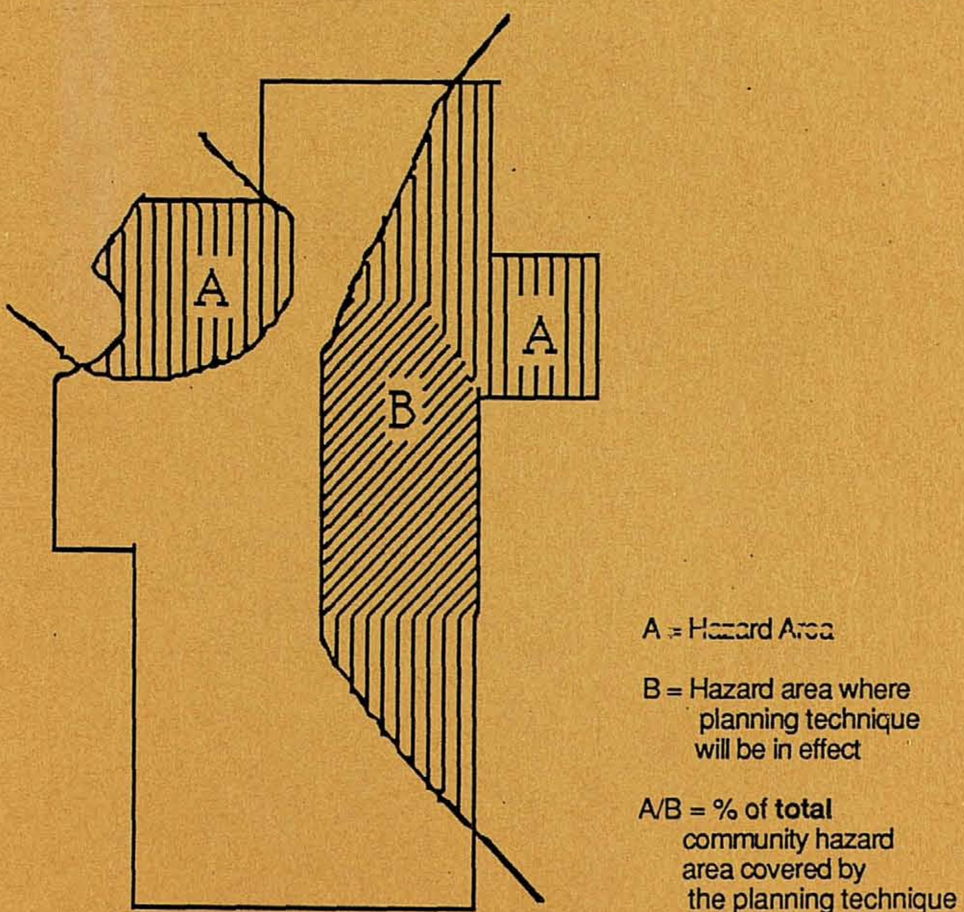
LAND USE PLANNING FOR EARTHQUAKE HAZARD MITIGATION:

A HANDBOOK FOR PLANNERS



LAND USE PLANNING FOR EARTHQUAKE HAZARD MITIGATION: A HANDBOOK FOR PLANNERS

Patricia A. Bolton

Susan G. Heikkala

Marjorie M. Greene

Peter J. May

Myer R. Wolfe, Project Director

Special Publication

14

Natural Hazards Research and
Applications
Information Center

Prepared with the Support of the
National Science Foundation
Design Research Program
Civil and Environmental Engineering Division
Washington, DC 20550

NSF Grant Number CEE-8118450

PREFACE

The risk of a major earthquake is faced by numerous jurisdictions all over the United States, from seismically active California to areas with great potential for a damaging earthquake, such as Charleston, South Carolina, central Utah, Puget Sound, and parts of Missouri and Tennessee. In fact, some 70 million Americans live in areas of significant earthquake risk, and 115 million people are exposed to less significant, but not negligible risk (National Academy of Sciences, 1975, p. 20).

The threats to human activities posed by earthquakes are many: deaths and injuries, property loss and damage, economic problems, and the breakdown of essential urban functions. There has been much research into mitigation practices and policies, and engineering techniques to minimize an earthquake's potential destructiveness to the built environment. Mitigation activities have included developing seismically resistant structural designs, implementing codes and ordinances that require such designs, using planning and development authority to redirect development to safer locations, and improving emergency preparedness.

This handbook--written by planners and hazards management specialists--has as its premise that land use planning techniques are useful and potentially less costly than some other mitigation measures, particularly structural ones, that decrease earthquake loss potential. In order to demonstrate the usefulness of such techniques in a more systematic manner, a comprehensive decision-making framework is presented. It outlines the steps local officials in an earthquake-prone area can take to determine the effectiveness of land use planning techniques to reduce losses in their community from an earthquake.

ACKNOWLEDGEMENTS

This handbook would not have been possible without support from the National Science Foundation. Beyond funding, Frederick Krimgold, program manager at the National Science Foundation, provided us with valuable advice and support in the initial stages of the project, a role that was picked up in the project's latter stages by William A. Anderson. We would like to express our special appreciation to them both.

During the course of the project, the principal investigators were assisted at various stages by Jim Hattori and Tom Laetz, and by the support staffs of the Department of Architecture and Urban Planning and the Center for Planning and Design at the University of Washington, and of Battelle Human Affairs Research Centers. We are very grateful to the many persons who helped out with the research, administrative, and report production tasks. Special thanks is given to Charleen Sager for her cheerful and skillful production of the many revisions and complex tables necessary in the development of this handbook. We would also like to express our appreciation to the many planners, city and county officials, and other local experts--too numerous to mention by name--who provided information and review during the field testing of our framework for this handbook in the communities of Bellingham, Washington; Provo, Utah; and Santa Rosa, California.

The process of formulating the concepts of implementation feasibility, cost, and effectiveness was greatly assisted by the professional advice of our Advisory Committee. For serving in the roles of critic and advisor we would like to thank the following: Nancy Fox, Planning Consultant, Seattle City Council; Richard Elmore, Department of Public Affairs, University of

Washington; Neil Hawkins, Chairman, Department of Civil Engineering, University of Washington; Rick LaValla, Washington Department of Emergency Services; George Mader, Planning Consultant, William Spangle and Associates, Portola Valley, California; the late Mehmet Sherif, Department of Civil Engineering, University of Washington; and Richard Zerbe, School of Public Affairs, University of Washington.

This handbook benefited from the careful and thoughtful review of the draft manuscript by several of our respected colleagues knowledgeable in planning and earthquake mitigation. For their extensive, timely, and useful comments, we would like to express our appreciation to: Nancy Fox, Steven French, Paula Gori, Martin Jaffee, William Kockelman, and George Mader.

Final editing of the handbook was done by Sarah Nathe of the Natural Hazards and Applications Information Center, the University of Colorado. Special thanks are due to NHRAIC for publishing this handbook.

THE AUTHORS

Patricia Bolton is a Research Scientist at Battelle Seattle Research Center. Dr. Bolton Received her Ph.D. in Sociology at the University of Colorado, Boulder, where she participated in the Natural Hazards Research Assessment led by Gilbert F. White. She had a major involvement in a study of the 1972 Managua earthquake that identified central issues in the recovery and reconstruction planning process, and recently completed a study comparing the use of disaster relief programs by various ethnic groups, including those affected by the 1983 Coalinga earthquake. She also has participated in a variety of studies on mitigation techniques for development projects and natural hazards.

Susan Heikkala, now a Planner with the Port of Seattle, undertook this project while a Research Associate in the College of Architecture and Urban Planning at the University of Washington in Seattle. Ms. Heikkala has a master's degree in Urban Planning from the University of Washington, and has had extensive experience as a land use planner in Alaska. As a Research Associate at the University of Washington, she concentrated her efforts on several projects relating to earthquake hazard mitigation and land use planning, including serving in 1981 as conference administrator for an international colloquium on urban-scale vulnerability and earthquake hazard mitigation in Italy, the United States, and Yugoslavia.

Marjorie Greene, currently a Planner with the Bay Area Regional Earthquake Preparedness Project in California, began work on this project while a Research Scientist at Battelle Seattle Research Center. Ms. Greene has a master's degree in Urban Planning from the University of Washington. While at Battelle she focused on the planning aspects of natural hazards and disasters, including studies on individual evacuation decision making and emergency management, citizen perception of the hazard during the Mount St. Helens volcanic eruption, and earthquake hazard information dissemination in Charleston, South Carolina.

Peter May is an Associate Professor in the Graduate School of Public Affairs and Political Science Department at the University of Washington. Dr. May received his Ph.D. in Public Policy from the University of California, Berkeley. His recent work has addressed the political and organizational influences on disaster policy and program implementation.

Myer R. Wolfe, the Project Director, is now Dean Emeritus of the College of Architecture and Urban Planning at the University of Washington. Professor Wolfe taught for almost 30 years in American and foreign universities in the area of planning, and has done extensive planning and urban design consulting in both national and international settings.

TABLE OF CONTENTS

THE STARTING POINT

Contents

Figures

THE STARTING POINT

This handbook provides a framework for assessing the effectiveness of various land use planning techniques for reducing a community's earthquake loss potential, and for determining the relative appropriateness of the techniques to the social and political reality of the community. A community can be interested in this framework for several reasons:

- The framework builds on a decision-making process that community officials often tacitly use now. By making these decision points more explicit, however, the framework can help to provide a stronger rationale for the decisions made, particularly in terms of implementation feasibility and costs.
- The framework discusses the potential usefulness of land use planning techniques in relation to community characteristics. Little work to date on planning and earthquake hazard mitigation has offered any kind of system for evaluation of usefulness in a particular setting.
- Since the framework recognizes that many land use management approaches are already used in communities--frequently to serve multiple purposes--it will be helpful to communities with limited resources.

Why Use This Approach?

The handbook begins with the twin assumptions that a community using it both recognizes its seismic risk and is prepared to consider and use loss reduction strategies. The handbook identifies several essential steps a local government will need to take in order to plan and implement loss reduction techniques. The handbook will enable a community to compare one or more land use planning techniques in terms of their applicability to the community, costs involved, and overall effectiveness in reducing potential losses.

