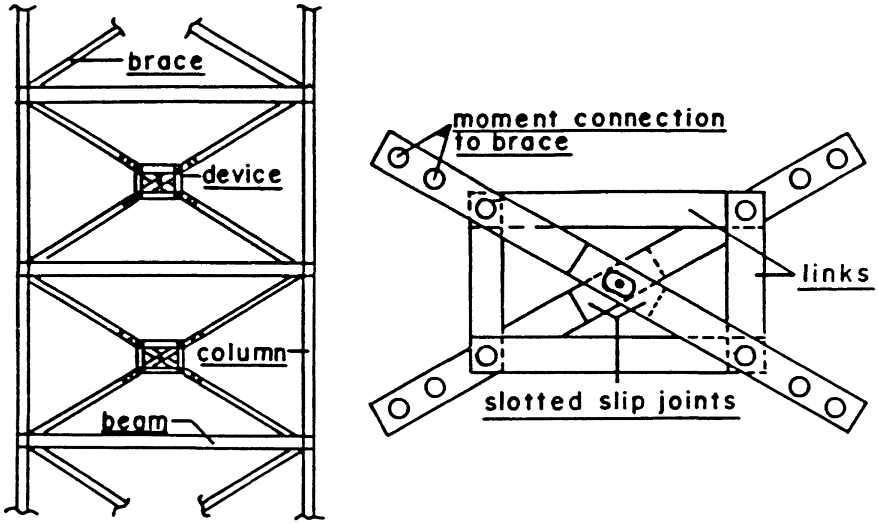

a. Typical Locations of Friction Device.

b. Friction Device.

FIGURE 9

FRICTION DAMPED BRACED FRAME

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Research, New Zealand. The steel-plate energy absorber addressed here evolved directly from this basic research. Subsequent efforts by this team have been focused on the application of energy absorbers in connection with base isolation (Kelly, et. al., 1980).

In response to the observed failure of conventional snubbers being used in nuclear power plant facilities in the United States, the Department of Energy (DOE), in the late 1970's, sponsored a comprehensive program for developing alternative pipe support systems. This program included a review of analyses procedures for reactor system piping, an evaluation of the energy absorption capacity of commercial steels, and current concepts of energy absorbing restrainers (Spencer, et. al., 1979). This DOE program augmented with funding provided by the Nuclear Regulatory Commission, produced the finding that the triangle-shaped steel plate energy absorber was "an extremely effective" means of reducing dynamic response (Stiemer and Godden, 1980).

Results of subsequent experimental shake table testing, sponsored by the Electric Power Research Institute led to the general conclusion that x-shaped steel-plate energy absorbers could be used to control the dynamic response of piping systems to values equal to or less than those measured using traditional snubber supports (Schnider, et.al., 1983). Another conclusion of this piping system test program was that for high intensity seismic excitation, energy absorbers provide better response control than snubbers as they provide high damping and some degree of local uncoupling between ground and pipe motion at the onset of yielding.

In addition, experimental tests of a nuclear power steam generator indicated that the combination of base isolation and energy absorbing restrainers might be a viable retrofit strategy for existing large nuclear power plant components having high potential seismic hazard (Kelly, 1983).

In a subsequent stage, Bechtel Western Power Corporation, with partial funding from the Electric Power Research Institute, has undertaken the development of design guidelines for the commercial application of steel plate energy absorbers. This effort has included the development of analytical procedures for evaluating the hysteretic energy dissipation feasible for a complete spectrum of x-shaped and triangle-shaped plate geometries, as well as nonlinear and equivalent linear procedures for predicting the response of piping systems with energy-absorber restraints. These developments are based on extensive experimental testing, including low-cycle fatigue evaluations to establish practicable design ductility limits for the steel plates.

Separate and distinct from the developments described thus far, research investigations to determine the feasibility of using elastomer materials for earthquake energy absorption applications in buildings are being conducted at the University of Michigan. Sponsored by the National Science Foundation, these investigations include both analytical evaluations (Ashour and Hanson, 1987) and experimental testing (Bergman and Hanson, 1986). The analytical work focused on providing answers to a number of questions related to math modeling and response evaluations. An important conclusion reached in this regard is that non-proportional damping can by treated as proportional in mode superposition calculations provided that discontinuities in damping distribution do not exist. Conclusive results from the experimental evaluations being conducted have not yet been presented.

The Friction Damped Braced Frame (FDBF) proposed by Pall (1986) involves the use of friction devices that slip and thus dissipate energy when exposed to severe earthquake forces. Analytical and experimental research conducted to demonstrate the effectiveness of the FDBF for reducing earthquake losses was begun in the late 1970's. This research has been conducted at Concordia University, Montreal, Quebec, Canada (Pall and Marsh, 1982) and at the University of British Columbia, Canada (Filiatrault and Cherry, 1986). Shake table testing of model frames conducted by Filiatrault and Cherry led to the conclusion that even an earthquake record with a peak acceleration of 0.90g did not cause any damage to the FDBF, while the Moment Resisting Frame and the Braced Moment Frame, that were investigated in the same test series, underwent large inelastic deformations.

The total funding for the research that has been conducted thus far in connection with the above described mechanical devices is difficult to assess accurately. It is estimated that specific committed funding thus far is in excess of $2 million.

Applications

Application of steel-plate energy absorbers for improving the earthquake response performance of structures has followed primarily from the detailed knowledge of the engineering characteristics of the absorbers. That is, those designers who have confidence in the energy absorbers have been willing to apply them in specific structure designs.

Thus far, applications of steel-plate energy absorbers are very limited. Two distinct types of applications have been made by the Bechtel Western Power Corporation, and one building has been constructed in New Zealand that incorporates steel-plate absorbers in conjunction with base isolation.

Figure 8 shows a schematic of the energy absorber developed by Bechtel Western Power Corporation for application to nuclear power plant piping systems. Thus far, the Nuclear Regulatory Commission (NRC) has given limited approval for use of the Bechtel Energy Absorber but, NRC approval for plant-specific applications is still required. Thus far, design services have been performed in connection with piping systems at 10 power plants, and energy absorber hardware has been installed at or is on order for 5 of these plants. The installation of energy absorber hardware is expected to increase significantly when generic approval of this mechanical device is granted by the NRC.

A second distinct application of the Bechtel Energy Absorber involves the dome service crane at the Diablo Canyon Nuclear Power Plant in California. The dome service crane, which is used and operated like a "cherry picker", is mounted on the gantry for the containment building crane. Because the dome service crane is anchored so high up in the containment building, it will experience large accelerations during severe earthquake shaking. A unique arrangement of eight energy absorber devices was designed and installed to reduce the acceleration that a service crane operator might experience during a severe earthquake.

Union House (see Figure 10) is a twelve story office building in Auckland, New Zealand that was designed as a base-isolated building, and steel plate energy absorbers are used to dampen earthquake response motion. The particular base

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Figure 10

Twelve – Story Union House Office Building in Aukland, New Zealand constructed base isolation and steel plate energy dissipators. (Photo by C. Arnold)

isolation system used is somewhat novel and is laterally very flexible. Added stiffness at the ground floor of the structure, using the energy-absorber concept, was provided to resist wind and earthquake forces. A total of 16 massive triangle-shaped steel plate energy absorbers, 4 on each side of the square building, were used. The plates are 75 mm. thick, and have a base width and triangle height of 600 mm. Figure 11 shows the installation of the energy absorber. Construction of the building has proved the system to be advantageous in terms of both cost and construction time (Boardman, et. al., 1986).

The Friction Damped Braced Frame device has been installed, or will be installed, in at least 4 buildings thus far. One installation is a new 9-story reinforced concrete frame building in Canada, and a second installation is a new hillside house in California. The other two installations involve retrofit strengthening of low-rise reinforced concrete buildings in Mexico.

Translation Activities that Contributed to Applications

Translation activities that have contributed to the application of ADAS elements have occurred in connection with both identifying the need for such devices and the technology base for the design of the devices.

Recognition of the need for reducing the earthquake response deformations has resulted primarily from postearthquake investigations. Implementation of this observation has been a long and arduous process. The relationship between drift and damage was recognized long ago, but it was not until 1976 that seismic drift limits were included in the Uniform Building Code. Note that this followed as quickly as was possible after the 1972 Managua, Nicaragua earthquake.

For nuclear facilities, it was plant operations that revealed the failure of conventional piping system snubbers. Had it not been for this translational observation, the energy absorber technology for nuclear piping systems would likely not have been developed.

The analytical technology required for designing ADAS elements involves nonlinear seismic response evaluations. Tremendous effort dating at least back to Jacobsen (1930) has been devoted to the development of the rigorous and approximate nonlinear analysis procedures that are available today. This represents an important translational activity that has clearly expedited the application of ADAS elements.

Research Dissemination that Contributed to Application

The publication of postearthquake investigation findings, which clearly demonstrate the types of structures that are damaged and those that are not damaged, has been very important for distinguishing the applicability of ADAS elements. Specifically, post earthquake investigation reports have contributed substantially to increasing the awareness among design professionals and building owners that flexible buildings are more severely damaged during earthquakes than stiff buildings. ADAS elements can be incorporated into conventional monment-frame structural systems to stiffen buildings.

a. Finished appearance of energy dissipation.

b. Energy dissipator connections exposed during construction.

Figure 11

Detailed views of energy dissipator used at Union House Building.
(Photos by C. Arnold)

Another form of research dissemination that is important to ADAS element application is the publication of theoretical parameter variation studies. These types of evaluations are of significant value for identifying structural parameters that are important in connection with reducing earthquake damage. Establishing the relative importance of strength, stiffness, damping, and ductility has been very valuable in connection with ADAS element applications.

Commentary on Applications Process

The application of ADAS elements for reducing earthquake losses is just beginning at this time. The principal factors that affect the application of ADAS elements are: 1) the awareness among structural design professionals and building owners of the need for or the benefit that results from the use of such devices, and 2) experimental test demonstration that ADAS elements increase safety and reduce damage.

The need for ADAS elements in connection with nuclear piping systems has become obvious. The continuing failures of conventional piping system snubbers is a costly maintenance problem and potentially jeopardizes the operation of nuclear power plants. Extensive proof testing has demonstrated that energy absorbers are effective in reducing the earthquake response of piping systems. Applications of the energy absorber in nuclear power plant piping systems have followed from the awareness of the need for a new technology device and the demonstration that these devices effectively control earthquake response.

The need to reduce interstory drift deformations in buildings during earthquakes (moderate and severe) has been clearly demonstrated from postearthquake observations of the response of buildings. While it is theoretically clear that ADAS elements, which are distributed throughout a building (Figure 7), are effective in reducing response deformations in buildings, shake table testing to demonstrate this hypothesis is still required.

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THE LEGISLATIVE PROCESS FOR ACHIEVING EARTHQUAKE HAZARDS REDUCTION, INCLUDING RESPONSE AND RECOVERY PLANNING

by

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Division of Emergency Management

Legislative and Executive commitment and support is vital to state and local government emergency management support. Without such commitment and support it is difficult, if not impossible, to achieve desired results in terms of response and recovery planning.

Another important and necessary part of the legislative process is local government. Local governments are the front-line response to emergencies and disasters. States and the federal government provide supplementary assistance when response requirements exceed local government capabilities. Since they are most directly involved and affected when emergencies and disaster occur, performing response and recovery planning is advantageous for them in reducing injury, loss of life and property damage. For this reason, local government support is important in the legislative process. State associations of cities and counties and related groups need to be included in the process. Their influence in the legislature is often more effective than that of agency heads or special interest groups.

Earthquake response and recovery planning in Washington State had been almost totally dependent on funding received under the National Earthquake Hazards Reduction Program (NEHRP). Various attempts to supplement NEHRP funding have been unsuccessful. In view of the Puget Sound Earthquake hazard and the fact that earthquake preparedness is a long-term activity, lack of state funding poses a serious problem. Unless this changes before the NEHRP funding support ends, Washington State will lack a meaningful earthquake preparedness program.

