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REDUCING EARTHQUAKE HAZARDS IN UTAH:

THE CRUCIAL CONNECTION BETWEEN RESEARCHERS AND PRACTITIONERS

by

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ABSTRACT

Translation and transfer of complex scientific and engineering studies to nontechnical users are necessary for their use in reducing earthquake hazards in Utah. Three elements are needed for effective translation for practitioners: likelihood of occurrence, location, and severity of potential hazards. Several examples of translated information for Utah are described and illustrated. Three activities are needed for effective transfer to nontechnical users: delivery, assistance, and encouragement. Numerous types of transfer techniques in Utah are described and illustrated.

The importance of evaluating and revising earthquake-hazard reduction programs and their components is emphasized. Fourty-four evaluations of various natural hazard reduction programs and techniques are introduced.

This report was prepared for research managers, funding sources, and evaluators of the Utah earthquake-hazard reduction program who are concerned about effectiveness. It provides an overview of the Utah program for those researchers, engineers, planners, and decisionmakers -- public and private -- who are committed to reducing human casualties, property damage, and costly interruptions of socioeconomic activities.

INTRODUCTION AND PURPOSE

Effective comprehensive programs having earthquake-hazard reduction as a goal need five components, each a prerequisite for its successor:

1. Conducting scientific and engineering studies of the physical processes of earthquake phenomena -- source, location, size, likelihood of occurrence, severity, triggering mechanism, path, ground response, structure response, and equipment response.

2. Translating the results of such studies into reports and onto maps at an appropriate scale so that the nature and extent of the hazards and their effects are understood by nontechnical users.

3. Transferring this translated information to those who will or are required to use it, and assisting and encouraging them in its use through educational, advisory, and review services.

4. Selecting and using appropriate hazard reduction techniques -- legislation, regulations, design criteria, education, incentives, public plans, and corporate policies.

5. Evaluating the effectiveness of the hazard reduction techniques after they have been in use for a period of time and revising them if necessary. Evaluation and revision of the entire program as well as the other components -- studies, translation, and transfer -- may also be undertaken.

These five components (Figure 1) encompass a broad range of activities which are often described or divided differently. Examples include: 48 resolutions by the United Nations Educational, Scientific, and Cultural Organization (1976), six general topics and 37 issues by the U.S. Office of Science and Technology Policy (1978), 48 detailed initiatives recommended by the California Seismic Safety Commission (1986), and 171 action items at a state governor's conference on geologic hazards (Utah Geological and Mineral Survey, 1983).

The purpose of this report is to emphasize the crucial connection between scientific and engineering studies and their ultimate use for hazard reduction by practitioners in Utah. The connection consists of two of the five components -- translation and transfer -- shown in Figure 1. Emphasis on this crucial connection is provided by a discussion of the problem -- failure to translate and transfer -- and efforts toward making the connection in Utah. Translation and transfer are defined, described, and then illustrated, first by the use of general examples and then by the use of specific examples in Utah.

Scientific and Engineering Studies

A prerequisite for a successful Utah earthquake-hazard reduction program is the production by researchers of adequate and reliable scientific and engineering information about potential earthquake hazards -- surface fault rupture, ground shaking, landsliding, liquefaction, seiches, tsunamis, subsidence and their effects. Actual hazards occur when land uses, or structures, or equipment are located, constructed, or operated in such a way that people may be harmed, their property damaged, or their socioeconomic systems interrupted.

Numerous geologic, geophysical, seismologic, and engineering studies are necessary to assess potential earthquake hazards in Utah. These studies are concerned with the physical process of earthquakes -- source, location, size, likelihood of occurrence, triggering mechanism, path, and severity of effects on a site, structure, or socioeconomic activity. These studies can be divided in several ways. To give the nontechnical reader an overview, some of the studies are shown in List 1.

A description of many of these studies can be obtained from perusing various scientific and technical reports and texts, such as: Richter (1958), Wallace (1974), Borcherdt (1975), Applied Technology Council (1978), Hays (1980), Ziony (1985), Power and others (1986), Evernden and Thomson (1988), and Schwartz (1988).

Most of these studies are interconnected, have limitations because of lack of data, and require special technical skills. For example, the uncertainties that affect ground response generally are identified and listed by Hays (1980, Table 23, p. 67); five levels of the reliability of the data used to calculate the probability of large earthquakes are given for each fault segment by a working group on California earthquake probability (Agnew and others, 1988); and in the case of the Wasatch Front, Hays (1987, p. R-7 and 8) identifies typical limitations of the technical data bases.

Many of these studies were envisioned and are described in the "Regional Earthquake Hazards Assessments" draft work plan for the Wasatch Front. This plan was reproduced in a workshop proceedings edited by Hays and Gori (1984, p. 17-44). The results of those studies may be seen in a two-volume report edited by Gori and Hays (1987).

Such studies are vital, because in the words of a former U.S.

List 1

Examples of scientific and engineering studies necessary to assess earthquake hazards 1/

Types of Studies 2/	Knowledge Derived
Geologic	
Detailed geologic mapping Lithologic investigations Stratigraphy Borehole sampling Trenching Paleontology Scarp analysis Stream offsets Geomorphologic studies Structural geology	Fault slip rates, physical properties, fault length, fault age, fault geometry, bedrock strength, zones of deformation, amplification of ground motion, lateral and vertical offsets, earthquake recurrence intervals, earthquake sources, depth to ground water, fault location, bedrock types, deformation patterns, plate tectonics context, driving forces, and other knowledge concerning surface rupture, ground shaking, landsliding, liquefaction, seiches, tsunamis, and subsidence.
Geophysical/Geochemical	
Geodetic leveling and trilateration Field monitoring: Stress and strain Tilt and creep Electrical changes Radon/helium emissions Water chemistry changes Water-well levels Electromagnetic soundings Gravity, electrical, and magnetic studies Seismic refraction and reflection profiling Radiometric dating	Precursor detection, ongoing deformation, fault zone properties, recurrence intervals, shear wave velocity, stress accumulation, crustal anatomy, crustal properties, wave attenuation, crustal velocity model, ground-motion characteristics, deformation patterns, buried faults or structure locations, and three-dimensional crustal geometry.

1/ These studies are just some of the ones necessary to assess earthquake "hazards;" many other types of studies are necessary to evaluate "vulnerable" structures, "secondary" hazards (fires, floods, and toxin spills), people "exposed," and socioeconomic activities at "risk."

2/ The term "studies" is loosely used here to include experiments, measurements, investigations, observations, models, techniques, analyses, mapping, monitoring, or testing. Many of the seismologic studies are a special type of geophysical research.

List 1 (continued)

Examples of scientific and engineering studies necessary to assess earthquake hazards

Type of Studies	Knowledge Derived
Seismologic	
Historical seismicity Earthquake monitoring Strong ground-motion monitoring networks Ground response Seismic wave propagation Segmentation analyses Wave propagation Rupture process	Asperity locations, velocity, severity of shaking, acceleration, displacement, seismic gaps, source zones, fault mechanism, rupture direction, seismic direction, recurrence interval, epicenters, epicentral intensity, fault type, fault length, fault width, maximum probable magnitude, seismic hazard zones, rupture characteristics, seismic moment, stress drop, local amplification, duration of shaking, focal mechanism and depth, and response spectrum.
Engineering	
Structural mechanics Engineering characteristics Risk analysis Monitoring of structures Damage inventories Soil-structure interaction Structural vulnerability Soil mechanics Rock mechanics Soil/rock acoustic impedance Standard penetration tests	Seismic risk maps, structural performance, hysteretic behavior, strength of materials, stiffness degradation, structural strength, structural reliability, design criteria, material properties, response spectra, seismic intensities, nonlinear behavior, inelasticity, ductility, damping, energy absorption, bearing capacity, soil properties, amplification levels, shear wave velocity, shear modulus, failure limits, load limits, ultimate load limits, and foundation design.

Note: Robert Brown, geologist, Robert Simpson, geophysicist, Allan Lindh, seismologist, and Mehmet Celebi, structural engineer, U.S. Geological Survey, provided critical comments and valuable suggestions that have refined and improved this list. However, because of its abbreviated form, the author remains responsible for its omissions and any errors.

Geological Survey director, Walter C. Mendenhall: "There can be no applied science unless there is science to apply." It has been my experience that it is not prudent for planners to develop land-use regulations, engineers to design structures, and lenders and public works directors to adopt policies reducing earthquake hazards without reliable scientific and engineering assessments. Hanks (1985, p. 3) observes that "implementation plans may not mean much if they are not based on the best scientific knowledge and data available."

Hazard Reduction Techniques

Numerous earthquake-hazard reduction techniques are available in Utah to engineers, planners, and decisionmakers, both public and private. These techniques have the following specific objectives: awareness of, avoidance of, accommodation to, or response to, the effect of the earthquake phenomena on people and their land uses, structures, and socioeconomic activities. The general goal of these objectives is to reduce human casualties, property damages, and socioeconomic interruptions.

Many of the reduction techniques are also complex, interconnected, and require special skills -- legal, financial, legislative, design, economic, communicative, educational, political, and engineering. To give the reader an overview, examples of specific reduction techniques are shown in List 2. These techniques can also be divided in other ways, for example:

- Pre-event mitigation techniques, which may take 1 to 20 years.
- Preparedness measures, which may take 1 to 20 weeks.
- Response during and immediately after an event.
- Recovery operations after an event, which may take 1 to 20 weeks.
- Post-event reconstruction activities, which may take 1 to 20 years.

These estimated time periods vary depending upon the postulated or actual size of the earthquake, its damage, the reduction techniques in place, and the resources available to the State of Utah, its communities, its corporations, and its families.

Many of the hazard reduction techniques identified in this report have been discussed and illustrated by Blair and Spangle (1979), Kockelman and Brabb (1979), Brown and Kockelman (1983), Kockelman (1985, 1986), Jochim and others (1988), Mader and Blair-Tyler (1988), Blair-Tyler and

List 2

Examples of specific techniques for reducing earthquake hazards in Utah

Incorporating hazard information into plans and programs

Community-facilities inventories and plans
Economic-development evaluations and plans
Land-subdivision layouts
Land-use and transportation inventories and plans
Public-safety plans
Redevelopment plans (pre-disaster and post-disaster)
Utility inventories and plans

Regulating development

Placing moratoriums on building
Reviewing annexation, project, and rezoning applications
Enacting building and grading ordinances
Adopting design and construction regulations
Requiring engineering, geologic, and seismologic reports
Requiring investigations in hazard zones
Enacting subdivision ordinances
Creating special hazard-reduction zones and regulations

Siting, designing, and constructing safe structures

Reconstructing after a disaster
Reconstructing or relocating community facilities
Reconstructing or relocating utilities
Securing building contents and nonstructural components
Evaluating specific sites for hazards
Siting and designing critical facilities
Training design professionals

Discouraging new development in hazardous areas

Disclosing potential hazards to real-estate buyers
Creating financial incentives and disincentives
Adopting lending policies that reflect risk of loss
Adopting utility and public-facility service-area policies
Requiring nonsubsidized insurance related to level of hazard
Posting public signs that warn of potential hazards
Making a public record of potential hazard locations
Clarifying the legal liability of builders and property owners

Strengthening, converting, or removing unsafe structures

Condemning and demolishing unsafe structures
Creating nonconforming land uses
Repairing or draining unsafe dams
Retrofitting bridges and overpasses

List 2 (continued)

Examples of specific techniques for reducing-earthquake hazards in Utah

Strengthening or anchoring buildings
Acquiring or exchanging hazardous properties
Reducing land use intensities or building occupancies

Preparing for and responding to emergencies and disasters

Estimating damages and losses from an earthquake
Preparing damage scenarios for critical facilities
Providing for damage inspection, repair, and recovery
Conducting emergency or disaster training exercises
Taking preparedness measures
Operating monitoring, warning, and evacuation systems
Initiating public and corporate education programs
Preparing emergency response and recovery plans
Creating community recovery information clearinghouses

Gregory (1988), and the United Nations Office of the Disaster Relief Coordinator (Lohman and others, 1988).

Utah's Draft Work Plan

A collective partnership of Utahans and others in 1983 created a unique State earthquake-hazard reduction program. The formulators of the draft work plan for the Wasatch Front not only envisioned the use of scientific and engineering studies to reduce the hazard, but provided for an "implementation" component having three priorities. These were: (1) determining the needs of users, (2) producing translated information that meets the need, and (3) fostering an environment for use of research results by local government. For the purpose of this report, users are defined as those who are interested in or who have responsibility for reducing earthquake hazards.

Examples of specific techniques to reduce hazards (List 2) and potential users of earthquake hazard information (List 3) were compiled. The techniques most appropriate for Utah would be selected by these users. These techniques and users were included in the draft work plan reproduced by Hays and Gori (1984, p. 37-44). This work plan provides a bench mark for evaluating its accomplishments. Descriptions and illustrations of the techniques are beyond the scope of this report. However, many of them were selected, successfully used, or are pending in Utah.

Descriptions of some of them may be seen in the volumes edited by Gori and Hays (1987, 1988). One of them -- a model natural hazards reduction ordinance drafted by the Salt Lake County planning staff (Barnes, 1988b) -- has been adapted and adopted by the city of Washington Terrace.

In addition, geologists, engineers, and planners -- public and private -- are evaluating the location or design of developments in relation to earthquake hazards, for example: rezonings and annexations by Utah and Juab counties' geologist R.M. Robison (written commun., 1985, 1986); subdivision layouts, apartment project locations, fire station design, and aqueduct relocation by Salt Lake County geologist C.V. Nelson (1988; written commun., 1985, 1986); and long-range environmental plans, subdivision layouts, and critical facilities, including water tanks, fire stations, jails, and waste disposal by Weber and Davis counties' geologist Mike Lowe (written commun., 1989).

List 3

Examples of potential users of earthquake hazard information in Utah

City, county, and multicounty government users

City building, engineering, zoning, and safety departments
County building, engineering, zoning, and safety departments
Mayors and city council members
Multicounty planning, development, and preparedness agencies
Municipal engineers, planners, and administrators
City and county offices of emergency services
Planning and zoning officials, commissions and departments
Police, fire, and sheriff's departments
Public works departments
County tax assessors
School districts

State government users

Department of Community and Economic Development (Community Services Office, Economic and Industrial Development)
Department of Business Regulation (Contracts and Real Estate divisions)
Department of Financial Institutions
Department of Health (Environmental, Health Care Financing)
Department of Insurance
Department of Natural Resources
Department of Public Safety
Department of Social Services
Department of Transportation
Division of Comprehensive Emergency Management
Division of Risk Management
Division of Water Resources
Division of Water Rights
Facilities Construction and Management
Geological and Mineral Survey
Legislative Fiscal Analyst
Legislative Research and General Counsel
Legislature
National Guard
Office of the Governor
Planning and Budget Office
Public Service Commission
Science Advisor
State Board of Regents
State Fire Marshall
State Tax Commission
State Office of Education
State Planning Coordinator

List 3 (continued)

Examples of potential users of earthquake hazard information in Utah

Private, corporate, and quasi-public users

Civic, religious, and voluntary groups
Concerned citizens
Construction companies
Consulting planners, geologists, architects, and engineers
Extractive, manufacturing, and processing industries
Financial and insuring institutions
Landowners, developers, and real-estate salespersons
News media
Professional and scientific societies (including geologic, engineering, architecture, and planning societies)
Utility companies
University departments (including geology, civil engineering, structural engineering, architecture, urban and regional planning, and environmental departments)

According to Utah Geological and Mineral Survey geologist W.F. Case (written commun., 1988), a residential development in Ogden was scrutinized because it was proposed to be located in a rockfall hazard area shown on his map (see figure 7). The developer hired an engineering firm to determine the extent of and to reduce the hazard.

Previously adopted techniques to reduce losses from natural hazards can be revised to include the latest earthquake research information. Examples of regulations that can or have been revised include: the site development regulations of the Salt Lake City Council (1981), Emigration Canyon master plan adopted by the Salt Lake County Commission (1985), multihazard mitigation plan for Ogden City and Weber County prepared by the Utah Multi-Hazards Mitigation Project Administrative Review Committee (1985), and the critical environmental zone by the Mapleton City Council (1985).

Others include: seismic risk reduction recommendations for primary and secondary schools by Taylor and Ward (1979), hillside site development regulations by the Spanish Fork City Council (1980), regulations governing dam safety by Hansen and Morgan (1982), structural seismic resistance regulation by the Ogden City Council (1983), sensitive area overlay zone ordinance by the Ogden City Council (1985), hillside development standards and sensitive lands development ordinance by the Provo City Council (1985), seismic hazard area regulations by the Orem City Council (1986), structural directives of the Headquarters Structural Engineering Staff (1987), development overlay zone by the Washington Terrace City Council (1988), emergency training exercises by the Utah Division of Comprehensive Emergency Management (Tingey and May, 1988), and the emergency recovery plans proposed by the Financial Institution Emergency Preparedness Committee (James Tingey, written commun., 1988).

THE PROBLEM IN UTAH

Sometimes planners, engineers, and decisionmakers fail to fully use the research information available. The connection between research (List 1) and its use to reduce hazards (List 2) simply is not made. According to several experienced and perceptive observers (McKelvey, 1972; Jacknow, 1985, p. 18; Reilly, 1987; Szanton, 1981, table 3-1, p. 64; Yin and Moore, 1985, p. 18 and 19; and Petak, 1984, p. 456), the reasons vary. They may be restated simply as: not all of the research information is in a language or format understandable or directly usable by nontechnical users, or is not effectively transferred to them.

Utah's User Needs

In Utah, nontechnical users -- government officials, corporate planners, land developers, and private citizens -- have needs that differ from those of scientists, engineers, and other technical people. The nontechnical users in List 3 do not constitute a homogeneous group. Rather, they differ widely in the kinds of information they need and in their capabilities to use that information. Thus, detailed technical information prepared by scientists or engineers often is unsuitable for and unusable by nontechnical users. For example, most professional land-use planners and local officials do not have the training or experience to directly apply earthquake-hazard research information (U.S. Office of Science and Technology Policy, 1978, p. 170). Few academic programs train students of planning or public administration to avoid, reduce or accommodate natural hazards.

Although many land-use planners and local officials in Utah have some experience with natural hazards, such experience is usually with flooding, landslides, or soil problems. Without translating and transferring the earthquake research information, the effective user community is limited to scientists and engineers. At the other extreme, if the users do not become familiar with and proficient in using research information, it is likely to not be used or worse, misused!

Problem Recognized

Both researchers and users of research information have recognized the problem and the needs of nontechnical users -- decisionmakers (Alexander, 1983, p. 49); state and local governments (Council of State Governments, 1976); city, county, and multicounty planners (Kockelman, 1975, 1976b, 1979); nonspecialists (Wenk, 1979); potential user groups (Yin and Moore, 1985); journalists (Peterson, 1986), nontechnical users (White and Haas, 1975), and the general public (Petak, 1984).

From the beginning of their five-year focused effort in 1983, both the Utah Geological and Mineral Survey (UGMS) and the Utah Division of Comprehensive Emergency Management (CEM) were aware of and concerned about the problems of research information being effectively used by nontechnical persons. For example, during a Utah Governor's conference on geologic hazards held in 1983, most of the 36 working groups identified specific problems or needs of nontechnical users as:

- ... officials need risk maps ....
- ... lack of knowledge concerning... expertise... available ....
- ... not aware of the availability ... of hazards information.
- Most local government ... requires technical assistance ....
- ... State and local agencies need a central data bank ....
- ... mechanism is needed to ... transfer ... information ....
- Lack of hazard susceptibility maps ....

According to UGMS deputy director D.A. Sprinkel (written commun., 1986), "most of the research scientists feel the amount of data collected can and should be translated into products for the public and disseminated as soon as possible."

Continuing Problem

Even when hazard information is available, translated, transferred, and used for hazard reduction, there is still the problem of lack of effective use. Recently, an experienced and successful translator and transfer agent (Perkins, 1986, p. 5) completed a comprehensive survey of local governments in northern California to identify uses of research information. She found that cities are not using the three strategies that they consider to be the most important, namely (1) hazardous building retrofit/abatement programs; (2) public information and education; and (3) building inspection. The most commonly listed reasons for inaction were limited staff time and limited funds. Other reasons cited were:

- lack of leadership, as well as lack of attention of upper management and elected officials, due to competing day-to-day problems;
- lack of interest or commitment;
- potential citizen opposition to a politically sensitive program; and
- the perception that the hazard was low so that existing effort was adequate.

TOWARD THE CONNECTION IN UTAH

Part of the solution to the problem has been widely recognized as simply one of adequate translation for, and effective transfer to, nontechnical users. International agencies (United Nations Educational, Scientific, and Cultural Organization, 1976), federal agencies and committees (Wallace, 1974; NEHRP Expert Review Committee, 1987), and state agencies (Utah Seismic Safety Council, 1981; California Seismic Safety Commission, 1986) have all addressed the need for translation and transfer of research information.

Recommendations for translation and transfer have been included in hazard-reduction programs for natural hazards other than earthquakes; for example, coastal area hazards (White and others, 1976), flood hazards (National Science Foundation, 1980), landslide hazards (U.S. Geological Survey, 1982), and for the major natural hazards considered by the Advisory Committee on the International Decade for Natural Hazard Reduction (1987).

Utah's Work Plan

Two of the five components (Figure 1) in the work plan adopted by Utahans directly relate to the connection between research and its use. The work plan clearly identifies "translated" scientific information as a prerequisite to its transfer to a user and its use for earthquake-hazard reduction. It then specifically addresses those actions likely to improve effective use of scientific information by nonscientists, particularly as part of the implementation component, namely:

- Identify the hazard maps and reports needed for hazard-reduction measures.
- Ensure that new information is prepared in detail and at the scales needed by the users.
- Make special efforts to present the information in a format language suitable for use by engineers, planners, and decisionmakers.
- Design the communications program after an assessment of potential users' needs and capabilities.
- Select the most effective educational, advisory, and review services appropriate to the targeted users.
- Design the communications program so that information can be effectively disseminated (including use of the scientists and investigators to help communicate).

According to Atwood and Mabey (1987, p. S-30), achieving this "requires communication of translated scientific information to responsible officials and interested parties seeking to reduce losses from the hazards. This is a major challenge to the program because many of the products of scientific research are not directly usable by responsible officials and the public. To accomplish this goal, it is essential to involve the user of the information early in the program."

In their book, In Search of Excellence, management consultants Peters and Waterman (1982, p. 145) observe: "Finally, and most important, is the user connection ... we will simply say that much of the excellent companies' experimentation occurs in conjunction with a lead user." A social scientist (Drabek, 1986, p. 416) remains "convinced that the quality of disaster research will be improved immeasurably if the interaction between practitioners and researchers is increased." A comprehensive review of the use of research (Yin and Moore, 1985, p. 70) includes a conclusion that "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." Taylor (1979, p. 278) notes that "if users participate in the research process -- most especially at the beginning when the problem is defined -- then they are likely to identify with the research project and with its outcome."

One of the ways for ascertaining nontechnical users' needs is that of arranging for a dialogue between researchers and users of hazard information (List 3). In the case of Utahans, this was done in several ways --conferences, workshops, and special sessions. Each required careful preparation, good-faith effort, and skillful facilitating. Three examples are discussed in more detail.

Governor's Conference

The conference was sponsored by the Utah League of Cities and Towns, Utah Association of Counties, Utah State Legislature, Federal Emergency Management Agency (FEMA), U.S. Geological Survey (USGS), and the University of Utah; it was coordinated by the UGMS and the Utah Division of Comprehensive Emergency Management (CEM). It was held on August 11 and 12, 1983, on the campus of the University of Utah.

The purpose of the conference was to bring together scientists and engineers, elected and appointed officials, leaders of business and private organizations, and private citizens to discuss geologic hazards and to recommend appropriate actions to all levels of government. The first day of the conference was designed to provide information on the principal geologic hazards in Utah. During the second day, 36 working groups met in half-day sessions to develop recommendations for actions by all levels of government to reduce the geologic hazards in Utah.

The working groups recommended 171 actions that they felt should be taken to reduce the impacts of geologic hazards on the lives of Utahans. They concluded that although much of the information needed to make site-specific decisions has not yet been developed, sufficient information exists on which to base public policy. The working groups determined that the primary support for research on geologic hazards should come from the Federal Government, and that the State should take a major role in identifying research priorities and applying research results. The working groups also concluded that information collection and dissemination is the role of State agencies, and that local governments should take a more active role in identifying their information needs and providing matching assistance. An excerpt from one of the working groups follows:

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33. HAZARDS INFORMATION FOR PLANNERS

Chairperson: James P. McCalpin, Geologist, Utah State University

Topic c: Interpretation of information

Problem: Planners are often unable to interpret available geologic hazards information and therefore cannot use it effectively in land-use planning or regulation. This problem has two related aspects: the data are presented in too technical and specialized a format for planners, or planners have insufficient geologic background.