Different communities have different reasons for considering a land use planning strategy for earthquake loss reduction. One community may have a citizens' group or city council member who is particularly concerned about seismic risk and prompts the local government to initiate action. Another community may have been damaged by an earthquake and want to minimize future losses. This handbook is designed for use at the point that community officials have come to be concerned about earthquake risk and are prepared to consider some planning action to reduce loss potential.

There is no one "best" planning technique for earthquake hazard reduction. Community characteristics and community concerns make planning technique effectiveness particular to individual communities. This handbook also recognizes that not all communities approach the problem from the same starting point. For example, initiatives to consider land use planning will be taken in response to various "questions" such as the following:

- As long as we are developing/changing this ordinance, what can be done to make it also apply to reducing losses from future earthquakes here?
- We don't want to do any more hazard-related data collection, but is there any land use planning technique that we can use with the information we already have?
- What can we do that will get [Group X] to stop doing [Practice Y], and thereby reduce what can be lost in an earthquake?
- How can we reduce the loss potential of development in areas identified as having an earthquake hazard?
- Couldn't we decide more easily if we had some idea of how [land use planning techniques X, Y, and Z] compare to each other in terms of cost and efficacy?

Whatever the specific starting point, the process of considering land use planning techniques involves an assessment of information needs. However, locating or collecting the necessary information for the implementation of a particular planning technique **is not enough** to assure that it will be put into use. Determining the feasibility of a technique is **a critical part** of the process. This handbook is organized to address both these aspects of selecting one or more land use planning techniques for use in earthquake hazard reduction for a particular community.

Land use planning techniques are most appropriate for communities that are growing and still have undeveloped land. Land use planning policies, subdivision and grading ordinances, land acquisition programs, and taxation policies work best in cases where there is adequate information with which to identify particularly hazardous locations. Another common approach to earthquake loss mitigation is to institute building codes and practices, or standards for new and existing construction. This can be done in a general way, being applied to all existing and new development, regardless of its location. Yet another strategy is to combine a structural approach with a locational approach, in which certain standards, codes, or design requirements are applied only to specific sites known to be particularly hazardous.

This handbook reflects to some extent the combination of these two latter strategies. Other approaches include the use of disaster preparedness plans for coping efficiently and effectively with an event should it occur, and loss reduction strategies that structurally modify the land to reduce losses from hazards like liquefaction and slope instability. Both of these can and should be used in conjunction with land use planning for loss reduction.

Organization of the Handbook

The handbook is divided into two sections. SECTION I: RISK ASSESSMENT AND PLANNING TECHNIQUES, discusses ways to obtain information and assess seismic risk, and to determine the appropriateness of various planning techniques. SECTION II: EFFECTIVENESS ASSESSMENT, describes the process for determining a planning technique's feasibility in the community, the costs that must be considered for various planning techniques, and the ways to evaluate the potential effectiveness of a particular planning technique (see Figure 1 for a schematic overview). The two analytical steps presented in Section I are as follows:

Part A: Information Sources and Risk Assessment. Determining what the earthquake-related hazards are in the area, how they affect the built environment, and what information currently exists on the hazards is a necessary step in selecting appropriate land use planning techniques. **Part A** contains discussions of data sources on local earthquake hazards, the nature of risks to the built environment, and approaches for conducting a community risk assessment.

Part B: Selecting Appropriate Planning Techniques. This step draws on information about the community's risk as addressed in Part A, and on knowledge of various planning techniques, including those currently used in the county and city. In **Part B,** the planning techniques that appear to have the greatest possibility of mitigating the earthquake hazard in the community are determined.

The four analytical steps addressed in Section II are as follows:

Part C: Implementation Feasibility. This step involves asking a set of questions that will help to determine the likelihood of adoption, compliance, and enforcement for each planning technique under consideration.

Part D: Considering Development Context and Community Objectives. The existing development pattern and the types of development pressures in the area narrow the choices among planning techniques. This step examines how the implementation of one planning technique will affect the ability to achieve other community objectives and/or how various land management programs interact.

Part E: Determining Costs of Techniques. In this step, an examination is made of the types of costs associated with developing and implementing a program, and who bears them. Once these are determined, the community can consider them in conjunction with the advantages of selected planning techniques.

Part F: Assessing Effectiveness of Each Technique. Effectiveness is defined as a combination of how much of the community-at-risk the technique will affect, how much the technique will reduce the loss potential, the likelihood of implementation, and the associated costs for each technique. In this step, these three elements are viewed simultaneously.

The order of the steps presented in the handbook is not necessarily the one which will be the best to follow. The process of determining a strategy for loss reduction may cause one to move from one step to another in an order

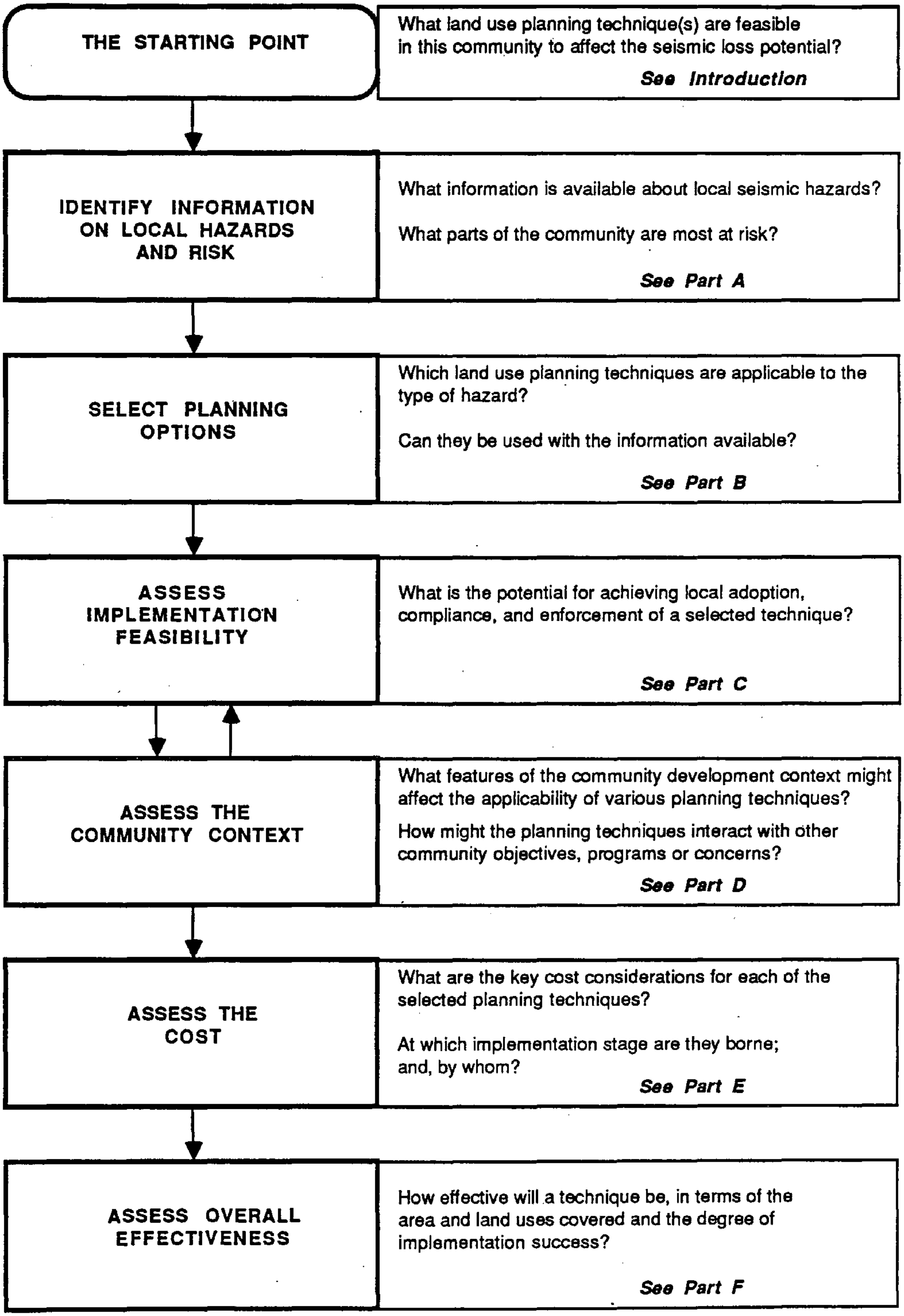


FIGURE 1 DEVELOPMENT OF A LAND USE PLANNING STRATEGY FOR EARTHQUAKE LOSS REDUCTION

different from that presented above. It is also likely that various steps will be returned to as, for example, more information is acquired on the hazard or on the community's likely acceptance of a particular approach.

Each part of the handbook, corresponding to a major analytical step, opens with an introductory discussion that explains the nature and the purpose of that step. This is followed by a practical description of how to conduct the analysis. A case study example illustrates how this step was carried out in a real community. This organization is application-oriented. After an introductory reading, a user can focus on the analytical activity described in each section, returning to the descriptive information and examples only as necessary for further reference.

For the reader unfamiliar with the range of hazards associated with earthquakes, a brief introduction is provided below. Many sources exist that provide a more complete technical explanation of these phenomenon, or local experts can be called upon to discuss the hazards in greater detail and in reference to the physical context of a particular community.

Earthquake Effects

The damage caused by an earthquake is a result of an interaction between the physical event and the built environment. Thus, to estimate potential losses, one must both understand an area's seismic risk and have information on the area's population, land use, and structures. The National Research Council states that three conditions determine the scope of an earthquake disaster: 1) the magnitude of the earthquake (a small earthquake may not involve sufficiently severe ground shaking to produce extensive damage); 2) the source of the earthquake (distance from the epicenter lessens ground shaking, and thus may be related to the level of damage in a certain location); and 3) the degree of earthquake preparedness in a community (good preparation and mitigation plans can help to reduce the extent of the damage and disruption) (Committee on Earthquake Engineering Research, 1982, p. 4). Since the magnitude and source of a specific earthquake can not be altered, the only way to reduce future losses is to adopt measures in communities at risk to counteract the effects of the physical event (see Part A for more detail).