It is important to remember that such programs are not accomplished quickly. Conversely, because the planning process does take time, it is vital that work not be interrupted or suspended due to lack of funding/legislative support. Therefore, one must guard against impatience or becoming discouraged. Some note worthy progress has been made in Washington State in recent years. Following are brief descriptions of several accomplishments:

- A Seismic Safety Council was appointed in 1985. The Council prepared and published an excellent report in

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1986 that includes a comprehensive list of recommendations. This report should serve as a broad framework for enhancing the state's program to mitigate, prepare for and respond to earthquakes.

- Washington State has entered into a modern Interstate Mutual Aid Compact with Idaho and Montana. Other western states are expected to follow suit. The new Compact was prepared by the Western States Seismic Policy Council.
- Media interest and coverage has been gratifying. Newspaper and television attention to the earthquake threat is ongoing.
- Local public works officials have formed an association to study earthquake effects on lifelines.
- The 1987 legislative appropriated funding to the State Superintendent of Public Instruction to perform a study of public education buildings.

STATE OF HAWAII
EARTHQUAKE PREPAREDNESS PROGRAM
RESEARCH APPLICATIONS

BY

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Background

In 1979 the Federal Emergency Management Agency (FEMA) awarded the State of Hawaii a contract to undertake an earthquake loss study and a subsequent contract in 1981 to define secondary threats and credible "surprises" unique to an earthquake event in Hawaii. Prior to this time, earthquake planning was addressed in more general terms, that is without specific contingency plans or detailed preparedness procedures. This is understandable when one considers that previously recorded earthquakes occurred before the mass construction of high-rise structures on the island of Oahu and that a Seismic Probability Zone 1 had been assigned Oahu, indicating the expectancy of only minor damage occurring.

Notwithstanding, the 1979 initial planning efforts were reinforced when the FEMA funded studies concluded that an earthquake of sufficient magnitude could occur along the Diamond Head Fault or the Molokai Seismic Zone causing considerable destruction and loss of life, especially in the downtown area of Honolulu and in Waikiki. (This conclusion was based upon earthquakes detected by ocean bottom seismographs and temporary land based seismographs deployed for a short period in the late 1970s.) This further highlighted the need for earthquake plans and mitigation strategies.

Accordingly, FEMA funds were made available to develop earthquake specific plans and procedures at the State and county level, plus a viable earthquake preparedness program to include the private business sector and lifeline utility systems. Fiscal year 1987 marked the transition in program development from early technical analysis to preparedness planning and the adoption of mitigation strategies.

Research Application Efforts

The planned purpose of the initial research application was to provide a rational basis for the preparation of earthquake contingency plans to facilitate disaster response and recovery operations in the Honolulu area should a destructive earthquake occur. The perceived needs stemmed from a joint concern on the part of Civil Defense authorities and seismologists that insufficient attention had been given to the problem of seismic risk in the State of Hawaii and in particular metropolitan Honolulu. "A Study of Earthquake Losses in the Honolulu Area: Data and Analyses," was then published in 1980 as described above. The "1980 Study," as it is referred to today, is the only overall earthquake hazard vulnerability analysis unique to the Honolulu area.[1] It serves as the technical basis and accreditation for the State preparedness program and attendant plan development process.

Principal consultants to the "1980 Study" were Dr. A. S. Furumoto, a seismologist and geophysicist at the University of Hawaii's Institute of Geophysics; also Walter Lum, N. Norby Nielsen and James T. Yamamoto, all of engineering backgrounds. Dr. Nielsen is also on the faculty at the University of Hawaii. All four co-authors are widely recognized authorities in their fields.[2]

A follow-on study which further enhanced the knowledge base was published in 1982 by Karl V. Steinbrugge and Henry J. Lagorio titled, "Earthquake Vulnerability of Honolulu and Vicinity: Secondary Threats and Credible Surprises." Referred to as the "1982 Study," this publication not only expanded the initial effort but fully endorsed the work of Furumoto and his colleagues, thus adding to the accreditation.

The first product of these research studies was published in 1983 in the form of an Earthquake Response Planning Guide for the State of Hawaii. Together these documents became the linchpin in the development and coordination of all earthquake preparedness plans and programs throughout the State.

The Legislative Process for Achieving Earthquake Hazards Reduction

It is interesting to note that in the "1982 Study," the following discussion of seismic zoning and building codes for Honolulu appears in the report:[3]

> . . . Conversations with the building officials of Honolulu confirm that Honolulu has used the "Uniform Building Code," including its earthquake provisions, for many years. For well over a decade, the "Uniform Building Code" has placed the island of Oahu in earthquake zone 1, and Honolulu buildings have been legally required to meet not less than Zone 1 seismic forces. It should be added that local adoption of the "Uniform Building Code" is at the discretion of the local governmental authorities, and not by Federal law. The earthquake provisions in the current Honolulu code apparently have the tacit concurrence of the majority of the design professionals and construction organizations.
>
> Complete concurrence has not been universal, nor is it today. "A Study of Past Earthquakes, Isoseismic Zones of Intensity and Recommended Zones for Structural Design for Hawaii" by Furumoto, Nielsen, and Phillips (1972, Center for Engineering Research, University of Hawaii) is instructive in this regard. Two of its authors (Furumoto and Nielsen) and that report's financial sponsor (Walter Lum and Associates) were also co-authors of the "1980 Study." We find on pages 43 and 44 of this 1972 publication:
>
> > . . . As far as actual design practice, we find that there is quite a variation in the design criteria used in determining the lateral loads. For example, Oahu, according to the "Uniform Building Code," is presently in zone 1. Nevertheless, a good many of the structural

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> engineers in Honolulu will routinely use the lateral force requirements specified for a zone 2. Moreover, all structures funded by the Department of Accounting and General Services, State of Hawaii, must be designed according to zone 3 requirements. This is specified in the "General Requirements for Consulting Services Contracts" by the Department of Accounting and General Services in item 5, "Consultants shall base structural design computations for seismic loads on zone 3."
>
> It is worth noting that this requires all State funded buildings to be designed according to zone 3 requirements, notably, all public school buildings are designed to meet zone 3 criteria.

If experience elsewhere is any indication, extreme economic pressures on the owners of speculatively constructed buildings have forced those to be designed to minimum code standards, namely zone 1. With notable exceptions, these are habitational such as hotels and condominiums, warehousing, industrial tracts, and the many instances where the owner plans for near-term resale. Many buildings in the tourist areas of Honolulu are therefore suspect in this regard . . . .

In concert with the above discussion, a bill designed to enhance the seismic zoning and earthquake resistant building requirements of Honolulu was introduced during the 1983 State legislative session. It was emphasized that Hawaii was in an area of more frequent earthquake activity than had previously been estimated and through convincing testimony, logic and technical evidence, it appeared the bill would be placed on the calendar for Third Reading and become law; however, this was not the case. Despite the persuasive testimony presented for enacting the bill, special interest groups were brought to bear during the legislative process and the bill died in committee. There has not been a similar effort since!

FOOTNOTES

1. *Earthquake Vulnerability of Honolulu and Vicinity: Secondary Threats and Credible Surprises*, 1982, Karl V. Steinbrugge, Henry J. Lagorio, page 6.

2. Ibid.

3. Ibid., page 9.

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Research and It's Application: The Case of NSF-Sponsored Planning and Policy Research in Alaska

By

Lidia L. Selkregg, Professor Emeritus
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Study Under Review: Seismic Hazard Mitigation Planning and Policy Implementation: The Alaska Case, Lidia L. Selkregg, (Principal Investigator) Richard L. Ender, Stephen Johnson, John Choon Kim, Susan Gorski, Jane Preuss, and Duncan Kelso, (NSF/CEE-84045)

The original time frame for the completion of the study was from September 1981 to September 1983. An extension of time to April 1984, was needed to complete the review, editing and printing.

The intent of the research was to present a full review of the recovery process that occurred after the Alaska earthquake, to assess the present status of the cities that had been affected by the earthquake, and to evaluate the success of the application of studies conducted and recommendations made by the National Academy of Sciences to insure that long range risk mitigation and hazard prevention methods would be applied to urban development. Study objectives also included recommendations for the type of actions needed to eliminate deficiencies found in the political and administrative processes, based on the expertise obtained since March 1964 in earthquake prediction, and seismic hazard mitigation and management throughout the country. The research was considered necessary in response to the general awareness that many of the original recommendations directed to development of "high risk areas" had been disregarded by local governments.

The research team included expertise in the fields of geology, planning, public policy and administration and political science. The principal investigator has first hand involvement with the recovery programs applied after the March 27, 1964 earthquake. As a practicing geologist and planner, the principal investigator was among the first professionals that assessed damages and organized recovery programs for the various communities effected, immediately after the earthquake. Throughout the years as a member of the Planning and Zoning Commission and the Anchorage Municipal Assembly, the principal investigator had closely followed the administrative and political processes that had affected the development and application of risk mitigation procedures. The composition of the team was directed by the intent to review the Alaska Earthquake from the physical, social,

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political and administrative standpoints and to provide recommendations for potential administrative changes.

Along with evaluating the recommendations made by the National Academy of Sciences and by task forces appointed immediately following the disaster, teams of researchers visited the various communities to conduct interviews with key players in the preparedness system. Telephone interviews complemented on-site efforts. These interviews played an important role in renewing awareness of earthquake risk and its consequences among the general public and policy makers.

The research reaffirmed the assumption that the development and implementation of hazard reduction policies and regulations involves actions of many players -- legislators, planners, administrators, physical/social scientists and practitioners and concerned public. It also stressed the fact that implementation of hazard reduction systems depends on the effectiveness of the administration charged with its management and legislative ability to finance, apply and enforce. The study suggested that federal and state governments failed to recognize the role of an informed public, and as well as recognize the level of organizational efforts necessary to create the incentives in local governments. The study suggests the need for development of national and state-level policies either through strong legislative directive or through a public education process to address these shortcomings. Executive action in terms of leadership was shown to be critical at all times during the response and recovery phases. Risk mitigation rarely has an organized constituency, though usually has opponents who can successfully organize and block action. Without strong political leadership at the top little or nothing is accomplished to protect the public. These findings prompted the development of strong recommendations directed to overcome the obstacles encountered in the application of available scientific research data and to the development of sound disaster reduction management programs.

Dissemination of the research results has been impressive but still incomplete. Only 200 copies of the report were printed reducing the number of copies available to the public. The study has been well received in Alaska and reviewed favorably by many in the fields of geology, engineering, political sciences, economics, public administration and education. It has been used as background by researchers, writers, and practitioners. The recommendations have resulted in actions by legislators, public administrators and the public. However, because Alaska has a very transient population, and politicians at the state and local level have a short tenure, public education must remain an ongoing goal to maintain this increased level of interest. To insure this, the University of Alaska in cooperation with the Division of Emergency Services has developed a series of seminars on Risk Management attended not only by staff of federal and state agencies, but also by interested public, students and local government staff. These educational programs have already generated interest for the development of an Earthquake Safety education program directed to the business community for the development of a safe workplace. As stated in the justification of a grant to the Department of Health and Social Services, "This project would expand the current view of earthquake mitigation strategies in Alaska by focusing on a large, at risk population, the employee." The director of the program has participated in the University Risk Management seminars and has become aware of such a need.

Another educational contribution has been the preparation of a number of papers and articles aimed at education of public administrators. Examples include a case study, "The Turnagain Slide", Richard Ender, Lidia L. Selkregg and John Choon Kim for publication in Crisis Management - A Case Book, Michael Charles, ed., 1987, Charles C. Thomas Publishing; and "Approach to Risk Management for Natural Disaster Mitgation Policy Implementation," by the same authors for publication in Managing Disaster, Louise Comfort, ed. 1988, Duke University Press.

Turning to other recommendations, the call for the establishment of a Seismic Safety Commission is being implemented. A proposal prepared under the auspices of the Alaska Division of Emergency services is now before the Governor for his consideration in the form of more comprehensive Natural Hazards Safety Commission which will incorporate seismic issues consideration.