Action: (1) Offer natural hazard information in derivative or interpretive maps .... Such interpretive maps would assess hazards directly with some kind of rating system (e.g., serious, moderate, slight) .... (2) Educate planners via technical workshops given by Utah Geological and Mineral Survey geologists to train them in hazard interpretation from existing geologic maps and forthcoming interpretive maps, or (3) Local governments in critical hazard areas should hire a full or part-time geologist to identify local hazards and to help draft local government natural hazard regulations.

The results of the conference -- suggestions for action, remarks of the Governor, action items of the working groups, and a summary of the questionnaire -- were published by the Utah Geological and Mineral Survey (1983). The dialogue between researchers and the users of geologic hazard information had begun!

Earthquake Hazards Workshops

The first of five workshops was held on August 14-16, 1984, in Salt Lake City. The workshop was sponsored by USGS, FEMA, UGMS, CEM, and the University of Utah. One hundred and fifteen participants having varied backgrounds in earth science, social science, planning, architecture, engineering, and emergency management participated in the workshop. They represented various industries, volunteer agencies, and academic institutions in Utah, as well as representatives of local and State governments of Utah, other states, the private sector, and the Federal Government.

The two primary objectives of the workshop were to: (1) strengthen the capability of the scientific and technical community to compile and synthesize geologic, geophysical, and engineering data needed for evaluating earthquake hazards, and (2) work with public officials in fostering an environment for implementation of research results, creating partnerships, and providing high-quality scientific information that can be used by local government to reduce hazards.

Four discussion groups were created, each composed of both researchers and users of hazard information. Two of the groups recommended translation and transfer activities. An excerpt from the "information systems" group moderated by a USGS research geographer reads:

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2) An extraordinary effort should be made to communicate. Possible actions include:

b) Devising outreach activities to involve a wide range of groups. These activities could use strategies such as workshops, small group meetings, exchange of technical information, demonstration of products and results of research neighborhood meetings, and generation of special information packets and audiovisual materials to give them a stake in the process.

An excerpt from the "implementation options" group moderated by a FEMA emergency manager reads:

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3) County geologists -- Local governments need to attain the capability to take the products (data, maps, reports, etc.) produced ... and apply them to solve problems in their jurisdictions. This application is the only way that the ultimate goal of reducing the loss of life and property from earthquakes will be attained. The Wasatch front counties ... are the places to start. The county geologists are the key resource. Such a process is needed now.

The results of this innovative workshop and recommendations of the discussion groups were published in the proceedings edited by Hays and Gori (1984). The results of the 1986 workshop were published in the proceedings edited by Hays and Gori (1987). These workshops resulted in early release of research findings, continued dialogue between researchers and practitioners, and an increased awareness of the earthquake hazard by the public.

User Needs Session

A special session was held in the evening following the workshop discussed above. The purpose of this session (convened and moderated by the State Geologist and the USGS earth-sciences applications planner) was to carry on a dialogue in order to determine needs of users for earth-science information and to identify any obstacles to its use. This special session was designed to provide an opportunity for users of earth-science information to communicate their needs to the UGMS, USGS, universities, consultants, and others who produce such information.

Invitations to participate in this session were sent to over 70 city, county, and State officials, planners, engineers, and university researchers and educators. Representatives of the Utah League of Cities and Towns, League of Women Voters, American Planning Association (Utah Chapter), Wasatch Front Regional Council, The Western Planner, and the Southeastern Utah Association of Governments also attended.

Seven speakers experienced in determining or meeting user needs made presentations that were prepared specifically for this session. The speakers' collective experience included conducting studies of user-needs, translating scientific information for nontechnical users, communicating information to nontechnical users, or using earth-sciences information to reduce hazards. Briefing materials emphasizing the needs of users were provided to participants.

Six panelists representing important city, county, State, and private planning and decisionmaking agencies participated. The panelists were selected on the basis of their experience in the use of earth-sciences information and on their need to have research information translated, transferred, and used. The panelists began the "brainstorming" session by commenting on the usefulness to their organizations of the techniques presented by the speakers. They were asked to list types of information that they felt rated the highest priorities.

The meeting then was thrown open to the nontechnical participants. A "brainstorming" approach was scrupulously followed and resulted in a blackboard filled with items needed. The items listed were organized into five categories: (1) scientific research topics, (2) translation of science for use by nontechnical users, (3) transfer of the information to the users, (4) use of the translated information to reduce hazards, and (5) evaluation of the uses of the information to ensure effectiveness.

After the items were organized, the moderators asked for a weighting of the importance of each need by a simple showing of hands. The users were then asked whether they would actually use the information if it were available. Both information producers and users fully understood that a "no" vote did not mean that the information was not necessary or useful to someone else, but rather that this particular group of users did not think that they would use the information. The spontaneous voting by only the <u>user</u> attendees resulted in a rating on a scale of 1 to 10. The number 10 indicating that virtually <u>all</u> the users present felt that their organizations needed and would, or should, use a specific type of information. Some of the needs (and weights assigned) follow:

- o Site-specific geologic reports that are legally and politically defensible (10).
- o Early warning "red flag" maps, scales 1:9600 (10).
- o Structure types susceptible to failure by shaking (8).
- o Location of fault-rupture zones (7).
- o Maps showing multi-hazards, scales of 1:2400 or more detailed (10).
- o Maps showing susceptibility to damage or hazard (10).

- o Retain five staff geologists to serve 10 counties (9).
- o "Red-flag" hazard maps for counties at a scale of 1:100,000 (6).
- o Maps interpreting research for ... nontechnical persons (10).
- o Model seismic-safety plans (5).
- o Education of local planning commissioners (10).
- o Increased awareness of hazards (10).
- o Educational materials explaining earthquake processes and their effects that are meant for adults but can be understood by sixth-graders (5).
- o Advisory services (10).
- o Training for local-government ... including planners (10).
- o Protypical community training exercises (9).

The names of the session's speakers, panelists, and participants, along with the papers, briefing materials, and the complete results of the "brainstorming" are included in the workshop proceedings edited by Hays and Gori (1984, p. 606-674). This session provided the researchers with the specific translation and transfer needs of the nontechnical users.

Researchers and Translators

Various views have been expressed concerning who is responsible for translating and transferring research information to nontechnical users. The following examples concerning the responsibility of researchers and translators are from several experienced and perceptive observers:

- o ... identify user groups, ... meet their needs, and plan on producing a major product aimed directly at users. (Yin and Moore, 1985, p. ix and x)

- o ... be prepared to make their analyses of earthquake danger comprehensi-ble in common sense terms by frequent and imaginative use of metaphors and examples from common experience. (Turner and others, 1981, part 10, p. 96)

- o ... not only be willing to face the adverse reactions but also to persist in finding truly effective ways of conveying information that is impor-tant to societal needs ... (Peterson, 1986, p. 245)

- o ... sees user problems as interesting and worthy of serious intellectual commitment beyond the theoretical implications for other scientists in the field. (White and Haas, 1975, p. 152)

- o ... much greater direct participation by geologists and by planners with better training and understanding of the significance and application of earth-science information ... (Nichols, 1982, p. 290)

In identifying problems and opportunities as experienced by USGS, Bates (1979, p. 29) in his Transferring Earth Science Information to

Decision-makers concluded that the entire earth-science community must mobilize to provide specialized, technical information in a form and language understandable to the intelligent citizen; and to engage in the educational, advisory, and review services necessary to assist the public and its representatives in making effective use of that information. The unusual and remarkable efforts taken in Utah to translate and transfer research information to the public and its representatives will be seen in subsequent sections of this report.

Other Aspects

Translation and transfer activities considered in this paper are only part of the solution to the problem of lack of effective earthquake-hazard reduction. Many other aspects must be considered; the following have been noted:

- Perhaps the most telling factor acting against adoption of earthquake-risk reduction measures is that Utah has not experienced a highly destructive earthquake in a heavily populated area. (Atwood and Mabey, 1987, p. S-19)

- Utah needs trained people to analyze the technical data bases, to extrapolate beyond the limits of the data, and to translate the basic data into maps and other products that can be applied in the community .... (Hays, 1987, p. R-8)

- ... the research begins with approval of the effort by those top officials who have power to see that results are utilized. (White and Haas, 1975, p. 152)

- Lack of leadership due to competing, day-to-day problems, lack of interest or commitment, potential citizen opposition, and inadequate educational programs. (Perkins, 1986, p. 3)

- ... the public lacks knowledge of and underestimates the hazardous quality of their environment ... these underestimations reflect busy people ... occupied with their own life priorities -- day-to-day issues of living. (Drabek, 1986, p. 320)

Hays (1988b, p. 100 and 101) emphasizes that the risk management process in every nation depends on seven factors: a perceived need for risk reduction, informed internal advisors, strong external champions, credible products, user-friendly products, balanced political, legal, and economic considerations, and a window of opportunity. Sprinkel (1988) in his review of the earthquake assessments program in Utah asks "Will Utah meet the challenge?" and then answers that question in the affirmative by noting the existence of the following key factors:

champions	challenge
symbiotic relationship	true believers
strong partnership	key players
early planning	long-time advocates
mutual buy-in	brimming with enthusiasm
science driven	excellent media coverage
credibility of the program	translation expedited
commitment of funds	potential devastating earthquake
talented people	

My report addresses only two of the factors required for a successful earthquake-hazard reduction program, namely:

- Translating the results of scientific and engineering studies so that the nature and extent of the hazards or their effects are understood by nontechnical users.

- Transferring this translated information to potential users and assisting them in its use to reduce earthquake hazards.

The following sections address the definitions, importance, obstacles, types or techniques of translation and transfer and present selected examples.

TRANSLATION FOR PRACTITIONERS

The objective of translating hazard information for practitioners is to: make them aware that a hazard exists which may affect them or their interests; provide them with information that they can easily present to their superiors, clients, or constituents; and provide them with materials that can be directly used in a reduction technique (List 2). The Utah work plan is quite specific as to what is expected of translated information:

- ... information that can be used by local government decision-makers as a basis for "calling for change."
- ... users will have easy access to data in media, scales, and formats, that will be most useful to them.
- ... selection of standard base maps and mapping scales ....
- ... interpreted information derived from basic scientific data.
- ... make it easy for local government, engineers, architects, planners, ... and emergency responders to use the technical information ....
- ... information in a format and language suitable for use by engineers, planners, and decisionmakers.

Definition

Much has been said about the need for and objectives of translation. No clear concise definition or criterion has been offered, nor can it be found in the literature except by inference or by an analysis of what is actually used by practitioners. However, various researchers, translators, and users of earthquake research information are specific about what is needed by nontechnical users. They range from Steinbrugge's (1982, p. 13) "Knowledge of the distribution of earthquakes in time, location, and size is essential for insurance ratings and underwriting purposes," to Keaton and others' (1987, p. 73) "Successful translation of science must 1) show hazard locations on maps at suitable scales, 2) provide some sense of the damage likely to result from occurrence of a hazardous event, and 3) provide some sense of when a hazardous event is likely to occur."

Three Elements

My experience with reducing potential natural hazards (primarily atmospheric, flooding, misuse of soils, landsliding, and earthquakes) indicates that hazard information successfully used by nontechnical users has the following three elements in one form or another:

1. Likelihood of the occurrence of an event that will cause casualties, damage, or disruption.

2. Location of the effects of the event on the ground.

3. Estimated severity of the effects on the ground, structure, or equipment.

These elements are needed because usually engineers, planners, and decisionmakers will not be concerned with a potential hazard if its likelihood is rare, its location is unknown, or its severity is slight.

However, concern varies widely with the individual user, the cost of hazard reduction, and who or what might be affected. For example, a pedestrian might prepare for a fifty-percent probability of rainfall tomorrow by carrying an umbrella; a lender might require flood insurance if the mortgaged property is within a 100-year-recurrence-interval flood zone; and a regulatory agency might curtail construction if a critical facility is being located near a fault that has moved in the last 100,000 years. The reader will note that both location (areal, zonal, or specific) and likelihood of occurrence are conveyed in these three examples; severity is provided in a much different way -- personal experience, documented damage, or fear of a disaster and possible liability.

Unfortunately, these three elements come in different forms and with different names, some quantitative and precise, others qualitative and general. Several examples follow for each element. In all cases, for a product to be defined as "translated" hazard information, the nontechnical user must be able to perceive likelihood, location, and severity of the hazard so that he or she becomes aware, can convey it to others, and can use it directly in selecting and adopting a hazard reduction technique.

Likelihood of Occurrence

This element can be conveyed for a selected size and location of damaging earthquake by the use of various concepts -- probability, return period, frequency of occurrence, or estimated, average, or composite recurrence interval. Sometimes a specific event is chosen -- design earthquake, hypothetical earthquake, characteristic earthquake, or postulated earthquake. Each of these terms has a specific definition which is beyond the scope of this paper. In all cases, each event chosen must be credible, that is have some likelihood of occurring.

In some cases, an engineering parameter is used for a specific ground failure: "the probability that the critical acceleration would be exceeded in 100 years" for liquefaction by Anderson and others (1986, p. 39) or for landslides by Keaton and others (1987a). Algermissen and others (1982) use a map showing probabilistic bedrock peak horizontal ground acceleration that has a 90 percent probability or likelihood of not being exceeded in a 50-year period. In another case, the term "opportunity for liquefaction" was used where "a return period of about 30 to 50 years is anticipated for ground motions sufficient to exceed the liquefaction threshold at a given susceptible site" (Tinsley and others, 1985, p. 315). The period of 30 to 50 years is selected because it embraces the economic or functional life of most buildings.

No matter what term is used, it must convey a likelihood of occurrence that is important to the user. This likelihood varies widely, depending upon the use. For example, the National Research Council (1986, p. 5) notes that "various public agencies define an active fault as having had displacements (a) in 10,000 yr, (b) in 35,000 yr, (c) in 150,000 yr, or (d) twice in 500,000 yr."

The interest of an engineer, planner, or decisionmaker in likelihood of occurrence also varies widely, for example:

Insuring agent	Premium period (1 yr)
Elected official	Term of office (2-6 yr)
Lending officer	Amortization schedule (10-30 yr)
Bridge designer	Structure's life (50-100 yr)
Waste manager	Hazard's life (1,000-10,000 yr)
Pyramid builder	Next world (10,000-10,000,000 yr)

Location and Extent

Once users are convinced of the likelihood of the occurrence of a damaging event, they want to know if their interests might be affected. This information is conveyed by showing the location and extent of ground effects or geologic materials susceptible to failure. These are usually shown on a planimetric map having sufficient geographic reference information to orient the user to the location and extent of the hazard. Geographic information, such as streams, highways, railroads, and place names is very helpful. Some maps show streets; others show property boundaries (Figure 3). The scales of such maps vary widely; examples from Utah vary from 1:36,000 (1 in. equals 3,000 ft) to 1:1,200,000 (1 in. equals approximately 3 mi). See figures 3 and 4.

The scale selected depends on the detail and amount of information to be shown, as well as the users' needs. For example, the seismic zone map of the United States adopted by the International Conference of Building Officials (1988, p. 178) and incorporated into the widely used Uniform Building Code is at a scale of 1:30,000,000; it is based on Algermissen and others (1982) national map which is at a scale of 1:7,500,000. Some building site hazards have been shown at scales of 1:1,200 (1 in. equals 100 ft) or larger. Most earthquake hazard maps are a compromise between detail, reliability, difficulty and cost of preparation and the purpose for which they were designed. There are no "best" scales, only more convenient ones.

Estimated Severity

After the users recognize the likelihood of an event which may affect their interests, their next question is: how severe will be its effects? In other words, is the hazard something that should be avoided, designed for, or should preparations be made to respond during, and recover and reconstruct after damaging events.

Severity of anticipated effects is best expressed by use of measurable engineering parameters for the various hazards, for example:

- vertical and horizontal displacements for surface fault ruptures.
- peak acceleration, peak velocity, peak displacement, frequency, and duration for ground shaking.
- exceedance of critical acceleration for landslides and liquefaction.
- contour lines of anticipated tectonic subsidence.
- height of run-up for tsunamis.

Modified Mercalli or Rossi-Forel intensity scales of observed or estimated damage are also very helpful. They are used primarily for ground shaking but can include the effects of surface fault rupture, landsliding, and liquefaction. These scales also include some of the observed or anticipated effects on structures, contents, and occupants.

Format

These three elements -- likelihood, location, and severity -- have been combined into various formats, some easy for the nontechnical user, and others requiring additional information, or an experienced user to appreciate, adapt, and use in a reduction technique. Sometimes all of the elements are placed on a single map; at other times, information in the text or volume must be combined, or outside supplemental information must be obtained. Many times, one of the elements (likelihood of occurrence) is one of public knowledge or experience. Sometimes the elements are available or combined for only a demonstration area. When adequate research information is available for other areas, additional translation work can be done; otherwise new research must be undertaken to cover the user's area of jurisdiction or interest.

At other times, the format is a "seismic-hazards zone" (sometimes called "seismic zonation") showing the location and severity of all the effects from one postulated event. Qualitative terms are often used to show relative susceptability (high, moderate, low, and very low) of geologic or other units to landslides or liquefaction, or to show relative severity (very violent, very strong, strong, and weak) of shaking. Examples of some of these formats follow:

Wesson and others (1975) and Ziony and Yerkes (1985) show location of faults that have, or may generate, damaging earthquakes or surface-fault rupture on index-scale maps. Maps at much larger scales (1:24,000) for surface-fault traces are easily available as part of the California law requiring fault-rupture zone investigations, city and county development regulations, and real-estate seller disclosures. Likelihood of occurrence (estimate of recurrence intervals) and severity (maximum surface displacement) are conveyed by discussions, tables, and graphs in the text accompanying the index maps. Both reports are in a volume that illustrates surface faulting as part of the predicted effects of a postulated earthquake (magnitude 6.5) for a selected fault.

Algermissen and others (1982) show location and severity (in terms of peak velocity and acceleration) by contours on a map for the ground shaking hazard. Likelihood of occurrence is conveyed by probability (percent) of not being exceeded for various exposure times (10, 50, and 250 yr) in the map caption.

Rogers and others (1985) show location of a demonstration site and severity (mean amplification factor compared with level of shaking at site on rock) by areas on maps for predicted relative ground response. Individual maps are used to show predicted relative ground respoinse in three period-bands having significance to buildings of specific heights (2-5, 5-30, and 30 or more stories). Likelihood of occurrence is conveyed by other papers in the same volume as well as being of general public knowledge and experience.

Wieczorek and others (1985) show location and extent (levels of susceptibility), and percentage of area likely to fail on a map for slope stability during earthquakes. Likelihood of occurrence is conveyed by a discussion of a lower-bound hypothetical (or "design") earthquake large enough to trigger landslides (Richter magnitude 6 or 7, depending on location of the earthquake). Severity is conveyed by a discussion on the map by noting that "structures generally cannot withstand more than 10 to 30 cm of movement without damage ...." and then by selecting 5 cm (2 in.) as a conservative design threshold.

Tinsley and others (1985) show location and extent (levels of relative susceptibility) of liquefaction on a map. Likelihood of occurrence (return period of liquefaction opportunity) for magnitude 5 or larger earthquakes is shown by contours on a separate map. Severity is partially conveyed by photographs showing liquefaction damage to three critical facilities -- causeway, juvenile hall, and an earth-filled dam. Their report is in a volume that illustrates liquefaction-related ground failure as part of the predicted effects of a postulated earthquake for a selected fault. Its text conveys severity as follows:

> The differential settlements and displacements that result from liquefaction-related ground failure likely will include disturbances and disruptions of public and private utilities services, including surface and subgrade water, gas and sewerage facilities, storm drains, irrigation works, channelized surface drainages, and shallow-seated foundations of structures.

Recently, a working group on California earthquake probability (Agnew and others, 1988) showed conditional probability of large earthquakes on a map for selected segments of the San Andreas, Hayward, San Jacinto, and Imperial faults. Probabilities are based on expected recurrence times, and calculated for the likelihood of occurrence during the next 30 yr. Severity is conveyed by the expected magnitude of a major earthquake, which is provided for each segment.

In some cases, the use of lists of damaging events, photographs of damage, or diagrams of effects on ground or buildings for similar events are used to convey severity. Examples include Youd and Hoose (1978) for ground failure, Ziony (1985) and Borcherdt (1975) for earthquake hazards, and Hays (1981) for several geologic and hydrologic hazards.

This type of information is an important part of the researcher's observations, but when used in translated information becomes an effective transfer technique, namely, the communication of possible effects -- casualties, damage, and socioeconomic interruptions. Sometimes this can be misleading because of differences in the user's environment and that depicted: earthquake location and size, ground conditions, structure's vulnerability, people exposed, and reduction techniques already implemented.

Successful Translation in California

One of the best ways to confirm that these elements -- likelihood, location, and severity -- are needed is to look at information that has been prepared for, and successfully used by, engineers, planners, and decisionmakers for earthquake-hazard reduction.

During the period 1970-1980, the USGS engaged in several urban studies projects. The largest -- the San Francisco Bay Region Environment and Resources Planning Study -- had as one of its goals the translation of research into information usable by nontechnical users. Reports included seismic zonation (Borcherdt, 1975), flood-prone areas (Waananen and others, 1977), relative slope stability (Nilsen and others, 1979) and others. All of these reports have the three elements -- likelihood, location, and severity -- in various forms and formats.

In one of these reports, Borcherdt and others (1975a) suggested a method for seismic zonation which contains the three elements of translated research. According to Kockelman and Brabb (1979), at least three cities and three counties in the San Francisco Bay region made use of this method to develop zones which then were used as a basis for their general plans, seismic safety plans, development policies, or development regulations.

Many other examples of the use of translated (and of course transferred) earthquake research information for specific reduction techniques can be cited. In other words, the connection between research and its use in hazard reduction techniques has been successfully made. Selected examples follow:

o Shaking intensity maps for major fault systems (Everenden and others, 1981) used for anticipating damage and interruptions to critical facilities and preparing for emergencies by utilities and local, regional, and state government agencies (Davis and others, 1982;

Steinbrugge and others, 1987).

- o Fault-rupture zone maps by various federal, state, university, and consultant researchers (Brown and Wolfe, 1972; Sarna-Wojcicki and others, 1976) used for statewide legislation, city and county regulations, and real-estate seller disclosures (Hart, 1980).

- o Fault rupture, tsunamis, liquefaction, shaking, and landsliding hazard information combined by computer and used for city and county seismic safety plans (Santa Barbara County Planning Department, 1979).

- o Maximum credible ground acceleration on bedrock map (Greensfelder, 1972) used to assign priorities and to design for strengthening of highway overpasses by a state transportation agency (Mancarti, 1981).

- o Maximum earthquake intensity map (Borcherdt and others, 1975b) used for estimating cumulative damage potential for different building types by a multicounty agency (Perkins, 1987).

- o Numerous studies of ground shaking acceleration, losses, and predicted intensities used as a basis for inventorying unreinforced masonry buildings and requiring the strengthening or demolishing of unsafe ones (Los Angeles City Council, 1981).

- o Probabilistic intensity (Algermissen and others, 1982) and local site amplification (Hays and others, 1978) maps used to estimate loss and replacement cost for various building types in Salt Lake City (Algermissen and Steinbrugge, 1984, p. 12-22).

- o Continuous monitoring and analysis of earthquake precursor information for a specific fault segment used to warn local governments, the public, and the press via a governor's office of emergency services (Bakun and others, 1986).

Discussions and illustrations of some of these and other examples can be found in Blair and Spangle (1979), Kockelman and Brabb (1979), Brown and Kockelman (1983), Kockelman (1985, 1986), Jochim and others (1988), Mader and Blair-Tyler (1988), and Blair-Tyler and Gregory (1988).

Comment

These examples of translation vary as to scale, area covered, format, postulated or probable occurrence, single- and multiple-hazards, limitations, and supplemental information required. What they all have in common is that they convey the likelihood of the occurrence of a damaging event, show location and extent of the hazard on a planimetric map, and provide some indication of severity of effects on the ground.

Some of these examples have gone, or can easily be taken, a step further to show potential response of structures, occupants, and

EXAMPLES OF SUCCESSFUL TRANSLATION IN UTAH

An unusual effort is being made in Utah to translate earthquake research information for nontechnical users. During 1986, the Utah State Geologist convened several meetings to discuss and develop criteria for "translated" research and to identify potential translators. D.A. Sprinkel, UGMS Deputy Director (written commun., December 24, 1986) reported that a common understanding was established, a logical progression from the research to its use was identified, and a tentative definition of translation was developed, namely, occurrence, location, and consequences.

