SEISMIC HAZARDS AND GEOLOGIC HAZARDS RELATED TO COMPREHENSIVE PLANNING IN UTAH

GUIDELINES FOR PREPARATION OF A SEISMIC SAFETY ELEMENT OF THE COMPREHENSIVE PLAN

SEISMIC SAFETY ADVISORY COUNCIL

STATE OF UTAH

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STATE OF UTAH

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TABLE OF CONTENTS

THE UTAH SEISMIC SAFETY ADVISORY COUNCIL: PURPOSES, ISSUES AND PROGRAMS

Purposes

The Utah Seismic Safety Advisory Council was created in 1977 under statutory authority of Section 63-34a of the Utah Code Annotated, as amended. Its charge is to recommend public policy and programs for earthquake hazards reduction.

Many actions can be taken to reduce earthquake hazards. Some actions are matters of good judgement by those who build in seismically hazardous areas. Other actions are appropriate by government in order to protect the vulnerable and sometimes unsuspecting public. Seismic safety in either situation can be achieved only through involvement of both the public and private sectors in ameliorative actions. A premise underlying the Council's work is that both the public and private sectors will act with good judgement if sufficient and accurate information is furnished about the earthquake hazards and mitigation techniques.

The Council is an advisory body to the Utah Legislature and Governor. In its advisory role, the Council identifies and evaluates various seismic risks, formulates programs and actions which will reduce the risks, and recommends and prioritizes programs and actions on mitigation of earthquake hazards to public agencies and the private sector. The Council has no authority to implement hazards reduction programs. Acceptance of recommendations and their implementation remains a public responsibility to be exercised through individual actions, and through elected representatives and the agencies they oversee.

By statute, the Council's specific responsibilities include:

- Recommending a consistent policy framework for seismic safety in Utah.
- Suggesting goals and priorities for earthquake hazards reduction.
- Recommending Statewide and local programs to reduce earthquake hazards.
- Assisting with coordination of seismic safety activities of government at all levels and of the private sector which may be involved in practices important to seismic safety.
- Requesting that State agencies devise criteria to provide or improve seismic safety.
- Recommending methods for-

  -improving building standards and construction compliance with the standards.

  -siting and design of critical facilities, such as hospitals, schools, and fire stations.

  -delineating fault zones which may require special investigation, regulation, and reporting procedures.

- Educating the public and private sectors on earthquake safety.
- Recommending training for specialized enforcement and technical personnel which may have responsibilities relating to earthquake hazards.
- Advising the Governor and Utah Legislature on matters relating to seismic safety.
- Reviewing proposed earthquake-related legislation.
- Recommending the addition, deletion, or changing of State and federal standards as deemed desirable to promote seismic safety.

Issues

Utah is recognized as a region of relatively high seismicity. Historic records confirm that earthquakes occur frequently and sometimes with large intensity throughout the State. Geologic evidence suggests that the earthquake activity will continue in future years.

Some areas, notably along the Wasatch Front, experience greater seismic activity than other areas, but the potential for earthquakes is found throughout most of the State. Investigations indicate that the central portion of the State, extending north-south from the Idaho border to Nephi and east-west along a strip which follows the Wasatch Mountains, has the potential for damaging earthquakes as severe as in most regions of California. It is noteworthy that the region of greatest potential seismicity also is the region of greatest population, and an even higher percentage of its economic wealth is concentrated along the same earthquake-prone central portion of the State.

Utah's seismologic characteristics appear to be different than California's in recurrence and ground attenuation, but the fundamental problems affecting life safety and property damage are the same. Utah's citizens therefore can learn from California's experiences with earthquakes.

Earthquakes are hazardous because of their effects upon buildings and other structures. Resulting damage can threaten the life safety of occupants as well as inflict immeasurable losses to property and productivity.

Earthquake events physically may be manifested in several ways--among them, ground vibration, cracking and differential slippage at the ground surface, vibration-induced landslides, subsidence (settlement or tilt of the ground), and liquefaction (vibration-induced failure of saturated sands). Any one of these physical manifestations can affect the structural soundness of buildings and other construction, possibly causing their collapse, breaking of components, and cracking.

Earthquake hazards can be reduced through land-use practices which respect the various susceptibilities of different sites to seismic effects and through design and construction practices which provide buildings capable of resisting the effects of ground vibrations. Since current technology does not allow either control of earthquake events or their

prediction, possible actions to mitigate risks to life and property are limited to prudent practices in building siting, design, and construction. The Council is developing its recommendations from this perspective.

Although Utah's citizens have a long-standing awareness that earthquake hazards are present, few policies have been implemented to deal systematically with the resulting problems. Individual actions occasionally have been taken to mitigate earthquake hazards, but routine application of hazards-reduction measures is uncommon in the State. One result is that Utah's citizens often are unknowingly exposed to seismic risks. Most property owners, buyers, and renters do not know if their buildings have earthquake resistance, even if the buildings are newly constructed. Neither do they know the degree of earthquake hazards for the particular site location where they live or work. Land development has proceeded indiscriminately across known faults, onto hillsides whose soil conditions may be susceptible to sliding due to earthquake-induced vibrations, and onto ground that may be susceptible to subsidence. Youngsters in the State regularly attend school in older buildings whose earthquake resistance never has been analyzed. And, downstream areas from dams and reservoirs do not have potential inundation areas delineated, nor is the available information shared with affected populations.