Another recommendation made to develop guidelines for defining high seismic risk areas as standards for state and local earthquake zoning and for land use decision has received the attention of the Anchorage Planning Department, and Building Safety Division. The amendments to Title 23 of the Uniform Building Code passed in July 1986 contains amendments requiring geotechnical site investigation criteria (GSIC), prior to construction in specific high risk zones.

Staff of various municipalities use the information presented in the study as a background for presentations to the planning and zoning commission and city council. The public has used the report for preparing presentations, and persuing legal action to prevent development in "high risk" areas. An example is the action of the public in trying to prevent development in the Turnagain Slide area.

The following by Ervin Paul Martin, Director of the Alaska Division of Emergency Services is representative of comments made by users of the study: "Overall, the Alaska Case provides an excellent blueprint of where state and local government should direct efforts relating to seismic mitigation. Specifically, we have increased our attention and participation in interagency coordination relating to Public Administration/Current Management Concepts of Risk Mitigation and promoting the recommendations regarding the Administration and Political Implementation

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Strategies as put forth in your study..." "The Alaska Case is a reference document which we refer to in making our progress on mitigation efforts. Long-range planning is essential for public policy implementation. The study provides milestones to measure our progress."

One of the problems encountered is the lack of availability of the report. To be effective copies should be available in every legislator's office and every school library in Alaska. The grant application had not considered the importance of public information seminars during the preparation and at the completion of the report, therefore, formal communication with the public to review findings and recommendations did not occur. Luckily, feature articles published in 1984 as part of the 20th anniversary of the Great Alaska Earthquake in the University of Alaska's "Magazine" (Volume 2 Number 2 - Winter 1984) and in the Alaska Academy of Engineering and Sciences (Number 3 - December 1983) along with Press interest at that time, assisted in the dissemination of the knowledge and recommendations presented in the report.

The fact that four of the researchers were professors at Alaska Institutions, teaching in the fields of applied sciences, planning, public policy, public administration and political science, and active in the community, allowed for communication with students, other colleagues and practitioners in the fields involved in the research.

As stated, the actual task of data collection and interviews created a heightened awareness of risk and mitigation issues. The act of doing the research itself had an impact in addition to the information gained.

Much remains to be done. The study has acted as a catalyst in a long incremental process. Public action continues to take place disregarding public risk. On balance, however, public awareness and education has increased, and local and state action, particularly executive and administrative has been more supportive of risk mitigation and disaster preparedness since the study's publication.

RESEARCH APPLICATIONS IN RESPONSE AND RECOVERY PLANNING

By

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This paper surveys some research applications that have influenced earthquake response and recovery planning in California since 1981, with particular emphasis on work at the state level.

Earthquake preparedness planning in California since 1981 has had a continuous focus previously absent except for a few years following the 1971 San Fernando earthquake. To a considerable extent that sharpened focus resulted from an important research application, namely the publication in late 1980 of a report by the Federal Emergency Management Agency and the National Security Council assessing the probabilities and level of preparedness for a large-magnitude earthquake in one of the state's metropolitan areas.

The 1980 FEMA/NSC report drew upon research studies that attempted to assess: (1) the long-term potential for earthquakes along California's principal fault systems and (2) loss-estimation studies undertaken by the National Oceanic and Atmospheric Administration (NOAA), the insurance industry, and post-earthquake investigations conducted by the Earthquake Engineering Research Institute. Interestingly, only the work on long-term earthquake potentials can be characterized as "new" knowledge. The other data, particularly the NOAA studies, were already widely known within the professional earthquake community.

At least two factors combined to make the 1980 report have a more tangible impact, or application, than previous efforts. First, in California a Seismic Safety Commission had been created in 1975 to provide policy advice to the Governor and Legislature and, in general, to serve as a catalyst for earthquake-related programs. Officials of the Commission worked with federal agencies in the development of the 1980 FEMA/NSC report. They sensed that this new report might serve as a spur for additional state funding to support earthquake safety planning. Indeed, legislation to provide the state funding for what became SCEPP was introduced in California even before the publication to the FEMA/NSC report.

A second factor influenced the favorable enactment of AB 2202, the initial funding bill for the Southern California Earthquake Preparedness Project (SCEPP). 1980 was a time of serious financial constraints in California. The impacts of Proposition 13, enacted in 1978, were being directly felt by the state. Legislation like AB 2202, that included a $750,000 state allocation to establish SCEPP, faced a problematic outcome. But 1980 was also a presidential election year. Jerry Brown, the California Governor, was rival of President Jimmy Carter for the Democratic nomination; for a brief time the anticipated publication of the FEMA/NSC report became an item of presidential politics.

The FEMA/NSC report has been commissioned by President Carter in May 1980 in the aftermath of the Mt. St. Helen's disaster. The report contained implicit criticism of the State of California, and indirectly it's Governor, for inattentiveness to earthquake preparedness. Governor Brown was anxious to defuse such criticism and, in a flurry of activity, lent his support to AB 2202 and set in motion the processes that led to the creation in early 1981 of a Governor's Task Force on Earthquake Preparedness.

Clearly the research findings embodied in the FEMA/NSC report gave the study it's essential credibility. Nevertheless, the political context was crucial in the successful translation of this report into public initiatives. Neither the legislature nor the Governor were persuaded to appropriate $750,000 because they were swept away by the logic of the research results embodied in the report.

The credibility of the FEMA/NSC report has remained an essential component in California's earthquake program. The report's essential findings have remained largely unchallenged since 1980, though the loss-estimation studies have required reconsideration. Equally important, the report was presented in a clear, brief style that readily translated into public awareness programs. The National Security Council involvement with the report eventually sparked commitment by the Department of Defense to seismic safety planning for their facilities and personnel in California.

A second major event in research application in support of preparedness in California came with the publication in early 1982 of the first scenario report by the California Division of Mines and Geology. As mentioned previously, Governor Brown had established a statewide Task Force on Earthquake Preparedness in early 1981. The task force faced a fundamental dilemma of determining, with some specificity, what was meant by the term "catastrophic" earthquake.

Under the auspices of the Task Force, and with the support of the Office of Emergency Services, the state Division of Mines and Geology began work on the first of what is to date a landmark series of four, soon to be five, reports that estimate the impacts on lifeline systems from large-magnitude earthquakes.

These scenario reports drew upon the latest research in estimation of ground shaking and its effects on lifeline systems, including transportation, communications, water, electrical power and gas. Again, utilization of this current research from many disciplines provided an essential credibility to the documents.

But other factors, unrelated to research, were equally important in the successful utilization of the scenario reports. First, the existance of SCEPP and the growing momentum for earthquake preparedness in California meant that there was an audience eager to utilize the results in an immediate, specific way as an aid in planning. Second, the personal interest of the state geologist in earthquake hazards assessment was invaluable in ensuring that the scenario reports would be completed in a timely fashion. This same individual's expertise meant that some of the most respected technical professionals were willing to lend their assistance to the development of the scenarios would be made available to the press and public. Indeed, the most valuable part of these scenario reports has been the fact that they are part of the public record and have received widespread dissemination throughout California.

Work on the scenarios has continued since 1982. Both SCEPP and BAREPP have added supplemental material to the scenarios and have worked to tailor them to individual local jurisdictions as an aid in preparedness planning.

At least one research effort, sponsored by the Task Force concurrently with the scenario studies, failed to impact preparedness planning. This effort addressed detailing economic empacts on various sectors of California's economy. The results of this work, which utilized elaborate input-output economic models, were confusing and complex. Disagreements among economists as to the efficacy of the model destroyed credibility; the sheer complexity of the reports dulled the intellect of all but the most passionate disciples of the "dismal science".

More recently two other research efforts have directly influenced response planning in California, though the applications process is still underway. The Mexico City earthquake has been widely assessed by investigators from both public and private organizations. Indeed one index of the burgeoning earthquake community in California is the number of local jurisdictions and private companies that dispatched their own investigation teams to Mexico City as well as providing one of the team members for the National Academy of Sciences investigation team.

The research into the Mexico City earthquake resulted in fundamental changes in California's earthquake response strategies. The most notable changes, embodied in the recently adopted Southern California Earthquake Response Plan, are in the emphasis on a more rapid response and the essential need for development of a rapid regionwide portrait of what has occurred so that response priorities can be established.

On-going work on applying research findings relate to studies on the search and reduce experience in Mexico City and the work on fire spread modeling that employs techniques developed in Japan. The Office of Emergency Services and the U.S. Forest Service are sponsoring a three-day workshop in July 1987 to hear directly from researchers in these fields and then consider how these findings should influence response strategies and operational procedures for the fire services at the time of a major regional earthquake in California.

The occassions of rather direct application of research findings to response and recovery planning referenced above both overestimate and underestimate the overall importance of research in the development of response policies and strategies. The instances cited overestimate the importance of research by suggesting that research results are prerequisite to change. Such is not the case, with many applications coming from the everyday experiences of professionals in emergency management, legal requirements, or the evolution of systems developed over time. By contrast, the work of the research community is widely known, reviewed and discussed by the staff involved in California's earthquake preparedness programs. Many of the staff have advanced degrees and are closely familiar with the research in several disciplines. They participate in conferences, review research proposals and generally monitor

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research activity. At least in the area of earthquake prediction and its public policy applications in California, the practioners have made direct influence on how research findings are to be used on a real-time basis to affect public policy. This process results in a continual dialogue between the practioners and the research community that is valuable and interesting, though not necessarily resulting in direct transfer of research findings.

Response and Recovery Planning with Consideration of the Scenario Earthquakes Developed by California Division of Mines and Geology

by
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Introduction

Planning for an uncertain future event is difficult in any case. Planning for an elusive catastrophic event, one which only happens every 140 years, one which could occur today or 50 years from today, is even more difficult. Planning for this event knowing only that its magnitude may exceed that of any prior catastrophic event to hit the United States is extremely challenging.

The magnitude of the task became readily apparent through research reported in two publications. First, in 1980 the Federal Emergency Management Agency (FEMA) and the National Security Council (NSC) published an assessment of the probabilities and level of preparedness for a large-magnitude earthquake. Second, in 1982 the California Division of Mines and Geology released Special Publication 60, which gave emergency planners the data needed to convince a multitude of audiences that they face horrendous problems that will affect everyone personally. Anyone who uses water, electricity or natural gas, telephones, freeways, banks and automated teller machines, hospitals or paramedics, will be affected.

Special Publication 60 made the 8.3 earthquake on the southern San Andreas fault REAL for Southern California. It provided a convincing basis for the horror stories of a major earthquake's potential impacts. It provided three invaluable tools:

1. A planning tool--with better data for decision making.
2. A marketing tool--to sell planning, mitigation and preparedness measures.
3. A basis for further studies.

This paper will outline several, but not all, of Los Angeles' responses to the availability of this tool. Los Angeles is attacking the earthquake hazard on a number of fronts, with a variety of programs. We do as much as can be done with the available resources. We face a sobering reality when we who are in the emergency management business hear the scenario that has been written for the southern San Andreas and learn that the potential losses total $17 billion in property damage and 3,000 to 14,000 lives. Knowing that this kind of threat exists in our backyard, it lurks constantly in our minds. And it affects all of our emergency planning efforts.

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What was attempted?

A whole series of actions have been taken beginning in 1980 to enhance response and recovery planning and capabilities in Los Angeles. Activities have been undertaken to achieve each of the following objectives:

1. Increase public officials' awareness and commitment
2. Increase public awareness and cause individual preparedness actions
3. Increase business and industry awareness and preparedness actions
4. Try to foment interagency coordination and regional planning
5. Create a more effective response organization in the City
6. Create a longterm recovery strategy for the City.

What happened? And why?

Progress has been achieved in each of these areas due at least in part to use of the tools provided by Special Publication 60. Many successes can be documented illustrating the impact on local government policy makers, public perceptions, and the local business community as well as emergency planners and responders. The specific activities which will be addressed in this paper are in the areas of:

- Exercises and Drills
- Budgeting for Response
- Earthquake Prediction Response, and
- Recovery and Reconstruction Planning.