Translators in Utah include university, state, and federal researchers, geotechnical consultants, and county geologists. Hazards being addressed include surface fault rupture, ground shaking, and failures induced by shaking -- liquefaction, landsliding, rockfalls, tectonic subsidence, and dam failure. An example and illustration of translated information from Utah for each of these hazards follows.

Surface Fault Rupture

Machette and others (1987) have prepared a text on surface fault rupture for the twelve segments in the Wasatch fault zone. Their text includes a discussion of recurrence of large earthquakes in the Wasatch front zone; a table giving minimum and maximum number of faulting events on eight of the segments; and introduces the idea of a composite-recurrence-interval between 255 and 435 years. See figure 2. Personius (1988) shows the location of faults that offset the surficial material on a topographic map (scale 1:50,000). Similar maps are being prepared for the urbanized portion of the Wasatch front.

Machette and others (1987) conclude that "recurrence intervals vary widely" on some segments, that some "earthquakes tend to occur in clusters," and that "recurrence intervals within clusters may be as short as 100 years." They suggest that the lack of faulting events in the past 400-500 years, and the relatively imprecise dating (± 100 years) of the most recent events, may indicate that "a major surface-rupturing earthquake is overdue on one or more of the segments." They include displacement, slip rates for the twelve segments, and length of surface rupture from recent large earthquakes in the northern Basin and Range province.

equipment. This next step is actually using translated information in a reduction technique (List 2); for example, development regulations, loss estimates, overpass retrofits, preparedness scenarios, and warning systems as seen in the above examples.

This next step requires the collection, analysis, and use of new information -- type, age, and condition of vulnerable structures, characteristics of exposed population, and importance of the socioeconomic systems at risk.

Numerous benefits are derived from translating earthquake hazard research for nontechnical users; for example:

- Reports and maps designed for one common user group -- intelligent and interested citizens -- provide a common basis for discussion during public hearings.
- Researchers are relieved from repetitive translation and repeated requests from individual users.
- Numerous nontechnical transfer agents are available to transfer nontechnical information.
- Transfer and use occur more rapidly.
- More correct and appropriate use is made of the research.
- Researchers become more sympathetic to users and their needs, and users become more appreciative and supportive of the researchers.
- Public decisionmakers and their constituents are more likely to recognize the hazard and their potential liability.

Machette and others (1987) begin their report: the "heavily urbanized part of the Wasatch Front -- between Ogden and Provo --coincides with the part of the fault zone that shows the highest slip rates, shortest recurrence intervals ... , and most recent fault activity" and conclude that major earthquakes have struck the central, heavily urbanized section of the Wasatch fault zone on an average of once every 310 years during the last 4,000-8,000 years; that a form of temporal clustering of earthquakes has been (and may still be) active; and that lack of movement along the Brigham City segment during the late Holocene is somewhat ominous.

Their work on recurrence intervals is applicable to, and frequently provides the likelihood of occurrence element for, the Wasatch Front hazards which are discussed in the following subsections.

In addition, McCalpin (1987) has analyzed the geometry of near-surface ground breakage across some normal faults, and defined reasonable setback distances. The three county geologists serving Davis, Juab, Weber, Salt Lake, and Utah counties are combining this and other information to show a surface fault rupture study zone on county maps (see figure 3). In addition, they are transferring this map information to nontechnical users by use of texts that discuss and illustrate fault characteristics, segments, boundaries, recurrence intervals, segment displacement, and suggesting use of the maps for hazard reduction. For example, Robison (1988a) summarizes displacement per event for each of 10 segments.

Ground Shaking

Youngs and others (1987, figure 37, p. M-88) show location and severity (peak ground acceleration) by contours on a map for ground shaking. Likelihood of occurrence is conveyed by probability (percent) of being exceeded for various exposure times (10, 50, and 250 yr) in their figure caption.

Tinsley (in press) has prepared a text and map showing increased shaking due to ground conditions in the Salt Lake Valley. Figure 4 is a generalized version of this map at a scale of 1:200,000. Location of increased ground shaking on unconsolidated deposits is shown by contours on the map. Severity is conveyed by use of Modified Mercalli intensity (MMI) units representing an increase in damage intensities to that which would occur on the underlying bedrock.

The size and location of a credible earthquake can be obtained by referring to Machette and others (1987). A map of MMI on bedrock for such an earthquake is available and Tinsley's increased intensities can be added to such a map to meet the needs of a nontechnical user.

Liquefaction Potential

Anderson and others (1986) have prepared a liquefaction potential map and report for Utah County. The base map used is a USGS 7½-minute quadrangle showing topography which has been reduced to a scale of 1:48,000 (1 in. equals 4,000 ft). See figure 5. They have also prepared similar maps and reports for other counties -- Davis, Salt Lake, Weber, Cache, Millard, Sanpete, Sevier, and Wasatch counties and the eastern portions of Box Elder and Juab counties.

The boundaries of four liquefaction potential areas are shown -- high, moderate, low, and very low. These four areas are based on the probability that a critical acceleration will be exceeded in a 100-year period. The critical acceleration for a given location is defined as "the lowest value of the maximum ground surface acceleration required to induce liquefaction." The categories of high, moderate, low, and very low correspond to probabilities of exceeding critical acceleration in the ranges of greater than 50 percent, 10 to 50 percent, 5 to 10 percent, and less than 5 percent, respectively. All of the information for a nontechnical user is shown on the map. The text includes discussions on methods, geotechnical conditions, existing ground failures, and techniques for reducing the susceptibility of site sediments to the liquefaction process.

In addition, Anderson and others (1986) have provided maps showing some information on soils, groundwater, geology, and slope which can be used in combination with the liquefaction potential map (Figure 5) to assess the type of ground failure likely to occur -- loss of bearing capacity, lateral spreading, landslides, flows, and translational landslides. These maps require further translation which is being done by county geologists.

Landslide Potential

Keaton and others (1987) have prepared an earthquake-induced landslide potential map and report for the urban corridor of Davis and

Salt Lake counties. The base map used is a USGS 7½-minute quadrangle showing topography which has been reduced to a scale of 1:48,000 (1 in. equals 4,000 ft). See figure 6.

Boundaries of four landslide potential zones are shown -- high, moderate, low, and very low. These qualitative terms were assigned on the basis of failure criteria, landslide susceptibilities, and acceleration exceedence probabilities. In the text, displacement related to these terms are given; for example, 10 cm or more in a "moderate" zone during a wet condition, 10 cm or more in a "high" zone during a dry condition. Severity is then provided by the sentence: "Such ... displacement would certainly cause substantial damage to structures on ... or utilities buried within a sliding mass" (p. 75).

These four zones depend upon the probability that a critical acceleration will be exceeded in a 100-year period. The period of 100 years is arbitrary, but useful for planning, and is the same as that used for liquefaction potential discussed above. The terms -- high, moderate, low, and very low -- for these zones are functions of the critical acceleration exceedence probabilities and the groundwater conditions similar to those used for liquefaction potential.

All of the information needed by a nontechnical user is shown on the map. The text includes discussion of method, geology, groundwater, and ground motion; a list of historical earthquake-induced landslides; and maps showing the historical limit of landsliding due to magnitude 7.5 earthquakes for all segments of the Wasatch fault.

<u>Rockfall Susceptibility</u>

Case (1987, p. V-1 to 36) has prepared a text and map concerning rockfall hazards in the central Wasatch Front between Layton and Draper (including Magna and Tooele) with particular emphasis on earthquake-induced rockfalls. The base map used is a USGS 7½-minute quadrangle map showing topography which has been reduced to a scale of 1:100,000. See figure 7. Field work was at a scale of 1:24,000 and is available from Case. Rockfall source areas are shown but the maximum downslope extent of the hazardous areas are not. According to C.V. Nelson (oral commun., 1988) three county geologists plan to identify such areas using a computer-simulated model program.

Although frequency of rockfall occurrence is not shown on the map, the text contains a table of historic rockfalls and a conclusion based on Keefer (1984) that reads:

> Widespread damage could occur in the Central Wasatch Front area if an earthquake of magnitude 7.0-7.5 should occur. Some of that damage would be due to thousands of rockfalls that would be the result of ground shaking during the event and aftershocks greater than magnitude 4. The Borah Peak and Hebgen Lake earthquakes are examples of such earthquakes that can be reasonably expected in the future somewhere along the Wasatch Front.

W.F. Case (written commun., 1988) makes the frequency of occurrence quite clear:

> Ground shaking during an earthquake can produce hundreds to thousands of rockfalls over an area of several thousand square kilometers. They are initiated by nearby earthquakes of magnitudes as low as 4. Aftershocks of large earthquakes will continue to produce rockfalls after the main shock, particularly if outcrops were loosened by the main shock. A "characteristic" (magnitude 7-7.5) earthquake anywhere in the Wasatch Front will trigger rockfalls throughout the entire Wasatch Front.

He describes the purpose of his mapping project: to "red-flag" hazardous rockfall areas that need site-specific studies. He then points out that such studies would require additional translation before use by community planners.

Tectonic Subsidence

Keaton (1987) has prepared a report and map on potential consequences of earthquake-induced regional tectonic subsidence. The area covered includes the Great Salt Lake and vicinity from Salt Lake City to Brigham City along the Wasatch Front, Provo and vicinity, and Juab Valley north of Nephi. The base maps used are USGS maps (1:100,000 and 1:125,000 scales) showing topography. See figure 8.

The location of effects of two earthquake events are shown on the maps: (1) the predicted subsidence that would accompany a "characteristic" Wasatch earthquake of moment magnitude 7.1, and (2) the observed subsidence that accompanied the 1959 Hebgen Lake, Montana, surface wave magnitude 7.5 earthquake. In the report, Keaton (1987, p. 19) restates earthquake occurrence as the "Wasatch fault is ... considered to be capable of generating earthquakes in the range of local magnitude ... 7.5" and "subsidence should be expected to accompany major earthquakes."

Severity is shown on the map by contour lines of subsidence in five-foot increments, by areas of potential ponding, and by areas of potential lake-margin flooding. In addition, the locations of sewage-treatment plants are shown along with directions and amount of tilt. Relatively slight change in hydraulic gradients at plants, outfalls, or other major drain lines will interrupt gravity flows. Such interruptions may cause ponding of sewage and health hazards.

The text contains general discussions of the effects of subsidence on several critical facilities -- transportation, oil refineries, and waste-water treatment plants. Similar critical facilities are likely to be interrupted by the same event reducing system backup and redundancy.

<u>Dam Failure</u>

McCann and Boissonnade (1985) assessed the impact of shaking on the Pineview Dam and its failure on portions of the city of Ogden. The base map used is a USGS 7½ minute quadrangle which has been reduced to a scale of 1:48,000. A design earthquake of Richter magnitude 7.5 with an epicenter in downtown Ogden is assumed. Several feet of vertical offset along the 31.5 mi of fault rupture is estimated. Ground acceleration in the range of 50 to 80 percent of gravity at the dam site is estimated. Since the Pineview dam is only 6 mi from the fault trace, they assumed (p. 5-1) that the ground motion exceeds the design basis of the dam and failure occurs.

In the event that Pineview Dam fails, the breach of the dam will release the reservoir. The boundaries of the inundated parts of Ogden for a filled reservoir are shown on a map (figure 9) with peak flood depths. The flood wave is expected to travel with velocities as high as 20 mph. As part of the study, damage to commercial and residential buildings from the design earthquake and flooding that results from the dam failure is assessed. In addition, casualties from both the earthquake and the dam failure are also estimated.

Even though location, severity, and event occurrence are given for the inundation hazard, the example is one of a failure and damage scenario only for the purposes of emergency management planning. McCann and Boissonade (1985, p. 3-2) are careful to point out that "no speculation is made concerning the likelihood that the consequences evaluated ... could occur."

This example is one of the uses of translated research for the purpose of assessing the impact of a secondary hazard (dam failure) as well as earthquake shaking. All dams impounding greater than 20 acre-feet of water, and all dams for which dam-failure inundation studies have been completed in Utah have been compiled by Harty and Christenson (1988).

Comment

In all of these Utah examples, the three elements -- likelihood, location, and severity -- may be found, although various formats are used. These examples include various scales, parameters, and formats; some require further translation for the nontechnical user. If these examples are easy to understand and use, it means that their scientists/authors are meeting the major goals of the Utah work plan.

In some cases, the translators have taken the opportunity to include discussions or illustrations of past casualties or damage. Some include recommendations concerning use of their work for hazard reduction. In other cases, county geologists are transferring this information by providing guidelines for use of the translated information: for debris flows and liquefaction (Lowe, in press); surface fault rupture and tectonic subsidence (Robison, 1988a, b); landslides (Robison, in press); rockfalls (Nelson, in press) and other geologic hazards (Lowe and Eagan, 1987).

Often the simplicity of format and ease of use misleads users to believe that the translated products are easy to produce. A familiarity with the references cited in each report will remind the reader that numerous geologic, geophysical, and engineering studies over many years along with many innovative and creative ideas were necessary to produce these examples.

According to C.V. Nelson (oral commun., 1988), the county geologists and others are performing additional studies or compilations which will result in translated information. For example, nonearthquake-induced landslide potential information will be combined with the earthquake-induced landslide potential map prepared by Keaton and others (1987) to produce a composite landslide hazards evaluation. A text has also been prepared discussing other hazards such as failure in sensitive clays, seiches, subsidence in granular materials, and hydrologic changes (Lowe, in press). Emmi (in press) has created maps showing the ground shaking hazard of Salt Lake County using Modified Mercalli intensity scales.

TRANSFER TO NONTECHNICAL USERS

The objective of transferring hazard information to practitioners is to assist in and encourage its use to reduce losses for future earthquakes. Translated hazard information is a prerequisite for transfer to nontechnical users. Its objective has been previously described as: making the users aware that a hazard exists; providing them with information that can be easily presented to their superiors, clients, or constituents; and providing them with material that can be directly used in a reduction technique (List 2). The Utah work plan is quite specific as to what is expected of transfer activities:

- foster the creation and implementation of hazard-reduction measures ....
- ... users will have easy access to data ....
- ... information is released promptly.
- ... most effective educational, advisory, and review services appropriate to the targeted users.
- Communication of scientific information consists of both its transfer and its effective use for hazard reduction.

Definition

Various terms are used to convey "transfer" of information to users, namely, disseminate, communicate, circulate, promulgate, and distribute. Often these terms are interpreted conservatively, for example, merely issuing a press release on hazards or distributing research information to potential users. This level of activity usually fails to result in effective hazard reduction techniques and may even fail to make users aware of the hazard.

According to Slovic (1986), communicators must appreciate the limitations of human understanding, namely: 1) people's perceptions are often inaccurate; 2) risk information may frighten and frustrate the public; 3) strong beliefs are hard to modify; and 4) naive views are easily manipulated by the format used to present other perspectives. He then suggests that research is needed in the areas of informed consent, information relevance, perceived risk, and the use of the media. Sorensen and Mileti (1987) provide an excellent discussion on the dilemmas of perception, the warning response process, the determinants of senders and receivers, the personalizing of warnings, and the nonbehavioral aspects of response.

No clear concise definition of, or criteria for, "transfer" has been offered, or can be found in the literature except by inference or by analysis of what actually works for those who have developed and adopted reduction techniques. Therefore, I suggest that we use "transfer" to mean the delivery of a translated product in a usable format at a scale appropriate to its use by a specific person or group "interested" in, or responsible for, hazard reduction. To delivery of a product, we must add assistance and encouragement in its use; in other words, an active ongoing learning experience!

This definition of "transfer" is somewhat analogous to the passing of a football or baton. Assume that the football or baton is understandable and in a usable format. Once the hand-off or passing has taken place, the receiver (for various reasons) may not run, win the race, or otherwise act appropriately.

It is the same with a receiver of earthquake hazard information. The information alone without action will not reduce casualties, damages, and interruptions. Obviously, something else is needed. My experience indicates that effective transfer must include not only delivery but assistance and encouragement in the selection and adoption of an appropriate reduction technique. Only then have the researchers, translators, and transfer agents fulfilled their professional obligation.

Transfer Techniques

Such delivery, assistance, and encouragement can be accomplished through specific transfer techniques which may be categorized into educational, advisory, and review services (List 4). These services were identified and tested by me during the 1960s, successfully used by the Southeastern Wisconsin Regional Planning Commission (1968, 1987), incorporated into the overall program design for the New Mexico State Planning Office (Kockelman, 1970, p. 34-41), brought to the attention of the USGS (Kockelman, 1976a), and incorporated into its national landslide hazard-reduction program (U.S. Geological Survey, 1982, p. 34, 37-47). In addition, these services are provided by some of the USGS's scientists, engineers, planners, and others as a personal commitment or under various

List 4

Examples of Hazard Information Transfer Techniques

Educational services

Providing serial and other types of publications reporting on hazard research underway and reduction techniques in process.

Assisting and cooperating with universities, their extension division, and other schools in the preparation of course outlines, detailed lectures, casebooks, and audio or visual materials.

Contacting speakers and participating as lecturers in state and community educational programs related to the use of hazard information.

Sponsoring, conducting, and participating in topical and areal seminars, conferences, workshops, short courses, technology utilization sessions, cluster meetings, innovative transfer meetings, training symposia, and other discussions with user groups.

Releasing information needed to address critical hazards early through oral briefings, newsletters, seminars, map-type "interpretive inventories," open-file reports, reports of cooperative agencies, and "official use only" materials.

Sponsoring or cosponsoring conferences or workshops for planners, engineers, and decisionmakers at which the results of hazard studies are displayed and reported on to users.

Providing speakers to government, civic, corporate, conservation, church, and citizen groups, and participating in radio and television programs to explain or report on hazard-reduction programs and techniques.

Assisting and cooperating with state and community groups whose intention it is to incorporate hazard information into school curricula.

Preparing and exhibiting displays that present hazard information and illustrate their use for hazard reduction.

Attending and participating in meetings with local, district, and state agencies and their governing bodies for the purpose of presenting hazard information.

List 4 (continued)

Examples of Hazard Information Transfer Techniques

Guiding field trips to disaster areas, damaged structures, and potentially hazardous sites.

Preparing and distributing brochures, TV spots, films, kits, and other visual materials to the news media and other users.

Operating public inquiries offices, sales offices, clearinghouses, etc.

Reporting on the adoption and enforcement of hazard reduction techniques.

Advisory services

Preparing annotated and indexed bibliographies of hazard information and providing lists of pertinent reference material to various users.

Assisting local, state, and federal agencies in designing policies, procedures, ordinances, statutes, and regulations that are based on, cite, or make other use of hazard information.

Assisting in recruiting, interviewing, and selecting planners, engineers, and scientists by government agencies for which education and training in hazard information collection, interpretation, and use are criteria.

Providing explanations of hazard information and reduction techniques during public hearings.

Assisting local, state, and federal agencies in the design of their hazard information collection and interpretation programs and in their work specifications.

Providing expert testimony and depositions concerning hazard research information and its use in reduction techniques.

Assisting in the presentation and adoption of plans and plan-implementation devices that are based upon hazard information.

Assisting in the incorporation of hazard information into local, state, and federal studies and plans.

Preparing brief fact sheets or transmittal letters about hazard products explaining their impact on, value to, and most appropriate use by local, state, and federal planning and development agencies.

List 4 (continued)

Examples of Hazard Information Transfer Techniques

Assisting users in the creation, organization, staffing, and formation of local, state, and federal planning and planning-implementation programs so as to ensure the proper and timely use of hazard information.

Preparing and distributing appropriate guidelines and guidebooks relating to natural hazards processes, mapping, and reduction techniques.

Preparing model state safety legislation, regulations, and development policies.

Preparing model local safety policies, safety plan criteria, and hazard reduction techniques.

Advising on and providing examples of the methods or criteria for hazard identification, vulnerability assessments, and risk management.

Review services

Reviewing proposed programs designed for collecting and interpreting hazard information.

Reviewing local, state, and federal policies, administrative procedures, and legislative analyses that relate to assessing and reducing hazards.

Reviewing studies and plans that are based on, cite, or otherwise use hazard information.

Reviewing proposed regulations, policies, and procedures that incorporate or cite hazard information.

earth sciences application and public information programs. The remarkable effort in Utah to provide these services can be seen in the following section.

Educational services range from merely announcing the availability of earthquake hazard information, through the publishing and distributing of newsletters and brochures, to sponsoring, conducting, or participating in seminars and workshops for potential users.

Advisory services range from explaining or interpreting earthquake hazard reports and maps, through publishing guidebooks and assisting in the design of regulations based upon the information, to giving expert testimony and depositions concerning the information.

Review services include review and comment on policies, procedures, studies, plans, statutes, ordinances, or other regulations, that are based upon, cite, interpret, or apply earthquake-hazard information.

The educational and advisory services should not supplant existing programs or activities of educational institutions, or replace services of private consulting firms or state and local organizations, instead they should supplement them!

The importance of educational and advisory services to accomplish delivery, assistance, and encouragement is obvious. The importance of review services is less obvious. When hazard information is used in a regulatory technique that affects land use and property values, it is eventually challenged in a courtroom or other public forum. At that time the researcher is requested or subpoenaed to explain or confirm the proper use of his research information.

If the researcher hasn't been given the opportunity to review its use and the opportunity to correct its potential misuse, the regulation will lose validity, the researcher embarrassed, and the user chagrined. It is foolish not to review when the effort to review is compared with the time and scarce resources needed to perform the required scientific and engineering studies, to translate and transfer them, and to prepare, adopt, and enforce a reduction technique (List 2).

Multiple ways of imparting information should be encouraged. A single exposure to new information, especially if the information is complex or differs from a user's previous knowledge, is often insufficient. Repeated exposure in different formats and through different conduits is needed. This strategy is particularly successful when new information is provided by persons who are customarily looked to for guidance, such as members of the same professional group. The most effective transfer techniques should be selected jointly (if possible) by the translator, transfer agent, and user.

Most public hearings or presentations to decisionmakers allow little time, and the transfer agent is competing with numerous other issues. The most concise, simplest translation and transfer techniques are the most successful. One of USGS's senior scientists (A.H. Lachenbruch, written commun., 1981) with experience in successfully transferring research information to Congress as well as local decisionmakers observed: "Simple maps with a few bright colors are needed ...." Obviously such maps must be derived from larger scale and more detailed information which, if needed to meet a challenge, is readily available.

Transfer Agents

For the purposes of this report, the term "transfer agents" is defined as those who deliver translated research information to potential users and assist and encourage them in selecting and adopting appropriate hazard reduction techniques.

In his final report on the County Hazards Geologist Program, Christenson (1988, p. 3) identifies several options for transferring geologic expertise to local governments, namely:

- Permanent, full-time city or county geologist.
- Circuit-rider geologist serving several governments simultaneously.
- Geologist employed by an umbrella agency (regional association of governments, state survey) but dedicated to serving local governments.
- Private consulting geologist on retainer or other under contract with local government.

It should be noted that consultants under contract with a local government may have the appearance of a "conflict-of-interest" if they represent parties other than the local government within its jurisdiction.

Potential transfer agents of earthquake-hazard information in Utah are given in List 5. Many of the users in List 3 will also be transferring such information. Bates (1979, p. 11) notes that: "although both the use of transfer agents and the education of planners in the earth sciences, ... are increasingly important components of the information-

List 5

Potential transfer agents for earthquake-hazard information in Utah

American Planning Association, Utah Chapter
American Society of Civil Engineers, Utah Section
American Society of Public Administrators, Utah Chapter
Association of Engineering Geologists, Utah Section
Bear River Association of Governments

Children's Museum
Church groups, church organizations, and church leaders
Civic and voluntary groups
Consultants (engineers, planners, geologists, and others)
County geologists and extension agents

Educators (university, college, secondary, and elementary)
Governor's Advisory Council on Local Governments
Hansen Planetarium
International Conference of Building Officials, Utah Chapter
League of Women Voters

Local building, engineering, zoning, and safety departments
Local seismic safety advisory groups
Media (journalists, commentators, editors, and feature writers)
Mountainlands Association of Governments
Neighborhood associations

Public information offices
Relief Society, Church of Jesus Christ and Latter-Day Saints
Researchers, engineers, and planners (local, state, and federal)
Society of American Foresters, Wasatch Front Chapter
Southeastern Utah Association of Governments

Speakers' bureaus (state, local, or project area)
Structural Engineering Board, Church of Jesus Christ and Latter-day Saints
University of Utah Seismograph Stations
Utah Association of Counties
Utah Division of Comprehensive Emergency Management

Utah Department of Social Services
Utah Geological Association
Utah Geological and Mineral Survey
Utah League of Cities and Towns
Utah Museum of Natural History

U.S. Forest Service
U.S. Geological Survey
U.S. Soil Conservation Service
Wasatch Front Regional Council
Western Governors' Policy Office

transfer system, nothing replaces intensive producer-user interaction ...."

