WASATCH FRONT FORUM

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EARTHQUAKE HAZARDS PROGRAM

The Wasatch Front Forum is published quarterly by the Utah Geological Survey. Information, contributions, questions, and suggestions concerning future issues may be sent to the Editor at the address listed below:

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DEADLINES FOR FUTURE ISSUES

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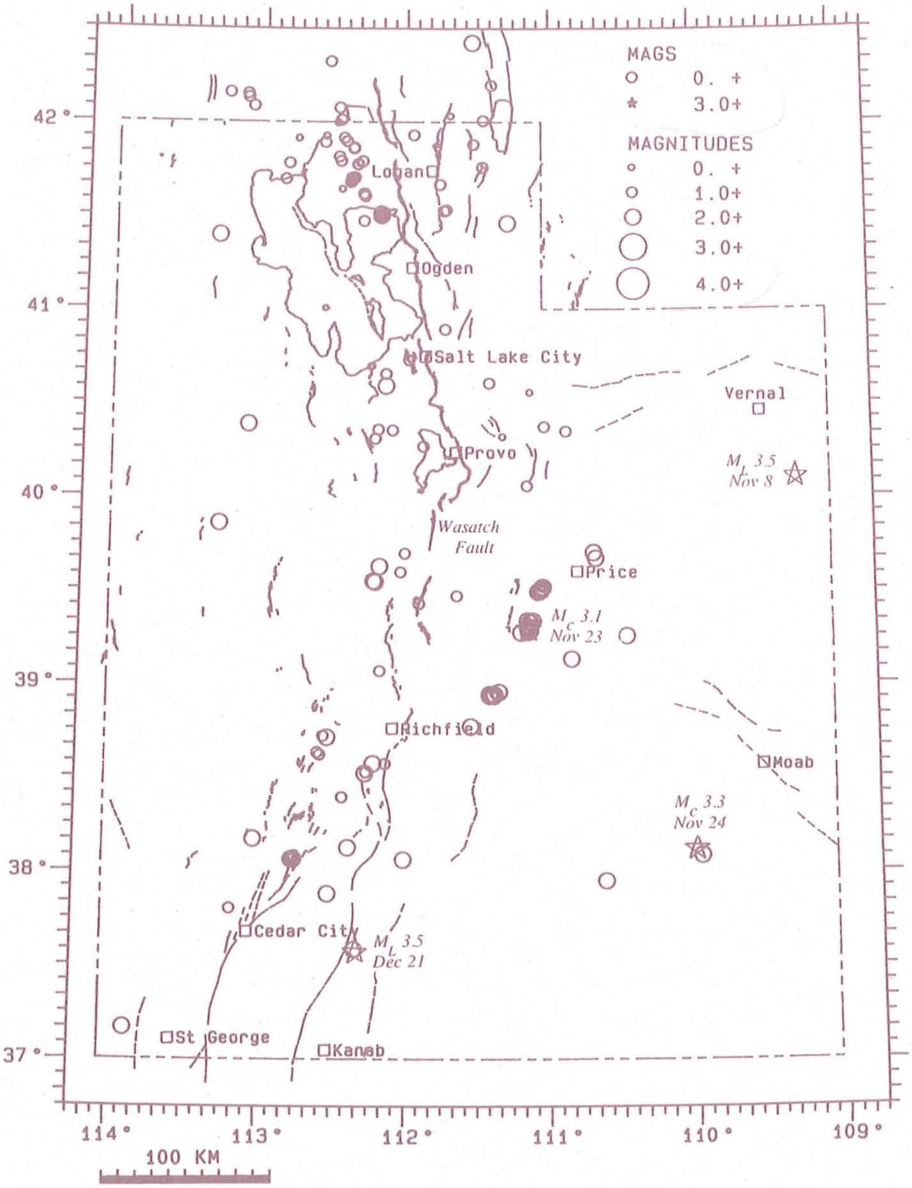
EARTHQUAKE ACTIVITY IN THE UTAH REGION

October 1 - December 31, 1991

by *Susan J. Nava*
University of Utah Seismograph Stations

During the three-month period October 1 through December 31, 1991, the University of Utah Seismograph Stations located 169 earthquakes within the Utah region (see epicenter map). The total includes four earthquakes in the magnitude 3 range, specifically labeled on the epicenter map, and 66 in the magnitude 2 range. [Note: Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times indicated here are local time, which was either Mountain Daylight Time (October 1- 31) or Mountain Standard Time (November 1-December 31).]



Significant Clusters of Earthquakes

- Southwest of Price (coal-mining related): Three clusters of earthquakes (magnitude 1.7 to 3.1) make up 25% of the shocks that occurred in the Utah region during the report period.
- West of Logan: - A cluster of 13 earthquakes, ranging in magnitude from 0.5 to 1.7, occurred 45 km W of Logan, in the Blue Springs Hills. This is approximately the same location as a magnitude 4.8 shock, which occurred on July 3, 1989.
  - A cluster of 17 earthquakes, ranging in magnitude from 0.5 to 2.2, occurred 40 km SW of Logan, just north of the Bear River.

Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations

Larger and/or Felt Earthquakes

• M_L	November 8	6:15 a.m.	28 miles SE of Vernal; felt in Vernal, and in Dinosaur, CO
• M_C	November 23	9:25 a.m.	7 miles WNW of Orangeville (see SW of Price)
• M_C	November 24	8:40 p.m.	40 miles SSW of Moab
• M_L	December 21	1:26 p.m.	8 miles ESE of Hatch (see E of Cedar City); felt in Henry, Tropic, and Bryce Canyon National Park

THE POLITICS OF EARTHQUAKES

by M. Lee Allison, Director
Utah Geological Survey
[From UGS Survey Notes, v. 25, no. 2 Ed.]

The past few months have been important for Utah's state earthquake program: the magnitude 4.3 western Traverse Mountains earthquake near Herriman on March 16 was the biggest seismic event on the Wasatch Front in nearly a decade [See the last issue of WFF, v. 8, no. 1, p. 3-4, for summary of the seismic event by Christenson and Olig. Ed.]; the Earthquake Advisory Board (EAB) was established and is now developing its strategy and program; the Governor and the Legislature agreed on establishing a state strong-motion instrumentation program and authorized funding for it; and creation of seismic zone 4 of the Uniform Building Code (UBC) along the Wasatch Front became a front-page controversy, albeit for a short time.

Earthquake Advisory Board

The EAB includes in its membership some who have long been active in the state earthquake program and others who have great expertise and interest but have not had that same involvement. In the first few meetings, discussion has focused on the role of the EAB and its direction. As a member of the Technical Committee of the EAB, it is my hope that we will adopt some of the more successful activities of California's Seismic Safety Commission. In particular, I think it critical that Utah prepare a comprehensive listing of the earthquake activities that are presently underway and those that need to be implemented. The EAB should prioritize the needs and assess the resources necessary to achieve them. [see WFF v. 7, no. 3, p. 3-6; v. 7, no. 4, p. 4-5; this issue, p. 7-8]

Strong-motion program

A significant step in acquiring information needed to better design Utah's buildings and other structures was taken by the Utah Legislature which approved the Governor's recommendation to begin funding a strong-motion instrumentation program. For three years this program has been the cornerstone of a comprehensive earthquake instrumentation initiative that is the earthquake community's highest priority. Because of the total program's $3 million price tag, it has never fared well in the Legislature. This year, the UGS proposed that the strong-motion instrument part of the program be funded separately and incrementally over a long period of time. The Governor's office supported the concept and the Legislature approved it handily. The original proposal three years ago was for $1.6 million for a minimum statewide program. The package approved this year is for $75,000 per year. Thus, although it will take at least 20 years to establish the basic network, our belief is that it is better to start sooner with a small amount and build a good program than have no program while we wait for full funding that may never come. [see WFF v. 7, no. 4, p. 3; v. 8, no. 1, p. 4-5]

The money was appropriated to the UGS to begin the program. We are committed to working with other agencies with seismic instrumentation in Utah such as the University of Utah Seismograph Stations, the U.S. Geological Survey, and the U.S. Bureau of Reclamation to establish a state strong-motion consortium. There is a good chance that the state's financial commitment can be leveraged with matching funds from federal and private sources.

Uniform Building Code

Usually, the UGS is not a very controversial agency. We don't have any regulatory powers but rather provide unbiased technical and scientific information for a variety of users. So we were more than a little surprised at the controversy generated by a proposal based on our work to amend the UBC to upgrade much of the Wasatch Front from seismic zone 3 to seismic zone 4. After five years of intensive study as part of the U.S. Geological Survey's National Earthquake Hazard Reduction Program, much new information is now available on earthquake ground shaking. The zonation proposal resulted from a UGS evaluation of the building-code implications of this new data. For more than a year UGS staff presented and explained our conclusions to building officials, professional groups, and the public. The UBC Commission, after receiving input at a well-attended public hearing, endorsed the change but decided to let the final decision go to the national body of the

International Conference of Building Officials (ICBO) which publishes the UBC and has more experience in these issues. Then, in the last weeks before the national meeting, opponents generated widespread apprehension about the proposal. The Utah Chapter of the ICBO abandoned its neutral stance and came out against the proposed change just before the decision was to be made. As a result of the controversy and the mixed signals coming out of Utah, the national ICBO voted against the proposal. [see WFF v. 7, no. 3, p. 6-7; v. 7, no. 4, p. 3-4; this issue, p. 11-12]

None of this changes scientific reality, however. Our interpretations and conclusions stand. The Wasatch Front exceeds the minimum criteria for seismic zone 4 and the UGS has fulfilled its duty to inform the appropriate authorities of the potential for greater ground shaking along the Wasatch Front. Those responsible for amending the UBC apparently decided that other, non-geologic concerns of implementing seismic zone 4 are more important than dealing with the effects of greater ground shaking.