Different planning approaches may be appropriate for specific types of earthquake effects. These earthquake hazards will be referred to in several of the parts of the handbook, so brief descriptions of the types of problems associated with them are given here. Included in the descriptions are indications of the effects of these hazards on the environment.

- **Ground Shaking**
  Ground shaking is vibratory ground motion caused by an earthquake. The Mercalli intensity of the ground shaking, which is a subjective measure of severity based on observed damage and other effects, will vary from location to location. Factors affecting changes in intensity include the Richter magnitude of the earthquake (or the amount of energy released), the composition of surficial geologic deposits, and the distance from the epicenter of the earthquake.

  Ground shaking becomes a risk to the built environment when the seismic waves moving through the earth's crust destroy or seriously damage buildings, roads, and other public facilities. The waves may also cause equally damaging secondary hazards, including landslides, soil liquefaction, and other types of ground failure.

  Ground shaking typically causes most of the damage associated with earthquakes. Local geologic conditions can change the characteristics of earthquake ground shaking. For instance, the intensity of shaking can be amplified by thick deposits of unconsolidated soil materials (Borcherdt **et al.**, 1975, p. A52).

  Damage from ground shaking also depends on the kinds of structures being shaken. Studies of the local ground shaking hazard can indicate the need to modify and/or strengthen local building codes and other construction standards. They can also guide decision making regarding the location of areas for community expansion, large-scale development projects, or other specified critical development proposals.

- **Surface Faulting**
  Faults are "planes or surfaces in earth materials along which failure has occurred and materials on opposite sides have moved relative to

one another in response to the accumulation of stress" (Nichols and Buchanan-Banks, 1974, p. 2). There are several different types of faults, and their classification is based on geometry and direction of relative slip.

Faults may be located far below the earth's surface, such as those in the Puget Sound area in Washington State, where the fault depth may be as much as 70 kilometers. An earthquake on a deep fault usually causes only ground shaking at the surface. On the other hand, faults located at or near the earth's surface, such as the San Andreas, may cause ground displacement as well as ground shaking. Displacement can take place suddenly during a severe earthquake or it can occur gradually over time. The latter is called "tectonic creep," and can be accompanied by the slow distortion of surface features.

For communities located on or near surface faults, gradual or violent fault displacement can cause damage to structures and/or their foundations, transportation corridors, utility systems, and other critical facilities. Little can be done to enable existing buildings and other community facilities to withstand fault displacement. Where surface faults do exist, knowledge of the location and nature of a fault can be used to help future development avoid these areas.

- **Soil Liquefaction**
  Soil liquefaction is "the transformation of a granular material from a solid state into a liquid state" (Youd et al., 1975, p. A-68). This is caused by earthquake-induced ground shaking. In a liquefied state, soils completely lose their strength and are unable to support any weight or stress. Liquefaction problems are generally confined to areas having certain geologic and hydrologic characteristics, particularly water-saturated, clay-free sediments that are relatively unconsolidated.

  Liquefaction becomes a hazard to the built environment when the ground fails to support overlying structures, or when the liquefied material flows laterally or downslope--it's then called earth flow--damaging buildings and other facilities. Liquefaction presents a particularly difficult problem in terms of engineering a solution.

- **Landslides**
  Landslides can be seen as a secondary hazard in association with earthquakes, since earthquake ground motion may shake loose an unstable hillside. Earthquake-induced landslides can cause serious damage to buildings and other urban facilities through the loss of foundation material and/or burial. Landslides may also block emergency road access and strand neighborhoods or entire communities. Even a mild earthquake can produce forces extreme enough to set a slide in motion.

  Unlike surface faulting or ground shaking--which occur independent of human activities--urban development can exacerbate or help control landslide hazards. Some of the more common human activities that affect the potential for landslides include earth fills for construction; construction of buildings, roads, or other structures;

and use of septic systems, lawn watering, or other landscaping (Erley and Kockelman, 1981, pp. 5-6).

Some of the following actions may help reduce the hazard: add surface or subsurface drainage, terrace the slope, stabilize the soil by grouting, remove or avoid adding external loads (additional development), protect the base of the slope from erosion, or support the slop with piling or retaining walls (Jaffe et al., 1981, p. 19).

- **Flooding**

  Earthquake-related flooding occurs in the form of tsunamis along coastlines, bays and estuaries; large-scale seiches in lakes and canals; and raging torrents after the failure of dams and levees due to ground shaking (Bolt et al., 1977, pp. 46-47).

  Tsunamis, generated by earthquakes under the ocean, can cause enormous devastation in coastal areas. A tsunami is a series of large gravity waves in the sea, and is sometimes referred to as a "seismic sea wave" or inaccurately as a "tidal wave" (Ayre et al., 1975, p. 93). It is generally accepted that an earthquake must have a magnitude of 7 Richter or greater to be accompanied by a tsunami of significant magnitude; however, earthquakes of lesser magnitude can produce tsunamis that may be damaging in a confined area (Ayre et al., 1975, pp. 93-94).

  Seiches are generated by a sudden fall of rock or soil (such as landslides caused by an earthquake) into a reservoir or lake. Seiches are undulations of water surface that travel back and forth across an enclosed body of water at regular periods determined by the depth and size of the water body (Bolt et al., 1977, p. 135). In certain circumstances, seiches may be produced by earthquake ground motion. The waves can be destructive to facilities along a shoreline, or may damage sewage and water storage basins slightly inland.

  Dam and levee failure can also result from ground shaking, and can be particularly problematic if there is a large population-at-risk downstream. The development of an adequate warning system is necessary.

SECTION I
RISK ASSESSMENT AND PLANNING TECHNIQUES

PART A: INFORMATION SOURCES AND RISK ASSESSMENT

Contents

Tables

This
page
is
intentionally
blank

PART A: INFORMATION SOURCES AND RISK ASSESSMENT

This section discusses several techniques for determining community vulnerability to earthquakes, and directs the user to experts and sources that can provide detailed information on both the seismic risk and the elements in the built environment that are vulnerable to earthquake damage.

Sources of Data on Local Earthquake Hazards

To determine the specific earthquake-related hazards facing a community, there are various data-gathering and mapping techniques that are used by geologists, seismologists, and geotechnical engineers. It is not our expectation that planners themselves use these techniques, but they can learn to recognize that certain areas may be prone to seismic problems and therefore require detailed and expert analysis.

Information and Experts

As a first step, it is often possible to find clues about hazards in basic land use planning information. Table A-1 lists information sources available in most communities, and describes what those sources might indicate about the seismic hazard. The examination of basic sources may show that there is some seismic risk; however, planners should not substitute their interpretations for those of qualified geologists, seismologists, or geotechnical engineers. If there are indications of seismic risk, technical expertise and/or some additional investigation is necessary. It is also possible that, during the review of available information, a planner may discover that more specific studies have been completed.

A review of regional-scale data should highlight potential local seismic problems. With reasonably complete information, a planner can tell whether a particular local area is stable, if it warrants somewhat closer analysis or even detailed site analysis before development is considered, or if it is so unstable as to put any development in jeopardy. The amount of available knowledge and the level of data resolution will also give an indication of the types of land use techniques that can mitigate that hazard.

Table A-2 identifies for planners the types of data that seismologists and geotechnical engineers would need to develop an understanding of the seismic risk. The types of data are outlined in terms of the degree of detail needed, from the more general regional, through a community-wide level, to the site-specific. Usually, detailed site analyses are undertaken only if more general data indicate that a particular problem exists. Not all geologic or seismic studies need to be conducted at a detailed or costly level; more general reconnaissance analyses using secondary data can also provide an adequate assessment of the severity of the seismic risk.

In most states, the state geologist, the U.S. Geological Survey, and the Federal Emergency Management Agency are the agencies most likely to collect and disseminate information on earthquake hazards. A preliminary check on the information these agencies have is recommended. Another good place for information is a nearby college or university. The geology, geophysics, seismology, and engineering departments can play several roles:

- An individual professor can brief a local official on the kinds of data that are available for the community/region in question, and can suggest the beginning steps for a hazard assessment;
- Individual professors can serve as consultants to a local government, either operating in an advisory capacity or, with the use of graduate students, actually conducting hazard assessments; and

- Groups of professors can form advisory panels to review work performed by geotechnical consulting firms, and can assist local officials in understanding technical reports and data.

Well-respected geotechnical firms, individual consulting geologists, and seismologists can also provide technical experts to perform studies. Additionally, it may be possible for a local jurisdiction to request that a state or federal agency gather some of the needed data. Other possible sources of experts include associations of consulting engineers and the Earthquake Engineering Research Institute.

Maps

One particularly complete tool for presenting information on a community's earthquake risk is a microzonation map. Seismic microzonation is a procedure of dividing a region into zones that indicate exposure to earthquake hazards such as ground shaking, surface fault rupture, landslides, liquefaction, and tsunamis. The intent of microzonation mapping is to estimate the location, recurrence interval, and relative severity of future seismic events so that potential losses can be estimated, mitigated, or avoided (Cluff, 1978).

Microzonation mapping can provide the informational basis for applying land use planning techniques to earthquake loss reduction through zoning, subdivision ordinances, special use and critical facility permits, lifeline (roads and utilities) planning, property acquisition programs, and other measures (Scawthorn, 1982, p. 730; Mader, 1982, p. 673; Gaus and Sherif, 1972, p. 4). The information can also be used to develop building code performance standards for seismic load factors; these can then be applied to new construction as well as hazardous building abatement programs (Mushkatel, 1982, p. 1575).

Microzonation requires information on both the physical risk and the expected structural responses to seismic forces. The actual content of microzonation maps may vary, depending upon availability of the data base, the nature of the local hazard, and the intended use of the microzonation map. For example, the following is a description of three microzonation products:

> [A]s a first step in microzonation, we might take empirically observed geologic data, attenuation data, and data on depth to water table and combine these with a model of radiation of energy from a fault plane to create a microzonation map of expected seismic intensity in a specified area for a fault of specified size situated in a specific place [see Evernden et al., 1981, for examples]. This map can then be combined with tables correlating intensity and percentage of damage to specific types of buildings, and with data on the distribution of building types, to yield a microzonation map of expected percentage of damage; this map could be combined with an empirically developed table correlating the average percentage of damage to residential structures with expected percentage of homeless to yield a microzonation map presenting the percentage of homeless (Evernden, 1982, pp. 1171-1172).