These are but a few of many types of earthquake hazards in Utah, but they serve to point out that there are many aspects of earthquake safety which merit attention.

Effective mitigation of earthquake hazards requires multiple actions in a variety of program areas. No single action can provide comprehensive risk reduction. Moreover, the needed actions fall within the purview of numerous State and local government authorities as well as the private sector. Cooperation from all sectors will be necessary if seismic hazards-reduction programs are to implemented and successful. The Utah Seismic Safety Advisory Council is confident that many appropriate hazards mitigation actions will be taken if the hazards and suitable remedies are identified and made known to Utah's citizens.

Programs

Seismic Risk Mapping

By Legislative authority granted in 1977, the Utah Geological and Mineral Survey has embarked upon a seismic risk-mapping program for Utah. The objective of this effort is to prepare and disseminate information regarding the geology, hazards, and seismic conditions which is needed by local governments in decision-making processes relating to land planning and construction standards.

Seismic risk analysis involves a great deal more than knowledge of fault locations. Yet, most seismic data other than identification of suspected fault locations have not been compiled or mapped for Utah.

An additional consideration affecting seismic risk mapping is the definition of risk. To assist the risk-mapping effort, the Council commissioned a study which is intended to provide guidance in the

development of the critieria to be used for the risk mapping. Earthquake experts have been contracted to suggest the degree of risk mapping possible in Utah with currently available information, and to suggest additional risk mapping which is needed and the additional information which must be collected to carry out the mapping. The Council's goal with respect to seismic risk mapping is to advance current capability to an implementation stage as rapidly as is feasible, to be followed with future refinement of the seismic risk maps as time, resources, and technology permit.

Seismic Safety Elements

Seismic Safety Element is a term used to describe the entire set of seismic hazards reduction activities and functions of a local planning agency. The simple term, in fact, encompasses a complex array of ordinances, maps, and procedures.

Planning agencies are acknowledged to have an essential role in seismic hazards mitigation. These agencies review plans for nearly all construction and development projects. Planning agencies therefore already are organized to carry out seismic safety programs which involve land-use practices--provided that they have the requisite earthquake safety knowledge and adopt the needed standards.

To a large extent, seismic safety is new to planning agencies in Utah, although the agencies have utilized some geologic data in reviews of proposed developments on hillsides and in flood plains. The Seismic Safety Advisory Council has undertaken to assist Utah planners with earthquake safety planning, first, by identifying seismic safety planning elements and their practical utilization, and second, by convening a planning working group within the Council. With participation by local planners from Ogden, Davis County, Salt Lake City, Salt Lake County, Sandy, and Provo, the goal of the working group is tailoring recommended seismic safety planning to current land planning practices in the State. From this effort, model guidelines for seismic safety elements are being produced for use by planning agencies throughout the State.

SEISMIC SAFETY AS AN ELEMENT OF COMPREHENSIVE PLANNING IN UTAH

Background

Earthquakes pose the greatest single-event natural hazard in the State of Utah. More than ninety percent of the population and economic activity in Utah are located in the "Wasatch Front" geographic area. This area is defined to include the counties of Utah, Salt Lake, Tooele, Davis, Weber, Box Elder, Morgan and Cache. Within this geographic area are the cities of Logan, Brigham City, Ogden, Bountiful, Salt Lake City, Tooele, Provo, Orem and Spanish Fork, which serve as the major metropolitan centers of the Wasatch Front.

The Wasatch Front, as defined above, is within the Intermountain Seismic Belt. This Belt has been subject to severe earthquakes during historic times, and such earthquakes are expected to occur again. As more concentrated urban development takes place on the Wasatch Front, more people and facilities will be exposed to the hazards of earthquakes.

Major Issues and Problems

The major land-use problem relating to earthquake hazards in Utah is that critical facilities and high-risk structures exist in, and continue to be constructed in, areas which are expected to experience the effects of moderate and severe earthquake events during the life-span of the facilities. Some of these facilities have greater importance in our daily lives than others. Still other facilities are used in ways that are essential to a community, or by occupants who are especially vulnerable to catastrophic events. These facilities have been called "critical facilities." The term "critical facilities" is used to include:

1. Lifelines such as major utilities and transportation facilities and highway structures.
2. Large structures where failure would be catastrophic, such as dams and water storage facilities.
3. High occupancy facilities, such as schools, hotels, offices, auditoriums and stadiums.
4. Emergency facilities such as police and fire stations, hospitals and communications centers.

Earthquake hazards have a relationship with land use and so must be recognized for the following reasons:

1. Awareness of earthquake hazards and recognition of actions which may be taken to mitigate such hazards has increased during the past few years. Action by the Federal Government to begin a systematic Earthquake Hazards Reduction Program at the national level is of recent (1977) origin.
2. There is a tendency to disregard known problems, especially when the time and place of a potential disaster, such as an earthquake, is unknown. Earthquakes are viewed as having a low probability of occurrence.

3. Existing earthquake hazard information is seldom adequate or in a form which is usable in preparing and implementing land-use plans for avoiding earthquake hazards or reducing risk to an acceptable level.

4. State and local government units and the private sector have at this time an inadequate understanding of earthquake hazards and the alternative actions which may be taken to avoid or to mitigate such hazards so that risks may be reduced to an an acceptable level.