The western Traverse Mountains earthquake is a gentle reminder of the seismic danger that hangs over all of us. I believe an important opportunity to strengthen at least our new buildings has been missed, and I fear that future generations will end up paying for this decision.

EARTHQUAKES NEAR CEDAR CITY, UTAH JUNE 28-29, 1992

by Walter J. Arabasz, Susan J. Nava, and James C. Pechmann
University of Utah Seismograph Stations

OVERVIEW

On Sunday morning, June 28, 1992, a series of earthquakes originating about 7 miles northwest of Cedar City in southwestern Utah began within an hour of a large damaging shock of magnitude 7.5 in southern California. The California earthquake struck at 05:57 a.m. Mountain Daylight Time (MDT), and was followed by a nearby magnitude 6.6 earthquake at 09:04 a.m. MDT. (unless otherwise noted, all times herein are Mountain Daylight Time, the local time in Utah.) Between 6:36 a.m. and 8:29 a.m. that same morning, a flurry of earthquakes occurred near Cedar City, including shocks of magnitude 2.6 and 2.7. A second flurry of Cedar City earthquakes occurred later in the day between and about 6:15 p.m. and 9:29 p.m. The largest shocks in this second burst of activity were, in chronological order, of magnitude 3.8, 3.0, 4.1, and 3.0. The Cedar City earthquake sequence continued intermittently into Monday morning, June 29, and included more than sixty shocks, the largest of which was the magnitude 4.1 shock on Sunday evening. Several of the Utah shocks that occurred on Sunday, as well as the California earthquake, were reported felt by residents in and near Cedar City.

PRELIMINARY SEISMOLOGICAL INFORMATION

Earthquake Chronology. Table 1 lists the times, locations, and sizes of 34 earthquakes that occurred near Cedar City during a 27-hour period beginning on June 28 and extending into June 29. Note that table 1 includes only instrumentally-recorded earthquakes large enough to be located. About thirty more earthquakes not large enough to be located were identified on records from a seismograph at station ARUT (see figure 1), situated 15 miles west of the earthquake source zone. Reports from residents in the Cedar City area confirm that at least seven of the local earthquakes listed in table 1 were felt. Residents in the Cedar City area also felt the two large earthquakes that originated in southern California, about 320 to 330 miles away, on the morning of June 28 and a magnitude 5.6 earthquake that originated 190 miles away in southern Nevada on the morning of June 29 at 04:14 a.m. (MDT).

Earthquake Locations & Relation to Geology. The epicenters of most of the earthquakes cluster about 7 miles northwest of Cedar City (see figure 1) along the northwestern margin of Cedar Valley. Seismographic instrumentation in southwestern Utah is too sparse to allow reliable determination of the depths of the earthquake—and hence, confident correlation with a specific fault (or faults). Nevertheless, figure 1 shows that the

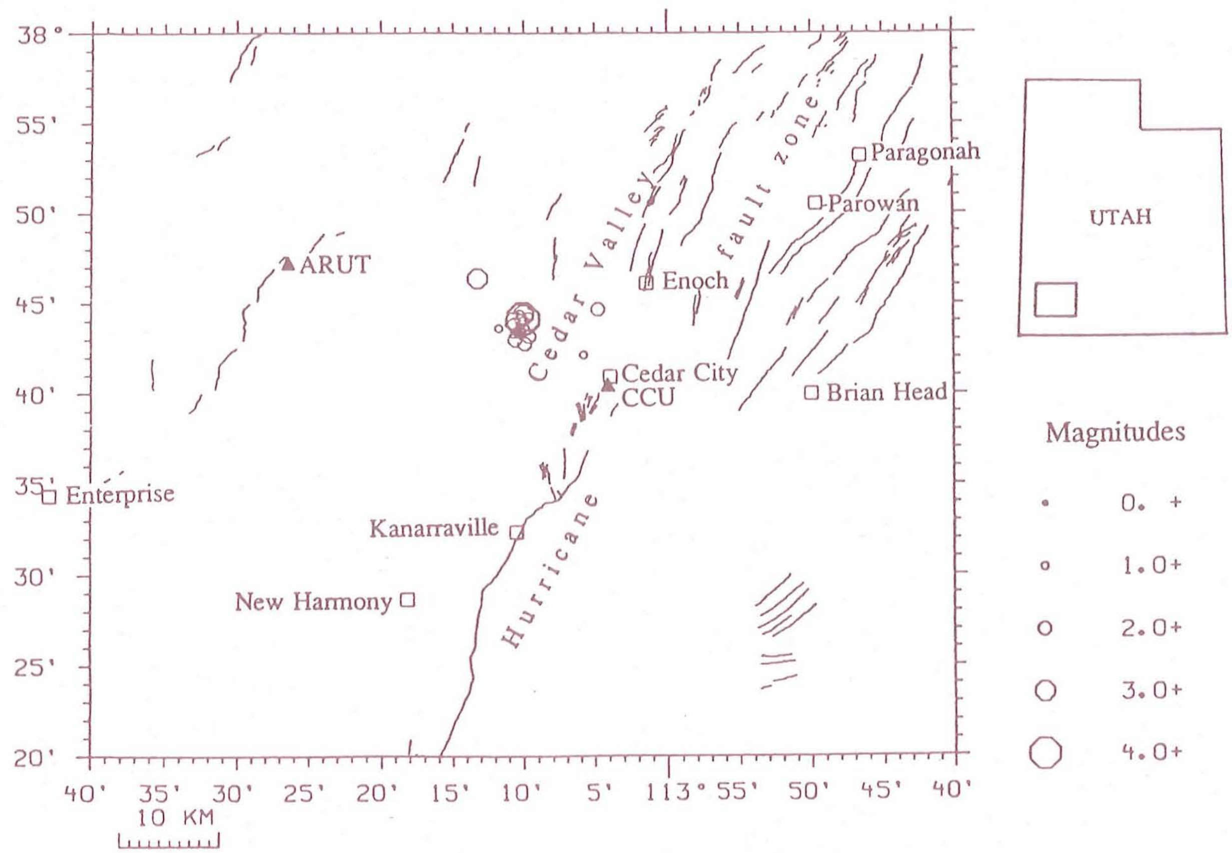


Figure 1. Map showing the epicenters (octagons) of earthquakes that occurred near Cedar City, Utah, on June 28 and 29, 1992, together with the locations of geologically young faults (after Hecker, in preparation) and nearby seismographs (triangles labeled ARUT and CCU).

earthquake epicenters lie within a broad zone of faulting which forms the Hurricane fault zone. This fault zone separates high-standing plateaus on the east from lower-lying basin-and-range topography on the west. Cedar Valley itself is a downfaulted valley that has been filled with alluvial sands and gravels eroded from the Hurricane Cliffs to the east. One speculative possibility is that the June 28-29 earthquakes occurred on a northeast-trending buried fault that Cook and Hardman (1967) have interpreted on the basis of gravity data to form the northwestern boundary of the Cedar Valley block. Earthquakes smaller than magnitude 6 in the Intermountain region have never been observed to produce surface faulting. These small- to moderate-size earthquakes commonly occur on secondary faults having no surface expression, rather than on major mapped faults.

Focal Mechanism. Seismographic recordings from earthquakes as sizable as magnitude 4.1 can usually be used to determine the orientation and direction of slip of the faulting that caused the earthquake. It will be difficult, if not impossible, to do this for the June 28-29 earthquakes near Cedar City for two reasons. First, the geographic distribution of seismographic stations in the region is unfavorable for this type of analysis. Second, the available recordings are complicated by having interfering seismic waves arriving from multiple earthquakes, including California aftershocks.

Historical Earthquake Activity. The largest historical earthquakes in the general region of Cedar City have been shocks of approximately magnitude 6. In November 1902, a shock of estimated magnitude 6 occurred in Pine Valley, Utah, about 30 miles southwest of Cedar City, and in August 1966, a shock of magnitude 5.3 to 6.1 occurred 60 miles west-southwest of Cedar City in southeastern Nevada (Smith and Arabasz, 1991). Geological studies of faulting and evidence of prehistoric earthquakes indicate that southwestern Utah has the potential for earthquakes in the magnitude 7 to 7½ range (Christenson and Nava, 1992).

The sequence of earthquakes that occurred near Cedar City on June 28-29, 1992, was "swarmlike" in character. An earthquake swarm

Table 1. June 28-29, 1992, earthquake sequence near Cedar City, Utah (list includes only instrumentally-recorded earthquakes large enough to be located).