These three maps are similar in that they are derived from empirical data sources and identify small geographic areas exhibiting a similar response to earthquake phenomena. Because of their precision, however, microzonation maps require detailed technical information to prepare; therefore, they may be prohibitively expensive for local governments to use (Olson and Nilson, 1982, p. 1553).

Estimating Earthquake Effects on the Built Environment

The identification of what is likely to be damaged or destroyed in a particular community is important for the development of appropriate mitigation, preparedness, and response actions. These actions include the adoption of building codes and land use regulations that can actually reduce potential losses, as well as preparedness plans that increase the ability of local officials to respond appropriately to a damaging event. Information can also be assembled in advance to guide recovery and reconstruction efforts after a damaging earthquake.

In assessing loss potential in a community, there are certain basic categories of information about the built environment that are important. These are briefly summarized here:

- **Land use Inventory.** The mapped inventory should include location patterns, use types, number of stories, building materials, and construction type.

- **Population Data.** In addition to basic demographic data, useful information includes mapped population distribution for critical time intervals or peak times, population projections, and economic development trends.

- **Hazardous or Seismically Vulnerable Building Inventory.** It is important to map date of construction, type of construction, structural configuration in plan and elevation, and nature and importance of occupancy. These data can be used to develop a map of potentially vulnerable buildings in the community (Arnold and Eisner, 1984).

- **High Occupancy or Involuntary Occupancy Structures.** Structures which have high levels of occupancy or involuntary occupancy include large apartment buildings, offices, major employment or shopping centers, theaters, auditoriums, stadiums, prisons, mental institutions, hospitals, schools, and convalescent and nursing homes. When located in areas of seismic risk, they represent a situation of high hazardousness. To define the loss potential, it is important to know not only the location of the structures, but their capacity populations, frequency of use, and time and duration of use.

- **Lifelines.** Lifelines include the transportation network, communications, water, sewer, gas, and electricity systems. Maps of individual systems should include critical components or linkages, such as airports, docks, phone exchange centers, water or gas storage facilities, power generating plants or stations, treatment facilities, shut-off valves, auxiliary suppliers, emergency power generators, bridges, and interchanges. If available, information on system age, condition, and type of structural material would also be valuable.

- **Hazardous Facilities.** Facilities whose failure or destruction in an earthquake would cause severe secondary damage should be located and mapped. The area affected by their failure should also be mapped if possible. Facilities such as nuclear power plants, dams, and storage facilities for toxic materials are of particular concern.

- **Essential Services and Supplies.** Facilities housing essential emergency services and supplies should be sited or built to ensure continued functioning should a disaster occur. Maintaining up-to-date maps of these facilities will aid both mitigation and response planning. These facilities include emergency communications centers, hospitals, clinics, medical supplies, critical equipment and fuel, and fire and police stations.

Assessing Loss Potential in the Community

There are several ways to combine information on seismic risk and on the built environment. Several examples of these techniques will be briefly summarized here: land capability analysis, probabilistic risk assessment, and hazardous building inventory.

Land Capability Analysis

Land capability analysis measures the ability of land to support different types of development (Laird et al., 1979, p. 2). This technique permits various comparisons: 1) alternative land uses can be judged in terms of their impacts on "natural" physical and biological systems; 2) the costs of hazard mitigation can be placed against the costs of earthquake damage should no mitigation take place; and 3) development options can be thought of in terms of tradeoffs with other community objectives.

There are several ways to develop land capability analyses. One method recognizes that certain lands are more prone than others to erosion, flooding, fire, water pollution, vegetation and wildlife disturbances, landsliding, faulting, and environmental disruptions that may be exacerbated by development. Potential conflicts between natural processes and development pressures can be determined using a composite map which rates the conflicts on a scale of natural system disruptions. A grid system can be used to enter this information into a computer (Patri et al., 1970, pp. 49, 63).

Land uses can also be compared by converting all projected impact costs (i.e., resource use, special studies required, mitigation measures) to some dollar value. This approach was used in the San Francisco Bay Area and is perhaps most appropriate for comparing relative costs of developing in seismic hazard areas. A quantitative approach to land capability can be quite complex and require a high level of sophistication, if all costs are to be identified and computed. In general, this approach would involve five major steps, as discussed in Laird **et al.** (1979, p. 3):

1) Collect earth science information and prepare basic maps. Basic geological information can be taken from maps prepared by U.S.G.S., S.C.S., or the state geologist. If more detail is needed, special staff or a consultant can be retained. All information should be mapped at the same scale.

2) Develop an interpretive map for each hazard problem from the appropriate basic information maps. For example, fault traces can often be identified from a geologic base map, whereas landslide potential requires the use of a map of photo-interpreted landslides, a geologic map, and a percent slope map. Interpretive maps are typically prepared by staff or a consultant.

3) Calculate the "social costs," or the dollar sum of all costs attributable to a problem (regardless of who pays) for each type of development and each geological condition (several may be evident on a given parcel). Costs can be grouped into three categories:
   - Engineering, design and mitigation costs--prior to and immediately after construction
   - Probable damage or disaster costs incurred in the future (e.g., replacing buildings, infrastructure, loss of income, relocation)
   - Opportunity costs--potential revenues and benefits that would have accrued from an alternative use of the land, which are now foregone. Costs that accrue at different times are normalized by calculating the present value of these costs using an interest discount rate. Costs which may occur at an unknown time are calculated by finding their average or expected value. Expected value is the sum of the probability of each outcome times the return if that outcome is realized.

4) Determine the measure of land capability for each use by totalling all the expected costs for all the conditions for each land use.

5) Display the sums of these costs on a capability map for each land use. This can be accomplished by hand calculation and mapping, or by computer application.

Quantitative land capability analysis relies heavily on interpreting maps and computing expected costs. The mapping component employed in all land capability analyses can be prepared manually or through the use of a computer. Both methods have their advantages and disadvantages. For example, the manual approach will be less expensive to do and will not require special expertise, but the resultant maps are less precise and less adaptable to other scenarios. The computer approach will allow for more flexibility in changing or combining maps, but it is costly to set up and frequently necessitates hiring a consultant or providing extra staff training. In either case, however, land capability maps will be only as accurate as the base input information. Important distinctions between approaches are as follows:

> The advantages of the manual approach include a low set-up cost, no hardware requirement, inexpensive information storage, and little special expertise to use the technique (although consultants may be required to develop the information). However, there are several drawbacks. Composite maps are generally less precise, difficult to reproduce quickly or to overlay more than two to three maps, time-consuming to alter, and prone to interpretation problems which grow with complexity. Because they are hand-drawn, it also is difficult to run multiple scenarios.
>
> The advantages of the computer mapping approach are ease of map and overlay reproduction, rapid map alteration, flexibility and adaptability for other planning purposes, and ease of changing variables or run scenarios. Drawbacks include high set-up cost, need to have access to or purchase/lease computer hardware, added cost to operate and maintain system, and likely need for consultants and staff training. Software and hardware for a small planning office can run from $10,000 to $40,000.

Probabilistic Risk Assessment

A risk assessment is a more comprehensive way to present information on both the earthquake risk and the built environment in a community. The following few paragraphs describe an assessment done in San Luis Obispo County, California. This case is mentioned because of its applicability to other medium-sized communities.

The first step in a risk assessment is to identify the types of hazards present and their potential severity. At a minimum, this entails knowledge of: 1) area seismicity, including the recurrence intervals (statistical probabilities for future earthquakes based upon the frequency of earthquakes in the past) for earthquakes of varying magnitudes; 2) surficial geologic mapping; 3) predicted attenuation curves for ground shaking; and 4) estimates of ground acceleration. The more sophisticated or precise the base data can be, the more refined will be the risk assessment. In the San Luis Obispo study, the cost of surficial geologic mapping (i.e., collecting primary geologic information) was between $10,000 and $20,000; assembling secondary information took 50 person-hours to cover an area of 144 square miles (French, 1983).

Various methods can be used to map the hazards. A probabilistic approach estimates the recurrence potential for an earthquake of a predicted magnitude. (Note: the selection of the recurrence interval is a key decision and implies that the community has arrived at a definition of acceptable risk.) The expected ground motion from such an earthquake is then modeled, based on knowledge of area attenuation characteristics. This analysis requires expertise that is generally beyond the capability of small planning staffs. The product is a hazard map that can be done manually, aggregating the hazard into several categories (e.g., high, medium, low), or by using a computer model. In San Luis Obispo County, a computer model was used to identify hazardous areas, based on a 10% probability of a 30-year recurrence. Modeling seismicity involved 200 person-hours; 120 hours were needed to put existing landslide and liquefaction maps into machine readable format. Input and operating the model required an additional 110 person-hours, for a total of 410 person-hours for the complete seismic risk analysis (French, 1983).

The second step is to inventory land use and key features of the built environment. The number of structures and complexity of detail logged in will have a direct bearing on the refinement, accuracy, and cost of the inventory. Greater detail results in a higher degree of accuracy, but depends on the available resources to do the inventory--staff or funds. For the San Luis Obispo study, only the total number and value of structures were assessed for a limited range of construction types: wood frame, steel frame, masonry and brick, and mobile homes. The study did not distinguish between uses, number of floors, or structural densities. This information required two weeks of field work. By comparison, in San Francisco, Algermissen **et al.** (1978) used a much more extensive list of building types, but they also did not evaluate building uses and assumed a uniform structural density throughout the study area.

The third analytical step in a risk assessment is to estimate the amount or proportion of expected damage to different buildings in different location. This step involves: 1) identifying the spatial distribution of building types by construction class; 2) developing for each construction type a relationship of the expected loss at different earthquake intensities; and 3) identifying the expected intensity at different sites. The expected loss for certain construction types at different locations in an earthquake of a specified intensity is then calculated using the above three determinations. This information can be expressed in terms of estimated dollar loss, percent loss, loss ratio, or an other relative measure.