5. Coordination between State and local government levels and between local governments to develop needed guidelines and exchange earthquake hazard information does not exist in an effective form at the present time.

6. Professional planning staff and other government officials at the local level have little training or experience in using earthquake hazards information in a comprehensive planning process.

State of Utah And Federal Legislative Background

The 1977 General Session of the Utah Legislature recognized the need to act on the problems of earthquake hazards in communities of the State. House Bill number 46 was enacted (now 63-34a, Utah Code Annotated) to address problems of seismic safety in Utah. Pertinent sections of H.B. No. 46 are as follows: (emphasis added)

Section 1. The Legislature finds that preponderance of evidence indicates that communities in Utah, particularly along the Wasatch Front, are in a high seismic risk area. There is a pressing need to provide a consistent policy framework and a means for educating the public and private sectors. There must be a means of coordinating the earthquake related programs of agencies at all governmental levels and their relationships with elements of the private sector involved in practices important to seismic safety. This need is not now being met by any state government organization.

Section 8. The Council shall be responsible for the following in connection with earthquake hazard reduction:
(1) Suggesting goals and priorities in the public and private sectors.
(2) Requesting appropriate state agencies to devise criteria to promote seismic safety.

(3) Recommending program changes to state agencies, local agencies and the private sector where such changes would reduce earthquake hazards.

(4) Recommending (a) methods for improving building standards and compliance with standards; (b) siting and design policy for critical facilities such as water and waste water facilities, hospitals, and schools; (c) methods and policies for the delineation of fault zones for which special investigation, regulation and reporting procedures may be required.

(5) Recommending training to improve the competence of specialized enforcement and other technical personnel.

(6) Assisting the coordination of seismic safety activities of government at all levels, and the private sector.

In October, 1977, the Congress of the United States enacted Public Law 95-124, cited as the "Earthquake Hazards Reduction Act of 1977." Sections of Public Law 95-124 which are of interest to State and local governments in Utah follow:

Section 2. FINDINGS

The Congress finds and declares the following:

(1) All 50 States are vulnerable to the hazards of earthquakes, and at least 39 of them are subject to major or moderate seismic risk, including Alaska, California, Hawaii, Illinois, Massachusetts, Missouri, Montana, Nevada, New Jersey, New York, South Carolina, Utah, and Washington. A large portion of the population of the United States lives in areas vulnerable to the earthquake hazards.

(2) Earthquakes have caused, and can cause in the future, enormous loss of life, injury, destruction of property, and economic and social disruption. With respect to future earthquakes, such loss, destruction, and disruption can be substantially reduced through the development and implementation of earthquake hazards reduction measures, including: (A) improved design and construction methods and practices, (B) land-use controls and redevelopment, (C) prediction techniques and early-warning systems, (D) coordinated emergency preparedness plans, and (E) public education and involvement programs.

(3) An expertly staffed and adequately financed earthquake hazards reduction program, based on Federal, State, and local and private research, planning, decision-making, and contributions would reduce

the risk of such loss, destruction, and disruption in seismic areas by an amount far greater than the cost of such a program.

(7) The implementation of earthquake hazards reduction measures would, as an added benefit, also reduce the risk of loss, destruction, and disruption from other natural hazards and manmade hazards, including hurricanes, tornadoes, accidents, explosions, landslides, building and structural cave-ins, and fires.

(8) Reduction of loss, destruction, and disruption from earthquakes will depend on the actions of individuals, and organizations in the private sector and governmental units at Federal, State and local levels. The current capability to transfer knowledge and information to these sectors is insufficient. Improved mechanisms are needed to translate existing information and research findings into reasonable and usable specifications, criteria, and practices so that individuals, organizations, and governmental units may make informed decisions and take appropriate actions.

Section 3. PURPOSE

It is the purpose of the Congress in this Act to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program.

Section 5. NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

(c) Objectives. The objectives of the earthquake hazards reduction program shall include:

(1) The development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant, giving priority to the development of such methods and procedures for nuclear power generating plants, dams, hospitals, schools, public utilities, public safety structures, high occupancy buildings, and other structures which are especially needed in time of disaster;

(2) the implementation in all areas of high or moderate seismic risk, of a system (including personnel, technology, and procedures) for predicting damaging earthquakes and for identifying, evaluating, and accurately characterizing seismic hazards;

(3) the development, publication, and promotion, in conjunction with State and local officials and professional organizations, of model codes and other means to coordinate information about seismic risk with land-use policy decisions and building activity;

(4) the development, in areas of seismic risk, of improved understanding of, and capability with respect to, earthquake-related issues, including methods of controlling the risks from earthquakes, planning to prevent such risks, disseminating warnings of earthquakes, organizing emergency services, and planning for reconstruction and redevelopment after an earthquake;

(5) the education of the public, including State and local officials, as to earthquake phenomena, the identification of locations and structures which are especially susceptible to earthquake damage, ways to reduce the adverse consequences of an earthquake, and related matters;

(e) Research Elements. The research elements of the program shall include:

(1) research into the basic causes and mechanisms of earthquakes;

(5) development of information and guidelines for zoning land in light of seismic risk in all parts of the United States and preparation of seismic risk analyses useful for emergency planning and community preparedness;

(7) development of methods for planning, design, construction, rehabilitation, and utilization of manmade works so as to effectively resist the hazards imposed by earthquakes;

(f) Implementation Plan. The President shall develop, through the Federal agency, department, or entity designated under subsection (b) (1), an implementation plan which shall be year-by-year targets through at least 1980, and shall specify the roles for Federal agencies, and recommend appropriate roles for State and local units of government, individuals, and private organizations, in carrying out the implementation plan.