Local Date (UTC Date)	Local Time MDT (UTC Time)	Latitude (N)°	Longitude (W)°	Magnitude	Reported Felt
June 28	6:36 a.m. (12:36)	37° 43.09'	113° 10.75'	1.6	yes
28	7:37 a.m. (13:37)	37° 43.44'	113° 10.58'	1.1	
28	7:40 a.m. (13:40)	37° 43.45'	113° 10.60'	1.5	
28	7:40 a.m. (13:40)	37° 43.71'	113° 10.39'	1.5	
28	7:42 a.m. (13:42)	37° 43.84'	113° 10.65'	2.6	yes
28	7:48 a.m. (13:48)	37° 43.99'	113° 10.59'	2.7	
28	8:00 a.m. (14:00)	37° 43.48'	113° 10.55'	1.5	
28	8:29 a.m. (14:29)	37° 43.64'	113° 11.74'	1.8	
28 (29)	6:20 p.m. (00:20)	37° 43.56'	113° 10.40'	1.2	
28 (29)	6:42 p.m. (00:42)	37° 44.83'	113° 09.58'	0.5	
28 (29)	7:10 p.m. (01:10)	37° 43.56'	113° 10.04'	2.2	
28 (29)	7:12 p.m. (01:12)	37° 44.14'	113° 10.04'	3.8	yes
28 (29)	7:21 p.m. (01:21)	37° 43.98'	113° 10.30'	1.1	
28 (29)	7:22 p.m. (01:22)	37° 44.71'	113° 04.77'	2.2	
28 (29)	7:23 p.m. (01:23)	37° 44.08'	113° 10.14'	2.5	yes
28 (29)	7:25 p.m. (01:25)	37° 44.38'	113° 10.02'	3.0	yes
28 (29)	7:27 p.m. (01:27)	37° 44.32'	113° 09.67'	1.9	
28 (29)	7:35 p.m. (01:35)	37° 43.48'	113° 10.24'	1.3	
28 (29)	7:36 p.m. (01:36)	37° 43.58'	113° 10.50'	0.7	
28 (29)	7:37 p.m. (01:37)	37° 44.44'	113° 10.25'	1.8	yes
28 (29)	7:38 p.m. (01:38)	37° 43.29'	113° 10.17'	1.4	
28 (29)	7:38 p.m. (01:38)	37° 42.18'	113° 05.80'	1.1	
28 (29)	7:39 p.m. (01:39)	37° 44.05'	113° 10.05'	1.1	
28 (29)	7:44 p.m. (01:44)	37° 43.36'	113° 10.32'	2.0	
28 (29)	7:49 p.m. (01:49)	37° 43.46'	113° 10.30'	2.0	
28 (29)	7:54 p.m. (01:54)	37° 42.99'	113° 10.61'	2.3	
28 (29)	7:59 p.m. (01:59)	37° 44.22'	113° 10.09'	4.1	yes
28 (29)	8:02 p.m. (02:02)	37° 43.19'	113° 09.66'	2.3	
28 (29)	8:04 p.m. (02:04)	37° 43.73'	113° 10.14'	2.7	
28 (29)	8:07 p.m. (02:07)	37° 46.41'	113° 13.25'	3.0	
28 (29)	8:11 p.m. (02:11)	37° 42.78'	113° 09.93'	2.2	
28 (29)	8:32 p.m. (02:32)	37° 43.33'	113° 10.71'	1.6	
29	7:18 a.m. (13:18)	37° 51.10'	113° 13.51'	1.6	
29	9:17 a.m. (15:17)	37° 43.20'	113° 09.34'	1.2	

is a series of shocks occurring closely in time and space that doesn't have one outstanding main shock, but instead peaks with a cluster of roughly similar size events. Such sequences are common in southwestern Utah, sometimes persisting intermittently over a period of weeks or months and typically having the largest events in the magnitude 3 or 4 range. At least nine previous earthquake sequences of this type have occurred in the southwestern Utah region since 1962—including seven within 45 miles of Cedar City. The last such sequence jostled residents of Parowan Valley, 30 miles northeast of Cedar City, in April 1991. The largest event in that sequence, which lasted from April 17 to June 20, was magnitude 3.8. Earthquake swarms are common in volcanic regions and also—as is the case in southwestern Utah—in areas of geologically recent, but not current, volcanic activity.

Connection Between Cedar City and California Earthquakes? A press release from the University of Utah Seismograph Stations on June 28 stated that, "In our judgment, it is unlikely that the current earthquakes near Cedar City are related to the damaging earthquakes that occurred early today in southern California." The primary basis for this statement was the distance of more than 300 miles between the California and Utah earthquake source regions, which conventional seismological theory and past observations suggest is too large for either of the California earthquakes to have "triggered" the earthquakes in Utah. Because of the generally random nature of earthquake occurrence, the temporal coincidence of earthquake activity in California and Utah did not necessarily indicate a causal linking. However, scientific studies of a possible linkage are now under way by the U.S. Geological Survey—prompted by the unusually coincident timing of earthquake activity in several parts of the western United States immediately following the magnitude 7.5 California earthquake on June 28.

ACKNOWLEDGEMENTS

Linda Hall and Paula Oehmich helped compile the seismological information contained in this report. Financial support for earthquake monitoring in Utah is provided to the University of Utah Seismograph Stations by the U.S. Geological Survey, the state of Utah, and the U.S. Bureau of Reclamation

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UTAH EARTHQUAKE ADVISORY BOARD "REGROUPS"

by Janine L. Jarva
Utah Geological Survey

and Bob Carey
Utah Division of Comprehensive Emergency Management

The Utah Earthquake Advisory Board (UEAB) was created in October, 1991 as a subcommittee of the Governors Disaster Emergency Advisory Council (DEAC) to provide coordinated leadership in promoting and supporting comprehensive and effective actions that address earthquake preparedness, mitigation, emergency response, and short- and long-term recovery planning in Utah. The primary responsibility for researching earthquake-related issues for UEAB has rested with the staff of the Utah Earthquake Preparedness Information Center (EPICENTER) within the Utah Division of Comprehensive Emergency Management (CEM). EPICENTER staff also have the responsibility for administering the Federal Emergency Management Agency (FEMA) Comprehensive Cooperative Agreement, which together with the State match, funds all of CEM's earthquake-mitigation work including the activities of the UEAB. Current funding and split responsibilities of the EPICENTER staff require that the UEAB streamline its agenda and become more internally driven. Achieving this end while maintaining its dynamic mission necessitates some organizational changes. These were discussed at the UEAB meeting on May 21, 1992 and the following changes were made.

Board membership has been reduced from sixteen to ten, the Technical and Socioeconomic Subcommittees have been eliminated and replaced with an Executive Group of five members, and meetings will be held quarterly. EPICENTER staff will continue to keep the UEAB informed of the earthquake-related activities and issues of CEM, the Utah Geological Survey (UGS), the University of Utah Seismograph Stations (UUSS), and other groups in and out of the State (such as the Utah Department of Community and Economic Development who need a risk and mitigation document to "sell" Utah to potential businesses and industries). EPICENTER staff will not raise issues outside of those involved in their federal/state contract and those which occur spontaneously (such as an earthquake which affects Utah). Input from members of groups whose seats were eliminated from the Board but retain membership in the DEAC (the Utah Office of Education, the Utah Department of Environmental Quality, the Utah Division of Information Technology, the American Red Cross, and a county government representative) will be included on an issue-by-issue basis through the DEAC.

The Executive Group would constitute a quorum and be the most proactive segment of the UEAB, bringing up important and relevant issues not already a part of the normal working agenda of the EPICENTER, the UGS, and the UUSS. The Executive Group will include Lorayne Frank (Director, CEM), Mike Stransky (American Institute of Architects, Chair of the Western Mountain Region Task Force on Disaster Preparedness), Les Youd (Professor, Department of Civil Engineering, Brigham Young University), Walter Arabasz (Director, UUSS), and Lee Allison (Director, UGS). The remaining members of the UEAB include Ken Bullock (Executive Director, Utah League of Cities and Towns), David Curtis (President, Utah Association of Structural Engineers), Frank Fuller (Project Coordinator, Utah Division of Facilities, Construction and Management), Jim Golden (Assistant Chief Structural Engineer, Utah Department of Transportation), and Steve Klass (Deputy State Planning Coordinator, Governor's Office of Planning and Budget).

Activities and issues which the UEAB plans to address in the coming year include creating a "California at Risk"-type document for Utah, obtaining a Governor's Resolution recognizing the creation of the UEAB, sponsoring an Earthquake Awareness/Preparedness Week focusing on Utah schools, preparing a policy for releasing UEAB post-earthquake statements, revising existing interstate mutual-aid agreements between the western states, developing a program for involvement of volunteer professionals during disaster response, and co-sponsoring a conference on earthquake hazards and safety.

USGS WASATCH FRONT PROFESSIONAL PAPER AVAILABLE

The regional element of the National Earthquake Hazards Reduction Program (NEHRP) was established to provide concentrated attention to geographic regions containing large urban areas at risk from earthquakes. In 1983, under this NEHRP element, the U.S. Geological Survey (USGS) targeted Utah's Wasatch Front for a five-year program of focused research on earthquake hazards and risk reduction. The program utilized past research and fostered partnerships with universities, the private sector, local governments, and state and federal agencies. The goals of the regional program in Utah were to accelerate the development of the knowledge base on sources, size, frequency of occurrence, and physical effects of earthquakes in a ten-county area along the Wasatch Front (including Salt Lake, Box Elder, Cache, Davis, Juab, Morgan, Summit, Utah, Wasatch, and Weber Counties). This knowledge was then used to foster implementation of earthquake-hazard-reduction measures. USGS Survey Professional Paper 1500, "Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah" documents the scientific knowledge gained by the research and implementation program along the Wasatch Front which resulted from the five-year collaboration between the USGS, the Federal Emergency Management Agency, the Utah Geological Survey, the Utah Division of Comprehensive Emergency Management, the University of Utah, and Utah State University.

Hot off the presses, the much-anticipated first volume, Professional Paper 1500-A-J, edited by Paula L. Gori and Walter W. Hays, is now available. This publication supersedes volume I of the "purple books" (USGS Open-File Report 87-585, volume I). It's papers deal with the tectonic framework and earthquake potential of the Wasatch Front region and define the nature of the area's earthquake hazards. The geological and geophysical studies are aimed at improving our understanding of the potential for large, damaging earthquakes in the area. It fulfills one of the major goals of the NEHRP program in Utah:

> to prepare synthesis reports describing the nature, extent, frequency of occurrence, and physical effects of the earthquake hazards of ground shaking, surface faulting, earthquake-induced ground failure, and tectonic deformation and to recommend future research to increase the knowledge base required for the creation and implementation of mitigation and loss-reduction measures, providing quality data that all professionals can use in a comprehensive information system of earthquake hazards evaluations and risk assessment.