Exercises and Drills

The City's emergency planners discovered in Special Publication 60 the perfect scenario for the practice of interagency coordination during tabletop exercises. Finally we had some insight into actual expected damage patterns, particularly to our principal lifelines. The types of problems that will confront us began to take shape. The need for integration of planning efforts by public and private entities such as utilities had also become self-evident. Both our plans and our exercises and drills to test those plans became more realistic and credible.

Our warnings to public officials, business leaders, and the public at large about how quickly our resources will be overcome in the immediate aftermath of the big earthquake have come to be taken more seriously. This improved the effectiveness of our efforts to reach the public through the media and to reach our public officials through the budget process. For example, it seemed to us that in order to interest the public in preparing for this awful, inevitable event we had to entice the media to get the word out. We needed a newsworthy story plus some fancy news footage to get much in the way of air time. So we wrote a

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scenario based on the 8.3 earthquake, we got together with our friends in show business, and we began creating and producing semi-spectacular disaster drills with the help of Universal Studio's special effects and their back lot. The media loved it.

We put together a sequence of events consistent with the after-effects of the 8.3 event and staged local government responses, highlighting some of our special capabilities such as search and rescue techniques including search dogs, helicopters, rappeling firefighting and paramedic personnel, ambulances, fire apparatus, communications systems, and in 1985, even a C-130 military air transport plane loaded with dozens of moulaged victims. The media's response was extremely positive: they learned something about our response, they showed footage of the events, and they followed up by broadcasting discussion of emergency preparedness needs. And what started as a fledgling effort in Los Angeles turned into an annual Statewide event involving the Governor, the Governor's Office of Emergency Services, SCEPP and BAREPP, and a growing contingent of emergency planners and responders the length of the state. Local, national, and even international coverage has occurred at these events for four years, and this has helped us to educate citizens as to the threat, our response, and what they need to do to be prepared.

Budgeting for Response

The scientific basis for our earthquake scenarios helped the City's emergency planners convince the public policy makers that it was in their interest to make some difficult decisions in the budget process to improve our emergency communications and response capabilities. In the spring of 1986 the Mayor and Council unanimously approved a $4.4 million command/control/communications equipment package to be acquired through a multi-year financing package. In the words of the Council's Finance Committee Chairman, the equipment "will bring us into the 21st century as far as emergency preparedness is concerned...This will take us to a new level of sophistication." The package, requested by the City's Emergency Operations Organization, was approved because the City officials could understand the need for secure communications systems, rapid observation and situation assessment capabilities, and interagency coordination of the deployment of emergency response and rescue crews.

Earthquake Prediction Response

In addition to improving our ability to assess and respond to an emergency or disaster situation, Los Angeles has taken innovative steps to develop plans in two virtually uncharted areas: earthquake prediction response and recovery and reconstruction. The City of Los Angeles is unique among local jurisdictions in having recognized and accepted the challenge of pre-planning its response to a potential short-term earthquake prediction or advisory. The City's prediction response efforts were

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initiated by Mayor Bradley in 1977, but it wasn't until the City entered a planning partner agreement with the Southern California Earthquake Preparedness Project (SCEPP) that a functional draft of the City's Earthquake Prediction Response Plan was completed in 1983. Then City representatives at SCEPP's June/July 1985 "Message from Earth to Public" earthquake prediction workshop at Asilomar State Conference Center determined that a City workshop was needed to bring prediction response planning back to our active agenda and develop a City policy linking the actual response actions in the plan to the decision makers' policy role. SCEPP assisted in planning and presenting the City's workshop in October 1986 at Asilomar, and it was a most productive meeting. Following the proven structure and working group format utilized in previous SCEPP earthquake prediction workshops, 48 City officials with SCEPP staff support developed through discussion and concensus a draft Prediction Response Policy. Twelve major department general managers, including the Police and Fire Chiefs and the City Administrative Officer, participated.

As follow-up to the workshop, the planning team is presently: (1) completing the Proceedings to document the workshop, (2) revising the Prediction Response Plan to conform to the draft Policy and to reflect the content and terminology of the April 1987 draft Short-Term Earthquake Prediction Response Plan of the State, and (3) completing the draft Policy for presentation and final approval by the Emergency Operations Board, the Mayor and the City Council.

Recovery and Reconstruction Planning

A second area in which the City of Los Angeles is taking innovative action at this time is recovery and reconstruction. Recognizing the prevailing neglect of this planning, the City's Emergency Management Committee established a subcommittee over a year ago to make recommendations for City policy and actions. The subcommittee's efforts were boosted significantly when the City's new Director of Planning demonstrated commitment to the project and encouraged the Emergency Operations Board to support staff efforts by requesting the subcommittee, in cooperation with the Director of Planning, to develop and report back with an approach to strengthening the recovery planning process for the City. The subcommittee then held a workshop to review existing City policies and programs related to recovery including:

- The City's General Plan
- Community Redevelopment Laws, Powers, etc.
- The Building Code and ordinances
- The legislative process and State laws
- City shelter policies and programs, and
- Public Works considerations.

The subcommittee also accomplished its second objective which was to begin formulating a work plan by identifying and prioritizing immediate tasks, based on guidance provided by the Emergency Operations Board.

The subcommittee has outlined the steps in the recovery and reconstruction planning process:

1. Review of existing City policies and programs.
2. A hazards vulnerability analysis.
3. Selection of the earthquake scenario on which to base determinations of resource needs, levels and gaps.
4. Determine appropriate organizational structure to implement the plan.
5. Identify appropriate responsibilities of each division in the organization.
6. Develop a streamlined permit processing procedure.
7. Coordinate with the private sector and other jurisdictions, and
8. Develop effective utilization of volunteers.

This project was further stimulated by the enthusiastic reception by SCEPP Director Paul Flores to the subcommittee's request that SCEPP work cooperatively with the City on recovery and reconstruction issues through an informal planning partner agreement. The Emergency Management Committee members already enjoy a very positive working relationship with SCEPP through previous joint efforts, especially in earthquake prediction response. Our proposed new partnership with SCEPP has been endorsed in concept by SCEPP's Policy Advisory Board at its June workshop convened at Arrowhead to develop the Project's 1987-90 Work Program.

It is anticipated by both the City and SCEPP that the resulting recovery and reconstruction plan, as well as the process and considerations which will go into its formulation, will be of value not only to the City but to other jurisdictions facing the same dilemmas. It will provide a transferable product and form the basis for subsequent regional planning for recovery and reconstruction at a future time.

Without an appropriate earthquake scenario on which to base such planning efforts, the City of Los Angeles and other jurisdictions in Southern California would be severely hampered in their efforts to deal aggressively with the tough planning issues created by the spectre of an inevitable but ill-defined future catastrophic event.

THE PARKFIELD PREDICTION EXPERIMENT: PLANNING AND PUBLIC POLICY APPLICATIONS

By
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The Parkfield Earthquake Prediction Experiment has generated more interest and activity among seismologists, public officials, planners and emergency managers than any similar event since discovery of the Southern California Uplift. The essence of the experiment conducted by the United States Geological Survey (USGS) is to detect, through an extensive observational network, precursory earthquake phenomena at the Parkfield site and issue a short-term (72 hour) prediction for a magnitude 6 event. This effort, which would trigger a state and local response mobilization, is being pursued in the context of an announced long-term earthquake prediction for the 25 km Parkfield segment of the San Andreas fault. This long-term forecast for an earthquake of moderate magnitude near Parkfield by 1993 was announced by the USGS in April, 1985.

The prediction is based on research carried out by USGS and University of California Seismologists which indicates that earthquakes of approximately M6 have occurred at Parkfield about every twenty-two years since 1857 with the most recent one having struck on June 28, 1966. The USGS announcement was made after the National and California Earthquake Prediction Evaluation Councils reviewed the prediction and determined that it was scientifically credible. The prediction review councils were also presented with evidence that the next Parkfield earthquake could be larger than earlier events. Although less likely to occur than the predicted M6 event, an earthquake as large as 7 on the Richter Scale could strike in the Parkfield region. This larger event would result in moderate to severe shaking intensities (Modified Mercalli intensity VII and VIII) in an area containing 175,000 residents. In areas severely shaken, casualties and damage could result from partial or complete collapse of unreinforced masonry buildings, glass breakage, hazardous materials spills and the effects of unsecured building contents. The M7 event would affect parts of Fresno, Kings, Monterey, Kern, San Benito and San Luis Obispo counties.

In January and February, 1986, the USGS circulated a document entitled "Parkfield, California Earthquake Prediction Scenarios and Response Plans " (Open File Report 86-365) which outlined procedures which would be followed in the Geological Survey's attempt to issue a short-term (3 day) earthquake prediction for Parkfield. The report identified five levels of alert (E-A) based on an observational network measuring seismicity, fault creep, strain and geodetic changes. The A level alert was defined as the highest level under which the 72 hour probability of the M6 earthquake was greater than 37 percent and a Geologic Hazard Warning would be communicated to the California Governor's Office of Emergency Services. The report also indicated that in 1934 and 1966, the Parkfield earthquakes were preceded by prominent foreshock activity. In both events, M5.1 shocks occurred 17 minutes prior to the mainshocks.

The USGS experiment at Parkfield stimulated scientific, planning and response activities first at the state level, then at the local jurisdictional level. The California Division of Mines and Geology (CDMG) became a partner in the Parkfield Prediction Experiment in late 1985 under legislation which allocated $1 million dollars for participation in scientific monitoring of the Parkfield site. The Governor's Office of Emergency Services (OES), as designated recipient of a Geologic Hazards

Advisory for Parkfield from the USGS, also began a fact finding and planning effort in mid-1985. After development of scenarios for both the M6 and M7 earthquakes at Parkfield, OES established the Parkfield Response Working Group to recommend prediction response policies and procedures to the agency's director. The working group was composed mainly of OES personnel (Planning Division, Telecommunications Division, Regional Managers of Regions I, II and V and the Southern California Earthquake Preparedness Project) but included representatives of the USGS, CDMG and the six counties likely to be affected by the larger Parkfield earthquake.

The recommendations presented to the OES director in October, 1986, included adoption of a policy statement which affirmed that OES would participate in the Parkfield Experiment and develop plans for response consistent with the larger M7 earthquake. In addition, OES was advised to implement procedures for the agency's Sacramento Warning Center to receive a Geologic Hazards Advisory from the USGS, notify the six affected counties and initiate an internal OES mobilization. The recommendations also called for a short-term prediction response role for CDMG; a request for CEPEC review of the USGS procedures for issuing a short-term prediction; consideration of prediction-related legal liabilities by the Attorney General's Office; initiation of a public information and awareness campaign; promotion of local government prediction response planning; and, the conduct of a Parkfield prediction communication and response exercise. As of mid-1987, all of these recommendations have been implemented or initiated.

The primary objective of this paper is to identify and explore planning and policy applications generated by the Parkfield Prediction Experiment which have had, or are likely to have, a lasting impact on California's Earthquake Prediction Evaluation, Warning and Response System. Any attempt to document lessons learned from the Parkfield Experiment at this stage must be attended by the caveat that the views presented are those based on current participation, not hindsight. Thus far, the experiment has not generated a short-term prediction and many pieces of the planning puzzle are yet to be set in place. Ultimate success or failure of the prediction will, in all likelihood, produce lessons which are far more profound than those presented here.

Public Policy Impact of the Parkfield Prediction Experiment

Scientific earthquake prediction in general, and the Parkfield Prediction Experiment in particular, are both research and needs driven. In Parkfield, the strictly scientific objective is to identify short-term precursory earthquake phenomena and gain a better understanding of earthquake occurrences through observation and recording of an actual earthquake sequence. Even if the USGS is unable to issue a short-term alert, it is assumed that valuable data will be obtained which will contribute to a fuller understanding of earthquake foreshocks, fault creep, strain and geodetic changes. Success at measurement of these phenomena will significantly affect the development and further application of the prototype earthquake prediction network operated by the USGS.