In the San Luis Obispo study, digitizing the land use information (for a relatively small population) and operating the model required 70 person-hours. Computer costs were approximately $50 per run, and at least four runs were required (French, 1983). If a computer model is developed, several future land use scenarios can be generated and then evaluated for comparative risk.

Hazardous Building Inventory

There are several ways to conduct a hazardous building inventory, including the method used by Los Angeles to determine that there are over 8,000 unreinforced masonry structures that were built there before seismic codes existed. These buildings were identified through a computerized listing and from building department field checking. Another method, which will be described briefly in the following paragraphs, was used to determine "seismically suspicious" buildings in Oakland (Arnold and Eisner, 1984). The Oakland inventory assumed that not all pre-code unreinforced masonry buildings are equally hazardous, and that many post-code buildings may also be hazardous (including large reinforced concrete buildings with non-ductile frames built before 1971, tilt-up concrete structures, and structures of mixed construction and poor architectural configuration).

All inventories start with field work to identify buildings with certain visible symptoms of potentially poor seismic performance. This field work results in a list of "seismically suspicious" buildings that are then further checked through conventional sources such as building department records, Sanborn maps, reports, and revisits. The term "seismically suspicious" refers to buildings that are not **necessarily** hazardous, but present visible evidence that they might be.

The criteria used in evaluating buildings are listed below.

- Date of construction
- Type of structural system

- Architectural/structural configuration (size and shape), and structural irregularities that can lead to torsion and stress concentration:
  - soft stories
  - discontinuous shear walls
  - complex plans (re-entrant corners)
  - weak column/strong beam conditions
  - variations in elevational strength and stiffness
  - extreme setbacks in elevation
  - extreme plan or section proportions
  - variations in column strength and stiffness
- Types of materials, e.g., unreinforced masonry, non-ductile reinforced concrete, tilt-up concrete, mixed materials
- Importance of occupancy
  - high-density
  - functionally critical
  - vulnerable (e.g., elderly, handicapped)

Sanborn maps, building department files, historical surveys, and assessor's records are used as supplemental data sources to the field survey. The result of a building inventory is frequently a map of seismically suspicious buildings.

HOW TO USE TABLE A-1

1) This table will guide the search for commonly available data sources on local earthquake hazards. The list of available sources will help you determine whether or not additional data are needed.

2) The left column of the table divides available planning information sources into three categories: natural systems, earthquakes and associated hazards, and the built environment.

3) The middle column describes how several pieces of information can be interpreted for a more complete picture of seismic risk and potential losses. Planners will need the expertise of a seismologist or geologist when reviewing the base data, particularly if there are any questions regarding the hazards.

4) The right column lists possible sources for much of this information, which typically has not been gathered into one location. Planners may be surprised at the amount of data that are available, but not commonly used by decision makers.

APPLICATIONS

Planners can use the table to learn what general geologic information is available, and then review those data for indications of seismic risk in their locale. Planners that are generally aware of the local hazards can identify the information sources that are likely to give them data on specific hazards and resultant community loss potential. If those data have not been collected for their jurisdiction, the community must determine whether it is worthwhile to gather additional data.

For example, in conducting the case study in Santa Rosa, we used the table to ascertain that the city's data base covers seismic activity, flooding, noise, hillside areas, sewer capacity, and traffic impact. Readily available information on earthquakes and related hazards includes several maps prepared by the State of California (a special studies map, a geologic map, geology for planning). Reports on the earthquake of 1969 also exist. The availability of these data, particularly on surface faulting and landsliding, indicates that certain planning approaches requiring geographic delineation of hazard areas could be considered: open space zoning, purchase of development rights, existing use taxation, and lifeline location. However, because the information on the ground shaking and liquefaction hazards is less geographically precise, these hazards are not amenable to management using the same planning approaches.

TABLE A-1 PLANNING INFORMATION TYPES AND HOW THEY CAN BE USED TO UNDERSTAND LOCAL SEISMIC RISK

Type of Information	What It Can Tell You	Probable Sources
NATURAL SYSTEMS		
• Topographic maps--trace the land contour at regular intervals	• Indicate areas with steep slopes; can be used to calculate slope • Interpretation of physiography may provide clues on faulting or landsliding • Relevant to developing dam inundation or flood plain maps	• U.S. Geological Survey • State geology offices • Most commercial map outlets
• Geologic maps (bedrock or surficial geology)--divide an area into homogeneous cells based on the age and type of geologic material; stratigraphic relationships are sometimes shown	• Fault location; may show direction of movement • Relevant to ground shaking attenuation estimates • Relevant to assessing susceptibility to slope failure and liquefaction	• U.S. Geological Survey • State geology offices • Geology department of local university
• Soil surveys--divide an area into homogeneous cells based on soil type and slope	• Relevant to landslide potential • Relevant to liquefaction potential; indicates soil engineering properties • Relevant to ground shaking attenuation estimates	• Local or regional office of the Soil Conservation Survey (U.S. Department of Agriculture)
• Slope maps--divide an area into homogeneous cells based on the slope percentage	• Relevant to landslide potential	

TABLE A-1 (cont'd)

Type of Information	What It Can Tell You	Probable Sources
• Aerial photos (stereographic) High-altitude or landsat Low altitude	• Indicate faulting through landform analysis • Indicate landslide deposits	• NASA • Commercial aerial photographers
• Maps of subsurface water location--indicate the depth, location, and distribution of subsurface water sources	• Relevant to identifying areas with liquefaction potential • Relevant to predicting landslides (information on changes in water levels, coupled with climate data, can help predict ground failure probability)	• State geology offices
• Maps of vegetation types--divide an area into homogeneous cells characterized by common native vegetation types	• Relevant to identifying areas subject to land-slides (vegetation plays a role in stabilizing hillsides) • Analysis of vegetation patterns may provide evidence of past faulting activity	• Regional office of U.S. Forest Service
• Map showing precipitation contours	• Relevant to predicting future landslide potential in unstable areas	• National Weather Service

TABLE A-1 (cont'd)

Type of Information	What It Can Tell You	Probable Sources
EARTHQUAKES AND ASSOCIATED HAZARDS		
• Map of tsunami run-up areas		• Flood Insurance Administration (FEMA)
• Map of flood inundation		• Flood Insurance Administration • State flood control agency
• Map of active faults	• Identifies probable hazardous areas	For all the remaining information:
• Map of historic earthquakes, showing area and intensity	• Relevant to all hazard mapping	• U.S. Geological Survey • State geologist • Local university
• Map showing predicted ground response due to ground shaking		
• Map of areas prone to liquefaction		
• Map of areas susceptible to landslides		
• Map of past land-slide deposits--a derivative map, usually compiled from air photo interpretation and field examination	• Identifies probable hazardous areas, which may fail again in an earthquake	

TABLE A-1 (cont'd)

Type of Information	What It can Tell You	Probable Sources
BUILT ENVIRONMENT		
• Land use map	• Relevant to estimate of potential earthquake damage	• Local planning or community development department
• Structural type map--indicatesthe type of construction, age, and number of stories; use may be included	• Relevant to estimate of probable earthquake damage (permits a more accurate estimate than a land use map)	• Primary data collection
• Map of transportation facilities--identifies roads, bridges, overpasses, tunnels, and traffic capacities if possible	• Relevant to estimating probable damage to transportation systems (lifelines) from an earthquake	• Local transportation or engineering department
• Map of sewer, water, other utilities	• Relevant to estimating probable damage to critical utility systems (lifelines) from an earthquake	• Appropriate city department, or • Various utility companies
• Population map--shows the distribution of population density; it may be useful to map both a daytime and night-time distribution	• Relevant to estimating exposure to risk and injury in the event of an earth-quake	
• Maps of hazardous installations--indicate the location of storage areas	• Relevant to identifying areas of high risk	• City/county fire department or emergency services office
• Map of dam inundation zone	• Identifies flood potential in the event of earthquake-induced dam failure	• Should be part of federal or state flood plain requirements

HOW TO USE TABLE A-2

1) Use this matrix to assess the resolution provided by existing data. Alternatively, once the level of information detail necessary for a particular purpose is known, this matrix can indicate the types of data that will meet that need.

2) Data on earthquake and associated hazards are developed at different scales, which, for the sake of simplification, fall in three main categories: **regional**, approximately 1:64,000-1:250,000 or greater; **city**, or 1:12,500-1:24,000; or **site-specific.** The level of data resolution reflects how precisely the hazard can be pinpointed. For example, even at a scale of 1:24,000, a line that is 0.01 inch thick covers 20 feet of actual area. At smaller scales, there is even less precision. The severity of the hazard will influence how important it is to be precise. In turn, the level of data resolution will affect the types of approaches that will be effective in hazard mitigation. This will be discussed in much more detail in Part B.

APPLICATIONS

Table A-2 can be used in two situations.

A) The planners have gathered all available information and they want to assess the level of detail prior to identifying planning approach options. For example, one of the city maps may be a 1:250,000 geological map showing faults. Referring to Table A-2, in the surface faulting row, it can be seen that a map that scale falls under the classification of regionwide mapping. Planners can see that knowledge of faults is accurate only to the regional scale.

B) If the city already knows what type of planning technique it wants to apply, Table A-2 will indicate the data that are needed to achieve the level of detail required for each planning technique. For example, the community may want to place a special hazard zone designation on areas with a landslide potential, and therefore it will need data that provide a geographic delineation of hazard areas. The matrix shows that a landslide inventory using time series photos and some fieldwork, or a slope stability map meet the requirements.