In her introduction, editor Paula Gori provides the following synopsis of the geological and seismological studies:

Paleoseismology of the Wasatch fault zone: a summary of recent investigations, interpretations, and conclusions, by M.N. Machette, S.F. Personius, and A.R. Nelson. Ten discrete segments have been identified on the Wasatch fault zone. The fact that eight of these segments have demonstrable Holocene movement increases the possible number of separate localities where earthquakes may occur.

Persistent and nonpersistent segmentation of the Wasatch fault zone, Utah: statistical analysis for evaluation of seismic hazard, by R.L. Wheeler and K.B. Krystinik. The Wasatch fault zone has been segmented as four salients - Pleasant View, Salt Lake, Traverse Mountains, and Payson - throughout much or all of its 10-m.y. history and will likely continue to be segmented there throughout the next several millennia, which is the time span of interest for hazard evaluation.

Subsurface geology along the Wasatch Front, by D.R. Mabey. Magnetic data suggest segment boundaries of the Wasatch fault zone that are generally consistent with segment boundaries inferred from surface mapping of the fault zone.

Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah, by W.J. Arabasz, J.C. Pechmann, and E.D. Brown. Background seismicity predominates on second-order faults in the Wasatch Front area. Small to moderate earthquakes are the largest contributor to the probabilistic ground-shaking hazard for exposure periods of 50 years or less. The earthquake data imply an average return period of 24 ± 10 years for potentially damaging earthquakes of magnitude 5.5 or greater along the Wasatch Front.

Superimposed late Cenozoic, Mesozoic, and possible Proterozoic deformation along the Wasatch fault zone in central Utah, by M.L. Zoback. Thrust ramping and late Cenozoic normal faulting may be localized by a major west-dipping normal fault zone formed during the early phases of late Precambrian rifting of the western Cordillera.

Neotectonic framework of the central Sevier Valley area, Utah, and its relationship to seismicity, by R.E. Anderson and T.P. Barnhard. Normal faults in the Wasatch fault zone such as the Sevier fault (Editor's note: this should read "Normal faults such as the Wasatch fault zone and the Sevier fault") probably cut one or more levels of potential structural detachment and penetrate to the base of the seismogenic part of the crust. Such faults are more likely to be the source of infrequent large earthquakes than are faults in the complex structural junctures where late Quaternary deformation is concentrated.

Neotectonics of the Hansel Valley-Pocatello Valley corridor, northern Utah and southern Idaho, by J.P. McCalpin, R.M. Robison, and J.D. Garr. The 1934 M_L 6.6 earthquake may be a typical interpluvial maximum event (that is, long recurrence time and small displacement in comparison with the larger, more frequent surface-faulting events that are triggered by pluvial lake water loading.

Structure of the Salt Lake segment, Wasatch normal fault zone: implications for rupture propagation during normal faulting, by R.L. Bruhn, P.R. Gibler, W. Houghton, and W.T. Parry. There are two potential sites of rupture initiation for large earthquakes at the central and southern ends of the Salt Lake fault segment of the Wasatch normal fault zone. The central site may have been the most common position for repetitive rupture initiation during the last 17 million years.

Quaternary displacement on the Morgan fault, a back valley fault in the Wasatch Range of northeastern Utah, by J.T. Sullivan and A.R. Nelson. Paleoearthquakes having magnitudes in the range of 6.5 to 7 have occurred on the Morgan fault.

Late Quaternary history of the James Peak fault, southernmost Cache Valley, north-central Utah, by A.R. Nelson and J.T. Sullivan. The James Peak fault, may be a westerly splay of the East Cache fault rather than a separate valley-bounding fault.

The second volume, Professional Paper 1500-K-Z, due to be published in 1993, will examine issues relating to predicting the effects of local site conditions on ground shaking in the Wasatch Front area and developing loss (risk) estimation procedures. This volume will supersede volumes II and III of the "purple books" (USGS Open-File Report 87-585, volume II and Open-File Report 88-680). It will address two more of the interrelated goals in Utah's NEHRP program:

to produce deterministic and probabilistic ground-motion models and maps of the ground-shaking hazard and commentaries on their use in building codes and land-use regulations;

to devise economical methods for acquiring inventories of structures and lifeline systems in urban areas, to create a standard model for loss estimation, to produce loss and casualty estimates for urban areas, and to prepare commentaries giving guidelines for use by agencies of state and local governments.

A third report, Professional Paper 1519 (supersedes volume IV of the "purple books", USGS Open-File Report 90-225), entitled "Applications of Research from the U.S. Geological Survey Program, Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah" will also be published in 1993 as a companion volume to Professional Paper 1500. It will include the results from ongoing research in Utah (since 1988) as well as address the issues of applying the research to lessen future risk from earthquakes and using earthquake-hazards information to reduce potential loss of life and damage to property after a major earthquake. Combined with some of the chapters in Professional Paper 1500-K-Z, it confronts the final goal of the Utah program:

to foster the creation and implementation of measures to mitigate the earthquake hazards of ground shaking, surface-fault rupture, earthquake-induced ground failure, and tectonic deformation in urban areas and to provide high-quality scientific information that can be used by local government decisionmakers as a basis for implementing and enforcing loss-reduction measures.

Along Utah's Wasatch Front, scientists, engineers, architects, urban planners, emergency planners, and state and local governments are not waiting for a major earthquake disaster. They are taking actions now to prepare for and to mitigate the physical effects of such an event. The Wasatch Front program is multidisciplinary and dynamic. Though ongoing, the timeliness and importance of the work completed to date make the publication of Professional Paper 1500-A-J very significant. In addition to documenting the coordinated efforts of scientists and engineers to understand the causes and effects of earthquakes in the Wasatch Front region, it provides the technical basis for public officials to devise and implement policies to reduce risk in urban and regional planning and development.

Professional Paper 1500-A-J can be purchased for $26.00 from the USGS Earth Science Information Center at the Federal Building, Room 8105, 125 South State Street, Salt Lake City, Utah, (801) 524-5652, or by mail from the U.S. Geological Survey, Book and Open-File Report Sales, Box 25425, Denver, Colorado 80225 (make checks payable to Department of Interior/USGS).

THE EFFECTS OF CHANGING THE UNIFORM BUILDING CODE SEISMIC ZONE FROM ZONE 3 TO ZONE 4 ON THE WASATCH FRONT OF UTAH (BRIGHAM CITY TO NEPHI)

The Utah Earthquake Preparedness Information Center (EPICENTER) of the Utah Division of Comprehensive Emergency Management, under the auspices of the Federal Emergency Management Agency, manages the state level project of the National Earthquake Hazards Reduction Program. The EPICENTER's function is training, awareness, education, mitigation, and the determination of the earthquake risk.

In March 1992, the EPICENTER requested proposals for a study of the potential impact of a change in the Uniform Building Code seismic zone map in Utah, from Zone 3 to Zone 4. Recently such a proposal was passed favorably by the Utah Building Code Commission [see WFF v. 7, no. 3, p. 6-7]. Subsequently, it was voted down in a committee of the International Congress of Building Officials [see WFF v. 7, no. 4., p. 3-4]. A study to determine quantitative and qualitative impacts of such a change will be useful to the state in making any future decisions on this or similar issues.

VSP Associates of Sacramento, California, the successful bidder, will receive $20,000 for a grant period of 6 months. The principal objective of this project is to evaluate and explain in lay person's language the expected <u>socio-economic impacts</u> of changing the Uniform Building Code from Seismic Zone 3 to Zone 4 along the Wasatch Front in Utah. The study area runs from Brigham City to Nephi, including the major population centers around Ogden, Salt Lake City, and Provo. In their proposal, they indicate that they will address the following issues:

1) economic impacts on development and the housing trades, including architects, engineers, developers, realtors, and the construction trades,
2) the impact on new building costs, for a range of major building types,
3) the impact on the change of use, renovation or rehabilitation of existing buildings,
4) the impact on the resale value of existing buildings,
5) the impact on the value of new buildings,
6) the impact on new housing and other building starts in the affected area,
7) the impact on homeowners insurance, including earthquake insurance rates, and
8) the subjective and objective attitudes of people who may be impacted by such a change.

VSP Associates' research team will also include: Reaveley Engineers (Lawrence Reaveley) in Salt Lake City, with 20 years experience in seismic engineering; J.H. Wiggins Company (John Wiggins), with more than 30 years experience in structural engineering and earthquake and property loss insurance; and James Russell, an engineer with extensive experience relating to the preparation and enforcement of seismic provisions in building codes for new and existing buildings, including training of local building officials.

In addition to the eight main tasks outlined above, VSP Associates will also perform:

1) a review of relevant legal subjects, including potential liability issues, and
2) an assessment of professional educational issues: to what extent will the knowledge and capabilities of engineers, contractors and building officials have to be increased to implement the prospective Zone change successfully?

VSP Associates final report is due by September 30, 1992.

A related publication that may be of interest to Forum readers is "Seismic Code Decisions Under Risk" (C.E. Taylor, A. Porush, C. Tillman, L. Reaveley, and G. Blackman, 1991, 157 p.). With support from the National Science Foundation, the consulting engineering firm of Dames & Moore undertook a demonstration project to develop methods for analyzing costs and benefits in order to address seismic code issues in regions of low to moderate seismicity but high catastrophic loss potential. One of the team's central goals was to develop a comprehensive means for understanding the economic implications of upgrading a region's seismic code. They produced estimates for Utah's Wasatch Front region and, for comparison, Los Angeles. The team specifically addressed 1) the process involved in seismic code decisions, 2) how the seismic code question can be reformulated in view of this type of process, 3) how detailed estimates of costs can assist in these seismic code risk decisions, and 4) how benefits of various seismic code decisions can be better understood. A limited number of individual copies are available upon written request from Craig E. Taylor, 5402 Via Del Valle, Torrance, California 90505.