(2) the development of ways for State, county, local, and regional governmental units to use existing and developing knowledge about the regional and local variations of seismic risk in making their land-use decisions;

Review of the sections of Federal legislation (P.L. 95-124), and State of Utah legislation (H.B. No. 46), has shown concern for problems of seismic safety at the State and Federal government level. Both identify the problems of earthquake hazards and indicate one of the most effective measures to meet current and future problems of seismic safety is through effective local land-use planning and implementation.

Local Planning To Mitigate Earthquake Hazards

Earthquakes are inevitable, but their damaging effects can be greatly reduced. Land-use planning based on maps showing hazards and seismic zones can be effective in reducing loss of life, injury, and property damage from earthquakes.

Effective local planning to reduce seismic risk is based on an evaluation of the nature and degree of risk. Seismic risk is defined as a function of the nature, severity, and frequency of seismic hazards and of the exposures of persons and property to those hazards. Assessing risk starts with recognizing the overall seismicity of the area and identifying the potential for ground shaking, landsliding, liquefaction, surface rupture, and flooding. A "design earthquake" is selected as a basis for predicting the location and severity of the various side effects. Cultural features are inventoried and mapped with special attention given to critical facilities and high occupancy structures whose failure could be catastrophic. Using this information, the degree of seismic risk may be established and expressed in terms of potential loss due to deaths, injuries, and property damage. Plans and regulations then can be formulated to reduce risk to a level which the public is willing to accept.

Local land-use planning and regulation can be used as an effective means to reduce seismic risk, particularly in undeveloped or partially developed areas and areas where use changes are occurring. Methods include considering seismic hazards in analyzing land capabilities, developing land-use policy and regulations consistent with seismic risk, and establishing project review procedures to ensure consideration of seismic hazards in land-use decisions and land development procedures.

The basic premise which should guide land-use planning is that actions can and should be taken to reduce the impact of earthquakes. Based on data which are available or can be acquired, land uses and design and occupancy of structures can be adjusted to significantly reduce losses from earthquakes.

Major Causes Of Earthquake Damage

The Wasatch Front in Utah has a history of frequent seismic activity. To the present time, most large earthquakes in Utah have occurred in sparsely populated areas, with the exception of a 1962 event which caused over one million dollars property damage to Logan, Utah, and vicinity. There is geologic evidence that large movements on the Wasatch Fault have occurred within the past 2000 years near the cities of Ogden, Salt Lake

and Provo. These cities of dense population and concentrated urban development are within close proximity to the Wasatch Fault and other faults where the greatest energy release could be experienced. Though these fault movements appear to occur intermittently with recurrence intervals of several hundred years, the seismicity is not well understood and so scientists are unable to provide data on when and where the next major earthquake will occur. We therefore are constrained to use the best information available.

In order to estimate damage and casualties that would result from severe earthquakes that may reasonably be expected to occur along the Wasatch Front in Utah, the U.S. Geological Survey published the following report: "A Study of Earthquake Losses in the Salt Lake City, Utah Area," Open-File Report 76-89, 1976. The study postulated an earthquake of magnitude 7.5, having the epicenter on the Wasatch Fault in or near Salt Lake City. There would be moderate to major damage sustained by medical resources, vital public facilities, and to private and public structures in Weber, Utah, and Salt Lake Counties. The following is quoted from page 333 of the study: "Analysis of the events indicate that under the worst conditions as many as 2,300 people would die, and 9,000 additional persons would suffer injuries requiring hospitalization or immediate medical treatment. The number of deaths could be as high as 14,000 if deaths from dam failure are included in the casualty total. Such casualties would occur under the worst conditions of exposure, as during the rush hours, but could be approximately as great at any time during the work day. ... It is possible that as many as 30,000 people would be homeless or would require temporary shelter pending re-establishment or relocation."

The State of California Division of Mines and Geology recently published Bulletin 198, entitled "Urban Geology Master Plan for California," addressing the nature, magnitude, and costs of geologic hazards in California and recommendations for their mitigation. The following is quoted from the abstract of the plan: "The results of a three-year study of geologic problems in California are presented. The total projected loss attributable to property damage, life loss and loss of mineral resources, including both direct and indirect costs, caused by ten geologic problems in California from 1970 to 2000 is estimated to be $55 billion. Four problems--earthquake shaking, loss of mineral resources, landsliding, and flooding--account for 98 percent of the total projected loss. ... An estimated $38 billion of the $55 billion total projected loss could be prevented by application of current state-of-the-art loss reduction measures. The total cost of applying these measures is estimated at $6 billion, for an overall benefit/cost ratio of 6.2:1. In addition, then, to satisfying the needs for increased public safety and the social and political concerns therefore, geologic hazards loss reduction is also 'good business.'"

The most widespread effect of an earthquake is ground shaking. This is usually, but not always, the greatest cause of damage. Structures of all types, including engineered structures and public utility facilities may suffer severe damage or collapse if inadequately designed or constructed to withstand the shaking force. Most deaths during earthquakes are a result of building failures due to ground shaking, and most such

deaths are preventable using present knowledge. New construction can and should be designed to withstand probable shaking without collapse. The greatest existing hazard is the continued use of older structures which were not designed to resist lateral forces and therefore are incapable of withstanding earthquake forces. Knowledge of earthquake-resistant design and construction has increased greatly in recent years, though much remains to be learned about earthquake hazards and mitigation of the hazards.