TABLE A-2 CLASSIFYING DATA ON HAZARDS BY LEVEL OF DETAIL AVAILABLE

Type of Hazard \ Level of Detail	Regional Mapping	City/Countywide Geographic Delineation of Hazardous Areas	Site-Specific Study
SURFACE FAULTING	1) Regional map showing known and inferred fault location 2) Recurrence interval and magnitude estimates	1) Location of faults using historic data, physiographic analysis, and instrumentation 2) Fault activity classification 3) Fault zone width identification	1) Location of faults and fault traces using instrumentation 2) Fault zone width identification using field investigation 3) Estimates of recurrence interval and magnitude using instrument data
GROUND SHAKING	1) Generalized regional ground shaking intensity map	1) Quantitative regional intensity or peak acceleration map	1) Ground motion modeling using detailed geographic and seismic information
LIQUEFACTION	1) Generalized lique-faction potential map based on soils and hydrologic data	1) Detailed liquefaction potential map using grain size distribu-tion data and estimates of peak surface acceleration	1) Site maps based on field investigations and/or laboratory tests of soil samples
LANDSLIDING	1) Regional map of past landslides using air photos, or 2) Evaluation of soils data and surficial geologic maps 3) Reconnaissance slope stability 4) Terrain analysis	1) Landslide inventory using time series air photos and field investigations, or 2) Slope stability map	1) Detailed landslide hazard inventory, or 2) Quantitative slope stability map

PART B: SELECTING APPROPRIATE PLANNING TECHNIQUES

Contents

Tables

This
page
is
intentionally
blank

PART B: SELECTING APPROPRIATE PLANNING TECHNIQUES

Eleven Planning Approaches

Planning techniques provide a way to modify urban or regional development--its location or building standards/characteristics--in order to reduce the earthquake damage potential. Because land use issues are traditionally the province of local governments, this project focuses on only those actions that local governments can initiate and carry on with little or no outside legislative action or financial support.

This part of the handbook identifies 11 techniques that are commonly used in guiding community development, or that have been developed specifically to deal with seismic and related hazards. The approaches are listed below:

- Zoning ordinances
- Subdivision ordinances
- Sensitive area ordinances
- Building codes
- Hazardous building abatement ordinances
- Special use or critical facility permits
- Environmental impact statements
- Infrastructure (lifeline) development standards
- Real estate disclosure requirements
- Property acquisition
- Tax credits

When evaluating the appropriateness the techniques for mitigating earthquake hazards, it is useful to examine the distinguishing characteristics of each. Four pertinent characteristics to consider are: 1) the means used for influencing development change, 2) the required local government action for adoption, 3) the amount of information required to use the technique, and 4) the aspect/s of the development process affected by each planning approach.

A majority of the techniques are **regulatory**, the most common local government strategy for shaping community development in a fair and equitable manner. Regulatory approaches directly influence land use and development activities by specifying use, structure location and type, construction standards, and building materials. Regulatory mechanisms are generally adopted legislatively and become the laws governing land use. Because of the legal standing and potential liability local governments assume when regulating land use, more precise development restrictions increase the need for a substantial data base. Of the eleven techniques mentioned, the following have regulatory aspects: zoning ordinances, subdivision ordinances, sensitive area ordinances, building codes, hazardous building abatement ordinances, special use permits, and environmental impact statements.

Most of these planning approaches are part of a local government's standard repertoire. However, just as zoning bonuses can be developed to provide public amenities such as street-level recalling or open space, it is possible to modify any planning approach to address earthquake hazards. More detailed descriptions of the techniques, and possible modifications to them, are provided in Table B-1.

Several other techniques work by offering **incentives** to owners and developers to modify development activity in hazardous areas. These approaches rely on presenting an incentive--in the form of increased information or tax benefits--to encourage risk-avoiding behavior. Tax credit programs and real estate disclosure laws are the two primary examples. The creation of the incentive program usually requires government action, for example, the local council will have to adopt a tax credit program or, in the case of real estate disclosure, it must require real estate agents to make hazardous conditions known to a prospective purchaser. Typically, these techniques are used to affect development location and intensity.

Lastly, there are several techniques that **preclude subsequent private development.** Two such techniques are property acquisition and lifeline development standards. Local government purchase of hazardous areas effectively eliminates inappropriate private uses. Standards for lifeline location can steer growth to "safer" areas where water, sewer, roads, and power are already provided. Alternatively, new lifelines can be designed and built in such a manner that they can withstand damage from a severe earthquake. Table B-1 provides greater detail about all 11 of the approaches.

Selecting Your Approach

It is advisable to screen the techniques first to narrow down the possible choices to those that seem potentially appropriate. Those techniques can then be subjected to more in-depth analyses. Four criteria can help you with the screening:

1) **What planning techniques are already adopted by the community?** The types of planning approaches in use, and how well they work, give an indication of what other options are likely to be applied successfully to new situations. For example, if a community already has a zoning ordinance, a modification of that ordinance may be relatively simple. If special studies are already required in flood plains, the same mandate could be extended to areas prone to seismic hazards. However, the list of currently used approaches should not limit what is given further consideration; in some cases, a fresh approach can succeed where more tried and true ones have not.

2 **What is the general nature of the development to be managed?** By clarifying the problem the planning techniques are meant to solve, it is possible to identify the more potentially useful approaches. To take an extreme example, if continued new development in known hazard-prone areas is the concern, zoning provisions would be more appropriate than, say, a building code to regulate structural design.

3) **What information is available on the hazard?** Some techniques require a substantial amount of base information--particularly when it is necessary to specify the boundaries of an area-at-risk. Table B-2 gives a general indication of the minimum amount of information

needed in order to apply each of the techniques presented in the handbook. A community can use the table to determine which approaches are appropriate given the information already available. On the other hand, the community could also decide it wants to utilize a particular approach, and then use the table to ascertain what information must be acquired in order to do so. A decision would then have to be made to expend the resources to collect/develop the needed information.

4) **Political considerations.** Subjective considerations will also affect the selection of planning techniques. For instance, the city council's current attitude towards regulatory proposals or program costs, or the availability of knowledgeable staff to operate a program will influence the choices that are made. Users of this handbook must rely on their own knowledge of the community to guide them.

Taken together, these criteria can guide the user in specifying techniques appropriate for further investigation.

Innovative Possibilities

The list of planning techniques presented in the handbook is not an exhaustive one. The list does represent the most commonly used techniques, but users are strongly encouraged to use it as only a starting point. Techniques may be combined in new ways, or entirely new approaches may be tried. For example, Provo City has established a Site Plan Review Committee to provide an interdisciplinary review of most major development projects. Provo could consider a modification of the existing review process to incorporate an assessment of the earthquake hazard. This could be done with an additional requirement that the developer provide a report on how earthquake hazards may affect the project, indicate how the design will mitigate losses, and provide engineering geology expertise to the committee. This option not only builds on existing approaches, but also adds that aspect of an environmental impact statement which requires applicants to address/discuss potential adverse project impacts.

HOW TO USE TABLE B-1

1) The left-hand column of the table lists 11 planning techniques that could be employed for earthquake hazard mitigation. Two of these techniques have been developed specifically to address the issue of earthquake hazard mitigation: a hazardous building abatement ordinance and real estate disclosure. The remaining techniques are more general, but can be modified by special provisions.

2) The left-hand column of the table identifies some of the options for modification. It is important to note that these represent just some possibilities, and communities should not limit themselves to these. Creativity in designing new tools or combining others is encouraged.

3) A brief description of each planning technique is provided in the center column.

4) The right-hand column briefly describes how the techniques can reduce the loss potential from earthquakes, or other hazards, for existing or future development. This information, coupled with an understanding of the nature of the hazard to be mitigated, is useful in narrowing the list of planning techniques for further consideration

---

HOW TO USE TABLE B-2

1) Table B-2 gives the user an indication of the level of detail on the existing hazard that is generally required in order to apply any one of the planning techniques.

2) The shaded boxes indicate the specificity of information needed. If a box is not shaded, that level of detail is generally considered insufficient for application of the technique. For example, a community with a ground shaking and landsliding hazard that is interested in developing an overlay zone for its zoning ordinance would require, at a minimum, data on the community's geographical area or, even better, on specific development sites. An overlay zone approach can not realistically be considered with only regional data.

3) If the community has data for the landslide hazard but not ground shaking, it might still be possible to develop the ordinance to cover landslides and not ground shaking. It is not necessary for one technique to address all hazards, but it may be more desirable from the community's point of view.

TABLE B-1 PLANNING TECHNIQUES APPROPRIATE TO EARTHQUAKE HAZARD MITIGATION

PLANNING TECHNIQUE	DESCRIPTION	LOSS REDUCTION FUNCTION
1) **ZONING**	Most cities and counties commonly use zoning to regulate the type and location of land uses, structure, siting, structure height and bulk, parcel size, land use intensity, and other development performance standards. Zoning ordinances can be tailored specifically to restrict development near earthquake hazard areas.	Restricts or prohibits new development (by location and/or type of use) in identified areas. Affects the built environment with respect to: • volume • allocation • location • density
Options for tailoring:		
a) **Special Seismic Study Zone**	A separate zone is created and applied to active faults, other well-defined hazards, or a combination of hazards. The ordinance specifies allowable uses and any special development standards (e.g., building setbacks from a fault trace, open space requirements). It would also be possible to write the ordinance requiring a special site evaluation as a means of determining the development standards. California's Alquist Priolo Special Studies Zone Act is an example of this type of zone. There, no structure for human occupancy is permitted to be placed across the trace of an active fault, and all development within the zone must be accompanied by a geologic report. Another option is to develop a series of graduated risk zones (e.g., high, medium, low) and attach appropriate development standards to each.	
b) **Hazard Overlay Zone With Performance Standards**	Rather than create a separate zone as above, a map overlay of hazard-prone areas would define development or performance standards in addition to those contained in the overlay. Supplemental standards might include setback regulations, clearing or grading restrictions, or additional construction standards.	

TABLE B-1 (cont'd)

PLANNING TECHNIQUE	DESCRIPTION	LOSS REDUCTION FUNCTION
c) **Open Space/ Conservation Zone**	Some hazardous areas can be included in a community's open space system, thus providing a dual benefit of meeting a community's open space needs, as well as precluding development that would pose a threat to life and property. For example, a potential landslide area might also be a wildlife or park area that should, according to community goals, be zoned as open space.	
2) **SUBDIVISION STANDARDS**	Most cities have an ordinance which sets procedures and requirements for all land subdivisions. The ordinance may specify development standards for the size and shape of lots and blocks, or street dimensions. Often these ordinances contain availability requirements and/or construction standards for streets, curbs, gutters, sewers, water mains, and sidewalks.	Restricts new development **location** in certain areas. Sets **standards** for site layout and services (roads, utilities, open space).
Options for tailoring:		
a) **Performance Standards for Sensitive Lands**	For certain identified lands, such as those with slopes in excess of 20% or areas with a high water table, the ordinance could allow the city to require special site studies and impose special development standards on a case-by-case basis. (Examples of types of special studies in a steep hillside area include a landslide/slope stability investigation report; a soil engineering investigation report; and a composite geologic and soil engineering report detailing sufficient mitigation measures to reduce potential for land instability.)	
b) **Planned Unit Development**	Planned unit developments (PUDs) can/may be established as a geographically defined zone, or they may be allowed to "float" and locate in any of a number of zones. Because PUDs generally require careful review on a case-by-case basis, hazardous conditions can be addressed in the development plan review. The plan submission requirements can be expanded to include a discussion of any potential hazards and appropriate actions to mitigate them.	