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nehrp
National Earthquake Hazards Reduction Program

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM EXPANDING PARTICIPATION IN THE 90s

by Deborah O'Rourke
Federal Emergency Management Agency

Within the last few years, the United States experienced a number of earthquakes which reinforced the fact that the earthquake threat is real. Many of us witnessed firsthand the Loma Prieta earthquake of October 1989, as it interrupted the last game of the World Series in Oakland, and sadly devastated many lives. Its epicenter was remotely located in the Santa Cruz Mountains, about 60 miles outside of the Bay area. Yet, this earthquake caused in excess of $6 billion in damages, over 60 deaths, more than 3,750 injuries, and left over 12,000 people homeless. Most recently, however, we heard about the Landers and Big Bear earthquakes in California, which were a frightening reminder that "the big one" is yet to come.

Over the last decade, combined federal, state, and local efforts have been rewarded by a general trend towards acknowledgment of the earthquake hazard in the United States and the potential catastrophic effects. With a greater recognition of the earthquake hazard, the National Earthquake Hazards Reduction Program (NEHRP) is addressing a much more attentive and concerned audience. The NEHRP agencies (Federal Emergency Management Agency (FEMA), U.S. Geological Survey (USGS), National Science Foundation (NSF), and National Institute of Standards and Technology (NIST)) have been promoting NEHRP nationwide, reinforcing the message that the potential for a catastrophic earthquake exists in the United States, and reiterating that participation at all levels must continue to grow if we are to effectively reduce our vulnerability.

Signing of the NEHRP Reauthorization Act (P.L. 101-614) on November 16, 1990, represented a major milestone in NEHRP. Congress essentially endorsed the direction that the agencies had established for NEHRP. This reinforcement stimulated the NEHRP agencies continued pursuit of a pro-active approach to earthquake hazards reduction in the 90s. This approach is evidenced in the NEHRP Five-Year Plan for 1992-1996, submitted to Congress in September 1991. So far this decade, the NEHRP agencies have been successful in implementing many of the activities and programs described in the Plan.

As evidenced in the Five-Year Plan, FEMA is continuing efforts to expand the number of states that participate in its state earthquake program and encourage the formation of multi-state organizations that can effectively address regional earthquake hazards. Developments over the last few years favor continued efforts in this area. FEMA currently provides funding to 32 states and territories, a considerable increase from only 17 in Fiscal Year 1990. These states and territories are actively pursuing individual earthquake hazards reduction efforts that meet the needs of their particular state/territory.

FEMA is also creating programs to expand the participation of various target audiences in NEHRP. In 1991, FEMA developed the NEHRP Outreach Campaign as an ongoing program that will eventually reach and expose all segments of our society to NEHRP. The first audience target by the campaign is small businesses. This campaign offers a variety of materials that provide small business audiences pragmatic suggestions to implement nonstructural mitigation and cost effective measures to protect the viability of their businesses from an earthquake. Full implementation of this campaign will begin upon completion and review of a pilot campaign currently underway in Jackson, Tennessee.

In addition to reaching out to "target audiences" through NEHRP campaigns, FEMA is also forming partnerships with many of its institutional counterparts in the earthquake community. FEMA has entered (or is entering) into cooperative agreements and memorandums of understanding with the Earthquake Engineering Research Institute (EERI), the National Center for Earthquake Engineering Research (NCEER), and the Southern California Earthquake Center (SCEC).

The cooperative agreement between FEMA and EERI sponsors activities such as earthquake conferences, seminars and workshops, publications, and a special effort - the NEHRP Fellowship. These activities ultimately contribute to the increase of NEHRP participants. The NEHRP Fellowship seeks the participation of professionals and graduate students involved in pursuing earthquake related research. FEMA provides the funds for this Fellowship under the agreement with EERI, while EERI, as the sponsor, administers the Fellowship. EERI has awarded one professional and one graduate Fellowship to date, and anticipates awarding two more Fellowships in 1992. In addition to the Fellowship program, FEMA provides support for EERI student chapters at universities nationwide. FEMA views these chapters as an opportunity to invite and encourage young, enthusiastic individuals offering new insight and innovative ideas, to join the earthquake profession.

FEMA's agreement with NCEER supports the Information Service at the State University of New York at Buffalo (NCEER's headquarters). This Service maintains a comprehensive collection of earthquake materials and information that are made available to the entire earthquake community and the general public. NCEER's work contributes to earthquake awareness and the involvement in earthquake hazards reduction among states east of the Rockies. FEMA and NCEER are also collaborating on other common projects and activities under a memorandum of understanding that was established in July of 1991.

SCEC was established as a means of expanding the earthquake hazards reduction and research effort in Southern California. Inaugurated in February of 1991, SCEC is one of NSF's Science and Technology Centers and is a consortium composed of seven core academic institutions throughout California. SCEC also receives a substantial financial commitment and involvement from the USGS. Through a cooperative agreement, FEMA provides financial support to promote translation and transfer of the research being developed by SCEC to the user community. SCEC's work will assist in further defining the earthquake hazard in southern California.

FEMA has also formalized the involvement and participation in NEHRP of earthquake experts outside the federal government through establishment of the NEHRP Advisory Committee in 1990. These experts, representing the various earthquake related disciplines, contribute a broad experience and expertise that helps the agencies to strengthen and improve NEHRP activities and define program needs.

These activities, as well as other developments, suggest progress for the 90s and continued NEHRP growth. Nevertheless, it is clear that a great deal of work lies ahead. As the program agencies continue to work towards their common goal, we are mindful that NEHRP's mission will not be achieved without the participation of all segments of society. This is an objective that we must continue to work towards. Earthquakes do no discriminate and without a cooperative and comprehensive approach, we are all threatened by a repeat of the devastating earthquakes in Armenia and Mexico City -- but this time, it may occur in our own back yards.

SECOND ANNUAL PROFESSIONAL FELLOWSHIP IN EARTHQUAKE HAZARDS REDUCTION ANNOUNCED

Under a cooperative agreement established with the Federal Emergency Management Agency, EERI is pleased to offer the 2nd Annual Professional Fellowship, to provide an opportunity for a practicing professional to gain greater skills and broader expertise in earthquake hazards reduction, either by enhancing knowledge in the applicant's own field, or by broadening his or her knowledge in a related, but unfamiliar, discipline.

WHO SHOULD APPLY?

This unique fellowship is aimed at the career professional and is designed to bring together an experienced practitioner with those conducting significant research, providing an opportunity to enrich the applicant's knowledge and skills and broaden the research base with challenges faced in practice.

THE AWARD

The fellowship provides a stipend of $30,000, commencing in January 1993, to cover tuition, fees, relocation, and living expenses for a six-month period.

CRITERIA

Applicants must provide a detailed work plan for a research project that would be carried out in the six-month period. The Fellow will be expected to produce a written report upon completion of the project. All applications must be accompanied by a professional resume and letter of nomination from the faculty host(s) at the cooperating educational institution(s). Faculty members should also indicate the institution's ability to provide research facilities, including library, work space, telephone, and computer access. Applicants must hold U.S. citizenship or permanent resident status.

TO APPLY

Candidates may obtain an application form from the Earthquake Engineering Research Institute, 499 14th Street, Suite 320, Oakland, California 94612. Tel: (510) 451-0905, Fax: (510) 451-5411. The deadline for receipt of all application materials at EERI is October 15, 1992. Announcement of the award will be made November 13, 1992.

THE BENEFITS OF A SEISMIC RETROFIT PROGRAM FOR COMMERCIAL UNREINFORCED MASONRY STRUCTURES: SALT LAKE COUNTY, UTAH

by Philip C. Emmi and Carl A. Horton
University of Utah Department of Geography

This paper assesses the benefits of a seismic retrofit program for commercial unreinforced masonry structures (CURMs) in Salt Lake County, Utah. The method is that of comparative risk assessment supported by geographic information systems technology. A policy evaluation time horizon of twenty years is set. Future rates of demolition and rehabilitation, with and without a seismic retrofit policy, are assumed. Damage functions for ordinary and retrofitted URMs are used to assess the risks of property damage under competing assumptions regarding retrofit policy implementation. Expected property loss is assessed probabilistically as loss having a 10 percent chance of being exceeded over a 50-year exposure period. With a retrofit program in place, expected losses are reduced by 57 percent from $492 million to $211 million when compared to the no-policy scenario. Expected injuries are reduced 86 percent from 4909 to 686. Expected fatalities are reduced by 89 percent from 216 to 24. These are minimal measures of the benefits expected from enforcement of the seismic provisions of the Uniform Code of Building Conservation.

INTRODUCTION

This paper is about a local building policy to encourage the structure reinforcement of commercial unreinforced masonry structures (CURMs)—a so-called seismic retrofit policy. The purpose of the paper is to estimate the benefits of implementing such a policy within the contiguously urbanized area of Salt Lake County, an area referred to as the Salt Lake Valley. The 1985 replacement value of the 11,840 taxable commercial structures in the Salt Lake Valley is $4.51 billion. This property is at risk due to a local earthquake ground shaking hazard. In a related study, loss to commercial structures having a 10 percent chance of being exceeded over a 50-year exposure period is estimated to be $1.3 billion or 30 percent of the replacement value of the stock (Emmi and Horton, 1992). Though CURMs represent only 22 percent of the value of the commercial stock, expected damage to CURMs equals 68 percent of the expected damage to all commercial structures. CURMs represent 4 percent of all taxable structures, both commercial and residential, yet expected damage to CURMs represents 37 percent of the expected damage to all occupied structures over a 50-year exposure period. CURMs represent the most seismically vulnerable class of building in the Salt Lake Valley. They are concentrated in zones of higher expected ground shaking intensities and, compared to residential structures, tend to be occupied at relatively higher densities. Because of these three factors, CURMs are the most important single source of casualty risk due to earthquake ground motion in Salt Lake Valley.