The ability to detect in advance various types of precursory earthquake activity also has obvious public safety implications. The long-term prediction of an earthquake in a particular region should trigger the initiation or intensification of efforts to mitigate earthquake hazards and prepare for the event. A short-term forecast, such as the one anticipated for the six county Parkfield region will signal the implementation of an intricate state and local government response effort. Actions to be taken during the 72 hour warning period include notification of the affected counties by OES, county activation of the Emergency Broadcast System and issuance of a public warning announcement, mobilization of response personnel and implementation of pre-established response procedures (e.g., activation of emergency operations centers, movement of fire and rescue equipment from structures, declarations of local emergency, media briefings, etc.). Thus, the cooperation of scientific investigators and response agencies has generated a melding of basic research and action in the public interest. Much of what has been learned in conducting the Parkfield Prediction Experiment has been, or could be, applied in other situations in which earthquake hazards are detected sufficiently in advance to provide at least short-term warning.

The circumstances under which an earthquake can be predicted and response planned and executed will vary depending on many factors. Nevertheless, it seems abundantly useful to preserve the potentially transferable planning lessons associated with the Parkfield experiment for future application. These lessons touch many aspects of prediction from scientific review and evaluation of predictions to the timing of notification and response.

1. Techniques to Expedite Prediction Evaluation and Warning

A potential short-term prediction at Parkfield presented a dilemma for response planners: how could the California Earthquake Prediction Evaluation Council, consistent with its mandate, provide both an adequate evaluation of short-term precursors and render a decision quickly enough to ensure a timely warning and response effort? This dilemma was exacerbated by the fact that foreshocks which would trigger an imminent alert situation might precede the mainshock by twenty minutes or less. Clearly, CEPEC, as a deliberative scientific body, was ill equipped to render a decision on the validy of the prediction under such severe time constraints.

The proposed solution, later approved and implemented, was for OES to request a review, not of the actual prediction once issued by the USGS, but rather of the procedures and decision rules used by the Survey to conclude that a Parkfield earthquake was imminent. Thus, review and "pre-validation" of a short-term prediction for Parkfield was designed to facilitate a more rapid warning and response by eliminating an obvious source of delay. This action did not mean that CEPEC was removed from a continuing role in the Parkfield Prediction. The Council was instructed to continue monitoring the situation at Parkfield and provide periodic briefings to the OES executive staff.

The "pre-validation" of short-term earthquake predictions may have limited application beyond the special circumstance of the Parkfield Prediction. Indeed this procedure may remain unique to Parkfield for some time given the state-of-the-art of earthquake prediction. Nevertheless, the issue of a rapid yet adequate prediction evaluation has been raised and must be resolved if short-term prediction response is to be effective. In the recently completed Short-Term Earthquake Prediction Response Plan for the State of California (Center for Planning and Research, 1987), the evaluation issue was discussed and a procedure recommended. This procedure assumes that a short-term prediction will be evaluated after it is issued but under special circumstances designed to expedite consideration. When OES becomes aware of a scientifically formulated earthquake prediction, contact with CEPEC is to be initiated immediately beginning with the Chair, then Vice Chair or any member should these two individuals be unavailable. This first contacted Councilmember may, after consideration of the information provided, declare the prediction valid and advise OES to initiate response actions. Other options include further Council contacts and/or declarations that the prediction not be regarded as valid or that further study is needed.

Prior to initiation of the Parkfield Earthquake Prediction Experiment, California's formal procedure for evaluation of earthquake predictions was inadequate for review of very short-term announcements. To convene a council of scientists in one location, review the data and render a decision regarding validity was inconsistent with a rapid warning and response mobilization. The Parkfield prediction made it necessary for scientists and seismic safety planners to devise new procedures to handle imminent alert situations. While yet untested, the system now in place at Parkfield should allow an Earthquake Hazards Alert to pass from scientists at the Parkfield site to members of the public in the affected six-county region within twenty minutes.

2. Professional Socialization within Key State and Federal Agencies

The Parkfield Prediction has compelled scientists, seismic safety planners and emergency managers to interact with one another at a level of detail seldom, if ever, experienced within the agencies they represent. While this interaction has not always been harmonious, it has served to socialize key functionaries through recognition of interdependencies, development of mutual respect and the reduction of disciplinary and organizational parochialism. The key organizational actions in the prediction planning effort are the United States Geological Survey, the California Governor's Office of Emergency Services, the California Division of Mines and Geology and the two prediction evaluation councils (the National and California Earthquake Prediction Evaluation Councils). At least two factors have contributed to the need for close organizational interaction in the Parkfield planning effort.

The possibility that the earthquake at Parkfield could be larger than the characteristic M6 and cause casualties and damage in cities and unincorporated areas within the six-county Parkfield region was perhaps the most compelling factor. Although the probability of an earthquake as large

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as M7 was considered slight by scientists, a CEPEC review resulted in the recommendation to OES that a larger earthquake was "sufficiently probable" to warrant planning actions consistent with an event of M7. The obvious significance of the larger earthquake is in the level of cooperation required if notification and warning are to be rapid and effective. In addition, the continued provision of public information, updates and rumor control are dependent upon a close working relationship between scientists and response officials. Perhaps the most important contexts in which this socialization process occurred were the Parkfield Response Working Group (established by OES) and the various meetings in which scientists and planners were required to explain the experiment to local residents, public officials and members of the news media. The Parkfield Response Working Group provided a source of ongoing contact between USGS and CDMG scientists on one hand and state and local emergency managers on the other. In a milieu of occasional heated debate, all agencies involved in the Parkfield Prediction made their interests and constraints known to other participants, and ultimately, solutions to issues of mutual concern were developed.

The second major factor which engendered a close intergovernmental working relationship was the recognition of the importance of the experiment to all agencies involved. The USGS clearly regards the Parkfield Prediction Experiment as a key element of its earthquake program, one which will have a profound impact on funding for continued prediction related research. It hardly requires mention that organizational prestige and individual scientific reputations are also at stake. For OES, there is the mandate to ensure public safety as well as the desire of key executive staff to respond to advances in science and technology with parallel development of new planning and public policy initiatives. Local emergency managers and elected officials generally perceived the significance of participation in an important scientific endeavor. However, the lure of participation had to be weighed against the strain of expenditures for response related actions and the threat of legal liability associated with local level prediction response measures. For this reason, the potential historical significance of the experiment has been a more salient factor in interagency cooperation at the state and federal levels of government.

3. Issue Resolution and Structural Change

The socialization of executive as well as key staff personnel afforded by close interaction in the Parkfield Prediction Experiment will have a lasting impact on California's Prediction System in a number of ways. Perhaps the most important legacy of this intense intergovernmental effort is in role clarification and issue resolution. Prior to the current experiment at Parkfield, California's Earthquake Prediction Evaluation, Warning and Response System was largely untested. It existed as an elaborate set of tenuous organizational linkages based on decision contingencies at each phase in the life cycle of an earthquake prediction. As the first prediction to advance beyond the evaluation stage as a "valid" scientific prediction, the Parkfield forecast has provided the needed stimulus to clarify, modify and formalize the system.

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Perhaps the most dramatic change in the system has taken place within the Governor's Office of Emergency Services and in the relationship between OES and the USGS. OES has traditionally been reactive; that is, it has responded after the occurrence of a disaster event. Participation in the Parkfield Prediction Experiment has forced the agency to become more proactive. This more proactive stance can be seen in several actions and arrangements which are likely to continue beyond a short-term prediction for the Parkfield region.

An important instance of role clarification brought about by the Parkfield Prediction Experiment involved CEPEC. The Council was formed in 1975 under the Emergency Services Act to advise the Office of Emergency Services (OES) on the validity of predicted earthquakes capable of causing damage in California. CEPEC, over the years, has met on an "as needed" basis with sessions organized and chaired by the State Geologist. The long periods of time which occasionally transpired between meetings and the strong leadership of the State Geologist (who is also Chief of the California Division of Mines and Geology) led to some confusion both among CEPEC members and others in the emergency management community as to what CEPEC's mission actually was and to whom members reported. The sense of urgency regarding a possible Parkfield prediction led to a May, 1985, directive from OES that CEPEC begin meeting quarterly. These more frequent meetings were also attended by at least one executive level representative of OES who monitored the proceedings and periodically explained OES policy regarding prediction evaluation, warning and response.

The Parkfield Experiment and the more activist posture of the Office of Emergency Services in earthquake prediction have led to the effective reassertion that OES be the recognized point of contact in California for official receipt of earthquake predictions, forecasts and seismic hazards advisories. While university and government-based scientists have generally recognized that OES has an earthquake prediction warning as well as response role, OES has not always been informed in a timely or direct manner that a prediction has been issued. In several instances in which members of the U.S. Geological Survey have felt compelled to issue statements of enhanced seismic or volcanic risk in California, the State Geologist, local officials or the news media have been the initial recipients. As a participant in the Parkfield planning process, OES developed procedures for receipt of an imminent alert from the USGS and rapid transmission of a pre-scripted warning message to local jurisdictions in the Parkfield region. In the prediction response plans being developed by counties likely to be affected by a Parkfield earthquake, OES has been acknowledged as the only recognized source of a short-term Parkfield prediction. In recent efforts to develop a statewide prediction response plan and in local prediction response planning outside the Parkfield area, OES has similarly been designated as the only appropriate source of an earthquake prediction warning.

The Parkfield Prediction Experiment has also highlighted the role and potential personal involvement of the Governor of California in a valid scientific hazards advisory. California state law specifies that "the Governor may, at his or her discretion, issue a warning as to the existence

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of an earthquake or volcanic prediction determined to have scientific validity" (Government Code Chapter 1284, Section 955.1). The significant feature of this legislation is that a decision to warn by the Governor guarantees state agencies and local jurisdictions immunity from legal liability for actions taken in response to the prediction. To date, the Governor has not issued a warning for Parkfield. The liability issue has been the most salient one to emerge in the Parkfield planning process with local jurisdictions looking to the Governor for issue resolution. The Governor's involvement, beyond addressing local concerns with liability, would serve to enhance the credibility of the prediction and set an important precedent. In all likelihood, pressure for gubernatorial involvement will be present in future earthquake predictions as well.

The same legislation which allocated one million dollars to the California Department of Conservation for a joint state-federal scientific monitoring effort at Parkfield, also mandated the development of a short-term prediction response plan for OES and other state agencies. The recently completed draft plan is designed to provide a coordinated response to a valid scientific earthquake prediction issued for any part of the state. The Parkfield Prediction Experiment not only provided the necessary stimulus for development of the plan, it also contributed technologies and response strategies which were incorporated into the statewide plan. Several local jurisdictions have also adopted short-term prediction response checklists or plans either as a direct response to a potential short-term prediction for Parkfield or concern that such an experiment could be set up in their regions. When work began on the state prediction response plan in June, 1986, much of the scientific experiment at Parkfield was already in place and the Parkfield Response Working Group had nearly completed its recommendations for OES participation in response to a Parkfield prediction. Thus, there were procedures, planning elements and proposed resolutions to issues available and directly applicable to development of the state plan.

4. The Parkfield Region as Laboratory for Observation of Societal Response

There is a small but provocative literature on community level response to earthquake predictions. Social scientists have probed a variety of societal aspects of earthquake prediction usually without the opportunity to observe and analyze an actual ongoing situation in which a prediction has been issued. Nevertheless, historic predictions and relatively elaborate prediction scenarios (Mileti, 1981) have served as a basis for analysis of the political and socioeconomic impact of scientific predictions, community attitudes and beliefs about predictions and both organized and emergent community response to prediction announcements. Unfortunately, the Parkfield Prediction Experiment has not generated a wealth of interest and proposed projects among social scientists.

On a superficial level, there is the rationale that there is very little societal response to measure, given that the area of probable impact is sparsely populated. It might also be argued that the impact of the characteristic Parkfield earthquake is likely to be minor and the threat of such an earthquake among a population which has experienced numerous small

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tremors over the years is unlikely to raise an eyebrow. Some researchers may feel that the changes which have occurred at the policy and organizational levels of decision-making are more compelling topics of research and analyses. Whatever the rationale for diversion of attention from community level response, it will be regrettable if this aspect of the Parkfield prediction remains unresearched.