Of course, geologists, seismologists, and other earthquake researchers will be available to provide some of the educational, advisory, and review services, but to rely solely or heavily on these skilled and scarce resources is unreasonable and would divert them from their work of understanding the process, assessing the hazard, and translating their research.

The role of professional associations -- planners, engineers, geographers, and geologists -- should be emphasized. For example, Petak (1984, p. 457) points out that "hazard and risk assessment must be ... fully supported by the efforts of the geotechnical profession."

The professions can not only contribute to identifying user needs, translating and transferring complex information, and fostering an environment for use, but are principal users themselves. The Yin and Andranovich (1987) study on getting research used in the natural hazard field concluded that the role of professional associations "is a diffuse model, in which multiple sources of ideas are mixed with multiple types of users ...."

Transfer agents should solicit and use the expertise of those members of the sociological community who are trained and experienced in reducing natural hazards. Examples of successful transfer agents and their transfer programs follow:

- Circuit-rider geologist in the State of Washington (Thorsen, 1981).
- Planning, reviewing, and enforcing by city and county geologists (McCalpin, 1985; Christenson, 1988).
- Advisory services unit of the California Division of Mines and Geology (Amimoto, 1980).
- Educational, advisory and review services by the Southeastern Wisconsin Regional Planning Commission (1968, 1987).
- Earth science information dissemination activities of the U.S. Geological Survey (Information Systems Council's Task Force on Long-range Goals for USGS Information Dissemination, 1987).
- Earthquake-hazard reduction activities of the staff, members, and committees of the California Seismic Safety Commission (1986).

Successful Transfer in the United States

One of the best ways to confirm that these transfer techniques are effective is to closely look at techniques that have been used and which have resulted in the reduction of natural hazards. For over 25 years, a midwestern multicounty planning commission has transferred geologic, hydrologic, and pedologic hazard information to public and private users. A perusal of an annual project completion report by the Southeastern Wisconsin Regional Planning Commission (1968) will show that almost every educational, advisory, and review service in List 4 was repeatedly used. A summary of a recent evaluation of the effectiveness of one of the techniques -- guidebooks containing model ordinances -- may be seen in figure 10.

Many other examples of the transfer techniques shown in List 4 including their transfer agents can be cited. Selected examples follow:

- Case studies on strengthening hazardous buildings by the San Francisco Bay Area Regional Earthquake Preparedness Project (1988).
- Earthquake-hazard reduction series by the Federal Emergency Management Agency (1985-1988).
- Home guide section on how a house withstands an earthquake in the Chicago Tribune by Kerch (1988).
- Guidebook on reducing earthquake risks for planners by Jaffe and others (1981).
- Isoseismal map users guide by the Central United State Earthquake Consortium (1987).
- Canoe trip to view evidence of probable magnitude 8 or 9 earthquake in the Pacific Northwest by Atwater (1988).
- Introduction to geologic and hydrologic hazards in the United States by Hays (1981).
- Using earth-science information for earthquake-hazard reduction in the Los Angeles region by Kockelman (1985).
- Guidelines for preparing a safety element of the city and county general plan by a governor's office of planning and research (Mintier, 1987, p. 146-153).
- Guidebook for disaster mitigation for planners, policymakers, and communities by Lohman and others (1988).

- Guidebook on identifying and mitigating seismic hazards in buildings including a model ordinance for rehabilitating masonry buildings by the California Seismic Safety Commission (1987).

- Guidebook on seismic safety and land use planning by Blair and Spangle (1979).

- Handbook on land use planning for earthquake hazard mitigation for planners by Bolton and others (1986).

- Analyzing and portraying geologic and cartographic information for land use planning, emergency response, and decisionmaking in San Mateo County, California, by Brabb (1987).

- Getting ready for a big quake by Sunset Magazine (1982).

- Landslide-hazard mitigation plan for Colorado by Jochim and others (1988).

- Trail signs describing the 1959 Hebgen Lake earthquake-triggered landslides and vertical displacement along the fault in the Gallatin National Forest, Montana, by the U.S. Forest Service.

- Workshop on the evaluation of regional and urban earthquake hazard and risk in Alaska convened by Hays and Gori (1986).

- Periodical on earthquakes and volcanoes (formerly Earthquake Information Bulletin) by the U.S. Geological Survey (Spall, 1971 to present).

- Bibliography and index to seismic hazards of western Washington from 1855 to 1988 compiled by Manson (1988).

- Review of state landslide-hazard maps by USGS physical scientist W.M. Brown (written commun., 1985).

- Peace of mind in earthquake country -- How to save your home and life by Yanev (1974).

- Selected annotated bibliography of recent publications concerning natural hazards by Morton (1986).

- Washington state earthquake hazards by Noson and others (1988).

- Pilot earthquake education projects in Arkansas, Tennessee, Mississippi, Washington, and South Carolina (Bolton and Olson, 1987b, app. B).

- Steps to earthquake safety for local governments by Mader and Blair-Tyler (1988).

Many researchers provide such services on a limited and informal basis. Federal and state scientists are frequently called upon to assist users. Such services should be formally recognized and included as a work element in any earthquake-hazard reduction program as was done in the Utah work plan.

Many of these services are provided in Utah through cooperative agreements, serial publications, report and map-sales offices, geologic-inquiries staff, public inquiries offices, professional groups, local and State geologists, municipal planners, engineers, and ordinary day-to-day contacts with the public by the researchers and translators of earthquake-hazard information. Specific examples from Utah are given in the following section.

Comment

The reader familiar with the successful transfer agents, programs, and techniques cited here will note that they accomplished the following:

- Delivered the information to those who are interested or required to use it.
- Conveyed the hazard in such a way as to result in the users' awareness.
- Provided the user with a wide selection of reduction techniques.
- Suggested a strategy for using the hazard information in a reduction technique through examples.

It is my experience that educational, advisory, and review services must accompany any successful earthquake research, hazard assessment, translation, and transfer program designed for planners, engineers, and decisionmakers.

Several benefits accrue to the transfer agents and those researchers and translators involved in transfer activities. These benefits include:

- Satisfaction that they have discharged their professional obligations and the "ball is now in another court."
- Sense of accomplishment when successful hazard reduction occurs.
- Perception of how local, state, and corporate decisions are made.
- Awareness of where and how they can now make a civic contribution to encourage appropriate decisions.

EXAMPLES OF SUCCESSFUL TRANSFER IN UTAH

A remarkable effort is being made in Utah to transfer earthquake hazard information to nontechnical users including real estate salespersons, financial institutions, and church groups. For example, in June 1985 three county geologists began providing educational, advisory and review services to five counties -- Weber-Davis, Salt Lake, and Utah-Juab. They were funded by USGS with other support being provided by the UGMS and the five counties. Financial support by their local government for 1989 is an indication of the success of this type of transfer program.

According to Christenson and others (1987, p. 4), the goals of the county hazards geologist program are to:

- o Compile geologic hazards information and produce maps to be used to delineate hazard areas where site-specific reports should be required.
- o Review engineering geologic reports.
- o Advise planners regarding hazards ordinances.
- o Provide geologic expertise as required.

These geologists are a part of their county planning department under direct supervision of the planning director; the UGMS provides technical supervision and other support as needed. The geologists are also available to perform the same services to the cities within their county. Some of the services provided over just a six-month period may be seen in the excerpt from the report shown in figure 11. A final report on their data collection, hazards mapping, ordinance reviews, and many other accomplishments has been prepared by Christenson (1988, p. 5-9; and in press).

Much of their work can be categorized as reduction techniques (List 2) and therefore are not discussed in this section on transfer techniques. According to county geologist Mike Lowe (unpublished speech, 1986), examples of such work include the site investigation and hazard evaluation for South Weber City, city of Washington Terrace, city of North Salt Lake, Emigration Canyon (Salt Lake County), and the Lake Mountain and Pine Flat areas (Utah County).

Several Federal, State, and county planners, geologists, and emergency managers identified the "provision of education, advisory, and review services" as one of their most significant accomplishments to date (Christenson and others, 1987, p. 84). Examples of some of the transfer techniques used in Utah follow. Each one can be categorized as an educational, advisory, or review service, or a combination of two or all of the services. In most cases, the transfer agents are not only delivering translated information as defined and illustrated in previous sections of this paper but are assisting and encouraging its use for hazard reduction.

Workshops

During the period from 1984 to 1988, six workshops were held in Utah on assessing and reducing earthquake hazards, two of them in 1985. A field trip followed the one in 1986 and preliminary reports for a professional paper (in press) were released at the one held in 1987.

Each workshop fulfilled a commitment made in 1983 to bring key researchers and users of hazard information together each year for the purpose of providing current information on the earthquake hazard, distributing translated reports and maps, describing how they can be used, and fostering an environment for use of the information for hazard reduction.

Each workshop had various sponsors including the University of Utah, Utah Geological and Mineral Survey (UGMS), State of Utah Division of Comprehensive Emergency Management (CEM), FEMA, and USGS. Five were attended by as many as 130 earth-scientists, engineers, planners, and emergency managers. One attended by over 400 persons addressed multihazards and comprehensive hazard reduction (May, 1988). An example of some of the topics addressed and reports made at one of these workshops may be seen in figure 12. The proceedings of two of the workshops were edited by Hays and Gori (1984, 1987) and published as open-file reports to ensure early release and transfer. The UGMS compiles examples of interim maps and reports available and uses the workshops as an opportunity to distribute them.

Serial Publications

Several serial reports designed to transfer earthquake-hazard information in Utah to nontechnical persons were continued or begun during the past five years. The attractive easy-to-read Survey Notes (figure 13) is published quarterly by the UGMS (Stringfellow, 1983 to present). It features excellent articles such as the historic and scientific content of earthquake hazards in Utah by Mabey (1985). It reports on UGMS information programs (Smith, 1985a), earthquake activity recorded by the University of Utah Seismograph Stations, hiring of county geologists, new publications, and related activities of interest -- ongoing geologic projects, status of applied geology programs, personnel changes, and how UGMS responds to disasters (Atwood, 1983).

The Wasatch Front Forum was specially created for the earthquake-hazards program and is published and distributed quarterly by the UGMS (Hassibe 1983-86; Jarva 1987 to present). It features timely articles on neighboring earthquakes (Crone, 1984), prediction in the Wasatch Front (Smith and others, 1985), earthquake-induced soil liquefaction (Keaton, 1986), disruption of critical facilities (Frank, 1987), and earthquake preparedness projects (Tingey, 1986).

This newsletter also reports on the regional earthquake hazards assessment program (Hays, 1984), accomplishments of the ground shaking hazards and loss estimation program (Rogers and others, 1986), Utah County Comprehensive Hazard Mitigation Project (Dewsnup, 1987), progress of the geologic, seismologic, and engineering research (Tarr, 1984), earthquake activities recorded by the University of Utah Seismograph Stations, and the results of surveys on the perceptions of risk by residents along the Wasatch Front. Notices of scheduled professional meetings, recent publications, out-of-state workshops of interest, new research programs, and reprints of timely articles such as Rogers (1986) are included on a regular basis. See figure 14.

In addition, the Earthquake Information Bulletin (now Earthquakes and Volcanoes) (Spall, 1975 to present) written for nontechnical readers is published bimonthly by the USGS. It contains feature articles such as "Earthquake Potential of the Wasatch Front" (Spall, 1985), as well as reporting on earthquake activity by states and countries. Notices of state, national, and international workshops and conferences on earthquakes -- research, engineering, preparedness -- and recent publications are also included on a regular basis.

Outreach Programs

The Utah Museum of Natural History contributes to the geologic education of the general public through exhibits, classes, lecture series, film series, field trips, teaching kits, and teacher workshops. Since the fall of 1985, "Utah Geologic Hazards" has been a popular outreach program.

According to the Museum's earthquake safety instructor, Deedee O'Brien (written commun., 1988), the program has reached 3,000 students and adults for each of two school years (1985-86 and 1986-87). During the following year (1987-88), the outreach program was phased down in favor of training teachers to use the materials (figure 15) and teach the information to their own classes. Three workshops were held in 1988 with instructors from the Museum, CEM, UGMS, and the University of Utah. Seventy-nine teachers from five Wasatch Front school districts completed the course. They may check out a teaching kit, which includes a two-foot square model, cardboard fault blocks, 150 slides with text, and a packet of follow-up earthquake safety activities.

In addition to the geologic hazards curriculum, Deedee O'Brien developed an earthquake safety curriculum appropriate for kindergarten through third grades. This has been tested in approximately 30 classrooms and has been offered to teachers in two in-service workshops entitled "Earthquake Safety in the Elementary Classroom." Forty-eight teachers attended. These workshops were cosponsored by CEM. The museum continues to offer earthquake safety in-service courses annually.

The Utah State Division of Comprehensive Emergency Management (CEM) has developed various hazards outreach programs which include educational and advisory services. A good example is an inexpensive booklet by Tingey (1989) which provides both an awareness of the earthquake hazard and suggested preparations to reduce the hazard. According to Tingey and Findlay (1987, p. T-11), CEM has made many presentations and during one year alone distributed over 730,000 brochures on earthquake hazards and their reduction. One project completed in 1986 was the production of a television program (video format) which succinctly covered the earthquake hazard, risk, and safety concepts specific to the Wasatch Front. Near the end of the project, the local CBS affiliate, KSL Television, 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 150 entrants from seven western states. Several copies of the video are being used to make presentations to school, church, business, and other interested groups.

Integrated into 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 postulated events. Translation of this research was performed by CEM, UGMS, scientific and public safety-oriented agencies, and the producer of the video program. According to Tingey (1988, p. 102), the producer "had a terrific feel for the material" and was able to distill and translate complex ideas into concepts understandable by the nontechnical audience.

The Utah State Office of Education (Burningham, 1983) has produced an inexpensive, well-illustrated comprehensive booklet on natural hazards entitled "I can make the difference -- Emergency preparedness." In chapter 2 (p. 15-28), it addresses the earthquake hazards through three personalized scenarios, questions and solutions, a quiz, and a word-hunt game.

The UGMS has provided one-page pass-out sheets for public use, for example, earthquake hazard situation, safety, and faulting in Utah by Kaliser (1984a, b, c). These sheets address scientific evidence, historic events, population exposed, past damages, expected magnitude, critical facilities vulnerability, retrofitting, topographic expressions, and other aspects of earthquake hazards and their reduction. Cogent, one-sentence "bullets" are used; see figure 16.

The county geologists are continually providing educational services. For example, as county employees, they are available to explain earthquake hazards and the techniques for reducing them to various county officials, staff, and citizens. They have increased community awareness through a slide-lecture program presented to university students, community councils, civic groups, and other local government organizations such as the Ogden City Seismic Committee, citizens groups in Nephi and Provo (Lowe, personal commun., 1986), Salt Lake Board of Realtors, and various community councils in Salt Lake County. The UGMS and the Utah County geologist conducted a class and field trip on geologic hazards for the 1988 annual education meeting of the Utah Section of the International Conference of Building Officials.

Field Trips

Field trips for both small and large groups have been conducted. A particularly comprehensive one-half day trip to selected geologic features and buildings in southern Davis and northern Salt Lake counties sponsored by UGMS and USGS was arranged and conducted by Keaton and Reavely (1986). Their well-illustrated text enhanced the opportunity for the nontechnical attendees to observe key geologic features and buildings in the metropolitan area.

Geologic features seen during the trip included surface evidence of movement along a fault plane, topographic scarps, and lateral spreads caused by earthquake-induced liquefaction. Vulnerable buildings visited included gravity-frame structures with masonry infill walls, potable water tanks straddling the Wasatch fault, sewage treatment plants subject to subsidence by tectonic deformation, and communications centers with little lateral force resistance. Seismic-resistant structures viewed included Salt Lake County Government Center buildings with concrete shear walls, braced and anchored brick-clad buildings, and the seismically-strengthened Veteran's Administration Hospital.

The three county geologists have conducted numerous field trips for their county commissioners, mayors, and other public officials to inform them of geologic hazards in their respective jurisdictions. The UGMS also conducts trips to trench sites for State and local government officials to inform them of research results and let them see the evidence first-hand.

News Media

The release of information and its subsequent publication and wide dissemination to television viewers, radio listeners, and newspaper readers is one of the most effective ways of delivering information about earthquake hazards to nontechnical users. A typical release by the USGS Public Affairs Office is shown in figure 17. Typical newspaper coverage is shown in figure 18.

According to Sprinkel (1988), 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 to raise public awareness of the potential threat earthquakes pose to Utahans. The news media are invited to all field trips, and nearly always attend. In addition, county geologists participate in local radio talk shows. The Utah Department of Natural Resources also performs much work to ensure good press coverage. Sprinkel observes that there is an eagerness by the Utah press community to cover most of the earthquake-related stories. The result is increased level of public understanding and awareness of Utah's susceptibility to their and earthquake hazards along the Wasatch Front.

Information Systems

At the inception of the regional earthquake hazards assessment program in Utah, Tarr and Mabey (1984, p. 148) specified the objective of the information system as follows:

- To make quality data readily available to meet the needs of researchers and policymakers.
- To create an information system that assures that new data will be available in the form most useful to meeting program objectives.
- To devise a system whereby potential users will have easy access to data in media, scales, and formats that will be most useful to them.

They suggested creating a "clearinghouse" with directories to its information. Much of what they envisioned is now reality (Sprinkel, 1988, p. 94).

During the past three years, UGMS compiled a comprehensive bibliography of geologic hazards in Utah. References were collected statewide from conventional sources of published information and some unconventional sources. All of the references were keyworded and entered into a computerized data base system for easy manipulation and retrieval. These sources were supplemented by many of the geotechnical engineering firms and government agencies in Utah that permit a review of their files for more site-specific information.

This compilation was initiated in October 1985 with the goal of not only compiling a computerized hazards bibliography but also producing generalized hazards maps for the State at a scale of 1:750,000. The hazards bibliography includes a comprehensive listing of all published and unpublished hazards information statewide. Information can be retrieved according to specific hazard, type of information, and geographic locality covered by each entry. When completed, the bibliography can be sorted geographically and printouts made available to various governmental entities (cities, counties, and multicounty agencies) so that they will be aware of what data are available for their jurisdictions.

In conjunction with the bibliography, UGMS maintains a file for each USGS 7½-minute quadrangle in the State which will include site-specific hazards reports (where appropriate), inventory sheets of each report's contents, and an index map showing the location of the sites reported on. Mapping and bibliography compilation are proceeding concurrently and are scheduled for completion in 1989.

The second phase of the UGMS hazards compilation project is a cooperative effort with the USGS and five Wasatch Front counties. The three county geologists serving the five counties have collected all pertinent hazards information and developed a hazards library for each county. They use this information, supplemented with additional field studies as necessary, to compile hazards maps for each county. Files of site-specific hazards information are being maintained and index maps showing locations of hazards information are being compiled.

Texts are being prepared to accompany each map to explain the hazard -- likelihood, location, and severity. A discussion of possible engineering and site design techniques for mitigation is included, as well as guidelines for the types of information that should be included in site investigation reports. Figure 19 shows the status of these texts and maps as of December 1988.

Public Inquiries

In addition to compiling and maintaining directories, the UGMS maintains a library, public inquiries section, and a sales office. According to Smith (1985b, p. 4), the library has several thousand items including materials on earthquake phenomena and hazards. The librarian has access to the computerized "Bibliography of Utah Geology" and can make searches by author, location, or type of study and is adding new titles to keep the list up-to-date.

The list of UGMS publications and maps is now on computer (PUBLIST). It is indexed by county and kind of study for easy location of specific publications. Its data processing section is preparing a new program to keep records of sales and inventories. All except the most recent UGMS publications are now available on microfiche so that no publication is ever completely "out-of-print."

The sales office fills mail orders for UGMS publications (over 70 percent of its business) as well as handling over-the-counter sales. Receipts for 1983-84 were $42,000; sales have been increasing annually. In addition, many materials are provided to the public at no charge. The

UGMS staffs an Applied Geology Program to assist State and local units of government in assessing and reducing geologic hazards. The USGS operates ten Public Inquiries offices in the United States; one of them is in Salt Lake City.

Advisories

Specific advice on reducing earthquake hazards may be in verbal or written form. Written information may consist of a general fact sheet that is widely distributed or a letter addressing a specific issue that is requested by a planner or decisionmaker. Figures 16 and 20 illustrate these two types.

The UGMS and county geologists provide varied advisory services. One example is providing explanations and advice along with hazard maps and hazard-reduction literature to prospective real-estate buyers, sellers, lenders, and developers. Building officials and planners, both city and county, frequently request advice on specific sites where geotechnical problems are encountered or suspected. The UGMS also advises the Utah state departments of Community and Economic Development and Facilities Construction and Management regarding use of earthquake-hazards information in State-funded projects.

The county geologists' advice has been sought and given to the cities of Salt Lake, Ogden, South Weber, Mapleton, Centerville, Riverdale, Washington Terrace and the counties of Salt Lake, Utah, and Weber on the content of ordinances regulating the use of hazardous lands.

Guidelines

The Utah Section of the Association of Engineering Geologists (1986, 1987) has been preparing guidelines concerning the preparation of engineering geologic reports and the evaluation of various geologic hazards including surface fault rupture, shaking, liquefaction potential, and landslide potential. Two of these have been published and distributed by the UGMS; one is shown in figure 21.

Sometimes a scientist/author includes a transfer technique in his translated material. A good example is a recommendation included in the earthquake-induced landslide potential report by Keaton and others (1987) that accompanies their seismic slope stability map. The recommendations in matrix format for critical facilities and other land uses are shown in figure 22.

Guidebooks

Several guidebooks were specially prepared for reducing earthquake hazards in Utah. Four of these books are:

- o Reducing losses from earthquakes through personal preparedness by Kockelman (1984).
- o Suggested approach to geologic hazard ordinances in Utah by Christenson (1987).
- o Utah's geologic hazards -- a review for realtors by Christenson and Mabey (1987).
- o Planning for natural hazards by the University of Utah Center for Public Affairs and Administration (1988).

The first guidebook introduces five phases of reduction -- pre-event mitigation techniques and preparedness measures, response during the earthquake, and post-event recovery operations and reconstruction activities. Several examples and citations are given for each. Because of the unique effort towards individual and community "self-reliance" in Utah, emphasis is placed on the relatively inexpensive actions that can be taken by responsible parents, neighborhoods, and employers. These include inspecting and strengthening the home, organizing the neighborhood, and securing contents and other nonstructural parts of buildings.

The second book encourages prudent land use in areas of geologic hazards, including earthquake hazards for the protection of the citizens of those cities and counties enacting ordinances. A concise discussion of hazards and availability of information is followed by a comprehensive survey of city and county geologic hazard ordinances in Utah. An outline of the steps to be included in a hazard-reduction ordinance in jurisdictions having geologic hazard maps and those without such maps is shown in figure 23. In addition, the Salt Lake County planning staff drafted a natural hazards-reduction ordinance (Barnes, 1988b) which follows the guidebook recommendations. It has been used as a model by other cities and counties.

The third book was prepared to provide Utah's realtors with information that will enable them to place the State's geologic hazards in proper perspective and to communicate this risk to prospective home-buyers and business clients. The hazards considered include floods, slope failure, earthquakes, subsidence, and expanding soils. The authors emphasize the need for hazard assessment and then provide general information about the availability of hazard information, status of various hazard-mapping projects, ordinances dealing with hazard warnings or mitigation, and work accomplished by the UGMS Applied Geology Program. The report concludes that realtors "have a unique opportunity to inform the property owners of Utah and thus contribute to making Utah safer and more prosperous."

The fourth book offers a guide to the first steps that may be undertaken at the local level to understand potential hazards and plan for their reduction. It includes a discussion of local government responsibility and liability, an outline of the planning process, and state and county contacts for information and assistance.

Geographic Information Systems

For the purposes of this paper, geographic information systems (GIS) are defined as the spatial representation of geologic, hydrologic, topographical, land use, land ownership, and other physical and socioeconomic information which can be readily combined and manipulated for various purposes by computer technology. The result is a quantifiable analysis of point, line, area, and volume data. The nature and capability of GIS provide an excellent basis for presenting and combining not only the various earthquake hazards, but critical facilities that might be affected. In addition, an easily used geo-reference map can be provided for the nontechnical user.