These findings suggest that a building code policy encouraging the structural reinforcement of CURMs would significantly reduce the risk of structural damage and associated casualty losses. The idea has not been lost on local building officials: the Salt Lake City Corporation currently enforces a seismic retrofit policy whenever a request for a permit to rehabilitate a commercial structure is made, and there is now a motion before the State of Utah Uniform Building Code Commission to require all political jurisdictions to enforce the seismic provisions to the Uniform Code of Building Conservation.

A time period of twenty years is used to structure a program evaluation focusing on such questions as: What effect will a seismic retrofit program have on the rates with which URMs are remodeled, reinforced and demolished: How many URMs will be left standing after a twenty year period with and without a retrofit policy: In each case, what is the seismic performance of the stock left standing: Given differences in both stock and performance, what are the risks of property damage and casualty loss with and without a retrofit policy?

To estimate the degree to which risk could be reduced, five classes of information are used: 1) assumptions about the rates at which URMs will be remodeled, demolished and reinforced with and without a seismic retrofit program, 2) seismic damage functions describing the vulnerability of ordinary and retrofitted URMs to various intensities of ground motion, 3) seismic casualty functions describing expected per capita casualty rates as a function of the expected degree of damage to occupied structures, 4) an assessment of risk to URMs and their occupants without a retrofit policy, and 5) an assessment of risk to URMs and their occupants with a retrofit policy in force.

Our method is one of comparative risk assessment. The current stock of CURMs is projected 20 years into the future under assumptions compatible with the two alternative policy options. Each projected stock is subjected to the intensities of earthquake ground shaking that have a 10 percent chance of being exceeded over a 50-year exposure period (Figure 1). Associated levels of property damage are found as a function of ground shaking intensity and the prevailing mix of unreinforced and retrofitted structures. Results are compared and differences in damage are noted. Differences in casualty losses are also noted. These findings serve as minimal measures of the benefits of a seismic retrofit policy for commercial unreinforced masonry structures.

DATA AND ASSUMPTIONS

A ground shaking hazard study by Emmi (1990) provides a point of departure. This study contains probabilistic assessments of the intensities of earthquake ground shaking to which different parts of Salt Lake Valley are subject over exposure periods of different lengths. It expresses the ground shaking hazard in terms of the ground shaking intensities that have a 10 percent chance of being exceeded over 10-year, 50-year and 250-year exposure periods. A related study employs data on the locations, values and structural frame

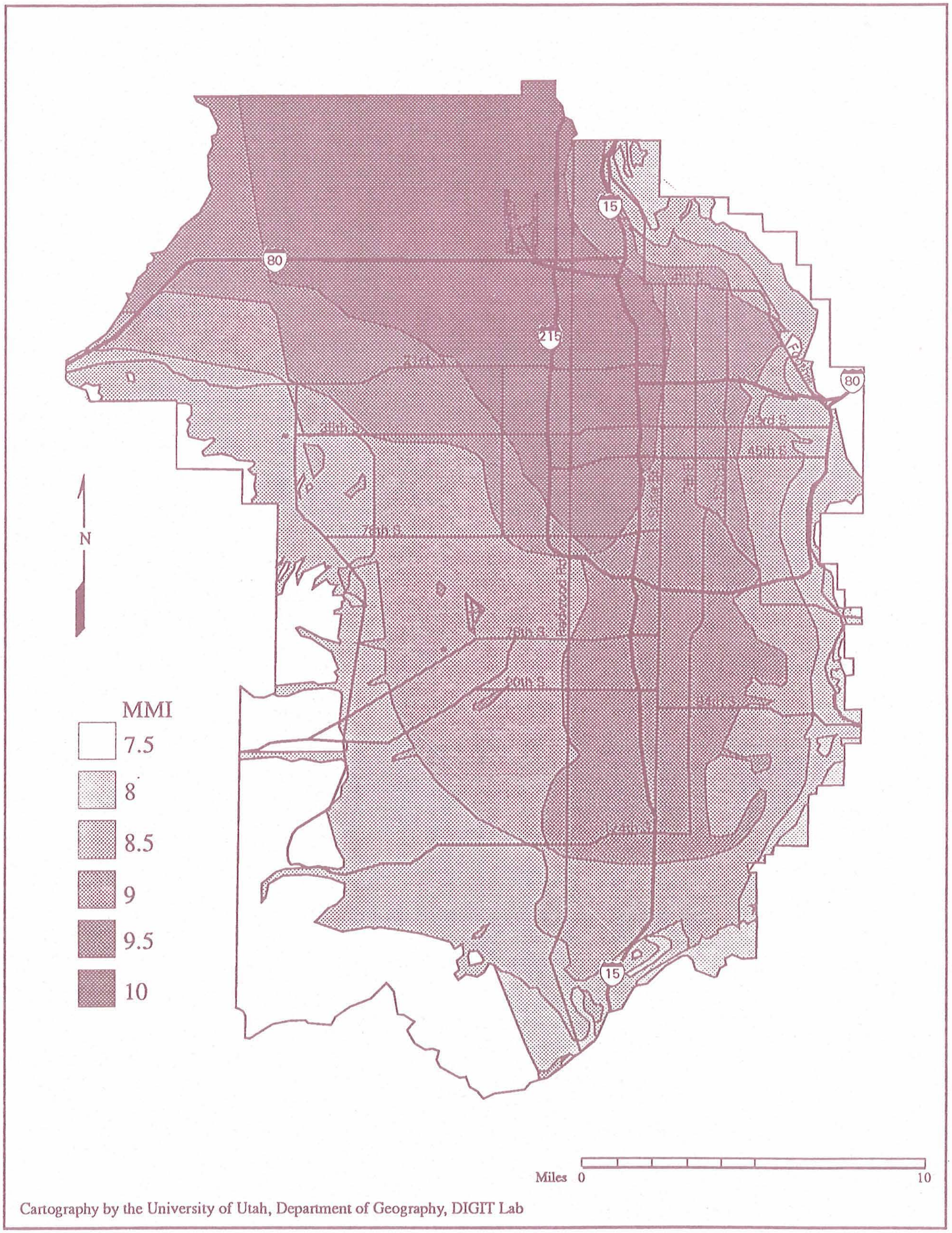

Figure 1. Modified Mercalli intensities with a 10 percent chance of being exceeded during a 50-year exposure period.

types of taxable commercial and residential buildings in Salt Lake Valley (Emmi and Horton, 1991). It uses seismic damage functions from Rojahn (1985) to compute the percentage of a building's value lost given data on expected ground shaking intensities and the building's structural frame type. The property loss computations are done in a vector-based geographic information system (GIS) by overlaying ground shaking maps on property value maps for each structural frame type and computing damage from data in related data files.

The Applied Technology Council, Report 13, presents tabular data on the seismic performance of a large number of common building types, including URMs (Rojahn, 1985). Data on damage to ordinary low-rise URMs (ATC-13 facility type #75) best fit the third-order polynomial equation given below where MMI equals ground shaking intensity measured on the Modified Mercalli intensity scale and where y equals the percentage of the building's reconstruction cost lost:

$$y = 376.59 - 148.05 \text{ MMI} + 18.28 \text{ MMI}^2 - 0.66 \text{ MMI}^3$$

In a recent study for the city and county of San Francisco, Rutherford and Chekene Consulting Engineers (1991) compile data and expert opinion on what is known concerning the seismic performance of retrofitted URMs. They estimate the seismic performance of retrofitted URMs for three increasingly higher levels of reinforcement. For this study, the lowest level of reinforcement is considered. That level of reinforcement includes: 1) parapet retrofit work with roof ties and anchoring of roof-line falling hazards, 2) exterior walls anchored to floors and roofs, 3) shear transfer devices supplied to the boundary between floor or roof diaphragms and exterior walls, and 4) out-of-plane walls strengthened. (It should be understood that this level of strengthening is modestly less that required by the Uniform Code of Building Conservation and will, therefore, result in a conservative estimate of the reductions in risk available through local implementation of that Code.) Estimates of damage to URMs strengthened to the first level of reinforcement best fit the second-order polynomial equation given below:

$$y = -24.14 - 0.26 \text{ MMI} + 0.67 \text{ MMI}^2$$

When these two equations are graphed, the difference in the seismic performance of ordinary and retrofitted URMs becomes clear (Figure 2). For example, at a ground shaking intensity of VIII, loss to an ordinary URM is expected to be about 25 percent of its value while loss to a retrofitted URM is expected to be about 16 percent of its value.

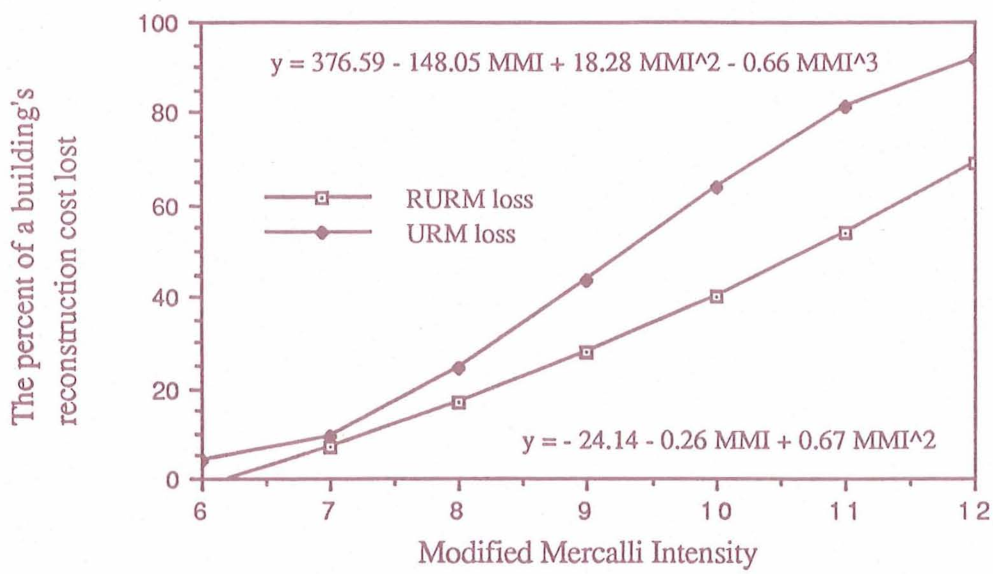

Figure 2. Seismic damage functions for unreinforced and retrofitted masonry structures.