A second effect of earthquakes is ground failure in the form of landslides, rock falls, subsidence and other surface and near-surface ground movements. This is sometimes the result of complete loss of strength of water-saturated subsurface foundation soils (liquefaction), such as occurred in the massive Turnagain Arm landslide in Anchorage during the 1964 Alaskan earthquake. Most such hazardous sites can be avoided or stabilized if adequate geologic and soil investigations are utilized.

Another damaging effect of earthquakes is ground displacement (surface rupture) along faults. Such displacement may be vertical, horizontal, or both and may offset the ground by as much as 30 feet. It is not economically feasible to design and build foundations of structures such as dams, buildings, and bridges or utility lines that will remain intact across such fault zones. Fault zones subject to displacement are best avoided in construction when possible to do so. In addition to regional investigations to gain basic understanding of faults, detailed site investigations are needed prior to approval of construction in suspected active fault zones. Linear facilities such as utilities, roads, and canals are particularly vulnerable to damage as a result of ground displacement.

Other damaging effects of earthquakes include:

tsunamis (seismic sea waves, often called "tidal waves"), such as the one which struck Crescent City and other coastal areas in California in 1964; and seiches (waves in lakes and reservoirs due to tilting or displacement of the bottom or margin). Tsunamis are not a hazard in Utah. The failure of dams due to shaking, fault displacement or over-topping from seiches or massive landsliding into reservoirs can be particularly disastrous. Some older dams are not designed and constructed to be earthquake-resistant. Inadvertently created temporary dams formed by earthquake-triggered landslides also are very hazardous since they will usually fail within a relatively short time.

Local Comprehensive Planning And Seismic Risk Reduction

Planning is the process of devising and carrying out a course of action to reach an objective. As a function of local government activity, planning seeks to improve the decisions of elected officials and administrators. Comprehensive planning considers all major factors of growth and change, including economical, political, social, and physical. A comprehensive planning process will be a major tool for seismic risk reduction if the process is structured in such a way as to incorporate information on earthquake and geologic hazards into the land-use planning element of the comprehensive plan.

Earthquakes are a recognized natural hazard in Utah. Seismic safety considerations should be an important part of comprehensive land-use planning to deal with the social, economic, and physical aspects of seismic risk and effective actions for reducing this risk. The degree of seismic risk depends on the type and location of structures and facilities in relation to seismic hazards. Thus, the land-use plan is a key element in reducing seismic risk to an acceptable level in Utah communities.

Land-use planning is primarily a function of local government. Power to prepare, adopt, and administer land development regulations through zoning ordinances, subdivision regulations, building codes, and other ordinances rests with local government. Legal authority for counties to prepare and adopt land-ues plans and to enact ordinances to carry out such plans is contained in Title 17, Chapter 27, Utah Code Annotated, 1953 as amended (UCA). The authority for municipalities is in Title 10, Chapter 9, UCA. The Attorney General, State of Utah, has issued an opinion stating that counties and municipalities have the requisite authority to engage in planning for seismic hazards reduction and to enact zoning ordinances which would include appropriate restrictions on the kind and intensity of land-use and development based upon identified seismic hazards. (Formal Opinion No. 78-008, September 8, 1978, attached as Appendix A).

The Scope And Nature Of Seismic Safety Planning As An Element Of The Comprehensive Plan

Comprehensive planning involves all major determinants of growth and change, including the economic, political, social, and physical elements. To be effective for seismic risk reduction, the comprehensive planning process must result in specific land-use decisions with the land-use plan forming a key component and a link between the general goals and policies and the pattern of land development. The land-use plan includes proposals for type, pattern, and intensity of land-use and specifies the general location of transportation lines and public facilities.

Land-use planning for seismic safety should include the following:

A. A general policy statement that:

   1. Recognizes seismic hazards and their potential effects on the community.

2. Identifies general goals for reducing seismic risk.

3. Defines and specifies the level or nature of "acceptable risk" to life and property.

4. Specifies seismic safety objectives for land-use.

As examples, policies which would be part of the seismic safety element of the comprehensive plan could include such statements as the following.

1. Urban development will not be permitted in those areas where residents would be exposed to significant potential danger to health, safety, and welfare from seismic and environmental hazards.

2. Low levels of "acceptable exposure to risk" shall be established for land uses and structures in which failure would be catastrophic, which are required during emergencies, or which involve involuntary or high human occupancy.

3. Risks from natural hazards shall be reduced as much as possible in areas where human activity is necessary or already exists.

4. Preventive measures to mitigate the effects for known natural hazards shall be taken simultaneously with new development.

5. Site-specific information on natural hazards shall be required for new development where identified hazards may preclude safe human occupancy.

6. Reasonable efforts will be made to promote an awareness and caution among citizens regarding possible natural hazards, including soil conditions, earthquakes, landslides, flooding and fire hazards.

B. Identification, delineation, and evaluation of natural seismic hazards.

C. Considers existing structural hazards. Existing substandard structures are usually the greatest hazard.

D. Evaluation of disaster planning program. In terms of near-term public safety, the most useful thing a community can do is to prepare plans to respond to and recover from an earthquake as quickly and effectively as possible, based upon the existing condition of the area.