For example, Alexander and others (1987), in demonstrating the use of digital mapping technology, entered surface fault rupture, liquefaction potential, and landslide potential into a GIS for the Sugar House Quadrangle in east-central Salt Lake County. In addition to the hazard maps used in their atlas, other maps were used to illustrate the kinds of information needed to reduce earthquake hazards, namely: political jurisdictions, roads, selected lifelines, and land uses. They then combined hazards with specific land uses, for example; lifelines in potential surface fault rupture zones, schools and residential areas in high liquefaction potential zones, and schools and residential areas on lands with the lowest stability during earthquakes.

University of Utah Department of Geography professor Phillip Emmi has entered Salt Lake County's lifelines, other critical facilities, and building inventories, into a GIS to estimate earthquake loss probabilities. A CEM planner Wes Dewsnup entered all information for the Utah County Multihazard Mitigation Project into the GIS operated by the Utah State Office of Automated Geographic Referencing. Salt Lake County uses the AUTOCAD system and, according to C. V. Nelson (written commun., 1989), this will greatly increase the transfer of hazard information which has been referenced to land ownership records.

Review Services

The State and county geologists are sometimes asked to provide the type of review services in List 4. For example, the Salt Lake County geologist has assisted West Valley City by providing geologic hazard information to be incorporated into their computerized data bank for land-use planning; the UGMS and Utah County geologist provided hazard maps and interpretations for a Utah Division of Comprehensive Emergency Management and county project in the Provo-Orem area to aid emergency response personnel; and the Weber County geologist assisted the city of Washington Terrace in including geologic hazards into its 1987 master plan.

Comment

In all of the examples, delivery of translated information was provided; in many others, assistance and encouragement in its use for hazard reduction was provided or offered. The users ranged from practitioners and professional societies to interested citizens including children. Several of Utah's transfer techniques included suggested reduction techniques.

Special mention should be made of the unique efforts of the UGMS, USGS, university, and consulting researchers to release research findings early to practitioners and other users. This was accomplished through oral briefings, workshops, workshop proceedings (Hays and Gori, 1984, 1987; Gori and Hays, 1987, 1988), serial publications (Stringfellow, 1983 to present), newsletters (Hassibe, 1984-86; Jarva, 1987 to present), and "official use only" materials.

EVALUATION AND REVISION

The last component in any comprehensive earthquake hazard-reduction program is evaulating the effectiveness of the reduction techniques and revising them if necessary. See figure 1. Evaluating and revising the entire program as well as the other components -- studies, translation, and transfer -- may also be undertaken.

The evaluation component was included as a task in the national earthquake hazard-reduction program by Wallace (1974), and as recommendations of the California Joint Committee on Seismic Safety (1974) advisory groups. Evaluation has been emphasized in a review of ten cities' efforts to manage floodplains (Burby and others, 1988, p. 9), in the comprehensive tasks of a national landslide ground-failure-hazards reduction program (U.S. Geological Survey, 1982, p. 44), and in the recommendations of the NEHRP Expert Review Committee (1987, p. 81-85).

In Utah, evaluation is included in the abbreviated recommendations for earthquake-risk reduction by the Utah Seismic Safety Advisory Council (1981), as an active item from a governor's conference on geologic hazards (Utah Geological and Mineral Survey, 1983), and as a task in the Utah work plan.

Importance

The effectiveness of each hazard-reduction technique varies with the time, place, and persons involved. Therefore, it is prudent to include a continuing systematic evaluation as part of any program for earthquake-hazard reduction. An inventory of uses made of the information, reports of interviews with the users, and an analysis of the results and responses will also result in identifying new users, innovative uses, as well as any problems concerning the research information, its translation, transfer, and use. The evaluation will be helpful, even necessary, to those involved in funding, producing, translating, transferring, and using the research information as well as managing the reduction program.

Performing the studies and then translating and transferring the research information is expensive and difficult because of the limited number of scientists and geotechnicians -- National, state, local, corporate, and consulting -- particularly when aligned with the needs of communities throughout the United States. The adoption and enforcement of an appropriate hazard-reduction technique is time-consuming, and requires many skills -- planning, engineering, legal, and political -- as well as strong and consistent public support.

Scarce financial and staff resources must be committed; necessarily persistent and difficult actions must be taken to enact a law, adopt a policy, or administer a reduction program over a long period of time. To discover later that the hazard-reduction technique selected is ineffective, unenforced, or its cost is greatly disproportionate to its benefits is not only disheartening but may subject those involved to criticism and withdrawal of financial support!

Few systematic evaluations have been made of natural hazards-reduction techniques, including earthquake hazards-reduction techniques. To my knowledge, no rigorous studies of the benefits-to-costs have been conducted; a few intensive evaluations have been made for flood, landslide, and other reduction techniques and programs which may be applicable to earthquakes.

The following examples of various evaluations are presented for introductory purposes; a discussion of their findings and recommendations are beyond the scope of this paper.

Evaluation of Reduction Techniques

Several reduction techniques (List 2) have been evaluated, problems identified, and improvements suggested. Some examples follow:

- Planning for urban land use in California by Wyner (1982).
- Preparing and implementing local seismic safety elements by the California Seismic Safety Element Review Committee (1985).
- Lending, appraising, and insuring policies of the 12 largest home mortgage lenders in California by Marston (1984).
- Disclosing of fault rupture hazards to real estate buyers in Berkeley and Contra Costa County by Palm (1981).
- School earthquake safety and education project in Seattle and community outreach education centers at Memphis State University and Baptist College in Charleston, South Carolina, by Bolton and Olson (1987b).
- Strengthening, redeveloping, abandoning, or demolishing of unreinforced masonry bearing-wall buildings in the cities of Long Beach, Santa Ana, and Los Angeles by Alesch and Petak (1986).
- Strengthening masonry-bearing-wall buildings in the city of Los Angeles after the 1987 Whittier Narrows earthquake by Deppe (1988).

- o Retrofitted highway bridges after the 1986 earthquake in Palm Springs by Mellon (1986).
- o Mapping, investigating, and regulating surface-fault-rupture zones in California by Hart (1986).

Translation and Transfer Techniques

Several translation or transfer techniques (List 4) have been evaluated, problems identified, and recommendations made. Some examples follow:

- o Announcing earthquake prediction and forecast information in southern California by Turner and others (1981).
- o Disseminating earthquake education material to California public and private schools by Bolton and Olson (1987a).
- o Disseminating earthquake-hazards information to public officials and private sector representatives in Charleston, South Carolina, by Greene and Gori (1982).
- o Using earth-science information in cities, counties, and selected regional agencies in the San Francisco Bay region by Kockelman (1975, 1976b, 1979), Kockelman and Brabb (1979), and Perkins (1986).
- o Translating and transferring information in the U.S. Geological Survey by O'Kelley and others (1982).
- o Conducting a workshop on preparing for and responding to a damaging earth-earthquake in the eastern United States by Tubbesing (1982, p. 57-59).
- o Adopting ordinances based on guidelines and model ordinances developed and transferred by the Southeastern Wisconsin Regional Planning Commission (1987, p. 24).

Evaluation of Programs

Several earthquake-hazard-reduction programs have been evaluated, problems identified, and revisions suggested. Some examples follow:

- o Community seismic safety programs before, during, and after the 1983 Coalinga, California, earthquake by Tierney (1985).
- o Planning and implementing seismic-hazard mitigation in Alaska by Selkregg and others (1984).
- o Use of earthquake hazard information for enlightenment, decisionmaking, and practice in California, Washington, Utah, South Carolina, Massachusetts, Idaho, Puerto Rico, Kentucky, Alaska, Missouri, U.S. Virgin Islands, and the eastern, western, and central United States by

Hays (1988a).

- o National Earthquake Hazards Reduction Program in the United States by the NEHRP Expert Review Committee (1987).

- o Effectiveness of the geology and planning program in Portola Valley, California, by Mader and others (1988, p. 55-61).

- o San Francisco Bay Region Environmental and Resources Planning by Study by Arthur D. Little, Inc. (1975) and Brown (1975).

- o Land use and reconstruction planning after the 1971 San Fernando, 1964 Alaska, and 1969 Santa Rosa earthquakes by Mader and others (1980).

- o Seismic Safety policies of local governments in California by Wyner and Mann (1983).

- o Structure design and behavior investigation after over 200 earthquakes by members of the Earthquake Engineering Research Institute (Scholl, 1986).

Various Evaluations in Utah

Several reduction and transfer techniques and programs in Utah have been evaluated, problems identified, and revisions suggested. Some examples follow:

- o Awareness and reduction of earthquake hazards by Perkins and Moy (1988, p. 9-19).

- o Multi-hazard mitigation project for Ogden and Weber County by Olson and Olson (1985).

- o Hazardous building abatement and sensitive lands development ordinances for Provo by May and Bolton (1986).

- o County Hazards Geologist Program by Christenson (1988).

- o Earthquake knowledge, risk perception, and mitigation priorities in Salt Lake County by Madsen (1988).

- o Adequacy of engineering geologic reports by Nelson and others (1987).

- o Perception of earthquake risk and support for regulations by Emmi (1987).

Reduction Techniques for Other Hazards

Several reduction techniques for other natural hazards have been evaluated, problems identified, and improvements suggested. Their evaluation methods, findings, and recommendations may be applicable to earthquake hazards. Some examples follow:

- o Disclosing hurricane-flood-hazards information to prospective home buyers in Florida by Cross (1985).
- o Providing state financial incentives for flood-hazard reduction to local governments by Burby and Cigler (1983).
- o Subsidizing flood insurance for property owners and their lenders by Miller (1977), Burby and French (1981, p. 294), and Kusler (1982, p. 36, footnote 55).
- o Notice, watch, and warning system for a potential 1978 Pillar Mountain landslide in Kodiak by Saarinen and McPherson (1981).
- o Warnings for the 1980 Mount St. Helens volcano eruption by Saarinen and Sell (1985).
- o Planning and engineering response and recovery to 1982 debris flows at Love Creek (Santa Cruz County) and Inverness (Marin County) by Blair and others (1985).

Evaluation Methods

There are numerous methods for evaluating the effectiveness of an earthquake hazard-reduction program and its components -- studies, translation, transfer, and reduction. The above examples of evaluation indicate that these methods vary widely because of the human and financial resources available, the region involved, and the evaluator's interest, experience, and commitment. A thorough discussion of these methods is beyond the scope of this report, however, the following will illustrate different levels of rigor:

1. Soliciting comments and suggestions from the research information producers, translators, transfer agents, and users.
2. Inventorying the documents where research the information is cited and conducting unstructured (but systematic) interviews with the users as to the types of information used and needed, problems with it, and improvements desired.
3. Comparing losses experienced in several areas having similar hazards and operating under the same type of reduction technique but where different levels of requirements, administration, or enforcement are in effect.
4. Collecting and comparing the benefits and costs -- public and private -- of several different reduction techniques before and after a damaging earthquake in a jurisdiction having a uniform geologic and tectonic environment.

The phrase "public and private costs" is used here to mean all direct and indirect costs and losses such as market value declines, road and utility repairs, emergency response activities, real-property damages, personal-property losses, deaths, injuries, tax revenue losses, industrial production losses, commerce interruption, and traffic delays. If it is demonstrated that the cost of a reduction technique is substantially less than the cost of anticipated damage we may conclude a favorable benefit-cost ratio for the use of the reduction technique.

The following will introduce the reader to several methods which address various topics and have different levels of rigor.

- o Use of earth-science products by city, county, and selected regional organizations in the San Francisco Bay Region by Kockelman (1975, p. 20-26; 1976b, p. 16-20; 1979, p. 27-31).
- o Natural hazard reduction-plan appraisal and cost/benefit analysis by Lohman and others (1988, p. 183-201).
- o Economics of landslide mitigation strategies in Cincinnati by Bernknopf and others (1985).
- o Methods of cost-benefit analysis for different building codes and for upgrading existing structures by Pate and Shah (1980).
- o Testimony on the costs and housing impacts of unreinforced masonry building rehabilitation before the California Seismic Safety Commission (Boswell, 1987).
- o Benefit-cost ratios for reconstructing over 1,350 California state-owned buildings by H.J. Degenkolb Associates (1981).

<u>Comment</u>

These examples of evaluation vary as to topic, area affected, type of technique, and comprehensiveness. What they all have in common is a critical look at the success or failure of a program or the translation, transfer, or reduction techniques used.

Even if adequate earthquake-hazard research information is available, presented in a language understandable by nontechnical users, effectively transferred, and properly used as is being done in Utah, the lasting effectiveness of each earthquake-hazard reduction technique (List 2) depends upon many other factors, usually outside the control of the researcher, engineer, planner, or decisionmaker. For example:

- o Continued awareness and interest by the public.

- Careful revision (if needed) of enabling legislation by state legislatures.
- Accurate site investigations by qualified geologists and geotechnical engineers.
- Conscientious administration of regulations by plan-checkers, inspectors, and other building officials.
- Sustained support of inspection and enforcement officials by political leaders and their constituents.
- Consistent enforcement by government inspectors and attorneys.
- Judicious adjustment of regulations by administrative appeal bodies.
- Skillful advocacy by public regulators and defendants, and proper interpretation by the courts.
- Genuine concern for individual, family, and community safety by real-estate buyers, developers, insurers, and lenders.

A consultant and expert witness who is a former state geologist and former president of a state board of registration for geologists and geophysicists reports in Slosson and Havens (1985) on his experience during the past 25 years:

> ... many of the problems and losses related to damage from earthquakes ... are directly or indirectly attributable to government's (local, state, and/or federal) inability and/or failure to enforce existing policies, codes, or regulations.

The benefits of evaluation and revision cannot be restated often enough: namely, to avoid an unconscionable waste of taxpayers' money and an usually irreparable loss of program managers' credibility.

CONCLUSION

The reduction of casualties, damages, and interruptions in Utah require that appropriate earthquake research be conducted and used by planners, engineers, and decisionmakers. A major part of any effective earthquake-hazard reduction program must be dedicated to the translation of research information and its transfer to nontechnical users as is being done in Utah.

The selection of earthquake areas or processes for study and performing the necessary scientific and engineering studies are only the first steps in any earthquake-hazard reduction program. If the information prepared is inadequate, inappropriate, untranslated, not transferred, or unused, earthquake losses will increase; public and private capital will be wasted; and demands will be made on Federal, state, and local government agencies for disaster relief and costly reconstruction.

Usually, public planners, engineers, and decisionmakers give most of their attention and resources to problems that are perceived to be serious or pressing. A 1977 study of 6 sites of varying political environments and attitudes toward seismic safety was conducted by Atkisson and Petak (1981, p. I-39). They found at that time that the "seriousness attributed to earthquakes in particular was consistently low in all sites." See figure 24. With the exception of floods (10th in Salt Lake City) and earthquakes (10th in Los Angeles), natural hazards at all sites were considered least serious -- 13 to 18 on the list of serious problems.

Recently, Perkins and Moy (1988, Report 3, table 4, p. 15) asked 15 city managers and county administrators in Utah to indicate what earthquake-hazard reduction techniques had been adopted in the past five years. According to Perkins (verbal commun., 1989), 13 responded: all 13 had adopted at least one technique; nine had adopted a technique primarily for reasons of earthquake safety, and four of these had adopted four or more techniques. Obviously, Utahans are not only more aware of the earthquake hazard but are continuing to take appropriate actions.

The effective use of research information in Utah depends upon: (1) the users' interest, capabilities, and experience in hazard-related activities; (2) enabling legislation authorizing State and local hazard-reduction activities; (3) adequate detailed information in a readily usable and understandable form; and (4) the use of effective transfer techniques. These four elements exist in Utah. All that remains is for Utah to continue to adopt appropriate reduction techniques and enforce them over many years.

The commitment of the U.S. Geological Survey to the transfer of research in Utah and the evaluation of its effectiveness may be seen in a recent award for a proposal by William Spangle and Associates, Inc. (1989). The summary of their approach follows:

> This project is designed to assist local officials in cities and counties of the Wasatch front region of Utah apply the information provided by the USGS regional assessment of earthquake hazards. The direct experience of the consultants in research, planning practice and information transfer will be shared with Utah officials, especially city planners, on a regular basis during the year. This will be done by participating in up to four meetings throughout the year and being available as needed for direct consultation with local (and state) officials about options for earthquake hazard reduction. A final report evaluating the effectiveness of the process and opportunities for transfer to other regions will also be prepared.

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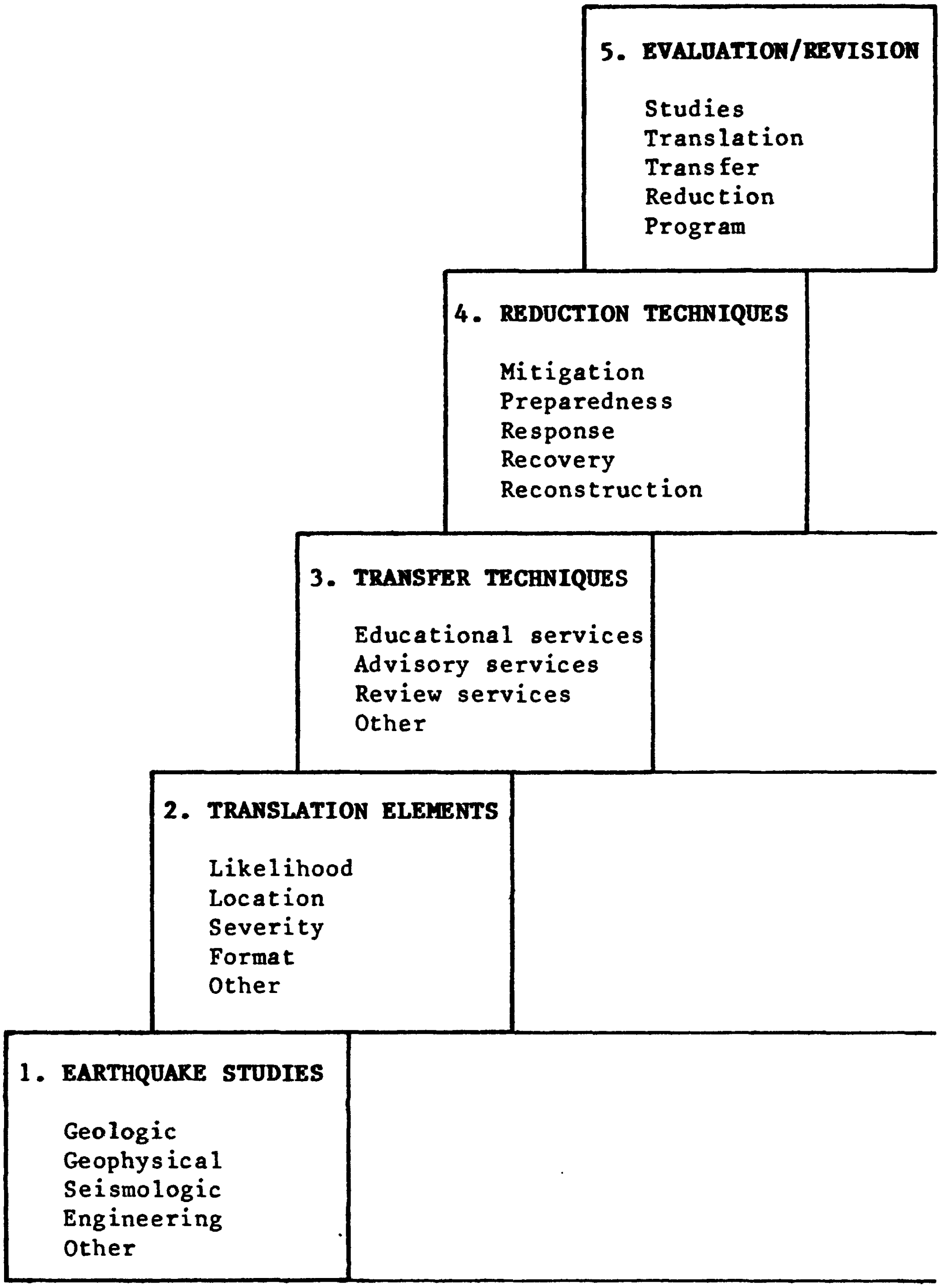

FIGURE 1. -- Five components needed for an effective comprehensive earthquake-hazard reduction program depicted as steps or building blocks, each a prerequisite for its successor.

[All values for age and time intervals (columns A-C) are rounded to the nearest 100 years. Ages based on calendar-corrected radiocarbon dates and thermoluminescence analyses. The average recurrence interval is determined by dividing the sum of time intervals (column C) by the sum of intervals between faulting events (column D). Time intervals (column C) for <u>some</u> segments include time between the oldest (undated) event at a site and the age of the datum; thus, some values in column C are maximum values. N/A indicates a value that is not applicable to the calculation]

		A	B	C	D	
Fault segment	Trench site	Oldest event (t) or datum (d) (years ago)	Estimated time since most recent faulting (years)	Time interval (A-B) (years)	Number of faulting events (and intervals)	
					Events	Intervals
Brigham City..	Brigham City	4,700t	3,600	1,100	2	1
Weber.........	East Ogden..	4,000t	500	3,500	4	3
Salt Lake City	Dry Creek...	5,500t	1,500	4,000	2	1
American Fork.	AF-1, AF-2..	5,300t	500	4,800	3	2
Spanish Fork..	Mapleton....	3,000t	600	2,400*	2*	1*
Nephi.........	North Creek.	5,300d	400	4,900	3	2
Levan.........	Deep Creek..	7,300d	1,000	>6,300 N/A	1	0
Totals* (based on five segments; segments 1-4, 6)...............				18,300	14	9
Totals (based on six segments; segments 1-6)....................				20,700	16	10

Calculated recurrence intervals (in years) for segments of the WFZ having repeated Holocene movement#	Minimum value	Maximum value
Average recurrence interval (RI) on a single segment..........................	2035	2070
Average composite recurrence interval (CRI)..................................	340	415

Notes: t—Time of oldest well-dated faulting event.
d—Age of datum from dating, stratigraphic, or tectonic considerations (rounded to nearest 100 years).
*—For a five segment model we use only the number of events and intervals from American Fork for the Provo segment).
#—Three significant figures are used to compute average values of recurrence from the totals in columns C and D. Values are rounded to nearest 5 years. Minimum values calculated from 20,700 years, 10 intervals, and 6 segments. Maximum values calculated from 18,300 years, 9 intervals, and 5 segments. The latter model (maximum value) is based on our preferred model of segmentation.

FIGURE 2. -- Example of a table showing average recurrence intervals on a single segment and average composite recurrence interval for several segments by Machette and others (1989, table 2).