Reductions in risk of property loss imply a lower risk of casualty loss. Seismic casualty functions for minor injuries, major injuries and loss of life are developed from tabular data presented in Rojahn (1985). The natural logarithms of this data are best fit to second-order polynomial equations so that by letting y equal the logarithm of the per capita rate of minor injuries and x equal the logarithm of the rate of damage (measured as the percentage of value lost), the casualty function for minor injury rates can be represented as:

$$y = 10.126 + 0.550\ x + 0.326\ x^2$$

The casualty function for major injury rates - the natural logarithm of y - is:

$$y = 13.682 + 0.271\ x + 0.436\ x^2$$

While these equations can be used to identify the before-and-after performance of URM structures, additional information is needed to assess the impacts of a seismic retrofit policy: a retrofit policy would not only encourage the structural reinforcement of CURMs but would influence rates of demolition and remodeling. At this point, the services of Dr. Larry Reaveley of Reaveley Engineers and Associates are used to determine, in consultation with city and county building officials, what historic rates of demolition and remodeling among URMs have been and how these rates might change with the implementation of a seismic retrofit policy (Reaveley, 1990). Demolition rates have not been uniform throughout the Valley. Demolition of CURMs has proceeded at about 0.20 percent of the stock per year within the Central Business District (CBD) and at about 0.50 percent of the stock per year outside the CBD. Without a seismic retrofit policy, these rates are assumed to hold constant over the period of policy evaluation. Rates of rehabilitation and structural reinforcement are assumed to be negligibly different from zero both within and outside the CBD. With a seismic retrofit policy, rehabilitation with structural reinforcement is assumed to proceed at 4.0 percent of the stock per year, while demolition is assumed to proceed 1.0 and 2.0 percent of the stock per year within and outside of the CBD, respectively. Assumptions concerning these rates are summarized in Table 1.

These assumptions, together with the information mentioned above, are nearly sufficient to assess the future risk to property and limb from CURMs with and without implementation of a retrofit policy. The only missing data item is data on the densities with which CURMs are occupied by employee populations. This data is not available, but data by traffic zone on the densities with which all commercial buildings are occupied is available. To estimate CURM occupancy densities and to compute CURM casualty risk, the proportion of the employee population in each traffic zone occupying CURMs is assumed to be proportional to the ratio of CURM-to-total commercial property value in that zone. The assumption allows a reasonably representative assessment of CURM occupancy densities and casualty risks without imposing unrealistic data requirements. Though, confidence in the resulting casualty estimates may be lower, the resulting numbers are adequate to express the order of effect one could expect from implementing, or failing to implement, the kinds of policy under consideration here.

METHOD

The method of analysis rests on the assessment of loss with and without 20 years of retrofit policy implementation. First, assuming no retrofit policy, the risk of loss to CURMs remaining after 20 years is computed. Then, assuming enforcement of retrofit policy, the risk of loss to the CURMs remaining in either an unreinforced or strengthened condition is found. The two loss figures are compared, the difference is noted and the subsequent effects on the risks of casualty losses are found. In all cases the earthquake hazard is represented by those levels of ground shaking intensity that have a 10 percent chance of being exceeded over a 50-year exposure period.

To project risk under the no action assumption, the amount of CURM stock left after 20 years is first projected. The rates of demolition given in Table 1 are used in a standard time discount formula $[1/1+d)^{20}]$ to estimate what portion of the stock will be demolished and what portion will remain. A GIS data file on the risk to commercial properties and employee populations documented in Emmi and Horton (1991) is then opened: properties within and outside the CBD are identified together with the costs of their

Table 1. Assumptions about future demolition and structural rehabilitation rates.

Policy options:	No retrofit policy		Active retrofit policy	
Location:	Demolition	Rehabilitation	Demolition	Rehabilitation
Within the CBD	0.2% per year	0.0% per year	1.0% per year	4.0% per year
Outside the CBD	0.5% per year	0.0% per year	2.0% per year	4.0% per year

reconstruction. Appropriate rates of survival are applied to identify the current value of CURMs remaining in the future. Future risk to the remaining CURMs is assessed by applying the seismic damage function for unreinforced masonry structures given in equation 1. The results indicate the future risk of damage to which the stock of CURMs will be subjected if no efforts are taken to encourage their reinforcement.

To project future risk under the positive action assumption, an estimate is made of the CURM stock demolished, strengthened and left unaltered after 20 years of policy implementation. Again, rates of demolition and rehabilitation given in Table 1 are used. The GIS data file is reopened, properties within and outside the CBD are identified, and appropriate rates of survival and rehabilitation are applied. Future risk to the unaltered CURMs is assessed by applying the seismic damage function for unreinforced masonry structures given in equation 1, while future risk to the strengthened CURMs was assessed by applying the damage function given in equation 2. The results indicate the future risk of damage to which the CURM stock will be subject if efforts are taken to encourage their reinforcement.

The difference between these two situations can be taken as a measure of the benefit that implementing a retrofit policy would have on the reduction of risk to the stock of CURMs. This amount is noted and expressed as both a total value and as a percentage reduction in risk. Casualties, with and without a seismic retrofit program, are then computed using the equations above.

FINDINGS

Without a retrofit program, 96 percent of the current stock of commercial unreinforced masonry structures inside the CBD is expected to remain standing 20 years hence. Outside the CBD, 90 percent of CURM stock is expected to remain standing. Under the assumption of an active retrofit policy, 18 percent of the current stock in the CBD is expected to have been demolished, 72 percent to have been strengthened and 10 percent to remain unaltered over the intervening 20 years. Outside the CBD, 33 percent of the current CURM stock is expected to have been demolished, 65 percent to have been strengthened and 2 percent to remain unaltered.

The effects of these changes on expected future losses are stated below and in Table 2.

Risk to property damage from exposure to the possibility of earthquake ground motion is measured by the dollar amounts of damage that have a 10 percent chance of being exceeded over a 50-year exposure period. Currently, there is a 10 percent chance of a 50-year exposure period that losses to the present stock of commercial unreinforced masonry structures will exceed $536 million or 53 percent of the value of the CURM stock. In 20 years, demolition will decrease the number of CURMs and, thus, the risk of property loss due to ground shaking: without a retrofit policy, there will be a 10 percent chance over a 50-year exposure period that losses to the reduced stock of commercial unreinforced masonry structures will exceed $492 million.

A retrofit policy will encourage both the active demolition of CURMs and their structural reinforcement. Because of these two effects, the stock of unreinforced masonry structures will decline rapidly: with a retrofit policy, there is a 10 percent chance over a 50-year exposure period that losses to the remaining stock of commercial unreinforced and retrofitted masonry structures will exceed $211 million -- a figure that is $281 million less or 57 percent less. The $281 million or 57 percent difference is an approximate measure of the benefit of implementing a seismic retrofit policy on expected loss to commercial property.

Table 2. Future expected losses to CURMs with and without a seismic retrofit policy.

	Property Loss[1]	Minor Injuries[2]	Major Injuries[2]	Fatalities[2]
Without a Policy	$492 million	4045	864	216
With a Policy	$211 million	592	94	24
Difference	$281 million	3453	770	192
% Reduction	57	85	89	89

[1]Expected loss having a 10 percent chance of being exceeded over a 50-year exposure period.
[2]Casualties associated with the stated degrees of property loss.

Expected casualties associated with current CURM property losses are estimated to be 4416 minor injuries, 943 major injuries and 236 deaths under conditions of full occupancy. Without any seismic retrofit policies in effect, the stock of CURMs will have been reduced in 20 years to 92 percent of its original numbers. It will house, presumably, 92 percent of its original employees, and its casualty potential will have been reduced by 8 percent to 4045 minor injuries, 864 major injuries and 216 fatalities. With a seismic retrofit policy, the current stock of CURMs will have been reduced by 97 percent, that is 66 percent will have been reinforced and 31 percent will have been demolished. Presumably, these structures will house 31 percent fewer employees. The CURM damage rate having a 10 percent chance of being exceeded over a 50-year period will have been reduced from 53 percent to 30 percent. At this lower intensity of damage, casualty losses are estimated to be 592 minor injuries, 94 major injuries and 24 fatalities. These figures are some 85 to 89 percent below the future casualty estimates under the assumption of no seismic retrofit policy. This difference, too, represents an important benefit associated with that policy.

CONCLUSIONS

A seismic retrofit policy encourages a more rapid retirement of commercial unreinforced masonry units as well as their structural reinforcement. Over a 20 year period, implementation of a minimal retrofit policy reduces expected loss to commercial unreinforced masonry structures due to earthquake ground shaking by 57 percent. Lower property loss reduces expected casualties by 85 to 89 percent, including 192 fewer expected deaths. Even with minimal improvements assumed, the cumulative policy effects significantly reduce expected property damage and human casualties. These reductions serve as minimal measures of the benefit produced by a seismic retrofit policy.

Research on the expected costs of structural reinforcement and structural demolition and on the relative merit of other methods for reducing risk from earthquakes would be helpful. Yet the measurable benefits shown here are sufficiently great as to warrant the consistent local enforcement of the seismic provisions to the Uniform Code of Building Conservation throughout the Salt Lake Valley.