TABLE B-1 (cont'd)

PLANNING TECHNIQUE	DESCRIPTION	LOSS REDUCTION FUNCTION
c) Development Standards	Where hazards are thought to be well understood, a community may choose to add specific development standards to their subdivision ordinance, which would be applicable to all subdivisions (e.g., all structures larger than a certain size may need engineered foundations). For hillside areas, for example, all developments could be required to have adequate drainage facilities to intercept and carry identified or expected surface and subsurface seepage flows to the nearest storm drain or sewer lateral for all hillside development; to have sanitary sewer installations instead of septic tank systems; to have egress and ingress from two independent road systems; to obtain right-of-way easements to preclude development directly adjacent to public improvements in unstable or potentially unstable areas.	
3) SENSITIVE AREA ORDINANCE	A sensitive area ordinance requires that any project falling within the boundaries of an identified area must submit a special study showing how fragile or hazardous conditions will be addressed in development, so that any potential degradation or hazards are minimized. This ordinance has some similarities with a hazard overlay zone.	
4) BUILDING CODES	Building codes protect public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location, and maintenance of all buildings and structures within a jurisdiction (UBC, Chapter 1, Section 102). Since 1961, special seismic standards have been included in the Uniform Building Code. Similar standards are contained in the Building Official Conference of America (BOCA) and the Southern Building Code Congress (SBCC).	Establishes structural standards for different types of new construction.

TABLE B-1 (cont'd)

PLANNING TECHNIQUE	DESCRIPTION	LOSS REDUCTION FUNCTION
Options for tailoring:		
a) Adopt Code Standards	Local governments may choose to adopt the basic building code and its seismic standards. Generally these standards are tailored to different seismic regions across the U.S.	
b) Supplemental Seismic Standards	Local governments can develop or adopt more stringent anti-seismic structural standards to address the hazards in their particular community.	
c) Sub-area Supplemental Seismic Standards	For communities concerned about particular hazards in selected areas, it is possible to adopt structural standards designed for these small areas. Such an approach is used relatively infrequently.	
5) HAZARDOUS BUILDING ABATEMENT ORDINANCE	This type of ordinance is used to require property owners to bring designated substandard and hazardous buildings (or portions of them) into closer conformance with the current building code or possibly be faced with condemnation and demolition. For example, buildings with parapets may be required to anchor the parapet or remove it, or unreinforced masonry buildings may be required to provide anchoring of floors to walls. The property owner is liable for the development costs.	Establishes standards for retrofitting specified existing buildings or building types. May relocation or demolition.
6) SPECIAL USE AND CRITICAL FACILITY PERMITS	A special permit review procedure can be developed for certain uses and critical facilities which the developer requires to prepare more detailed studies, demonstrating that the project will meet applicable safety standards. This would apply to uses which, because of the nature of their use or function (e.g., emergency facility, dangerous operations, dependent population facility or high occupancy building) require a reasonably high margin of safety.	May restrict the location of identified facilities or set design and structural standards for development.

TABLE B-1 (cont'd)

PLANNING TECHNIQUE	DESCRIPTION	LOSS REDUCTION FUNCTION
7) ENVIRONMENTAL IMPACT STATEMENTS (OR REPORTS)	For those states requiring an impact report prior to permit issuance, this review can be used to ensure that seismic concerns are addressed and mitigation options considered. Where state regulatory code allows, special conditions could be attached to the permit, based on the findings in the impact statement. For example, the state may have an impact reporting requirement that could be used or adapted for this purpose.	
8) TAX CREDITS	This program reduces the property owner's tax liability as long as the land is left undeveloped or developed at a very low density. Tax credit programs may take a variety of forms including current use value, deferred use, or a restrictive agreement.	Provides incentive for owner to limit development in seismically vulnerable areas.
9) REAL ESTATE DISCLOSURE	Within identified areas, realtors are required to provide prospective purchasers of real property information on the existence of a natural hazard. Information on the hazard is intended to work as an incentive to take risk avoidance action, such as not locating in the hazardous area, purchasing earthquake insurance, or building to higher structural standards.	Informs purchaser of existing hazard affecting all real estate transactions.
10) PROPERTY ACQUISITION OR PURCHASE OF DEVELOPMENT RIGHTS	These actions put the management of identified hazardous areas into the hands of local government. Once purchased, the lands can be managed to protect public safety and, in some cases, meet other community objectives such as providing open space or low intensity recreation areas.	Restricts or limits development location through property purchase.
11) INFRASTRUCTURE (LIFELINE) LOCATION AND DESIGN STANDARDS	Policies and plans to locate lifelines away from known hazardous areas reduce the community's exposure to losses by steering private development from these areas. Better lifeline design standards can also reduce community loss exposure by insuring that lifelines are more able to withstand damage in an earthquake.	Directs new development location away from hazardous areas. Ensures new lifelines are constructed to meet standards of seismic safety.

TABLE B-2 DATA DETAIL NEEDED TO USE EACH PLANNING TECHNIQUE

Planning Techniques	Hazard Analysis and Mapping	SURFACE FAULTING			GROUND SHAKING			LIQUEFACTION			LANDSLIDING		
		For Region	For Community	For Site	For Region	For Community	For Site	For Region	For Community	For Site	For Region	For Community	For Site
1) ZONING ORDINANCE	Special seismic study zones			●			●			●			●
	Hazard overlays with performance standards		●	●		●	●		●	●		●	●
	Open space/recreation zones		●	●		●	●		●	●		●	●
2) SUBDIVISION ORDINANCE	Design standards		●	●			●		●	●		●	●
	Planned unit development		●	●			●		●	●		●	●
	Location (specified) standards			●			●			●			●
3) SPECIAL USE AND CRITICAL FACILITY	Location specifications			●			●			●			●
	Development standards			●			●			●			●
	Performance standards		●	●		●	●		●	●		●	●
4) BUILDING CODE	Adopt UBC				●	●	●						
	Modify UBC					●	●						
	Modify UBC by sub-area						●						
5) HAZARDOUS BUILDING ABATEMENT ORDINANCE	Performance standards		●	●		●	●		●	●		●	●
	Development standards			●			●			●			●
6) LIFELINE SEISMIC REQUIREMENTS	Locational			●			●			●			●
	Structural		●	●		●	●		●	●		●	●
7) REAL ESTATE DISCLOSURE			●	●			●		●	●		●	●
8) TAX CREDIT				●			●			●			●
9) PROPERTY ACQUISITION	Fee simple purchase			●			●			●			●
	Development rights			●			●			●			●
10) SENSITIVE AREA ORDINANCE			●	●			●		●	●		●	●
11) ENVIRONMENTAL IMPACT STATEMENT		●	●	●	●	●	●	●	●	●	●	●	●

APPLICATION

Bellingham, Washington, is a moderate-sized, growing community located in the northern reach of Puget Sound. It is the largest city in Whatcom County and is, therefore, a major regional service center. It is situated in an area of multiple natural hazards. In applying this framework there, we answered the following questions to select planning techniques for further analysis:

1) **What planning tools are already used?** Current planning approaches in Bellingham include the zoning ordinance, subdivision ordinance, building permits, special permits for shoreline and flood plain developments, the environmental impact statement process, and a development standard for unsuitable areas (steep slopes or unstable soils).

2) **What is the general nature of the development to be managed?** In Bellingham, the hazards in most of the developed parts of the city is ground shaking or subsidence. The city is also growing at a moderate rate and expanding into adjacent areas of the county. Areas of high attractiveness in the urban fringe include some with steep slopes or landslide hazards.

3) **What information is available on the hazard?** Mapped information does exist on geologic hazards in the city and county, although not at sufficient detail to allow application of planning techniques to existing development in the city.

4) **Political considerations?** We identified support among some staff for a sensitive area ordinance. Other staff said that the city council would be very reluctant to consider adoption of a new regulation aimed at earthquake hazard mitigation unless they could compare damages expected without such a regulation.

All the information available led us to conclude that for purposes of further analysis we should consider: a) techniques that only required modifications to existing ones (perhaps reducing some costs associated with implementation); b) techniques directed at future development; and c) techniques that could rely, to at least a certain extent, on existing mapped information.

Thus, we selected for further analysis: 1) modification of the zoning ordinance to more specifically address the seismic risk, 2) modification of the subdivision ordinance to more specifically address the seismic risk, and 3) development of a sensitive area ordinance.

SECTION II

EFFECTIVENESS ASSESSMENT

PART C: IMPLEMENTATION FEASIBILITY

Contents

Tables

This
page
is
intentionally
blank

PART C: IMPLEMENTATION FEASIBILITY

It is important to remember that the availability of the best information possible does not necessarily ensure that a planning technique will be effective in reducing loss potential in the community. Even the most apparently appropriate planning measure, based on the most sophisticated information, will not reduce earthquake damage if it is not implemented. If the political and/or economic trade-offs are viewed by the community as unacceptable, the measure will not work. To determine a technique's chance of being implemented, it is helpful to answer the following question: what kinds of hazard mitigation measures have the best likelihood of being adopted and enforced by the city, and complied with by the populace?