E. Determination of sepcific land-use standards related to level of seismic hazard and risk.

Work Program For Seismic Safety Plan

The characteristics of each community should be analyzed to determine those aspects of seismic safety which will receive emphasis. Developed

communities with little vacant land would place emphasis on structural hazards of existing structures and disaster planning, as would communities whose greatest hazard will be from ground shaking. Communities with extensive undeveloped areas subject to urbanization may emphasize efforts to locate natural seismic hazards and formulation of land-use policies and development regulations to reduce exposure to hazards in new development.

A. Initial organization.

(1) Formulate and adopt an interim policy based on general evaluation of earth science information readily available.

(2) Evaluate the adequacy of existing information in relation to kind and severity of problems.

(3) Prepare a specific work program needed to complete the seismic safety plan.

B. Identification of natural seismic hazards.

(1) General structural geology and geologic history.

(2) A geologic and tectonic model of the area expressed as as a set of seismic source areas which may be faults, fault zones, tectonic regions, or other seismic descriptors of the region.

(3) Locate active or potentially active faults and evaluate past displacement and probability of future movement.

(4) Evaluate slope stability and soils subject to liquefaction and differential subsidence.

(5) Assessment of potential for the occurrence and severity of damaging ground shaking and amplifying effects of unconsolidated soils.

(6) Maps identifying location of seismic hazards.

C. Identify and evaluate present land-use and circulation patterns as related to seismic safety policies.

D. Identify and evaluate existing structural hazards relating to structural characteristics, type of occupancy, and geologic characteristics in order to formulate policies and programs to reduce structural hazards.

E. Formulate seismic safety policies and recommendations.

F. Prepare an implementation program.

Evaluating Seismic Risk

Seismic safety planning is the process of evaluating seismic risk and formulating public policy to reduce that risk. It is necessary to understand the distinction between hazard and risk. A seismic hazard is an effect of an earthquake such as surface faulting, ground shaking, liquefaction, landsliding, or other forms of ground failure. Seismic risk is the exposure of individuals or structures to potential injury or loss

from seismic hazards. As an example, an active fault is a hazard but the degree of risk depends on the location, type of construction, and occupancy of structures with respect to the fault. Little can be done to modify or control the fault hazard, but much can be done through careful land-use planning to control risk or exposure to this seismic hazard.

Risk evaluation consists of two steps. The first step is to identify and evaluate the type and severity of the seismic hazard. The second is to determine the degree of exposure of individuals and structures to those hazards.

Identify Seismic Hazards

Review of the seismic history of an area is the first step taken to determine the potential for damaging earthquakes and to identify any active or potentially active faults. Faults are indicators of past earthquake activity and therefore any information about them is helpful in establishing the earthquake potential for an area as well as for locating future development so as to avoid them. Such faults may be located from geologic evidence of surface displacement, excavation logs, trenching, and other physical investigations.

Evaluating earthquake potential or seismicity of an area requires information concerning the following:

1. The past history of earthquakes in the surrounding region--distribution, strength, and other characterstics.
2. The location of faults capable of generating damaging earthquakes.
3. The magnitude of earthquakes anticipated on these faults.
4. The amount of fault displacement anticipated.
5. The nature and areal distribution of deformation accompanying earthquakes or fault movement.
6. The frequency of recurrence of earthquakes on a known fault.
7. The soil conditions of the area and their possible influence in amplifying ground vibrations.

After the seismicity record has been compiled and faults are identified and evaluated in the steps outlined above and it is determined that damaging earthquakes can be expected, the individual seismic hazards should be considered. These are described briefly below.

Surface Rupture

Active or potentially active faults include those faults which have displaced the surface of the earth in the recent geologic past. They may be expected to cause surface rupture in the future and are of concern for land-use planning. Not all earthquakes result in surface rupture and in any one event the surface rupture is unlikely to occur along the full length of a major fault. The likelihood and amount of potential surface displacement will vary for different faults and for different segments of the same fault. Even though the probability of surface displacement is small on a fault, structures should not be allowed astride a known fault,

since even small horizontal or vertical displacement can severely damage the structure. When utilities, transportation facilities, or other lifelines must cross an active fault, special geologic investigations are needed to anticipate the amount of displacement and to design such facilities to take this displacement into account.

In addition to fault rupture there should be defined what is known as "the zone of deformation" associated with fault displacement. It is seldom possible to locate and define precisely the zone of deformation, and estimates are made from geologic evidence. The zone may vary in width from a few hundred feet to several thousand feet, depending upon the type and size of fault present. Zone widths can be more precisely defined through extensive subsurface investigation, including trenching. Detailed subsurface investigation and trenching is expensive and usually would be done for specific building sites to determine foundation and other structural requirements.

Ground Shaking

Ground shaking is the major cause of earthquake damage. The severity of ground shaking depends upon the magnitude of the earthquake, and type of movement, distance from the epicenter, and local geology. The most violent ground shaking usually occurs in a fairly narrow band adjacent to the line of fracture. Intensity of the shaking tends to decrease with distance from the epicenter. Local geologic conditions may modify this pattern. As an example, the unconsolidated sedimentary deposits in valleys adjacent to the Wasatch Mountains in Utah may amplify bedrock motion and produce strong ground shaking far from the fault upon which the earthquake originated. The effects of ground shaking are expected to be least for sites underlain by bedrock, intermediate for sites over alluvium, and greatest for those sites underlain by artificial fill. The precise prediction of ground shaking intensity at a particular site is difficult, but the relative potential for ground shaking may be estimated from previous earthquake records and from empirical studies of amplification of bedrock motion in different earth materials.