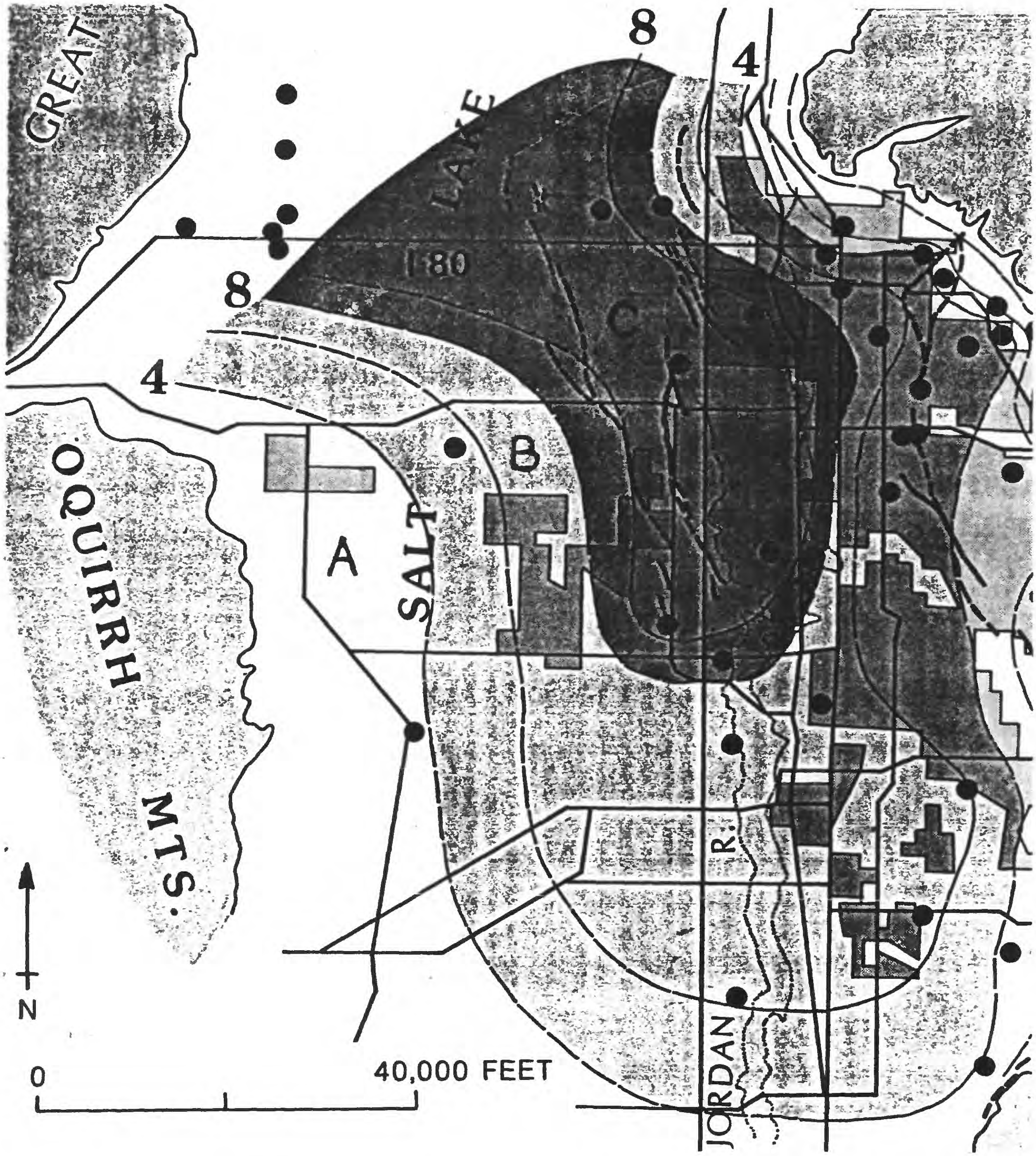

FIGURE 4. -- Map (scale 1:200,000) showing three levels of ground shaking on alluvium relative to bedrock in the period band 0.2-0.7 sec in the Salt Lake Valley by Tinsley (this volume (ck.)). Contours were drawn on the basis of geology and show alluvium/rock spectral ratios recorded and computed by Kenneth King and Robert Williams. Map is preliminary and contours may be modified owing to further analysis of the data. Letters indicate an increase in Modified Mercalli intensity units: A(+1), B(+2), and C (greater than 2).

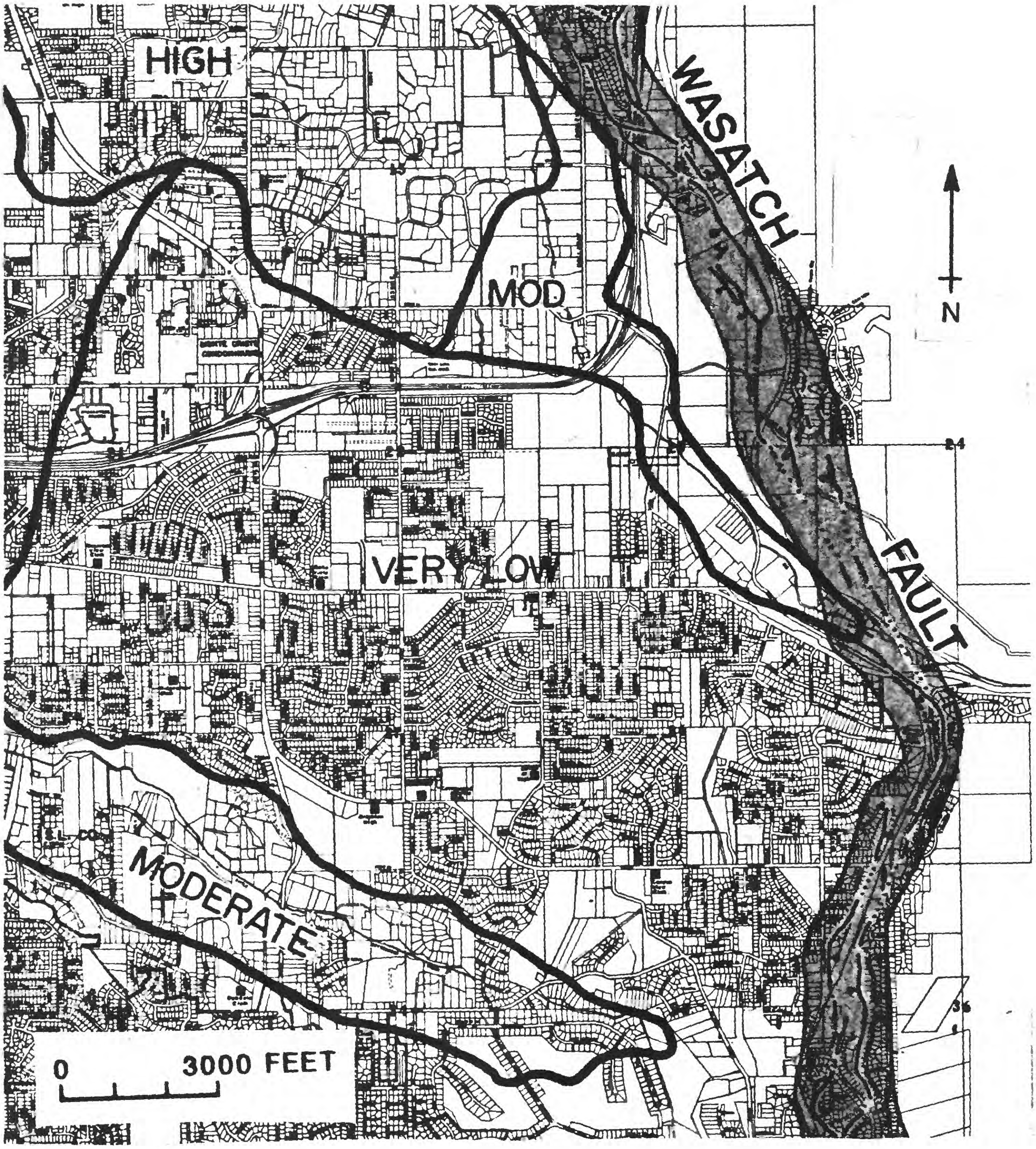

FIGURE 3. -- Part of a cadastral map (scale 1:36,000) of Salt Lake County upon which Nelson (1987) shows a surface fault rupture zone and potential liquefaction areas. Fault traces are indicated by a solid line where location is known from scarps or trenching; dashed where approximately located or infer-red; dotted where concealed. Bar and ball symbol indicates downthrown side. Shaded area indicates where site specific studies addressing surface rupture should be performed prior to construction. Areas labeled high, moderate, and very low indicate their potential for liquefaction during an earthquake.

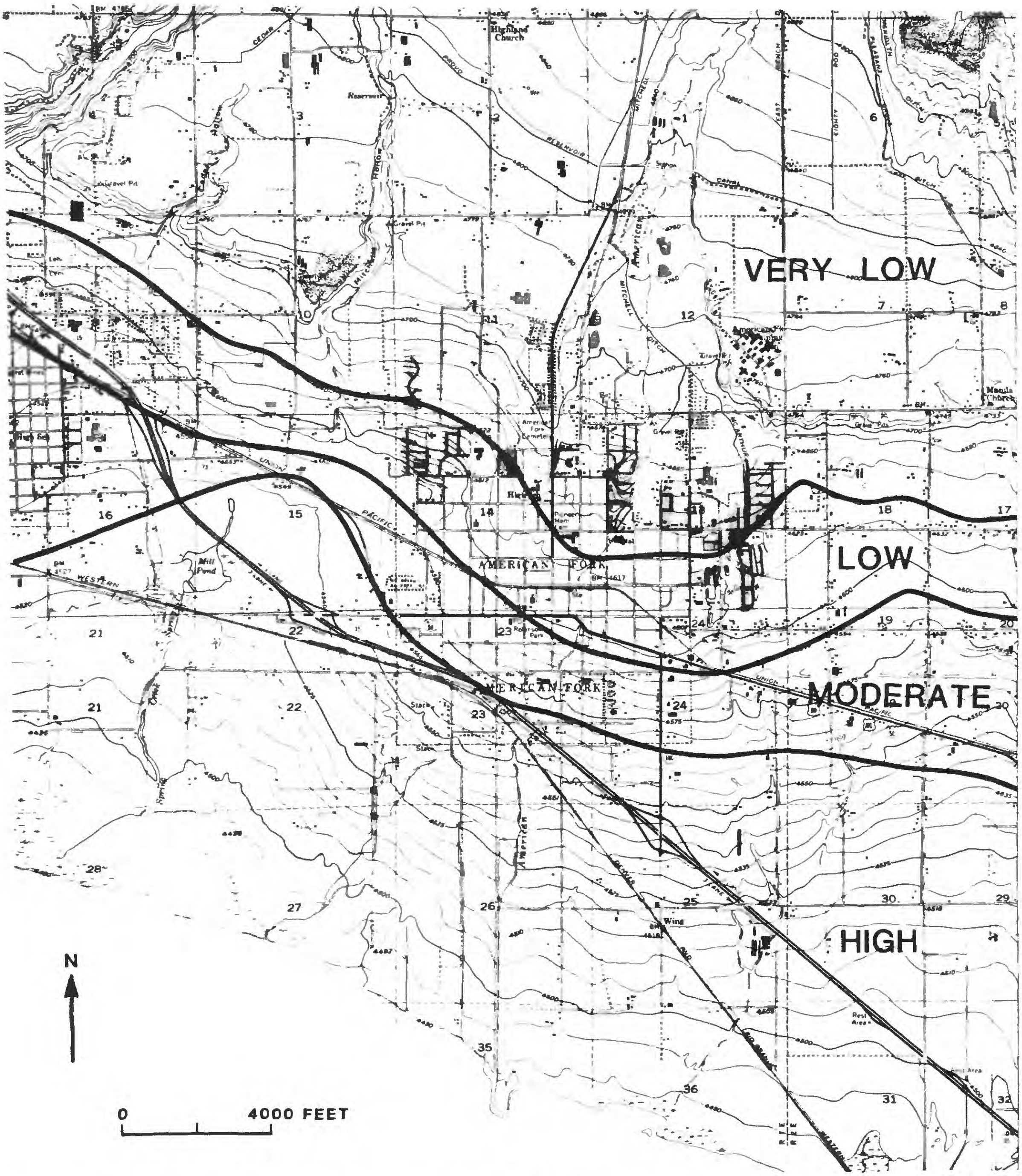

FIGURE 5. -- Part of a topographic map (scale 1:48,000) of Utah County upon which Anderson and others (1986, plate 4B) show areas with high, moderate, low, and very low potential for liquefaction corresponding to the probability of exceeding a critical acceleration.

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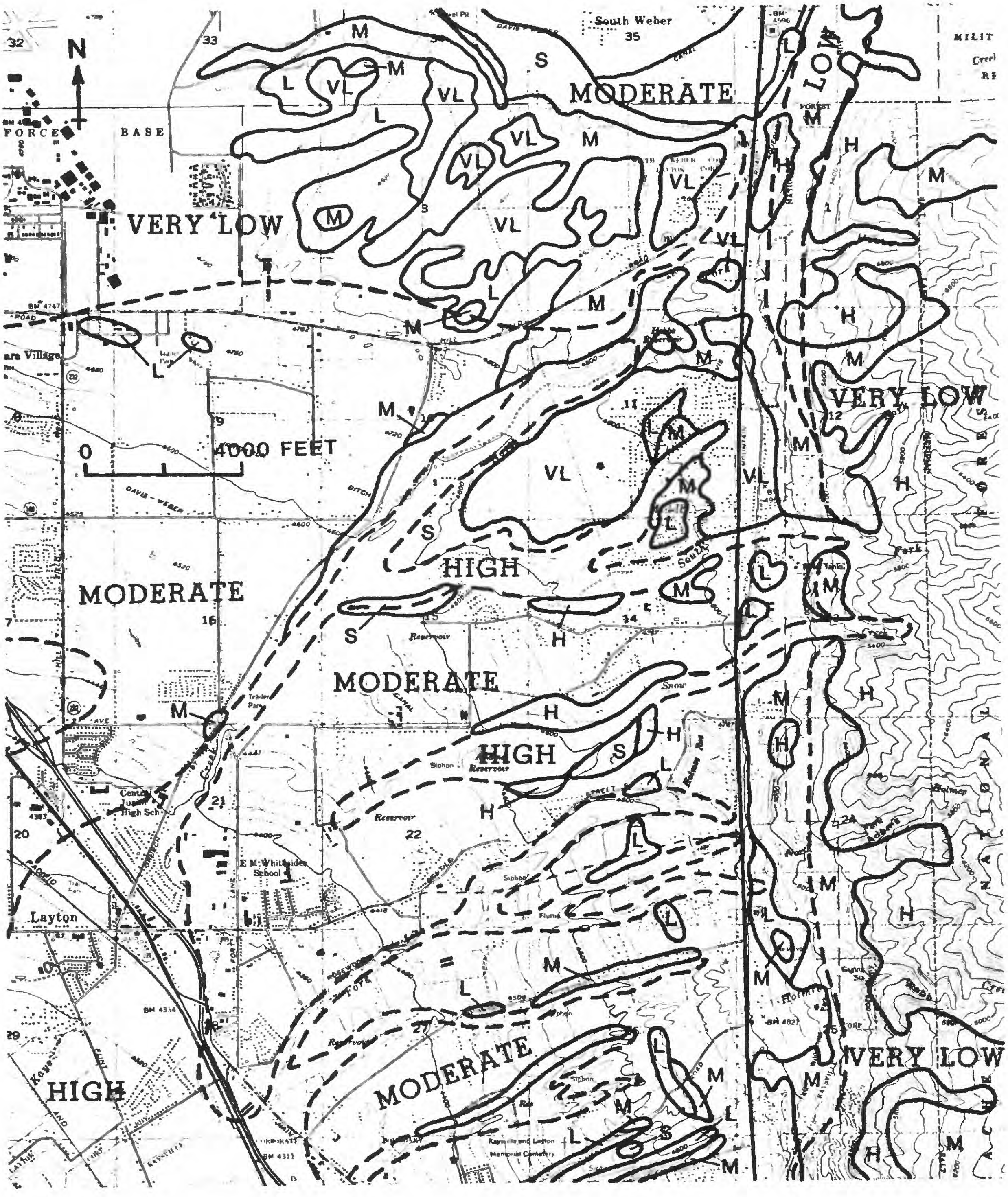

FIGURE 6. -- Part of a topographic map (scale 1:48,000) of Davis County, Utah, upon which Keaton and others (1987, plate 1b) show potential for earthquake-induced landslides and liquefaction. Letters H, M, L, and VL indicate high, moderate, low, and very low potential for landslides. The letter S indicates existing landslide. Words -- high, moderate, low, and very low -- indicate potential for liquefaction.

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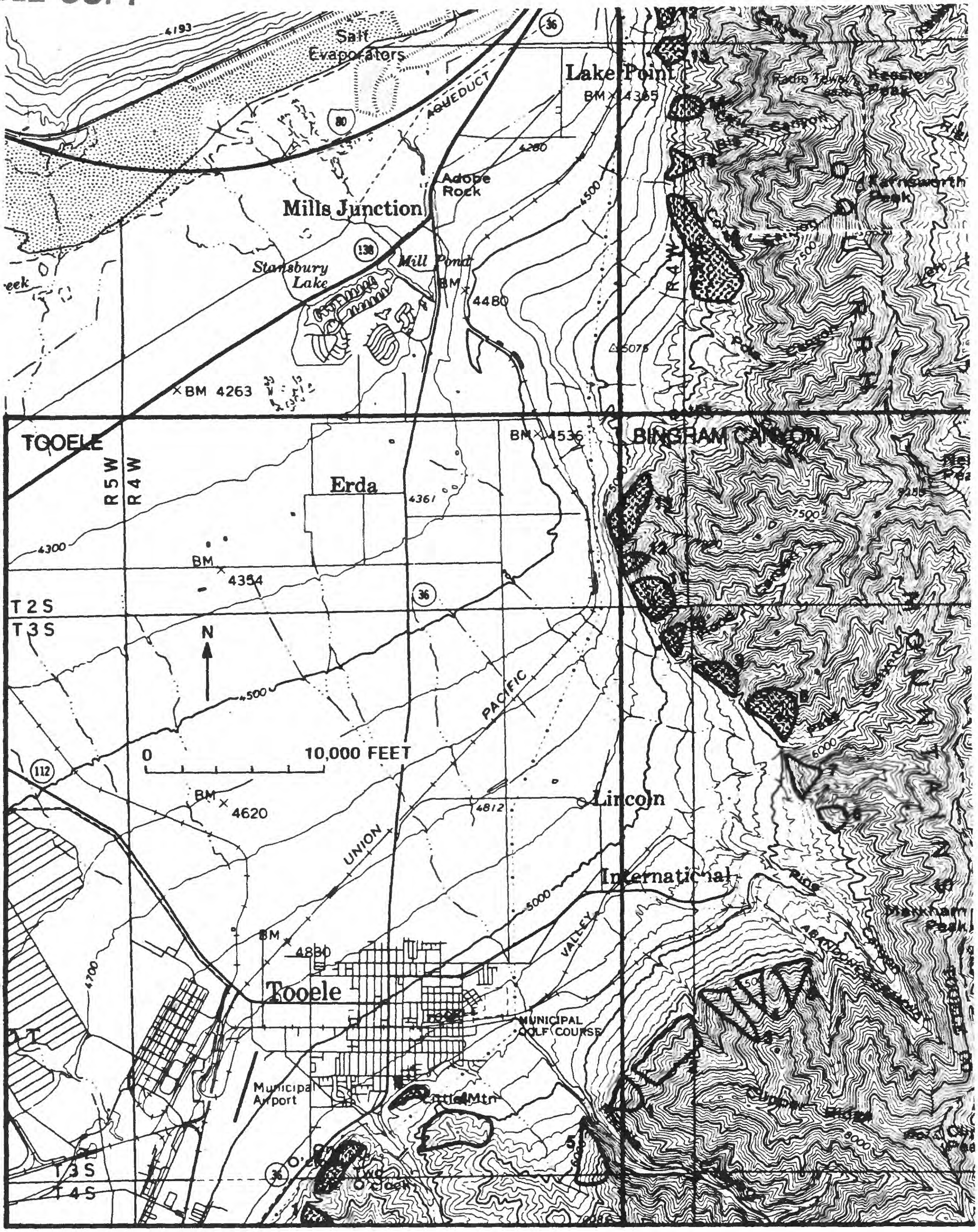

FIGURE 7. -- Part of a topographic map (scale 1:100,000) of Salt Lake and Tooele counties upon which Case (1987, p. V-11) shows mountain spur areas susceptible to rockfalls. Those areas with a rockfall hazard are stippled. Numbers within each USGS 7½-minute quadrangle are referred to in his text.

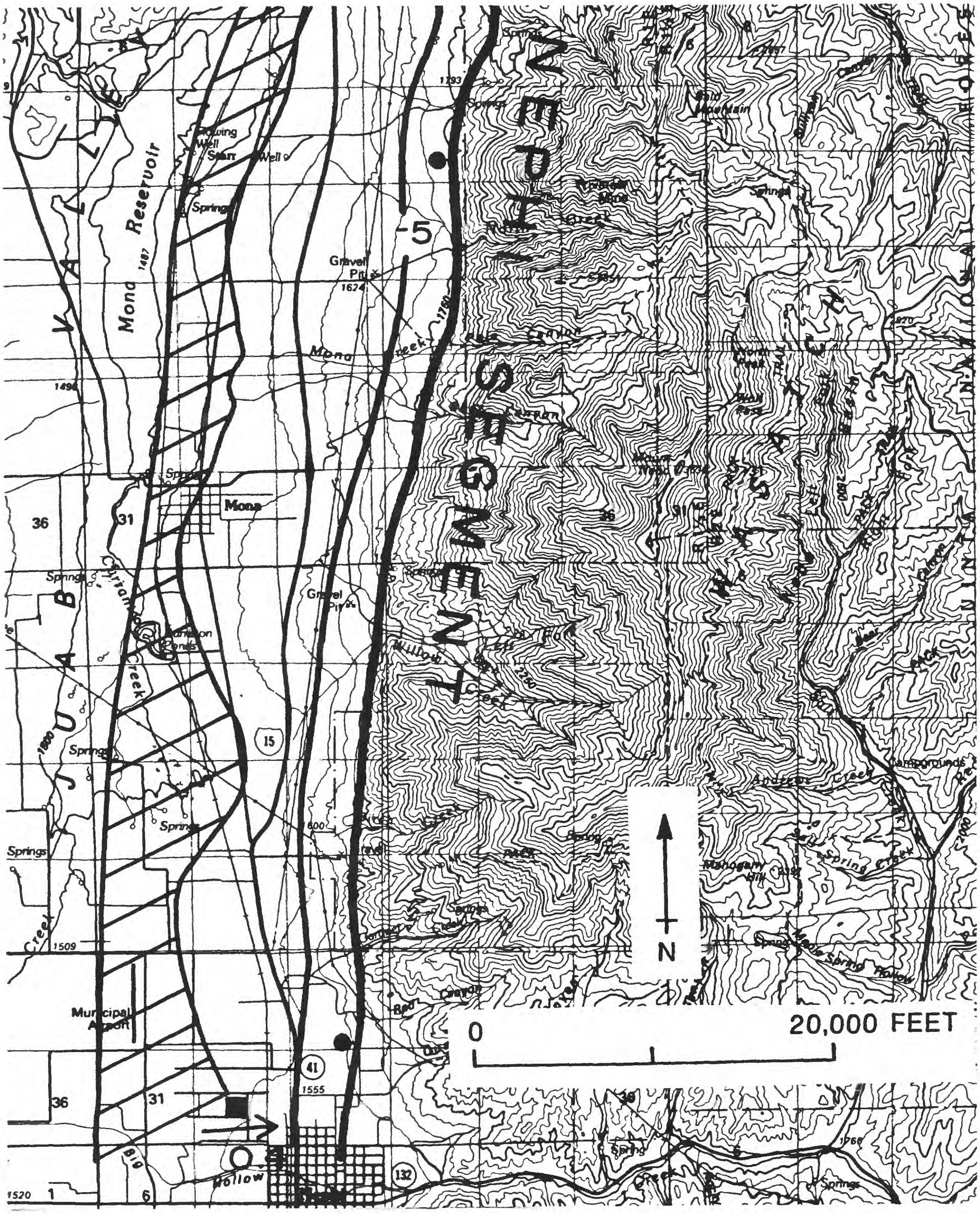

Figure 8. -- Part of a topographic map (scale 1:100,000) of northern Juab Valley, Utah, upon which Keaton (1987, pl. 6) shows potential consequences of tectonic deformation along the Nephi segment of the Wasatch fault. Fault trace is indicated by a heavy line and contours of subsidence in ft by a less heavy line. Cross-hatched area indicates potential ponding of shallow (less than 3 ft) groundwater due to subsidence. Solid square indicates the location of a sewage treatment plant with direction and amount of anticipated tilt (ft/mi) shown.