ACKNOWLEDGEMENT

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MEETINGS AND CONFERENCES

September 13-16, 1992, Association of State Dam Safety Officials 1992 Annual Conference, held in Baltimore, Maryland. This conference will address all aspects of dam safety, including seismic design, underwater inspection, mining issues, dam rehabilitation, insurance, slope stability and design, hydrology and hydraulics, computer software applications, geotechnical issues, environmental issues, and current technical research. Interested individuals should contact the Association of State Dam Safety Officials, P.O. Box 55270, Lexington, KY 40555, (606) 257-5146, fax 606-258-1958.

September 27-30, 1992, American Institute of Professional Geologists (AIPG) 1992 Annual Meeting, held in South Lake Tahoe, Nevada. Of the five technical sessions planned, one will focus on the "Role of the geologist in predicting earthquakes" and another on "Geological common sense regarding environmental hazards." For details, contact Jonathan G. Price, Nevada Bureau of Mines and Geology, Mail Stop 178, University of Nevada, Reno, NV 89557-0088, (702) 784-6691, fax 702-784-1709.

October 2-9, 1992, Association of Engineering Geologists Annual Meeting, held in Long Beach, California. For information contact John Byer, Kovacs-Byer, Inc., 11430 Ventura Boulevard, Studio City, CA 91604, (818) 980-0825.

October 8-10, 1992, Utah Geological Association Annual Field Trip, "Engineering and Environmental Geology of Southwestern Utah," to be held in Cedar City, Utah. For information, contact Robert C. Rasely, U.S. Soil Conservation Service, P.O. Box 11350, Salt Lake City, UT 84092, (801) 524-5026.

October 26-29, 1992, Geological Society of America Annual Meeting, held in Cincinnati, Ohio. For general information about the annual meeting, contact GSA Meetings Department at 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020.

November 9-12, 1992, National Earthquake Training Conference and Seismic Products Exhibit, sponsored by the Masonry Institute of Tennessee, held in Jackson, Tennessee. This conference will focus primarily on earthquake preparedness and will include workshops on seismic design and construction for architects, engineers, contractors, and codes and building officials. Sessions also will be offered on rescue and emergency procedures for emergency management personnel and utility companies, and earthquake liability for insurance agents. For information about the conference, or to be placed on the mailing list to receive a registration form, contact the Masonry Institute of Tennessee, 1136 North Second Avenue, Nashville, TN 37208-1702, (615) 244-3090.

February 11-13, 1993, Earthquake Engineering Research Institute Annual Meeting, held at the Sheraton Seattle Hotel and Towers in Seattle, Washington. The meeting will include case studies from recent earthquakes, panel discussions, and individual presentations on designing and constructing new seismic-resistant structures, retrofitting old structures, building earthquake-resistant lifelines and infrastructure, and establishing effective codes, enforcement procedures, and public policy. For more information, contact the Earthquake Engineering Research Institute, 499 14th Street, Suite 320, Oakland, CA 94612-1902, (510) 451-0905, fax 510-451-5411.

April 14-16, 1993, Seismological Society of America Annual Meeting, held in Ixtapa-

Zihuatanejo, Mexico. Abstracts of papers reporting original research in seismology and earthquake engineering are invited. Abstracts must be received no later than January 10, 1993. Copies of the instructions for submitting abstracts may be obtained from and should be submitted to Program Chair, c/o SSA Headquarters, 201 Plaza Professional Building, El Cerrito, CA 94530, (510) 525-5474.

April 19-21, 1993, ASCE Structures Congress '93, Structural engineering - leadership in natural hazard mitigation, held in Irvine, California. For information, contact R. Villaverde, Secretary, Steering Committee, Structures Congress '93, Department of Civil Engineering, University of California at Irvine, Irvine, CA 92717.

May 19-21, 1993, Geological Society of America Cordilleran/Rocky Mountain Section Meeting, held in Reno, Nevada. For more information, contact Vanessa George, GSA, 3300 Penrose Place, Boulder, CO 80301, (303) 447-1133.

June 1-6, 1993, Third International Conference on Case Histories in Geotechnical Engineering, held in St. Louis, Missouri. One of the themes of this conference will be geotechnical earthquake engineering. Abstracts were due by February 28, 1992. For further information on the conference or the call for papers, contact Shamsher Prakash, Conference Chairman, III CHGE, 308 Civil Engineering, University of Missouri-Rolla, Rolla, MO 65401, (314) 341-4489, fax 314-341-4729.

RECENT PUBLICATIONS

Applied Technology Council, 1992, Proceedings of workshop for utilization of research on engineering and socioeconomic aspects of the 1985 Chile and Mexico earthquakes: Applied Technology Council, ATC-30, 113 p. Contact Patti Christofferson at ATC at (415) 595-1542 for ordering information.

Berke, P.R., and Beatley, Thomas, 1992, Planning for earthquakes - risk, politics, and policy: Johns Hopkins University Press, 228 p., $38.00, 701 West 40th Street, Suite 275, Baltimore, MD 21211.

Doherty, Neil, Kleffner, A.E., and Kunreuther, Howard, 1992, The impact of a catastrophic earthquake on insurance markets: Boston, National Committee on Property Insurance, 24 p. Price and ordering information are available from Karen Gahagan, National Committee on Property Insurance, 10 Winthrop Square, Boston, MA 02110, (617) 423-4620, fax 617-423-7633.

Earthquake Engineering Research Institute, 1991, Proceedings -- Fourth International Conference on Seismic Zonation, volumes 1-3: Oakland, Earthquake Engineering Research Institute, vol. 1 - 896 p., vol. 2 - 838 p., vol. 3 - 784 p. Available only as a three-volume set for $125 from the Earthquake Engineering Research Institute, 499 14th Street, Oakland, CA 94612-1902, (510) 451-0905.

Kimball, Virginia, 1992, Earthquake ready -- the complete preparedness guide: Malibu, Roundtable Publishing, 250 p. Available for $18.95 from Roundtable Publishing, 29169 Heathercliff, Suite 215, Malibu, CA 90265, (213) 457-8433, fax 213-457-8404.

Lagorio, H.J., Olson, R.A., Scott, Stanley, and Shefner, Jonathan, 1991, Knowledge transfer in earthquake hazard reduction - a challenge for practitioners and researchers: Center for Environmental Design Research, publication #CEDR-01-91, 50 p. Available for $5.50 from Center for Environmental Design Research, 390 Wurster Hall, University of California, Berkeley, CA 94720, (415) 642-2896.

Litan, R.E., 1992, Earthquake economics - confronting the inevitable: Boston, National Committee on Property Insurance, 24 p. Price and ordering information are available from Karen Gahagan, National Committee on Property Insurance, 10 Winthrop Square, Boston, MA 02110, (617) 423-4620, fax 617-423-7633.

Litan, R.E., Krimgold, Frederick, Clark, Karen, and Khadilkar, Jayant, 1992, Physical damage and human loss - the economic impact of earthquake mitigation measures: The Earthquake Project, 77 p. Single copies free from Karen Gahagan, The Earthquake Project, National Committee on Property Insurance, Ten Winthrop Square, Boston, MA 02110-1273, (617) 423-4620, fax 617-423-7633.

Madsen, G.E., 1992, Developing a natural hazards videotape - the challenges and rewards: Natural Hazards Observer, v. 16, no. 3, p. 4-5. (See WFF, 1990, v. 7, no. 2, p. 5, for a review of the videotape being discussed in this article.)

Mileti, D.S., Fitzpatrick, Colleen, and Farhar, B.C., 1992, Fostering public preparations for natural hazards -lessons from the Parkfield earthquake prediction: Environment, v. 34, no. 3, p. 16-20, 36-39.

OAK Engineering, 1992, Evaluation of the performance of seismically retrofitted buildings: Applied Technology Council, ATC-31, 75 p., $25.00 from Applied Technology Council, 555 Twin Dolphin Drive, Suite 270, Redwood City, CA 94065.

Page, R.A., Boore, D.M., Bucknam, R.C., and Thatcher, W.R., 1992, Goals, opportunities, and priorities for the USGS Earthquake Hazards Reduction Program: U.S. Geological Survey Circular 1079, 66 p.

Paulay, Thomas, and Priestley, Nigel, 1992, Seismic design of reinforced concrete and masonry buildings: John Wiley & Sons, Inc., 744 p., $90.00.

Ross, K.E., and Winslow, F., editors, 1991, Proceedings from the implementation of earthquake planning and education in schools - the need for change - the role of the changemakers: National Center for Earthquake Engineering Research, Technical Report NCEER -91-0022, 240 p. Available for $20.00 from the Publications Department, NCEER, State University of New York at Buffalo, Red Jacket Quadrangle, Buffalo, NY 14261, (716) 636-3391, fax 716-636-3399.

Science and Technology Program, Center for Strategic and International Studies, 1991, Managing the economic consequences of catastrophic earthquakes: Science and Technology Program, Center for Strategic and International Studies, 27 p. A limited number of free copies are available to interested persons by contacting Lisa Jackson, CSIS, 1800 K Street, N.W., Suite 400, Washington, D.C. 20006, (202) 775-3239.

Smith, R.B., and Arabasz, W.J., 1991, Seismicity of the Intermountain seismic belt, in Slemmons, D.B., Engdahl, E.R., Zobeck, M.D., and Blackwell, D.D., editors, Neotectonics of North America: Geological Society of America, Decade of North American Geology Map Volume 1, p. 185-228.

Stephenson, W.J., Smith, R.B., and Pelton, J.R., 1991, High-resolution seismic imaging and gravity analysis of deformation across the Wasatch fault, Kaysville, Utah: U.S. Geological Survey Open-File Report 91-582, 30 p.