A number of themes might be suggested. The Parkfield situation offers an opportunity to study various aspects of earthquake culture or subculture. There is some evidence (Turner, 1981) that distinctive patterns of awareness and threat perception emerge in zones and regions which have been assigned special earthquake significance by the larger community. These subcultures develop around earthquake experience and perceptions of local hazard vulnerability. They are maintained and transmitted to those who have not directly experienced a local earthquake event through word of mouth and the mass media. Whether the Parkfield region constitutes a distinct earthquake subculture is an empirical question. Given the earthquake history of the area, the current scientific effort and news media coverage of the prediction, it is likely that one exists. What are the elements of this culture? How might it contribute to, or detract from, an adaptive response to a short-term prediction? Does the presence of an earthquake culture have an impact on receptivity of communities in the Parkfield region to appeals for preparedness and mitigation activities?

Parkfield offers an opportunity to closely observe and analyze the effects of a short-term warning announcement on community activities and beliefs. Currently, Parkfield is under a long-term alert which was publicly announced in April, 1985. While systematic studies of socioeconomic impact have not been undertaken, there have been few indications that the announcement has had a significant impact on the local economy or on population movement. However, a widely publicized 72-hour warning for an earthquake which could measure 7 on the Richter scale might stimulate substantial activity in the region. How will this warning be perceived? What actions will it generate within communities identified as vulnerable? Given the possibility that a warning may not be followed within 72 hours by occurrence of the predicted earthquake, will "false alarms" have a significant negative impact on response to subsequent warnings?

While other themes and research agendas could be mentioned, the point here is that the Parkfield Prediction Experiment provides an important social science research opportunity. From a research applications standpoint, it is important that this opportunity not be missed. Historically, the work of Sociologists, Political Scientists, Anthropologists and others has served as an important basis for planning and policy decisions in the emergency management community. It is clearly in our collective interests that this important contribution continue.

Conclusions and Implications

Clearly, the observations and actions documented in this paper do not represent a simple straightforward application of research funded under the National Earthquake Hazards Reduction Program. The conduct of scientific research should be expected to produce both anticipated and unanticipated or unintended results. Aside from those outcomes which are the stated goals of research, scientific work may become the basis for procedural or technological innovation, realignment of organizational functions or roles or the definition of new research agendas. The Parkfield Prediction Experiment, with its scientific goal of detecting precursory earthquake related phenomena, has generated a wealth of "applications" which were hardly anticipated by the USGS at the outset of the study. Fortunately, we can report that most, if not all, of these unanticipated outcomes have been positive.

New legislative mandates and organizational changes which can be traced to the research underway at Parkfield have served to streamline and strengthen California's Earthquake Prediction Evaluation, Warning and Response System. There is now in place an intricate intergovernmental plan to respond to a short-term Parkfield prediction. Beyond the immediate warning and response needs of a Parkfield prediction, the state has developed a plan to respond to any short-term earthquake advisory within its borders. Specific elements of the prediction system have undergone important modifications: the evaluation process has been adjusted to the exigencies of very short-term predictions; both the content of, and dissemination methods for, public warning have received close scrutiny in terms of motivating appropriate response and in expediting transmission of the message; and, specific response procedures have been established for the Office of Emergency Services, other state agencies and local jurisdictions. The critical point to emphasize here is that the state has realized a significant enhancement in earthquake preparedness and response readiness as a direct or indirect consequence of the experiment at Parkfield.

Parkfield has not only provided the incentive to develop new earthquake prediction policies and procedures, it will, in all likelihood, provide an opportunity to exercise the system. Scientists estimate the probability of a Parkfield earthquake to be over ninety percent by 1993. If a short-term prediction can be issued sufficiently in advance of the event to allow a state and local response mobilization, an important and low risk (if the earthquake is the characteristic M6 event) test of the system will have been achieved. Under these circumstances, further adjustments and modifications to the system could be made bringing our response capacity into line with the demands of a prediction with greater consequences on the population and economic structure of a region.

Most scientists and response officials believe that a successful Parkfield prediction will bring about a substantial infusion of new resources into the prediction program. The most immediate manifestation of this success would be the proliferation of similar experiments in other seismically active zones. The National Earthquake Prediction Evaluation Council has already discussed potential sites for future intense monitoring. Success, however, will not mean that a new era of reliable scientific earthquake predictions is at hand. It will mark a very encouraging point of departure, not only in scientific understanding, but in planning and public policy as well.

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INITIAL PUBLIC RESPONSE TO THE 5 APRIL 1985 PARKFIELD EARTHQUAKE PREDICTION

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A. The Earthquake Prediction

The 5 April 1985 Parkfield earthquake prediction was a unique event. Scientists had collected data that led them to conclude that they could predict the next Parkfield earthquake and speak to the four elements of an earthquake prediction: time, place, magnitude and probability. The basis for this prediction was presented to the National Earthquake Prediction Evaluation Council (NEPEC) on November 16, 1984. This council reviews such predictions and evaluates their scientific merit. Additionally, on February 13, 1985 the California Earthquake Prediction Evaluation Council (CEPEC) met to evaluate the prediction. Both councils judged the scientific merits of the prediction to be sound, and on 5 April 1985 the U.S. Geological Survey (USGS) issued a public statement predicting the next earthquake in Parkfield, California. This prediction (see Appendix A) constituted a scientifically credible earthquake prediction.

B. Purpose and Method

The purpose of this research was to catalogue initial impacts of the 5 April 1985 Parkfield earthquake prediction on the members of the public in-and-around the area of Parkfield. We sought to gather information on this topic by doing field work and interviews as soon after the public announcement of the prediction as was possible, but not so immediately that people would not have had a little time to think about the prediction. We began our field interviewing approximately 2 weeks after the prediction was announced.

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Interviews were conducted on a non-randomly chosen set of Parkfield residents. The official population of Parkfield is 34. We interviewed 9 adults and 9 school-aged children. The interviews were qualitative and largely unstructured; however, some structure was imposed upon the interview format in that five routine questions were asked in reference to the prediction. These were: (1) what has changed?, (2) what is better?, (3) what is worse?, (4) what are you and others doing? and (5) what are you and others not doing?

Additionally, we conducted a review of all local newspapers (The Daily Press) from 1966--the time of the last characteristic Parkfield earthquake--through eight months after the 5 April 1985 prediction. We reviewed these papers for three things: stories about earthquakes and earthquake-related issues, stories about the 5 April 1985 prediction, and stories about earthquake and earthquake prediction research.

C. Findings and Conclusions

The findings and conclusions that can be drawn from this work are tentative because of the limited scope of the data collection effort. Nevertheless, several insights can be drawn from this research. These findings and conclusions are best viewed as grounded hypotheses induced from the limited data collected, and each is in need of more elaborate systematic investigation.

Our general conclusion regarding initial public response to the Parkfield prediction is that there was virtually no response. The prediction was issued on 5 April 1985, and it would have largely gone unnoticed by the residents of Parkfield and its environs had not national media attention been focused on the event. Locally, the

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prediction was not even newsworthy. The daily Press, the local newspaper for Northern San Luis Obispo County, for example, did not run a story on the prediction. On April 16th, 17th and 19th--all about two weeks after the prediction was issued--the paper covered earthquake stories concerning Earthquake Preparedness Week, the 1906 San Francisco Earthquake, and an earthquake drill in Los Angeles, respectively. In May of 1985, the paper ran six earthquake-related stories (on May 2, 3, 7, 10, 17 and 30th). The 17 May 1985 story covered earthquake research in Parkfield, and how the quake history of Parkfield was attracting scientists to do research. June of 1985 also saw stories published about earthquakes, but not in Parkfield. The point is that the Parkfield prediction, while the target of national newsmedia attention in April on the heels of the prediction, was not newsworthy in the local community. When a story about the prediction surfaced in mid-May, some 1 1/2 months after the prediction was issued, it focused on earthquake research and not the prediction.

The prediction did not go unnoticed by local residents. Locals learned of the prediction from the national media. The national media not only publicized the prediction, they also decended upon Parkfield to film and interview residents. They found locals, as did we, altered by the prediction in two ways. First, locals were talking more about earthquakes in Parkfield than they would have had the prediction not been issued. However, this was not the result of the prediction. It was a consequence of having the media in the area asking questions about the prediction and Parkfield earthquakes. Second, children in the local school had earthquake issues made part of their lessons. Again, however, this was more a response to national media interviews than the prediction per se; that is, lessons on earthquakes were above all else an attempt to educate children so that they might not become scared from the questions being posed by national reporters.

The significant question regarding initial public response to the Parkfield prediction, therefore, becomes why was the prediction virtually ignored. There are four answers to this question provided by the Parkfield case.

1. Earthquake Culture. An "earthquake culture" exists among the residents of Parkfield and its environs. It appears that locals have long ago--and well before the 5 April 1985 prediction--fully incorporated the earthquake hazard into their local culture, beliefs and norms. Resulting perceptions and behaviors include not only recognition and acceptance of earthquake risk, but also ideas about what to do to "successfully" live with earthquake risk and earthquakes.

Earthquakes are both experienced and anticipated by the residents of Parkfield; they are expected and defined as much as a part of living in the areas as is true for any other local characteristic. The earthquake hazard, and ideas about what to do because of it, are such a strong component of local culture that the belief system surrounding the hazard is passed on from generation to generation in much the same way as other more basic cultural traits transcend and are shared across generations.

That people in Parkfield and its environs have fully incorporated the earthquake hazard into their local culture is not a surprize. Earthquakes occur there often; for example, Richter magnitude earthquakes of approximately 6 have occurred there in 1881, 1901, 1922, 1934 and 1966. Many local residents recollect the 1966 event, and many other well-know of prior earthquakes either because they too were personally experienced, or because others have told them stories of their experiences with these historical events. It is common folk knowledge, based on the historical record of the characteristic Parkfield earthquake, that earthquakes occur every now and then, and that more should be anticipated in the future. In this way the residents of Parkfield and its environs have also incorporated earthquake prediction into their local culture; most presume that earthquakes will occur in their locale in the future. The historical track record of earthquake occurrences provide a standing folk prediction for the future that locals understand and accept.

The earthquake culture in Parkfield does more than accept and anticipate earthquakes. It also clearly defines and limits the risk posed by Parkfield earthquakes. Local residents contemplate the risk of loss in future Parkfield earthquakes on the basis of prior events experienced and recollected. Relatively recent events--recent in the sense that their intensity, magnitude and impacts are part of the collective knowledge shared by residents--have not posed a serious threat to life and property. Consequently, locals anticipate that future earthquake events will be of the same sort. For the most part, locals have adjusted to accommodate this perceived level of risk. People have, for example, kept cupboard doors tied shut in anticipation of a future earthquake and anticipated minimal damage. People take pride that their homes are able to withstand Parkfield earthquakes. People are even reassured that it's safer to live closer to the San Andreas Fault as they do because damage, in their minds, would likely be higher further away.

The Parkfield earthquake culture, therefore, fully recognizes that earthquakes have and will occur in Parkfield; anticipates future earthquakes on the basis of a standing folk prediction based on the historical record; limits perceptions of future damage in future earthquakes based on experiences with Parkfield earthquakes that are part of the local collective recollection.

Given the Parkfield earthquake culture, it is quite understandable why the 5 April 1985 prediction went virtually unnoticed by locals. One of our respondents summed up the local viewpoint: "When scientists started doing research on earthquakes around here, that meant scientists finally realized what we always knew: earthquakes happen here. When that panel of government people issued their prediction, that just meant that government finally noticed too." From a public viewpoint, the Parkfield prediction was not one cast in the model of how earthquake prediction is typically viewed by scientists, scholars and government officials; scientists find something out and tell officials who in turn inform the public; instead, the Parkfield prediction is better cast in the opposite direction. The public viewed the prediction as "they" finally noticed what we have always known.

2. Earthquake Ownership. Earthquakes and predicted earthquakes in the Parkfield area, and likely other places as well, are "owned." Parkfield residents were very familiar with their earthquake history, but they define the recent earthquake in Coalinga as Coalinga's. Conversely, Coalinga citizens recollect Parkfield's historical earthquakes as Parkfield's. People in Coalinga and Paso Robles, for example, when questioned about the Parkfield prediction, viewed the predicted quake as someone else's problem. This is unfortunate since the predicted Parkfield earthquake could cause damage in, for example, Coalinga.