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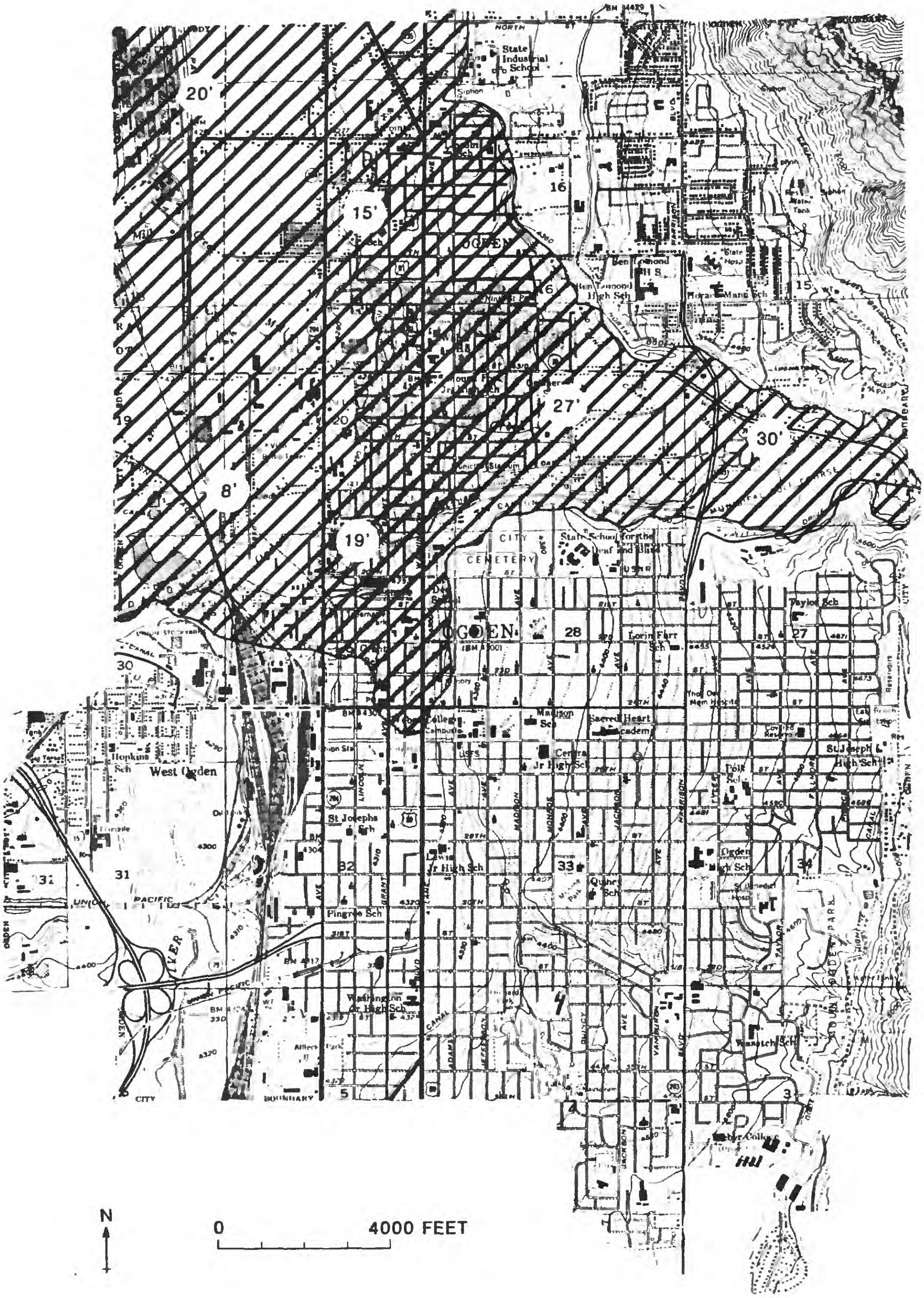

FIGURE 9. -- Topographic map (scale 1: 48,000) of Ogden/Pineview, Utah, study area upon which McCann and Boissonnade (1985, fig. 3-4a, p. 3-27) show inundation area from a failure of Pineview Dam. Numbers indicate peak flood depths in ft.

Phase II (year 2) -- Wasatch Front County Hazards Geologist Program

Date: June 7, 1987
Grant No. 14-08-0001-G991
Grantee: Utah Geological and Mineral Survey
Don Mabey (principal investigator)
Title: Wasatch Front County Hazards Geologist Program
Grant effective date: February 7, 1985
Grant expiration date: June 7, 1988
Period covered by report: December 7, 1986-June 7, 1987

This report covers the six-month period from December 7, 1986, to June 7, 1987, completing the second year of this three-year program. Phase I (data collection and compilation) and Phase II (basic data map compilation) are complete or nearly complete, and Phase III (preparation of interpretive or translated maps and text) is about to begin. In February, the UGMS and county geologists met with planning directors and others from each county .... All planning directors indicated firm support for the program and will include the geologists in their budgets for 1988. The principal need now is to convey the importance of the program to the county commissions who must approve the budgets. To do this, special presentations and field trips for commissioners and others are planned for June 1987. Also, the UGMS is planning to devote an issue of its quarterly publication, Survey Notes, to the county geologist program, with copies going to commissioners, mayors, and others involved in the decisionmaking. Final budgets must be approved in December 1987, at which time we will know whether or not the counties have decided to maintain the geologists.

Services provided to cities and counties during this report period include aid in developing ordinances, reviews of engineering geologic reports, and memos to planners and developers indicating potential hazards at proposed developments requiring geologic investigations. Major special projects have included preparation of: 1) a gravel resource assessment for county property in Davis County, 2) a surface fault rupture hazard study for a proposed Provo City landfill in Utah County, 5) a review of a proposed county fire station site along the Wasatch fault in Salt Lake County, 6) the engineering geologic section for the Pineview Reservoir Clean Lakes study to control development near the lakeshore to avoid contamination, Weber County, 7) a geologic hazards evaluation of property owned by Payson City proposed for development in Utah County, and 8) an engineering geologic report regarding geologic hazards, slope stability, and potential for ground-water contamination at the North Davis Refuse Dump and new burn plant in Davis County. The county geologists and UGMS have also given talks to various civic groups and governmental organizations, participated in radio talk shows, and been involved in a variety of technical and policy publications ... related to the program.

FIGURE 10. -- Part of a final performance report on educational, advisory, and review services over a six-month period prepared by G.E. Christenson (written commun., 1987). These types of services are identified in list 4.

FIGURE 11. -- Part of a table of contents from a workshop proceedings edited by Hays and Gori (1987a). This type of workshop is a good example of a successful transfer technique.

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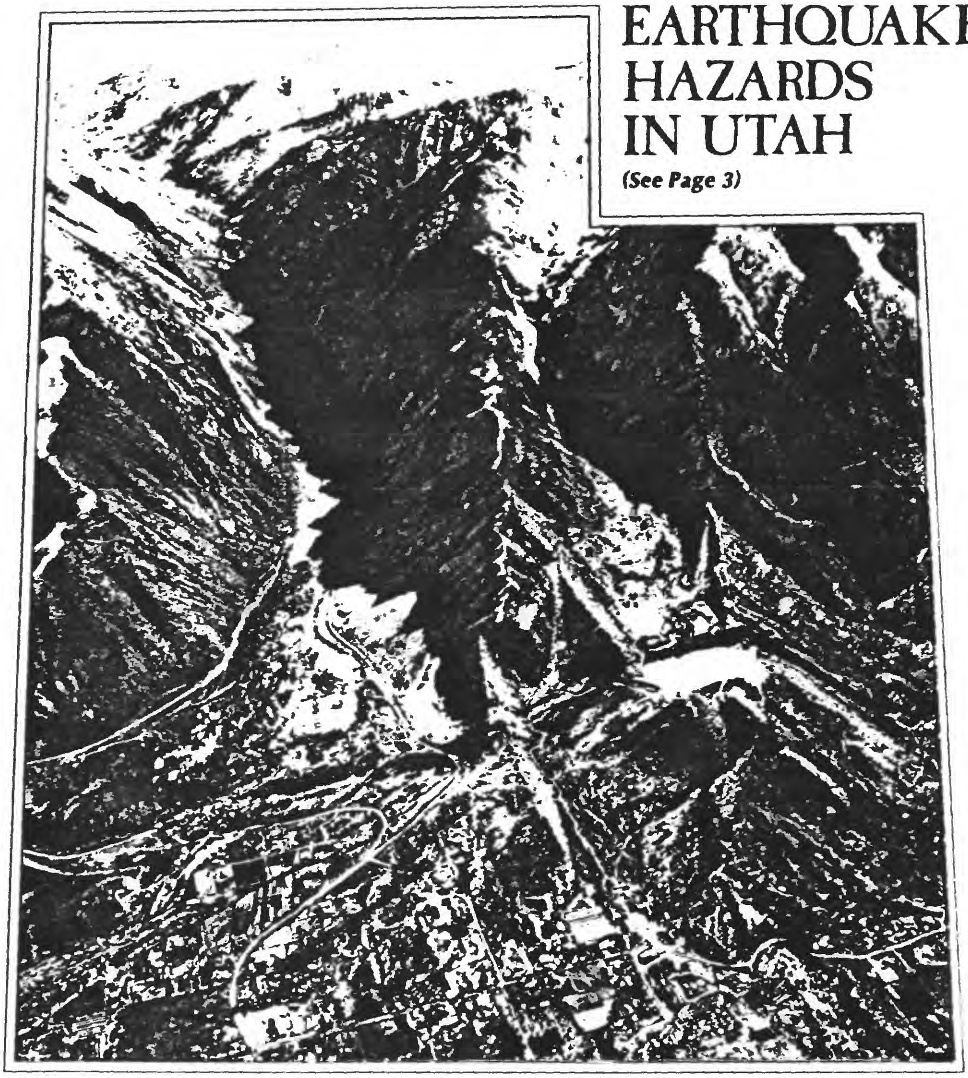
PUBLISHED QUARTERLY BY UTAH GEOLOGICAL AND MINERAL SURVEY

SURVEY NOTES

VOL. 18 NO. 4 SERVICE TO THE STATE OF UTAH WINTER 1985

EARTHQUAKE HAZARDS IN UTAH

(See Page 3)



Wasatch fault at the mouth of Little Cottonwood Canyon, Southeast of Salt Lake City. Latest movement on the fault here pre-dates historic record but the fault has displaced young Quaternary alluvium and glacial moraine probably during the last 1000 years. Photograph courtesy of Lloyd Cluff and George Brogan.

FIGURE 12. -- Typical cover of a serial publication which addresses geologic hazard and resource issues. This type of publication is an excellent example of an information transfer technique identified as an educational service in list 4.

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COLLECTING, COMPILING, TRANSLATING, AND DISSEMINATING EARTHQUAKE-HAZARDS INFORMATION FOR URBAN AND REGIONAL PLANNING AND DEVELOPMENT IN THE WASATCH FRONT AREA, UTAH

By Gary Christenson, Jerold Barnes, Joseph Moore Craig Nelson, Robert Robison, Mike Lowe, William Kockelman

MOST SIGNIFICANT ACCOMPLISHMENTS

Much of the work planned under existing programs is in progress but will not be completed for one or two more years. Under the UGMS Wasatch Front County Geologists Program, a series of translated (interpretive) maps (1:100,000) depicting hazards along the Wasatch Front are planned along with a report describing these hazards. Collecting and indexing hazards information and providing technical assistance to planners are being emphasized under this program. Under the UGMS Applied Geology Program, statewide hazard maps (1:750,000) are being completed. Other projects emphasize specific hazards mapping, evaluation of reduction techniques, education, and information dissemination.

Some of the most significant accomplishments to date are:

- Education of planners and decisionmakers in the Wasatch Front area regarding earthquake hazards through meetings, workshops, and placement of geologists on planning staffs in five Wasatch Front counties.
- Creation of county hazard information libraries with ready access to existing hazards information in five county planning department offices.
- Quality control over geotechnical investigations, particularly seismic hazards studies, by providing geological review of reports submitted to local planning agencies.
- Compilation of liquefaction potential maps and reports for three counties.
- Increased communication between earthquake hazards investigators.
- Incorporation of the School Outreach Program into the Museum's overall program,staffing, and budget.
- Provision of educational, advisory, and review services to State and local units of government.

RECOMMENDATIONS AND PRIORITIES FOR THE NEXT TWO YEARS

Because technical and scientific information is a prerequisite for effective implementation, it is recommended that information collected during the first three years be made available for translation and dissemination. It is further recommended that emphasis during the remaining two years of the program be placed on implementation projects. Many of the projects that have been funded will extend into this period, but priority should be assigned to projects which:

- Continue the building excavation inspection program (UGMS staff)
- Continue the compiling of the statewide hazards bibliography (UGMS staff)
- Provide occurrence intervals and severity of various hazards to give planners and decisionmakers a basis for estimating risk (USGS staff and grantees)
- Provide State and local hazards susceptibility maps and reports (County geologists; UGMS staff)
- Develop guidelines for local governments to use in writing earthquake hazard ordinances(UGMS staff)
- Continue providing educational , advisory, and review services aimed at State and local planners and decisionmakers (UGMS staff; County geologists; CEM staff; Museum staff)
- Incorporate collecting, compiling, translating, and disseminating work into ongoing programs of state and local governments.

During the past two years, some additional needs have been identified; the following specific needs should be assigned priority:

- Developing model ordinances, which address earthquake hazards, for local governments
- Collecting examples of reduction techniques for each hazard, and evaluating them for effectiveness

....

GROUND MOTION ELEMENTS

(from a presentation by Al Rogers at July, 1986 Workshop)

SOURCE

- SIGNIFICANT ACCOMPLISHMENTS

  > Revised segmentation of the Wasatch Front

  > New segmentation slip rates for some segments

  > Suggestion that slip rates are related to paleo-lake level

  > Discovery that some scarps in the Great Basin may be terminated by detachment faults at shallow depths

  > Successful testing of experimental high-frequency reflection techniques for studying Quaternary fault geometry and exploration for Quaternary faults.

  > Discovery of strike-slip faulting in both the geologic and seismic records for a portion of the Colorado Plateau-Basin and Range Transition Zone.

  > Borah Peak
  Reaffirmation of segmentation

- KNOWLEDGE REQUIRED

  > Continued segmentation studies and slip rate estimates

  > Continued studies of active fault geometry

  > Strong ground motion measurements in the vicinity of Great Basin earthquakes.

TRANSMISSION PATH

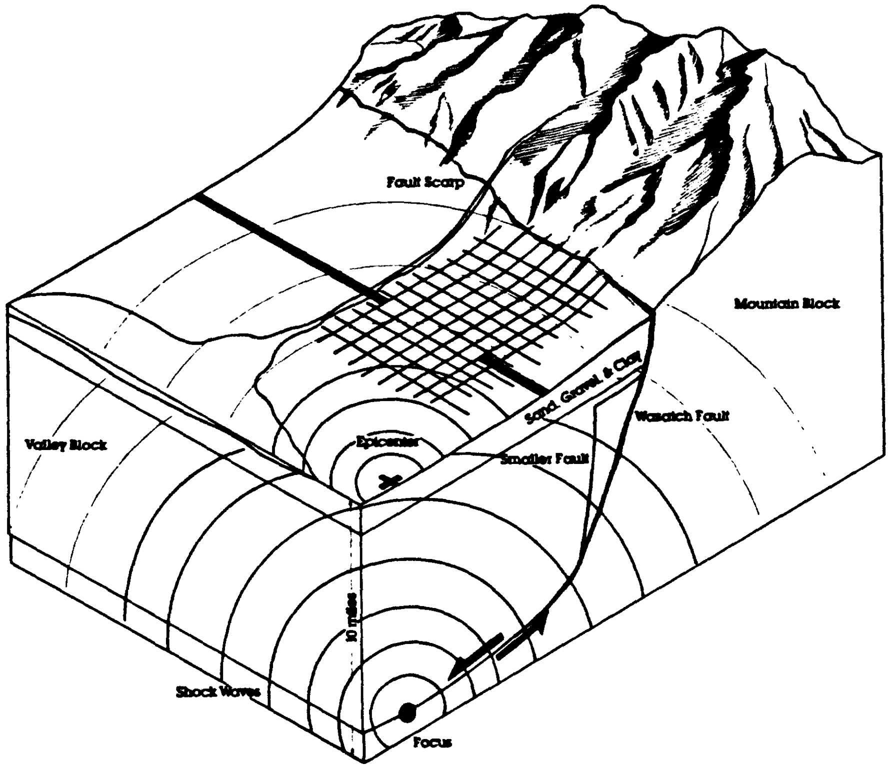
- SIGNIFICANT ACCOMPLISHMENTS

  > Revised peak acceleration and velocity curves for western Utah based on regression models and a world wide strong motion data set

  > High and Low Q versions

FIGURE 13. -- Typical article reporting on the status of the Utah earthquake-hazard reduction program in the Wasatch Front Forum (vol. 2, no. 4, p. 5). This type of newsletter is a unique example of a transfer technique in Utah identified as an educational service in list 4.

EARTHQUAKE HAZARDS



A MAJOR EARTHQUAKE (UP TO M 7.5) COULD OCCUR ALONG THE WASATCH FAULT AT ANY TIME!

Such an earthquake could cause:

I. RUPTURE OF THE EARTH'S SURFACE—SCARP FORMATION

A. Distruction of buildings on the scarp
B. Breaking of utility lines that cross scarp
  (1) Disruption of gas, water, & electric services
  (2) Fire hazards
C. Flooding—shifting of the Great Salt Lake and Utah Lake

II. GROUND SHAKING

A. Damage to rigid manmade structures such as buildings, freeway overpasses, dams
B. Liquefaction—soil becomes quicksand, so cannot support buildings
C. Landslides, Rockfalls, Mudflows
D. Falling objects that cause injuries

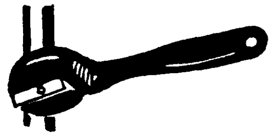
FIGURE 14. -- Example of materials provided to students, teachers, and the general public under an outreach program by the Utah Museum of Natural History (1985). They are an innovative transfer technique identified as an educational service in list 4.

EARTHQUAKE SAFETY

I. BE PREPARED AHEAD OF TIME

A. EARTHQUAKE PROOF YOUR HOME

1. Identify possible hazards; anchor or rearrange.
2. Reduce risk of fire.
   a. Learn how to turn off utilities. (gas, electricity, water)
   b. Anchor water heater.



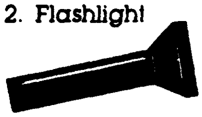
B. DEVELOP FAMILY RESPONSE PLAN

1. Determine "safe" areas in each room.
2. Hold earthquake drills.
3. Discuss actions each family member should take during and after quake.
4. Identify out-of-state contact person.

C. PUT TOGETHER POST-QUAKE SURVIVAL KIT

1. Water & Canned Food

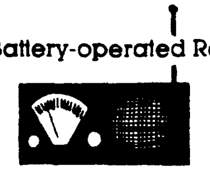
2. Flashlight



3. First-Aid Kit

4. Fire Extinguisher

5. Battery-operated Radio



II. KNOW WHAT TO DO DURING

A. Stay Calm!

B. DUCK & COVER.

1. **If Inside, Stay There.**
   Duck under table, or
   stand in door frame, or
   brace yourself in inside corner
   away from windows.

2. If Outside, Stay There.
   a. Move into open away from buildings & electric wires.
   b. Park car & stay inside until shaking stops.

III. RESPOND AFTERWARD

A. Administer first-aid.

B. Check for utility damage & turn off if necessary.

C. Use telephone only for medical emergency.

D. Be prepared for aftershocks.

FIGURE 14. (cont'd). -- Example of materials provided to students, teachers, and the general public under an outreach program by the Utah Museum of Natural History (1985). They are an innovative transfer technique identified as an educational service in list 4.

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UTAH GEOLOGICAL AND MINERAL SURVEY
606 Black Hawk Way, Salt Lake City, Utah 84108

BUILDING OR BUYING A HOME IN UTAH

Prepared by Bruce N. Kaliser, Chief Engineering Geologist

BEFORE YOU BUY:

- Most geologic hazards such as landslides, floods, ground settling and aggravated earthquake ground motion can be avoided by proper site selection. Careful examination of sites during *initial* househunting searches can avoid costly water, wastewater, foundation and terrain stability problems later.

- Whether buying a vacant lot or existing structure, observe the property carefully and thoroughly. Look for: ground cracks • ground holes • disturbed earth • deposits of sediment or debris left by receding flood waters • signs of erosion • steep slopes, including on neighboring parcels • salt efflorescence on ground surface • surface depressions • wet ground • anomalous vegetation • cracked or disturbed foundations, walls, driveways, sidewalks • man-placed fill, engineered and non-engineered • water bodies or conveyances (canals, ditches) on or above the property • distribution of bedrock and/or boulders at ground surface.

  Interpretation of the significance of each of the above items must be done with caution; if any are present, professional advice should be sought.

  Be aware that operations such as landscaping and utility installation may alter the ground surface appearance to resemble or conceal a natural phenomenon.

  Modification of terrain in the vicinity of your parcel, either before you buy or after you build, particularly up-slope, may prove critical for you. Examples might include cutting into a slope, filling over a slope, drilling of an uncontrolled flowing well, diverting a spring, or installation of a deeply buried utility line.

  Ground surface observation normally is sufficient for the evaluation of a residential property; if there is doubt, one or more holes will need to be dug or drilled and soil samples taken to resolve difficult questions. *All* examinations for subsurface fluid waste disposal require percolation tests in the soil by Health Authorities.

  Ask questions of the realtor, homeowner, neighbors, but MOST IMPORTANT, conduct your own investigation, preferably with competent professional assistance (engineering geologist, geotechnical engineer).

- Consult State and Federal real estate and environmental documents for a broad statement of terrain conditions, but do not confine your examination of a particular parcel to the literature search.

WHEN YOU BUILD:

- Avoid constructing a home in the vicinity of moving earth, flood paths, fault traces or rock fall zones; do not build over underground openings or in depressions.

- Cost of construction, particularly in rural areas, can be reduced by knowing foundation conditions, depth to bedrock, depth to shallow groundwater, suitability of soils for wastewater disposal leach fields and groundwater depth and quality for primary or secondary water supply purposes.

- Adjust construction to accomodate these potential problems: moisture sensitive soils, high water table (shallow groundwater), low density soils, shallow bedrock or hardpan, severe earthquake ground-shaking zone, poor surface drainage, erosion-susceptible soil, steep or irregular topographic slope, boulders buried at shallow depth, springs or seeps on the property, variability of permeability of soils for fluid waste disposal.

- Maintenance problems can be reduced by prevention of erosion and soil movement under pavement, retaining walls and landscaping. Earth retention structures should all be properly engineered.

- Risk from earthquake to a single-family dwelling can be reduced by proper siting and construction.

Where you choose to build, even within a given parcel of land, can make a considerable difference.

4-8/81 BNK

FIGURE 15. -- Example of a general fact sheet widely distributed in Utah. It illustrates a common type of transfer technique identified as an educational service in list 4.

United States
Department of the Interior
Geological Survey, Western Region
Menlo Park, California 94025

Public Affairs Office Pat Jorgenson (415) 329-4000

For release: UPON RECEIPT (Mailed August 26, 1988)

EAST-CENTRAL UTAH AREA HAS UNEXPECTED EARTHQUAKES

A series of earthquakes that have been shaking east-central Utah and western Colorado for the past two weeks (since Aug. 14, 1988) occurred in a part of Utah where earthquakes have been rare in the past, according to a U.S. Geological Survey scientist.

"These quakes happened in a relatively inactive seismic area," said Ernest Anderson of the USGS Office of Engineering Geology and Tectonics in Golden, Colo. The tremors have been centered about 35 miles south of Price, Utah, in a sparsely populated area of Emery County.

Most of Utah's earthquakes have occurred along the Wasatch fault, a north-south fracture in the Earth's crust, generally paralleling the western base of the Wasatch Mountains just east of the Great Salt Lake. But Dr. Anderson said the Wasatch fault zone, which runs about 220 miles from Malad City, Idaho, south to Gunnison, Utah, about 120 miles south of Salt Lake City, would not have been a factor in the current series of earthquakes.

Carl Stover, a USGS geophysicist in Golden, Colo., who has compiled a series of seismicity maps for individual states, confirmed that the area of the August earthquakes has "no record of historic seismicity." The seismicity map he prepared of Utah shows only one other recorded earthquake in that area since 1850. It occurred Sept. 7, 1962, and had a magnitude of only 3.3.

The largest of the current earthquakes occurred Aug. 14 and was recorded at a preliminary magnitude of 5.6 on the Richter scale. The tremor, which occurred at 2:03 p.m. MDT, was preceded by a 3.5 magnitude earthquake at 12:59 p.m. and a 4.3 magnitude 4.3 magnitude tremor at 1:08 p.m. The area has continued to have aftershocks, with the largest (maggnitude 3.5) occurring on the morning of Aug. 15.

Although the August earthquakes have caused no injuries and little damage, the 5.6 magnitude earthquake Aug. 14 was the fourth largest recorded earthquake in Utah's history. The only larger ones were a 6.1 magnitude earthquake in a remote area of the Utah-Idaho border in March 1975 and two earthquakes of magnitudes 6.0 and 6.6 in northwestern Utah in March 1934.

* * * USGS * * *

EARTH SCIENCE IN THE PUBLIC SERVICE

FIGURE 16. -- Typical press release by the USGS Public Affairs Office illustrating a common but effective transfer technique. It is identified as an educational service in list 4.

Salt Lake Tribune 2/18/87

Tests Warn Of S.L. Earthquake

By Joan O'Brien
Tribune Staff Writer

The trenches tell the story of the past, and sound the warning.

Trenching studies along the Salt Lake section of the Wasatch Fault show that a major earthquake occurs every 2,200 to 2,500 years — and the last one was 2,200 to 2,400 years ago.

"We are right in the window of vulnerability for the next earthquake," said Salt Lake County Geologist Craig V. Nelson.

The Wasatch Front is replete with geologic hazards, but residents can take precautions and mitigate the damage that would occur in a "characteristic" earthquake measuring 7.2 on the Richter Scale, Mr. Nelson said.