Liquefaction

Liquefaction is change of a loose, water-saturated, granular material from a solid to a semi-liquid state. It can be caused by ground shaking and may in turn cause major ground failure. The relative potential for liquefaction may be mapped using criteria such as follows.

Saturated, clay-free granular sediments with less than sixty-five percent density are considered to have high liquefaction potential even in a moderate earthquake. Such sediments having relative densities greater than ninety percent are considered to have low potential for liquefaction. The liquefaction potential of soil also depends upon the intensity and duration of ground skaing. For liquefaction to occur, materials usually must be within 100 feet of the ground surface, saturated, subject to strong ground shaking, and not confined. For some geologic units, site investigations are necessary to determine that a particular site is not underlain by liquefiable materials.

Landsliding

Earthquakes may trigger landslides. The potential for landsliding depends upon factors such as soil moisture, soil characteristics, steepness of slope, erosion rates, high seasonal rainfall, type and amount of vegetation cover, and the intensity of ground shaking. Maps of an area may be prepared showing relative slope stability based upon these factors and may show where landsliding potential exists from earthquakes. Geologic site investigations are necessary to pinpoint those areas where landslides are most likely. While it usually is not possible to predict which potential landslides will move in an earthquake, the areas can be shown where factors are present that indicate the potential exists for movement.

Flooding

Major flooding may be caused by failure of dams or dikes during an earthquake. Areas which may be flooded in event of dam failure have been mapped for certain urban areas in Utah. A significant urban area along the Wasatch Front in Weber, Davis, Salt Lake, and Utah County could be flooded in the event of sudden dam failure. Studies are being made to identify the vulnerability of particular dams to earthquake damage. It is essential to evaluate the depth and velocity of flood waters and to determine the length of warning time residents may have in the event of dam failure.

Selecting The Design Earthquake

Information concerning possible earthquake magnitude and location is needed to estimate possible surface rupture, ground shaking, ground failure and flooding in an area. The hypothetical earthquake that is used as the basis for assessing seismic effects is called the "design earthquake." Criteria for establishing the magnitude of the design earthquake is discussed in the following paragraphs.

Maximum earthquake magnitude and frequency may be estimated based on several items of information: (1) The rate of fault slip and historic records of ground deformation based on geologic information, (2) The seismic history of the fault, (3) Geologic evaluation of the tectonic setting, and (4) The empirically derived relation between magnitude of earthquakes and fault length and other parameters. It is realistic to assume that the largest historic earthquake can occur again on the same fault or on a geologically similar fault and that potential magnitude increases with fault length. It has been postulated that the largest expected earthquake on the Wasatch fault is 7.5 on the Richter magnitude scale. It should be recognized that this estimate is based on relatively limited historic observation and on comparison of the Wasatch fault with geologically similar faults.

Because of the difficulty of precisely predicting earthquakes or their effects, a conservative approach is prudent in establishing the design basis earthquake. This would be especially applicable when planning for areas or structures containing intensive uses or facilities which are critical to the functioning or recovery of a community during and after an earthquake. Choice of magnitude for a design earthquake is

also influenced by the projected frequency of occurrence. For example, if a maximum magnitude earthquake can be expected to occur once every thousand years, one of lesser magnitude may be selected for the design earthquake. It should be recognized that recurrence intervals for major earthquakes are difficult to determine, which would again argue for use of a conservative approach to selecting the design earthquake.

The magnitude chosen for the design earthquake may not always be the one expected on a fault closest to the area of interest. All faults and fault segments near the planning area need to be evaluated since the design earthquake is the maximum event on the largest active fault affecting the area. A design earthquake does not indicate the overall seismicity of the area or susceptibility to damage from lesser magnitude events in the planning area. However, measures to reduce risk from the design earthquake will reduce risk from other events in the area.

CONCLUSION AND RECOMMEND REFERENCES

This paper has described the legislative and legal background for seismic safety planning in Utah and has recommended procedures for local planning agencies in Utah to incorporate considerations of earthquake hazards into local comprehensive plans and land development policies and ordinances. Earthquake hazards reduction through land-use planning is a matter that has received increasing attention and research effort during the past few years at the federal, State and local government level. This paper is intended as an introduction to the subject and can provide guidance to local planning agencies in utilizing information and resources to mitigate earthquake hazards in Utah.

The following publications of the United States Geological Survey are recommended as references that are valuable to local planning agencies in meeting the challenge of earthquake hazard mitigation:

1. Studies for Seismic Zonation of the San Francisco Bay Region (U.S. Geological Survey Professional Paper 941-A, 1975).
2. Seismic Safety And Land-Use Planning - Selected Examples From California (U.S. Geological Survey Professional Paper 941-B, 1979).
3. Progress On Seismic Zonation In The San Francisco Bay Region (U.S. Geological Survey Circular 807, 1979).