It appears that the naming and labelling of earthquake predictions with the names of towns can act as a perceptual constraint to action by members of the public in other places to mitigate earthquake loss. Predictions labelled with the name of one town may actually constrain preparedness and mitigation in other towns because to so name a prediction "labels" the impending quake as someone else's problem. Initial public response to the Parkfield prediction in neighboring Coalinga and Paso Robles suggests that an alternative scheme for labeling earthquake predictions could do much to increase action by the public-at-large to prepare for and mitigate losses from predicted earthquakes.

3. Research as a Prediction. The Parkfield prediction is one earthquake-related event in a long history of such events in that area. Stories and explanations provided by many respondents suggest another reason why the prediction went virtually unnoticed by local residents. The field investigations and research carried out by scientists in the area, which provided the scientific basis for the prediction, was more the actual prediction for residents than was the prediction itself. In fact a large amount of newspaper coverage was devoted to the emerging science of earthquake prediction and prediction research long before the 5 April 1985 prediction. This coverage described at-length the scientific research being conducted to predict the next Parkfield earthquake.

Public definition of earthquake predictions may not be equal to scientific and government definition of earthquake predictions, e.g., time, place, magnitude and probability. In Parkfield, the act of stepping up highly visible earthquake prediction research was itself perceived as an earthquake prediction. If this phenomenon is

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generic, it may or may not have consequences in a community depending on the amount of earthquake culture in-place, and local perception of risk from the impending quake which was low in Parkfield. The Parkfield case, therefore, perhaps suggests a useful way to view predictions in other areas is to use the act of prediction research to help locals gradually become used to the idea that an earthquake may occur. Precluding other earthquake predictions from "falling from the blue" may be a worthwhile model that can he borrowed from Parkfield and used in other future predictions.

RESPONSE AND RECOVERY PLANNING IN ST. LOUIS*

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Social science research indicates a number of factors that increase the effectiveness of community response to and recovery from earthquakes (Mileti and Nigg, 1984). For example, effective response and recovery are more likely when tasks are clearly defined, priorities established, and responsibilities delineated. It is recommended that tasks be flexibly established so as to accommodate unforeseen contingencies (Dynes and Aguirre, 1979). Both response to and recovery from earthquakes is further enhanced when the effort is coordinated across different levels of government and all responding organizations (Dynes, 1970; Gillespie et al., 1986). Effectiveness is increased when response plans are based on knowledge of how people behave during emergencies rather than popular misconceptions and myths (Quarantelli, 1984; Wenger, James and Faupel, 1980). Finally, social science observers have noted the importance of incorporating and facilitating the work of self-help volunteer efforts (Quarantelli, 1984), especially in urban areas (Gillespie et al., 1986).

There are plans in St. Louis for response to and recovery from a midwestern earthquake. Although the area is making progress in its earthquake preparedness, it is doing so with little direct benefit of research findings and conclusions. Any direct use of scientific data in response and recovery planning appears to be rare, and the research that has been considered is mostly geophysical estimates of probable damage. Social science research seems to enter the planning process only indirectly, if at all. This greatly limits the potential effectiveness of the response planning and recovery efforts.

This paper reflects on response and recovery planning in St. Louis. The purpose is to consider conditions and practice in the light of recommendations advanced from research as a basis for stimulating ideas on ways to increase the use of research in planning for a major earthquake. The discussion here draws from (1) planning documents currently in use across the St. Louis metropolitan area, (2) a 1984-86 study of preparedness networks in St. Louis (Gillespie et al., 1986), and (3) recent discussions with several St. Louis emergency management officials.

FEATURES IN ST. LOUIS RELEVANT TO EARTHQUAKE RESPONSE AND RECOVERY PLANNING

The City of St. Louis forms a rough half circle against the western bank of the Mississippi River in the State of Missouri. Several surrounding counties in Missouri and across the river in Illinois combine with St. Louis City to make up the metropolitan area. The area has a long history of flooding because of its location near several major rivers: the Mississippi, the Missouri, and the Meramec. Also St. Louis is located in an area of high tornado occurrence. In general, both floods and tornadoes are a "part of life" in St. Louis. More recently, attention has been focused on the possibility of a major earthquake in the midwest which could have a destructive impact on the St. Louis metropolitan area.

While the general population in St. Louis is becoming more aware of the earthquake danger, it is still not well informed and very few people have taken measures to prepare for the earthquake hazard. A large percentage of residential dwellings are made of brick and mortar; many of the buildings in St. Louis City are 50 or more years old; and many home owners are without earthquake insurance. Building codes for commercial real estate do not include requirements for earthquake resistence, and therefore, many commercial buildings would be badly damaged in a major earthquake.

Politically, several key jurisdictional issues affect planning for earthquake response and recovery. Perhaps most striking, the Mississippi River, which forms the boundary between Missouri and Illinois, is like a wall between two separate disaster response systems. The two states cooperate very little. Only the American Red Cross and a few smaller voluntary organizations have a policy of "crossing the river." The recent work of the Central United States Earthquake Consortium (CUSEC) is helping to overcome this situation at the regional level (Jones, 1987), but boundary problems are equally perplexing at the local level.

There is another long-standing barrier to cooperation between St. Louis City and St. Louis County. The City is not part of St. Louis County or any other county; it exists as a totally separate political juridiction. And, at best, the City and County have an ambivalent relationship and this ambivalence has

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a long history. Despite efforts to integrate resources for response and recovery planning, City-County cooperation remains elusive. It has been more than a decade since County personnel and resources went into the City to assist with a disaster.

The City of St. Louis has a population in excess of 400,000 and the metropolitan area (including both Missouri and Illinois) has a population of approximately 2,250,000. Up until about 1980, the City had been losing population while the County had been gaining, but overall, the metropolitan area has remained fairly stable. There are an increasing number of non-English speaking people -- Indochinese, Africans, Russians, Hispanics -- but census figures are not yet available to document their number. The problem of dealing with non-English speaking people is almost completely unaddressed in the planning for response and recovery in St. Louis.

The area is racially segregated. The northern part of St. Louis City is predominantly black and the southern part is predominantly white. In the event of an earthquake, blacks probably would suffer disproportionately greater damage because they live, on the average, in more poorly constructed or maintained dwellings, carry less insurance protection, have less access to medical care, and know less about the sources of disaster assistance that are available (Dynes, 1970; Torry, 1979).

Within St. Louis County, there is still another major political issue. Some of the 90 municipalities which make up St. Louis County are in conflict with the County's Office of Civil Defense. These municipalities place a high value on local control and they do not want to relinquish responsibiltiy for their municipalities to the County. In 1985, the County proposed a ballot initiative to gain greater authority in "taking charge" of disaster situations wherever they might occur with the County's boundaries. Municipalities, acting through an amalgamated group -- The Emergency Preparedness Council of St. Louis County -- objected. The Council objected both to the intent of the resolution and to its introduction without prior consultation between the municipalities and the County office. The objection raised by the Council prompted the County to withdraw the proposed amendment in early 1986.

There is currently a proposal to redistrict St. Louis County. The proposal sets forth a plan to reduce the number of municipalities from 90 to 21. The stated rationale is to improve the business climate and increase government efficiency by streamlining the county's patchwork tax base and pattern of government. The decision to act now appears to be associated with a push by municipalities to acquire valuable, tax-producing land through annexation or outright incorporation. Municipalities have learned that they can improve their own tax base by reaching over into county land and picking up a shopping center or housing development. The county, in turn, thereby loses a piece of revenue generating real estate. The reorganization, if successful, will effectively give the county control of emergency planning and response.

While the potential for damage from an earthquake is high (Nuttli and Herrman, 1981), levels of community preparedness in St. Louis are low. Key government officials in St. Louis and the State of Missouri have begun to recognize the importance of seismic safety, but a great deal of response planning and activity remains to be undertaken (Drabek et al., 1982). As one planning official recently put it: "We have a hell of a long way to go."

ST. LOUIS PLANNING IN RELATION TO RESEARCH RECOMMENDATIONS

Social science research has shown that response and recovery are more effective when clearly defined tasks have been prioritized and responsibilities spelled out. Written plans prepared by St. Louis City, St. Louis County, the Bi-State Chapter of the American Red Cross, some of the municipalities, utility companies, and a few of the larger business concerns each put forth reasonably clear task structures with departmental and official responsibilities specified.

The problem is that coordination across levels of government and various community organizations is at an embryonic stage of development. A coordinating body called the Disaster Resource Council (DRC) has only in the past year established some loose ties between emergency managers, a few businesses, and voluntary organizations area-wide. The effort is voluntary with very limited operational funds being siphoned from St. Louis County and St. Louis City Disaster Offices. Given the history and conditions which exist in St. Louis, the DRC is commendable. But it falls far short of meeting the need to coordinate response and recovery planning for the various levels and divisions of St. Louis.

Although the need for flexibility is acknowledged by emergency management officials, the plans currently in place appear overly structured, at least as far as thinking about an adequate response to an earthquake is concerned. Responsibilities are assigned to particular officials, albeit with as many as five layers of alternates indicated in some

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plans. The legal requirements are stressed in reference to the goals or responsibilties of the particular organization. It is likely that such a rational-legal response plan is not the most appropriate way to respond to the excessive task demands following an earthquake (Dynes and Aguirre, 1979:73). Something more flexible is needed.

Gillespie et al. (1986) have drawn attention to the theoretical concept of "planned emergence." There is great fluidity in preparedness networks and the circumstances of a particular earthquake determine, in many ways, how roles knit together to form a response pattern. Planned emergence describes a system of disaster response which is a planned, yet flexible, system which can assume different patterns depending on the needs and constraints of a particular emergency situation. One example of such a structure is the Incident Command System (ICS) model which has been adopted in California (Boise Interagency Fire Center, 1983). This system is based on prescribed roles and is designed so that different individuals and organizations can be assigned to different roles as needed. While the ICS model was developed as an integrated response approach to range and forest fires which burn across jurisdictional boundaries, it can easily be adapted to all disasters, large and small, so that the system can be commonly used and accepted. This regular use of a planned-emergent system is vital to its acceptance in a major earthquake situation.

Volunteers are a critical resource in any community's response to an earthquake. Because of the wide-spread destruction and uncertainty of an earthquake, it is unrealistic and potentially wasteful to rely on only paid staff to respond to an event which in any given fiscal period may or may not occur. While paid staff may be seen as the first official line of defense in an earthquake situation, effective response does not and cannot occur without volunteers. The Red Cross does a very good job in this area. But many of the emergency management officials in St. Louis, following the dictates of a rational-legal response, tend to view unofficial people in general and volunteers in particular as part of the problem, rather than as a resource (Gillespie and Perry, 1984).

BUILDING A BRIDGE BETWEEN RESEARCH AND PLANNING

The emergency management practice community in St. Louis echoed La Valla and Stoffel (1983) with criticisms and problems in using disaster research findings. They claimed: (1) results are too "scientific" or too vague for practitioners; (2) limited dissemination of research findings; (3) resistance on the part of practitioners to dissemination of research results

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for political or personal reasons; (4) frustration, and hence resistence, on the part of practitioners who perceive that scarce dollars are on research rather than practice; (5) perceptions on the part of emergency managers that much research is only for the self-gratification of the research community; and (6) emergency management and training programs often do not use research results. Each of these problems could be reduced if there were more contact and communication between researchers and practitioners.

It seems clear that policies, plans, and practice efforts are influenced by personal predilections, social and political pressures, and various local traditions. If research findings and recommendations are going to be used, they must be developed and presented in a manner that fits into the existing social system. This suggests that it is the responsibility of <u>both</u> practice people and knowledge producers to improve the transfer of findings from research to practice. Given equal responsibility, it may be useful to think of ways to involve practitioners and researchers together in the knowledge building process. On the one hand, involvement is a way to develop commitment. While, on the other hand, knowledge without commitment is unlikely to be used.