For the last year and a half Mr. Nelson has been translating hard geological data into a language city planners can understand. His maps detailing "red flag" zones will be available to developers and the public within a few months.

Mr. Nelson's federally funded position was created, in part, so the Salt Lake County Planning Commission could take geologic hazards into consideration in development proposals. The United States Geological Survey has also provided funding for similar positions in Weber and Davis counties and Utah and Juab counties.

The Wasatch Fault, stretching from Nephi to Brigham City, is actually a series of fault segments that could produce earthquakes independently of other segments, Mr. Nelson said.

Unlike California's San Andreas Fault, the Wasatch Fault does not creep. "Unfortunately, the Wasatch Fault does not creep and the strain is accumulating." Mr. Nelson said. "What we see in the trenches is that there are 6-foot breaks and then nothing, so it all builds up to a critical point."

When that critical point is reached, scientists expect a "characteristic" earthquake with a magnitude of over 7 on the Richter Scale.

County Geologist Advocates Long-Range Planning

Special to The Tribune

FARMINGTON — Mike Lowe, Davis County geologist, believes long-range planning is the key to protecting residents from geologic hazards.

Mr. Lowe, speaking to members of the Davis County Council of Governments, summerized his findings after one year as county geologist.

He said recent landslides, flooding, debris flows and the rising Great Salt Lake have created a high degree of public awareness concerning geologic hazards.

As a result of threats and damages by such hazards, Mr. Lowe was hired to collect and translate technical information for use by planners and local government officials in Davis and Weber counties.

Mr. Lowe said, during the Aug. 20 meeting, the county and many cities have adopted ordinances requiring geologic reports in potentially hazardous areas.

"By requiring these reports, hazards and mitigative measures can be identified and assessed," said Mr. Lowe.

"If development is allowed to proceed based on the report's recommendations, with zoning enforcers and building inspectors ensuring that those recommendations are followed, problems related to geologic hazards are less likely to arise," he added.

The geologist said he also has performed recent site evaluations focusing on new water tanks in North Salt Lake and Layton, three sites for a proposed new county jail and several landslide locations in the county.

In addition, the geologist said he did a number of site investigations of Bountiful and Farmington homes experiencing foundation cracks.

Salt Lake Tribune 8/24/86

Deseret News 9/9/86

Geologist gathering data for hazards ordinance

PROVO — Utah County doesn't have a geological hazards ordinance yet, but by the time Robert Robison finishes a three-year stint as a special consultant for the county, there will be more than enough information to write the ordinance.

Robison is one of three geologists assigned to the Wasatch Front by the federal government.

His work area includes Utah and Juab Counties and he is also available to work with cities in both those counties.

This week Robison told Utah County commissioners he is moving into his second year of work for the county. He said that during the past year he has established a library with 700 maps and articles pertaining to soils and geology in Utah County.

"The purpose of my assignment is to collect information, establish a library, index maps and act as a technical assistant to the county and cities," said Robison.

Jeff Mendenhall, Utah County planner, said Robison has provided much valuable information to the county.

"By the time he has finished gathering all the information, the county will be able to design the hazards ordinance and that will be a big help to us," Mendenhall said. "Most of the cities have one, but we haven't had the expertise to draw one up until now."

FIGURE 17. -- Typical local newspaper coverage of earthquake-hazard reduction activities. Permission to publish. These examples are valuable information transfer techniques shown in list 4.

	Text	Weber	Davis	Salt Lake	Utah	Juab
1. Surface fault rupture (1:24,000)	F	F	F	F	D	D
2. Ground shaking (1:250,000)	D	-	-	-	-	-
3. Liquefaction potential (1:48,000)	F	Anderson and others (1982, 1986a, 1986b)				
4. Seismic slope stability (1:48,000)	F	Topham and others (1987)				
5. Tectonic subsidence (1:100,000)	F	Keaton (1987)				
6. Dam failure (variable scales)	D	U.S. Bureau of Reclamation				
7. Landslide hazard (1:24,000)	F	D	D	D	D	D
8. Rock fall hazard (1:24,000)	F	D	D	D	D	D
9. Debris flow hazard (1:24,000)	F	F	F	D	D	D
10. Lake/stream flooding	F		NO	MAP	PLANNED	
11. Shallow ground water (1:48,000)	-	Anderson and others (1982, 1986a, 1986b)				
12. Problem soils (1:24,000)	-	-	-	-	-	-
13. Other (seiche, sensitive clay, hydrologic effects)	F		NO	MAP	PLANNED	

FIGURE 18. -- Status of geologic-hazard maps and texts being produced by county geologists as of June 1988 (rev. December 1988) from Christenson (1988, table 1, p. 7). Letter F indicates final completed, D indicates draft text or partial mapping completed, - indicates completion planned for subsequent years. References are given for maps completed by others in Christenson's report (p. 14).

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United States Department of the Interior

GEOLOGICAL SURVEY

Office of Earthquakes, Volcanoes, and Engineering
345 Middlefield Road, MS 922
Menlo Park, CA 94025
415/323-8111 x.2312
FTS: 467-2312

EXPRESS MAIL

May 6, 1986

Mr. Jerold H. Barnes, AICP
Salt Lake County Planning Commission
2033 South State Street
Salt Lake City, Utah 84115

Dear Jerry:

In accord with your request yesterday, please find selected materials for use in developing a geologic-hazard-overlay amendment to the county zoning ordinance. These materials include examples of ordinances, discussions of need or use, and the content of geotechnical reports, all of which are paperclipped and highlighted for your convenience:

Ordinances

Potentially hazardous geologic conditions (Sonoma County, 1974)
Safety geologic (S-G) overlay (San Bernardino County, 1980)
Liquefaction investigation (City of San Diego, 1984)
G-H geologic hazard overlay district (Jefferson County, Colorado, 1983)
Geologic hazard maps (Santa Clara County, 1978)
Model geologic hazard area control (Colorado Geological Survey, 1974)
Resource management zoning district (San Mateo County, 1973)

Discussions

Site investigations in hazardous areas (Brown and Kockelman, 1983)
Engineering geology at the local government level (McCalpin, 1985)
Landslide hazard zones (Weber, 1980)
Role of geotechnical consultants and reviewers (Leighton, 1975)
Geologic review process (Hart and Williams, 1978)
Hazard avoidance and mitigation (Unknown)

Geotechnical Report Guidelines

Guidelines to geologic/seismic reports (CDMG, 1973)
General guidelines for geological reports (Ventura County, 1974)
Minimum standards for geotechnical reports (San Mateo County, 1977)

I deliberately selected a wide range of materials to provide you with the greatest flexibility, for example:

FIGURE 19. -- Example of a letter addressing a specific issue in Utah. It illustrates a type of transfer technique identified as an advisory service in list 4.

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- The ordinances range from Sonoma County's one-page regulation requiring a site investigation and recommendations for preventive and corrective measures to San Mateo County's 24-page resource management zoning district that reduces dwelling unit density in soil- and scenic-resource areas as well as fault-rupture and landslide-hazard areas.

- The discussions include a case history on "challenging a geologic-hazard zone," use of a 1:12,000-scale hazard-overlay cadastral map, and land development goals from the viewpoints of the developer, the geologic consultant, and the public agency involved.

- The guidelines range from very general notes to four types of geologic reports requiring detailed data and descriptions, including county certification forms.

According to Jeff Keaton, the Utah Section of the Association of Engineering Geologists is preparing guidelines for engineering geologic reports, including surface-rupture, seismic-shaking, liquefaction, and slope-stability hazards. Genevieve Atwood advised me today that the UGMS is considering publishing these guidelines as UGMS notes.

As we discussed, it would be desirable to keep the geologic-hazard-overlay regulations succinct (as you did with the "hillside protection zone") and to adopt by reference both the official hazards maps and the required geotechnical reports. My experience indicates that such an approach makes it much easier for the public to understand; reduces direct pressure on the local government when references can be made to outside experts (State, Federal, university, consultants, and professional societies); and makes it easier to update them without amending the ordinance.

Caveat

The enclosed materials are in a raw form directly from my files and, of course, can not be endorsed or recommended by the U.S. Geological Survey. Although many of them have been in effect for several years without successful legal assault, others may have been revised, repealed, or not properly enforced. If a particular example seems promising for your needs, I would be pleased to make one or two inquiries concerning its status and provide you with the administrator's name and number for direct contact.

I hope these materials will be of some help to you, the Commission, and Salt Lake County. Please call me if you have any questions or if I can be of any further assistance.

Sincerely,

Bill

W.J. Kockelman

Enclosures

cc: G. Atwood
J. Keaton

FIGURE 19. (cont'd). -- Example of a letter addressing a specific issue in Utah. It illustrates a type of transfer technique identified as an advisory service in list 4.

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UTAH GEOLOGICAL AND MINERAL SURVEY

GUIDELINES FOR EVALUATING SURFACE FAULT RUPTURE HAZARDS IN UTAH

by
The Utah Section of the
Association of Engineering Geologists

These guidelines have been compiled to assist geologists in the investigation of possible hazards due to surface fault rupture and to enable reviewers to evaluate the thoroughness of such investigations. The guidelines were developed by the Guidelines Committee of the Utah Section of the Association of Engineering Geologists, for the purpose of protecting the health, safety, and property of the people of Utah. Previously published guidelines for the State of California (California Division of Mines and Geology, 1975; Slosson, 1984) were used as models. The guidelines do not include systematic descriptions of all available techniques or topics, nor is it suggested that all techniques or topics be utilized on every project. Variations in site conditions and purposes of investigations may require more or permit less effort than is outlined here. All elements of these guidelines should be considered during the preparation and review of engineering geologic reports.

Future faulting generally is expected to recur along pre-existing faults (Bonilla, 1970, p. 68); the development of a new fault or reactivation of a pre-Quaternary fault is relatively uncommon and generally need not be a concern in site development for typical facilities. Generally, the more recent the faulting, the greater the probability of future faulting (Allen, 1975; Ziony and others, 1973). Regional and urban earthquake hazards and risk in Utah are reviewed by Hays and Gori (1984).

The evaluation of future fault rupture hazards involves careful application of skills and techniques not commonly used in other engineering geologic investigations (trenching, absolute dating). Many active faults are complex, consisting of multiple breaks which may have originated during different surface-faulting events. To accurately evaluate the potential hazards due to future surface fault rupture, the geologist must determine:

I. Fault Locations

This involves locating and accurately mapping all tectonic features at the site, at a scale large enough to be used for site planning (1 inch = 200 feet).

II. Nature of Deformation

Surface deformation over active faults may involve single large displacements, multiple small displacements, monoclinal flexure, backtilting, or a combination of all of these (see Bonilla, 1982). The way in which the surface deforms influences the type and degree of risk posed to various types of structures.

III. History of Fault Ruptures

The absolute age of past displacements should be obtained over as long a period of geologic time as possible. Two key measurements are: 1) the age of latest faulting, and 2) the average recurrence interval between surface-rupturing events.

Few structures intended for human occupancy are designed to withstand surface rupture of their foundations without serious damage. If such a structure is sited astride an active fault, the subsequent fault rupture hazard cannot be mitigated unless the structure is relocated. Therefore, the scope of the investigation depends on not only the complexity and economics of the project, but also on the level of risk acceptable for the proposed development. Because of variability in the risk and in the complexity of site geology, not all investigative techniques described here need to be or can be employed in evaluating a single site. The guidelines provide a checklist for preparing complete and well-documented reports.

Regardless of the size of the project (single-family residence vs high-rise building) the conclusions drawn from geologic data must be consistent and unbiased, and must not tie to the design life or perceived economics of the project. Recommendations must be clearly separated from conclusions, since recommendations are not solely dependent on geologic factors.

**Suggested Outline for Reports
Evaluating Surface Fault Rupture Hazard**

The following subjects should be addressed in any geologic report on faults. Some of the investigative methods listed below should be extended well beyond the site being investigated. Not all of the methods identified will be useful at every site.

A. Purpose and Scope of Investigation

B. Geologic and Seismotectonic Setting

1. Regional Geology
2. Tectonic Setting
   a. Location and style of known active faults (see Anderson and Miller, 1979; Nakata and others, 1982).
   b. Major earthquakes in historic time (see Arabasz and others, 1979).

C. Site Description and Conditions-Include information on depth to ground water, geologic units, graded and filled areas, vegetation, existing structures, and other factors that may affect the choice of investigative methods and the interpretation of data.

D. Office Methods of Investigation

1. Review of published and unpublished literature, maps, or records concerning geologic units, faults, ground-water barriers, and other factors.
2. Stereoscopic interpretation of aerial photographs or other remotely sensed images to detect fault-related topography, soil and vegetation contrasts, and other lineaments of possible fault origin. Low-sun-angle photographs are particularly useful for fault scarp recognition (see Cluff and Slemmons, 1971).
3. Personal communication with those who have first-hand knowledge about geologic conditions or pertinent land-use history of the site.

E. Field Methods of Investigation

1. Surface
   a. Geologic mapping—distribution, depth, thickness and nature of geologic units, both surficial and bedrock.
   b. Location and relative ages of tectonic surface features, including fault scarps, sag ponds, aligned springs, offset bedding, disrupted drainage systems, offset ridges, faceted spurs; locations of zones of crushed rock (fault breccia). Relationships with dated alluvial terraces or shorelines (Currey, 1982) may yield indication of age. Surface topographic profiling of fault scarps may permit an age estimate if scarps result from a single rupture event (Nash, 1980, Hanks and others, 1984) or may show evidence of multiple events (Wallace, 1977).
   c. Locations and relative ages of other possibly earthquake-induced features caused by lateral spreading, liquefaction, or settlement. Locations of slope failures should be noted, although they may not be conclusively tied to earthquake causes.
2. Subsurface
   a. Trenching or other excavations across features of suspected tectonic origin. A detailed trench log should be prepared at a scale of 1:60 or larger showing geologic units, soil profiles, and all discontinuities (unconformities, fractures, shear zones, fault planes, sand or rubble-filled cracks, burrows). The position of all samples used for absolute dating must appear on the log. Systematic photographs should be taken to document the presence or absence of tectonic features. Because the location of trenches is critical in obtaining

UTAH GEOLOGICAL AND MINERAL SURVEY
Genevieve Atwood, Director
606 Blackhawk Way
Salt Lake City, Utah 84108

MISCELLANEOUS PUBLICATION N

APRIL 198?

FIGURE 20. -- Example of guidelines for evaluating a hazard and preparing reports in Utah. It is a type of transfer technique from list 4. When adopted by state or local governments as a requirement, it becomes a reduction technique identified in list 2.

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tectonic or stratigraphic data, investigators are encouraged to discuss trench location, orientation, depth, and length with reviewers in advance of excavation. Multiple trenches, if needed, should be excavated concurrently, not sequentially. All critical excavation should be left open for at least 48 hours after logging is completed to allow access by reviewers. Fencing, posting, and shoring of all the trenches is strongly recommended (see Woods, 1976).

b. Absolute dating to determine timing of past surface rupture events. Methods commonly used for Quaternary deposits are reviewed by Colman and Pierce (1977, 1979) and McCalpin (1986). Samples should be collected which most tightly bracket the time of faulting; e.g., from the youngest parts of faulted units and from the oldest parts of unfaulted units.

c. Borings and test pits to collect data on geologic units, fault-plane geometry, and ground-water elevations. Data points must be sufficient in number and adequately spaced to permit valid correlations and interpretation.

3. Geophysical investigations. These are indirect methods that require knowledge of specific geologic conditions for reliable interpretation. Geophysical methods alone never prove the existence or absence of a fault, nor can they assess the recency of activity. Types of equipment and techniques used should be described. Methods commonly include seismic refraction, seismic reflection, electrical resistivity, gravity, magnetic intensity, and ground penetrating radar.

4. Other investigations; where special conditions or requirements for critical structures demand more intensive investigation.
   a. Aerial reconnaissance overflights.
   b. Geodetic and strain measurements.
   c. Microseismicity monitoring.

F. Conclusions

1. Locations of mapped faults; style of associated displacement and age of past surface rupturing events.
2. Anticipated amount and pattern of earth displacements in the next probable surface-faulting event; delineation of areas of high risk.
3. Probability or relative potential for future surface displacements. The likelihood of future faulting may be estimated from the recurrence intervals between past events, plus the age of latest faulting, or from slip rates and amount of anticipated earthquake slip determined for the specific site or from an identified fault segment which includes the site (for Wasatch Fault segments, see Anderson, in press).
4. Comparison of conclusions developed from site data with previous interpretations on the same fault trace or segment.
5. Degree of confidence in and limitations of data and conclusions.

G. Recommendations

1. Recommended building restrictions or use limitations within any designated high-risk areas.
   a. Setback distances from hazardous faults. Most Utah local governments currently have no laws dictating minimum setback. Therefore, justification must be clearly provided for recommended setback distances (see McCalpin, 1987).
   b. Restrictions arising from causes other than discrete surface rupture (e.g., ground tilting, induced mass movements).
2. Risk evaluations relative to the proposed development. Any probabilistic estimates of fault rupture within the design life of the development should be supported with assumptions used and probable error ranges.
3. Need for additional studies.

H. References

1. Literature and records cited or reviewed.
2. Aerial photographs or images interpreted—list type, date, scale, source, and index numbers.
3. Other sources of information, including well records, personal communications, and other data sources.

I. Illustrations-These are essential in understanding the report and reducing the length of the text.

1. Location map—identify site locality, significant faults, geographic features: 1:24,000 scale recommended.
2. General geologic map—shows geologic setting of site, geologic units, faults, other geologic structures, geomorphic features, lineaments, springs, epicenters of historic earthquakes of M≥4, 1:24,000 scale recommended.
3. Site map—combines a detailed, large-scale geologic map of the site with pertinent development-related data (site boundaries, existing and proposed structures, graded areas, streets, exploratory trenches, boring locations, geophysical traverses, and other data). Site geology must correlate with the regional geologic map but should provide refined data on surficial deposits. Recommended scale of 1 inch equals 200 feet or larger (1:2,400).
4. Geologic cross-sections, to extend to the depth of exploratory borings or foundation elements, whichever is greater; same horizontal scale as the site map.
5. Logs of exploratory trenches or borings. Trench logs in particular should show all relevant detail at a scale of 1:60 or larger within zones of suspected deformation; no vertical exaggeration.
6. Geophysical data and its geologic interpretation.
7. Photographs—of scarps, trenches, samples, or other features which enhance understanding of the pertinent site conditions.

J. Appendix-Supporting data not included above (e.g., water well data).

K. Signature of Investigating Geologist-The report must be signed by the engineering geologist who conducted the investigation. The State of Utah currently has no statutory definition of an engineering geologist; however, some local governments do define the minimum qualifications of geologists who can submit reports. Current registration as a geologist in another state may be used in support of demonstrating qualifications.

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FIGURE 20. (cont'd). -- Example of guidelines for evaluating a hazard and preparing reports in Utah. It is a type of transfer technique from list 4. When adopted by state or local governments as a requirement, it becomes a reduction technique identified in list 2.

FACILITY CLASS	EARTHQUAKE-INDUCED LANDSLIDE POTENTIAL ZONE: HIGH	MODERATE	LOW	VERY LOW	EXISTING LANDSLIDE	HIGH LIQUEFACTION POTENTIAL
CRITICAL Hospitals, Fire Stations Police Stations Other Emergency Facilities	YES	YES	YES	YES	YES	YES
LIFELINES Communications Transportation, Water Supply Electric Power, Natural Gas	YES	YES	YES	MAYBE	YES	YES
HIGH OCCUPANCY PUBLIC-OWNED Schools, State Capitol City Hall, Airports County Courts, Convention Centers	YES	YES	YES	MAYBE	YES	YES
HIGH OCCUPANCY PRIVATE-OWNED Office Buildings Apartments, Hotels Shopping Malls	YES Appropriate Disclosure Required	YES	MAYBE	NO	YES	YES
INDUSTRIAL-SEVERE CONSEQUENCE Refineries, Sewage Plants Hazardous Waste, Explosives	YES Appropriate Disclosure Required	YES	MAYBE	NO	YES	YES
INDUSTRIAL-MINOR CONSEQUENCE Trucking, Shipping Light Manufacturing	MAYBE Appropriate Disclosure Required	MAYBE	NO	NO	NO Appropriate Disclosure Required	MAYBE
RESIDENTIAL SUBDIVISION	MAYBE Appropriate Disclosure Required	MAYBE	NO	NO	NO Appropriate Disclosure Required	YES
RESIDENTIAL SINGLE LOT	NO Appropriate Disclosure Required	NO	NO	NO	MAYBE Appropriate Disclosure Required	MAYBE

FIGURE 21. -- Example of a matrix with recommendations for site-specific stability analysis for critical facilities and other land uses in several hazard zones by Keaton and others (1987a, table 4, p. 76). It is a special type of transfer technique in list 4. It was designed by the scientists/authors for nontechnical users. When adopted by state and local governments as a requirement, it becomes a reduction technique identified in list 2.

A

1) Define boundaries of geologic hazards areas by establishing Geologic Hazards Zones (or equivalent) or officially adopting maps referenced to an ordinance.

2) Require geotechnical reports by qualified engineering geologists and engineers addressing hazards and, if necessary, recommending mitigation measures prior to development in geologic hazard areas.

3) Require review of geotechnical reports by county geologists or other qualified engineering geologists acting on behalf of local government.

4) Submit report and review comments to planning commission for action.

5) Amend geologic hazard area boundaries (zones or adopted maps) if proven necessary by site report.

B

1) Provide for review of all development proposals by county geologists or other qualified engineering geologists acting on behalf of local government to determine need for geotechnical reports.

2) Require geotechnical reports by qualified engineering geologists and engineers to address potential hazards indicated in review and, if necessary, to recommend mitigation measures. If initial reviews of development proposals are not performed, complete reports may be required for all sites.

3) Require review of geotechnical reports by county geologists or other qualified engineering geologists acting on behalf of local government.

4) Submit report and review comments to planning commission for action.

FIGURE 22. -- Suggested topical outline for geologic-hazards ordinances in areas with geologic-hazards maps (A), and without geologic-hazards maps (B) by Christenson (1987, table 1, p. 9). This is another type of transfer technique identified as an advisory service in list 4.

Problem Seriousness Scores in the Six Sites

	CA		LA		MA		BOSTON		UTAH		SLC	
	X̄	RANK	X̄	RANK	X̄	RANK	X̄	RANK	X̄	RANK	X̄	RANK
INFLATION	7.6	1	6.6	4	7.5	4	7.1	5	7.2	1	7.5	1
POLLUTION	7.2	2	7.5	1	6.0	8	4.4	13	5.7	3	6.7	2
UNEMPLOY.	7.0	3	7.0	3	8.6	1	7.6	2	4.2	8	4.5	9
CRIME	6.9	4	5.9	8	7.3	5	7.3	4	5.5	4	5.6	3
WELFARE	6.9	5	7.1	2	8.2	2	7.4	3	5.9	2	5.0	6
EDUCATION	6.2	6	6.3	5	5.4	11	7.0	6	4.1	9	4.3	11
DRUGS	6.0	7	6.0	7	6.1	7	6.6	8	5.1	5	4.9	7
TRAFFIC	5.7	8	6.2	6	5.1	12	6.5	9	3.8	10	4.7	8
HOUSING	5.5	9	5.7	9	6.4	6	6.4	10	4.8	7	5.5	4
FIRES	5.3	10	4.2	14	6.0	9	5.9	11	3.4	12	3.7	12
TOO LITTLE GROWTH	5.0	11	5.0	12	7.8	3	7.7	1	3.7	11	3.3	14
RACE	4.7	12	4.4	13	5.4	10	6.9	7	2.6	16	3.4	13
QUAKES	4.6	13	5.5	10	1.2	18	1.3	18	3.2	15	1.2	16
PORNOGRAPHY	4.1	14	5.3	11	4.0	14	5.4	12	5.0	6	5.1	5
FLOODS	3.3	15	2.8	15	4.5	13	2.2	15	3.3	13	4.5	10
TOO MUCH GROWTH	2.5	16	1.6	16	1.3	17	1.3	16	3.3	14	3.0	15
HURRICANES	1.3	17	1.0	17	3.1	15	2.3	14	1.0	17	1.2	17
TORNADOES	1.1	18	1.0	18	1.5	16	1.3	17	1.0	18	1.0	18
X̄ =	5.05		4.95		5.30		5.26		4.04		4.17	

FIGURE 23. -- Rankings by key public and private decisionmakers as to the relative seriousness of 18 state and local issues for 3 states and 3 cities from Atkisson and Petak (1981, table I-9, p. I-40).