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

SEISMIC SAFETY ADVISORY COUNCIL

807 EAST SOUTH TEMPLE • SUITE 103 • SALT LAKE CITY, UTAH 84102

October 10, 1978

AUTHORITY OF LOCAL GOVERNMENTS TO REGULATE LAND USE BASED UPON SEISMIC HAZARDS

Utah's counties and municipalities have authority under current statutes of the State to prepare and adopt land-use regulations based upon seismic hazards, according to an opinion recently issued by the Attorney General of the State of Utah. The opinion was requested by the Utah Seismic Safety Advisory Council in order to establish current authority of local governments to carry out seismic hazards mitigation programs involving land use.

Earthquake hazards to life, safety, and property in Utah may be mitigated most effectively through prudent practices in the siting of facilities and their construction. Because land use and construction are regulatory functions of local government, earthquake hazards reduction, if it is to be effective, must become an objective of local government. The legal opinion, furnished below in its entirety, should help to reinforce the view that seismic safety planning is a legitimate function of local planning agencies in Utah.

FORMAL OPINION NO. 78-008

September 8, 1978

Prepared By:
ROBERT B. HANSEN, Attorney General
MICHAEL L. DEAMER, Deputy Attorney General
LELAND D. FORD, Assistant Attorney General

Question: Do existing provisions in the Utah Code Provide necessary power to local government units in the State of Utah to prepare and adopt land use regulations based upon seismic hazards?

Answer: Yes.

Title 17, Chapter 27 and Title 10, Chapter 9 of the Utah Code Annotated 1953 contain the legal authority for counties and municipalities respectively to adopt comprehensive zoning plans and to enact ordinances in connection therewith.

It is our understanding that the Seismic Safety Advisory Council questions whether or not these code provisions are broad enough to enable a county or municipality to adopt a seismic risk zone map which could have the effect of regulating the kinds and intensity of land uses that would be allowed, based upon identified seismic hazards. We further understand that these requirements might be in addition to those otherwise contained in portions of the comprehensive zoning plan.

As you know, zoning laws and regulations are part of the powers of government generally referred to as "police powers." They are grounded in the traditional legal concepts that private interests and rights must sometimes yield to the interest of the public when it is necessary to "promote health, safety, morals, order, convenience, prosperity or the general welfare." The sections found in the two chapters referred to above contain the broad general language quoted. They further provide for the creation of zoning districts, adoption of master plans, the adoption of regulations designed to accomplish the purposes of the law and grant these local jurisdictions the right to generally regulate zoning and development.

As to specific authority for counties we would cite Section 17-27-13, Utah Code Annotated 1953, which reads in pertinent part as follows:

> "Such regulations shall be designed and enacted for the purpose of promoting the health, safety, morals, convenience, order, prosperity or welfare of the present and future inhabitants of the State of Utah, including, amongst other things, . . . securing safety from fire and other dangers, . . . classification of land uses and distribution of land development and utilization, protection of the tax base, securing economy in governmental expenditures, fostering the State's agricultural and other industries, and the protection of both urban and nonurban development."

For cities and towns, Section 10-9-3 of the Utah Code appears to contain the necessary authority. The pertinent parts of said section read as follows:

> "Such regulations shall be made in accordance with a comprehensive plan designed to . . . secure safety from fire, panic and other dangers, to promote health and the general welfare, . . . to prevent the overcrowding of land, to avoid concentration of population, to facilitate adequate provision for transportation, water, sewage, schools, parks and other public requirements. Such regulations shall be made with reasonable consideration, among other things, to the character of the district and its peculiar suitability for particular uses, and with a view to conserving the value of buildings and encouraging the most appropriate use of land throughout the city.

The sections cited in our opinion contain reference both specific and general which can be construed as authorizing the adoption of land use regulations such as those you suggest based on identified seismic hazards.

There is a substantial body of law in this state construing the authority of local jurisdiction to exercise zoning authority. We would cite the following cases for the propositions indicated as follows:

1. "Cities and counties are to have wide latitude in the exercise of discretion in carrying out the purposes of these statutes." *Naylor v. S.L. City Corporation,* 17 U.2d 300, 410 P.2d 764 (1966);
2. "The Court will only interfere if discretion is abused." *Phi Kappa Iota Fraternity v. S.L.C.,* 116 U. 536, 212 P.2d 177 (1949);
3. "The Court will act if the action is confiscatory, discriminatory or arbitrary." *Dowse v. S.L. City Corporation,* 123 U. 107, 255 P.2d 723 (1953);
4. "The Court will act if the power exercised is clearly beyond the power of the functioning authority." *Gayland v. S.L. County,* 11 U. 2d 307, 358 P.2d 633 (1961);
5. The Court has stated what its rule in zoning cases should be in the case of *Crestview-Holladay Homeowners Association, Inc. v. Engh Floral Co.,* 545 P.2d 1150 (1976) as follows:

> " . . . In the review of zoning cases the function of the Court is narrow and its scope is limited to a determination of whether or not the action of the Board of County Commissioners as a legislative body is illegal, arbitrary, discriminatory or capricious . . . . "

We therefore conclude and it is our opinion that counties and municipalities do have the requisite authority to enact zoning ordinances which would include appropriate restrictions on the kinds and intensity of land use and development based upon identified seismic hazards. Obviously, these ordinances could only be adopted after the usual procedure of legal notice and public hearing has been followed. So long as the decision of the governing body concerned is not illegal, arbitrary, discriminatory, or confiscatory and is necessary to protect the public and would "promote health, safety, order and the general welfare," it would appear to be within the grant of statutory authority.