IDEAS FOR RESEARCH TO STRENGTHEN RESPONSE PLANNING

Several ideas which might increase research applications have been derived from experiences with the NSF funded St. Louis study of preparedness networks (Gillespie et al.,1986). The first idea suggests eliciting user group input from the very beginning of a proposal. The second idea indicates some potential gains from actually involving user representives in the research project. The third idea describes the need for special marketing efforts. All three ideas deal with ways of reducing barriers between research and user groups. It is expected that, to the extent that such barriers are eliminated, the results of research efforts will fit well and flow efficiently into community policies and practices. It is also understood, however, that complete elimination of the barriers between research and user groups is impossible.

<u>Involve User Groups from Beginning of Research Idea</u>

The proposal to study preparedness networks in St. Louis was conceived with reference primarily to the academic literature on interorganizational relations. Personal experience and understanding of the community were drawn upon to ferret out the potential applications. Information about the project was withheld from the community until it was funded. Contacts with key planners and officials were initiated when funding for the project was announced. The relevance of the project, however, was not immediately apparent to the potential user groups, so the project team spent a considerable amount of time developing relationships with key organizations and individuals to legitimate the project. Much time would have been saved had these people been involved earlier in the proposal writing stage.

In addition to gaining cooperation and legitimating the project, earlier involvement of user groups would have increased the efficiency and effectiveness of project implementation. The eventual acceptance of the project by potential users led to their devoting careful attention and constructive criticism to the construction of our data collection instruments. Much more time than originally allotted was required to handle the extensive feedback. This work unquestionably contributed to greater relevance and validity of our instruments. This process supports the value of what Johnson-Fisher (1987) calls "working backwards" in the development of our research efforts. That is, start with problems, issues, and conceptualizations as presented by planners and practioners and work back to the specification of a researchable question. In the case of the St. Louis study, it was a process of simultaneously working backward and forward as we educated the practioners about research and they educated us about many aspects of the preparedness networks.

Another useful byproduct of involvement with potential users was that the project developed a rich collection of qualitative data to complement the quantitative results. Each member of the project team began taking field notes to compare things we were learning from the different community meetings attended, and discussions with planners and practioners. These observations made it clear that the emergency preparedness networks and central actors were experiencing rapid change. It became apparent that the networks were dynamic rather than static. A purely quantitative and cross-sectional network analysis would never have captured this dynamic character of the networks. Learning from the field in this manner led to some revision of the project goals.

Involve Potential User Groups Throughout Implementation

While getting to know potential users during the formative stages of research is important, it is equally important to facilitate involvement during the project. It was noted above how community feedback led to a number of adjustments and revisions which increased the relevance and validity of the project results. But the contact with the planners and practitioners was a two-way bridge, and some of our ideas were most effectively communicated through these informal discussions and special advisory meetings.

The process of constructing an earthquake scenero for our instrumentation provides an illustratation of informal communication during the project. We wanted an earthquake scenero which was as realistic as possible, and so to draft one we used the damage assessment literature. The planners urged us to use a "worst case" scenero, giving the rationale that preparation for a worst case helps a community be ready for anything. We discussed social implications of using a worst case scenero, including the possiblity of preparedness being undermined by people adopting a fatalistic view. Although we did not explicitly recommend in our report that preparedness efforts be developed in line with realistic expectations, it is nevertheless the case that preparedness efforts in St. Louis and the midwest are now using probable earthquake magnitudes rather than the worst case sceneros of two or three years ago.

Information is often more effectively communicated in a dialogue fashion through interpersonal relations than it is through the more formal standard scientific channels. We need to increase the opportunities to talk directly with potential users about our research. Involving user groups as field consultants on research projects is one way to increase interaction between research and practitioners.

Prepare Special Marketing Materials for User Groups

The initial budget for the proposed St. Louis study was deemed by the sponsoring agency to be too large. To resolve the problem, a part of the study was chopped out, the amount of release time for the investigators was reduced on paper, and money for publications and dissemination of the results was all but eliminated. In retrospect, it appears that dropping the funds for dissemination insured minimal use of the study's findings and recommendations.

Although the final report was mailed to all known user groups and included a special section of practice guidelines, it was too much information and it was presented as a scientific report. Presentation of the results in a scientific report was appropriate both to the goals of the project and to the sponsoring agency, but this format did not appeal directly to the potential community users. Because it did not appeal to them, they read it in a cursory fashion, if at all. The findings and recommendations which have been disseminated are those we have talked about in subsequent discussions with community leaders and in presentations before user groups.

Dissemination of the NSF study is still struggling along in St. Louis today, but it could be greatly improved with professionally produced graphics and visual aids, brochures or slick pamphlets highlighting the practice guidelines and recommendations, as well as other workshop materials to help carry the information to users in a way that draws their attention, holds their interest, and perhaps promotes policy and practice changes. If research is going to be used, it must be presented in a manner that appeals to the user. Most researchers have not been trained to do this kind of writing and graphic depiction. Perhaps we should consider including a media representative as part of any target group identified as potential users.

The earthquake research initiative and community planning and recovery efforts can facilitate and reinforce each other through mutual involvement. The specifics of involvement will be different for different projects and communities. The skills, talents, demands, and conditions of the policy and practice worlds are different than the those facing research. These differences can never be erased, nor would it benefit us to have them erased. Still, each has much to give and receive from the other. We need to think of ways to build better bridges between the different disciplines concerned with earthquakes, both academic and applied.

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APPENDIX A

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APPENDIX B

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APPENDIX C

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APPENDIX D

Proceedings of Conferences in the National Earthquake Hazards Reduction Program

Hays, W. W., ed., 1982, Proceedings of Conference XV, a workshop on "Preparing for the responding to a damaging earthquake in the Eastern United States:" U.S. Geological Survey Open-File Report 82-220.

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Hays, W. W. and Gori, P. L., eds., 1983, Proceedings of Conference XXIII, a workshop on "Continuing actions to reduce potential losses from future earthquakes in Arkansas and nearby States:" U.S. Geological Survey Open-File Report 83-846, 234 p.

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Gori, P. L., and Hays, W. W., eds., 1984, Proceedings of Conference XXIV, a workshop on "Geologic hazards in Puerto Rico:" U.S. Geological Survey Open-File Report 84-761, 143 p.

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Hays, W. W., and Gori, P. L., eds., 1985, Proceedings of Conference XXIX, a workshop on "Continuing actions to reduce potential losses from future earthquakes in New York and nearby States:" U.S. Geological Survey Open-File Report 85-386, 150 p.

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Brown, W. M., Kockelman, W. J., and Ziony, J. I., eds., 1986, Proceedings of Conference XXXII, a workshop on "Future directions in evaluating earthquake hazards in Southern California:" U.S. Geological Survey Open-File 86-401, 421 p.

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Hays, W. W., and Gori, P. L., eds., 1986, Proceedings of Conference XXXVII, a workshop on "Earthquake hazards along the Wasatch Front, Utah:" U.S. Geological Survey Open-File Report 87-154, 146 p.

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Hays, W. W., and Gori, P. L., eds., 1987, Proceedings of Conference XXXVI, a workshop on "Assessment of geologic Hazards and Risk in Puerto Rico:" U.S. Geological Survey Open-File Report 87-008, 385 p.

Hays, W. W., and Gori, P. L., eds., 1988, Proceedings of Conference XLI, a workshop on Earthquake Research Applications in the National Earthquake Hazards Reduction Program Program, Open-File Report 88-13.

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APPENDIX E

CONFERENCES TO DATE

Conference I	Abnormal Animal Behavior Prior to Earthquakes, I Not Open-Filed
Conference II	Experimental Studies of Rock Friction with Application to Earthquake Prediction Not Open-Filed
Conference III	Fault Mechanics and Its Relation to Earthquake Prediction Open-File No. 78-380
Conference IV	Use of Volunteers in the Earthquake Hazards Reduction Program Open-File No. 78-336
Conference V	Communicating Earthquake Hazard Reduction Information Open-File No. 78-933
Conference VI	Methodology for Identifying Seismic Gaps and Soon-to-Break Gaps Open-File No. 78-943
Conference VII	Stress and Strain Measurements Related to Earthquake Prediction Open-File No. 79-370
Conference VIII	Analysis of Actual Fault Zones in Bedrock Open-File No. 79-1239
Conference IX	Magnitude of Deviatoric Stresses in the Earth's Crust and Upper Mantle Open-File No. 80-625
Conference X	Earthquake Hazards Along the Wasatch and Sierra-Nevada Frontal Fault Zones Open-File No. 80-801
Conference XI	Abnormal Animal Behavior Prior to Earthquakes, II Open-File No. 80-453
Conference XII	Earthquake Prediction Information Open-File No. 80-843
Conference XIII	Evaluation of Regional Seismic Hazards and Risk Open-File No. 81-437
Conference XIV	Earthquake Hazards of the Puget Sound Region, Washington Open-File No. 82-19
Conference XV	A Workshop on "Preparing for and Responding to a Damaging Earthquake in the Eastern United States" Open-File No. 82-220
Conference XVI	The Dynamic Characteristics of Faulting Inferred from Recording of Strong Ground Motion Open-File No. 82-591
Conference XVII	Hydraulic Fracturing Stress Measurements Open-File No. 82-1075
Conference XVIII	A Workshop on "Continuing Actions to Reduce Losses from Earthquakes in the Mississippi Valley Area Open-File No. 83-157
Conference XIX	Active Tectonic and Magmatic Processes Beneath Long Valley Open-File No. 84-939
Conference XX	A Workshop on "The 1886 Charleston, South Carolina, Earthquake and its Implications for Today" Open-File No. 83-843

Conference XXI	A Workshop on"Continuing Actions to Reduce Potential Losses from Future Earthquakes in the Northeastern United States" Open File No. 83-844
Conference XXII	A Workshop on "Site-Specific Effects of Soil and Rock on Ground Motion and the Implications for Earthquake-Resistant Design" Open-File No. 83-845
Conference XXIII	A Workshop on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in Arkansas and Nearby States" Open-File No. 83-846
Conference XXIV	A Workshop on "Geologic Hazards in Puerto Rico" Open-File No. 84-761
Conference XXV	A Workshop on "Earthquake Hazards in the Virgin Islands Region" Open-File No. 84-762
Conference XXVI	A Workshop on "Evaluation of the Regionald and Urban Earthquake Hazards in Utah" Open-File No. 84-763
Conference XXVII	Mechanics of the May 2, 1983 Coalinga Earthquake Open-File No. 85-44
Conference XXVIII	A Workshop on "The Borah Peak, Idaho, Earthquake" Open-File No. 85-290
Conference XXIX	A Workshop on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in New York and Nearby States" Open-File No. 85-386
Conference XXX	A Workshop on "Reducing Potential Losses From Earthquake Hazards in Puerto Rico Open File No. 85-731
Conference XXXI	A Workshop on "Evaluation of Regional and Urban Earthquake Hazards and Risk in Alaska" Open File No. 86-79
Conference XXXII	A Conference on "Future Directions in Evaluating Earthquake Hazards of Southern California" Open-File No. 86-401
Conference XXXIII	A Workshop on "Earthquake Hazards in the Puget Sound, Washington Area" Open-File No. 86-253
Conference XXXIV	A Workshop on "Probabilistic Earthquake-Hazards Assessments," Open-File 86-185
Conference XXXV	A Workshop on "Earth Science Considerations for Earthquake Hazards Reduction in the Central United States," Open-File Report No. 86-425
Conference XXXVI	A Workshop on "Assessment of Geologic Hazards and Risk in Puerto Rico" Open-File 87-007
Conference XXXVII	A Workshop on "Earthquake Hazards Along the Wasatch, Utah Open File 87-154 ,
Conference XXXVIII	A Workshop on "Physical & Observational Basis for Intermediate Term Earthquake Prediction Open-File 87- [in press]

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Conference XXXIX	Directions in Paleoseismology Open File 87- [in press]
Conference XL	A Workshop on "The U.S. Geological Survey's Role in Hazards Warnings" Open-File Report 87-269
Conference XLI	A Review of the Earthquake Research Applications in the National Earthquake Hazard Reduction Program: 1977-1987 Open-File 88-13

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