Adoption, Compliance, and Enforcement

Adoption, although fraught with its own difficulties, is a one-time process. Compliance and enforcement are ongoing challenges that demand vigilant personnel and available financial resources. A planning technique is sometimes unpopular in a community for such economic reasons; in another community, the technique may be unpopular for political, social, or similar complex reasons. For instance, since many of the planning techniques have a regulatory dimension, they involve governmental actions to change development or building activities in hazardous areas. The "targets" of the regulation are the individuals, builders, or developers whose activities are supposed to change. In principle, the target groups behave as the regulation specifies, thereby reducing present or future loss potential. In practice, however, some target groups do not abide by regulations because to do so runs contrary to their own vested interests. Needless to say, regulations that are not followed will not have the desired affect of mitigating the earthquake hazard. It is necessary to gather information on how likely it is that a planning approach will be adopted, complied with, and enforced.

Adoption

The adoption of a planning approach can be interfered with by an administrative inability to delineate the hazardous area, or to specify performance criteria for building projects in the hazardous area. For example, information necessary to mapping hazardous areas may not be available and the community may not want to spend the money needed to get it. On the other hand, there may be sufficient information, but there might not be expert staff in key agencies to review all the projects and separate the safe from the unsafe. To ensure adoption, all such local exigencies must be recognized and dealt with.

Compliance

There is no point in securing adoption of a land use planning measure without also providing for compliance to its specifications. Levels of compliance will be influenced by various considerations--social, political, economic, psychological--all of them incentives (or disincentives). For instance, some groups will think that it costs too much to comply, others will see compliance as ethically correct, and still others will will think that community acceptance of a certain regulation is politically and socially desirable. If noncompliance is unlikely to be detected, or if the penalty for noncompliance is not viewed as greater than the benefits derived from engaging in the prohibited activity, the degree of compliance is likely to be low. Therefore, provision must always be made for monitoring activities in the hazardous areas, and for enforcing the regulations.

Enforcement

In general terms, the effectiveness of enforcement depends on 1) how easily noncompliance can be detected, 2) the number of cases to be regulated, 3) the economic and political importance of the cases being regulated, 4) the number of enforcers, 5) the enforcers' incentives to do their jobs, and 6) the ease with which exemptions and variances are granted (the greater the ease, the more difficult the enforcement).

Ways to Determine Implementation Feasibility

The following points must be addressed with respect to each planning technique in order to judge its implementation feasibility:

- Requirements for enabling officials to adopt the technique must be met.
- The technique must be made acceptable to various interests.
- The likelihood of the interests' compliance must be estimated.
- Enforcement difficulties must be anticipated.
- The technique must be made as compatible as possible with other community objectives.

Tables C-1 through C-11 present the ABCs of determining implementation feasibility for each of the 11 planning techniques. Table C-12 summarizes important considerations for all techniques.

HOW TO USE TABLES C-1 THROUGH C-11

A separate table is provided for each planning technique.

1) The left column indicates the types of questions that need to be answered about the feasibility of getting it adopted, having a high level of compliance with it, and being able to enforce the way in which it is applied. Other considerations affecting implementation feasibility also are addressed where applicable.

2) The right column indicates types of information that will be gathered on implementation feasibility when it suffests that less than full implementation can be expected for one or more reasons, the planning technique should be considered with caution.

3) However, it should be noted that a negative assessment of the implementation feasibility of a particular technique, rather than simply being considered as grounds for rejecting the tool, can be used as a guide for what elements in the implementaiton process will take extra attention.

HOW TO USE TABLE C-12

Table C-12 summarizes for each technique other important considerations for implementation potential

1) Each of the techniques is listed down the left-hand column.

2) In the columns to the right, description is given of additional important analytical elements to consider. As the individual column heads indicate, the implementation of any technique involves: the target group (whose behavior is to be affected); who is likely to be in control of the implementation process; what additions or modifications need be made to establish the technique; what will be enforce or monitored; and what is the most likely barrier to full implementation.

TABLE C-1 IMPLEMENTATION FEASIBILITY: ZONING

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. **Can it be adopted?**	
1. Can hazardous areas be delineated?	Mapping can be time-consuming and expensive, depending on level of existing information and level of detail required.
2. Are there undeveloped areas where zoning would apply?	Zoning would be most effective in lesser developed areas.
3. Can performance standards be developed?	Additional study would likely be necessary to establish standards. Possible further staff expertise required to review plans to ensure standards are met.
B. **How likely is compliance?**	
1. Is there much existing development in the hazardous areas?	Where there is already nonconforming use, variances are more likely.
2. How much change would be required in existing zoning designations?	Large changes create greater pressure for granting variances and may entail higher "opportunity costs."
3. What is the size and value of parcels in affected areas?	Large, high value parcels are in a better position to negotiate variances.
4. Is there a legal incentive for developers to comply?	If failure to comply might make developers liable, compliance more likely.
5. Is there an economic incentive for developers to comply?	Direct economic incentive may make compliance more likely.

TABLE C-1 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
C. **How difficult is enforcement?**	
1. Will the city have the ability to assess conformance with zoning categories or development standards?	Inability to detect nonconformance diminishes enforcement success and thereby undermines effectiveness.
2. Is it possible to detect nonconformance with specific project requirements?	Inability to detect nonconformance undermines effectiveness.
3. Is there much willingness to grant variances?	Variances from standards undermines their utility.
4. What is the economic value of future developments in the hazardous areas to the jurisdiction in terms of tax revenues, employment?	Jurisdiction may be more willing to permit variances in order to not lose high value developments.
5. Is there likely to be follow-through on implementation by the local jurisdiction?	Less than total implementation undermines effectiveness.
D. **Other considerations**	
1. Primarily, who will be affected by the zoning ordinance?	Most likely to affect developers. Target groups can influence political acceptability of tool.
2. Political support.	Ease with which tool can be adopted and enforced may depend on political endorsement and support.

TABLE C-2 IMPLEMENTATION FEASIBILITY: SUBDIVISION ORDINANCE

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can hazardous areas be delineated?	Mapping can be time-consuming and expensive, depending on level of existing information and level of detail required.
2. Can seismic safety design and performance standards be developed?	Establishes whether or not such requirements can be used.
3. Are future subdivisions anticipated?	This tool would only apply to future subdivisions.
B. How likely is compliance?	
1. Are there legal and economic incentives for the subdivision developer to comply?	Requirements viewed only as economic disincentives may prompt developer to go elsewhere, ignore requirements or dispute requirements.
2. Are there alternative sub-division sites available in nonhazardous areas?	If other sites are available, developer is likely to use them.
C. How difficult is enforcement?	
1. Will requirements be developed for individual subdivisions?	Negotiating requirements for each subdivision requires staff skilled in such negotiations and knowledge of subdivision problems.
2. What is the economic value of future subdivisions to the local jurisdiction in terms of tax revenues, employment?	Jurisdiction may be more willing to weaken requirements in order to not lose high value developments.

TABLE C-2 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
3. How difficult is it to detect nonconformance with the requirements for each subdivision?	Enforcement effectiveness related in part to ease of detecting nonconformance.
D. Other major considerations	
1. Primarily who will be affected by such a modification to the subdivision ordinance?	Most likely to affect developers. Target groups can influence political acceptability of tool.
2. Political support.	Ease with which tool can be adopted or enforced may depend on political endorsement and support.

TABLE C-3 IMPLEMENTATION FEASIBILITY: SENSITIVE AREA ORDINANCE

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can sensitive areas be delineated?	Mapping can be time-consuming and expensive.
2. Is it possible to specify the types of reports to be required for different developments?	Necessary to formalize requirement to apply ordinance consistently.
3. Is it possible to develop "performance standards"?	Such standards would be necessary to establish development conditions
4. Are there undeveloped areas where this ordinance would apply?	Ordinance most applicable to undeveloped areas.
B. How likely is compliance?	
1. Is there much existing development in the potential sensitive areas?	Where development already exists in areas to be designated as sensitive, variances are more likely.
2. Is there an economic incentive for developers to comply?	If such an incentive exists, compliance more likely.
3. Are there alternative development sites available?	If other sites exist a developer could choose to go there; however, this ordinance most likely to lead to design or structural modification, not total restriction.

TABLE C-3 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
C. **How difficult is enforcement?**	
1. Is it possible to assess the adequacy of special site reports and prepare development standards or mitigation requirements on a case-by-case basis?	Inability to assess report adequacy diminishes enforcement success and thereby undermines effectiveness.
2. What is the economic value of future developments in these areas to the jurisdiction in terms of tax revenues, employment, etc.?	May affect willingness of jurisdiction to condition development proposals.
3. What is the willingness to reduce development standards for particular projects?	Much willingness may weaken ordinance; however, some flexibility necessary for adoption.
4. Is it possible to detect nonconformance with specific project requirements?	Inability to detect nonconformance undermines effectiveness.
5. Is there likely to be follow-through on implementation by the local jurisdiction?	Less than total implementation undermines effectiveness.
D. **Other considerations**	
1. Primarily who will be affected by a sensitive area ordinance?	Most likely to affect developers. Target groups can influence political acceptability of tool.
2. Political support.	Ease with which tool can be adopted and enforced may depend on political endorsement support.
3. Compatibility with other goals and programs?	The more compatible the better.

TABLE C-4 IMPLEMENTATION FEASIBILITY: BUILDING CODE SEISMIC REQUIREMENTS

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can seismic safety standards be developed, or amended?	Such standards would be necessary to establish code requirements.
B. How likely is compliance?	
1. What are the economic or legal incentives of builders to comply?	If there are few incentives, requirements may be ignored.
2. What is the availability of building sites in non-seismically hazardous areas?	Adequate knowledge of nonhazardous areas makes it more likely that building activity will relocate rather than build to more stringent standards.
3. What are the size and value of buildings affected?	Large, high-value parcels may be in a better position to negotiate exemptions.
C. How difficult is enforcement?	
1. How difficult is it to assess conformance with building requirements?	Inability to detect nonconformance diminishes enforcement success and thereby undermines effectiveness.
2. What is the willingness to grant exemptions?	Exemptions from standards undermines their utility.
3. What is the economic value to the jurisdiction of buildings subject to seismic standards?	Jurisdictions may be more willing to grant exemptions or otherwise weaken the requirements in order not to lose high-value development.
D. Other considerations?	
1. Political support.	Suggests ease with which policy tool can be adopted, plus willingness to grant exemptions/impose sanctions.

TABLE C-5 IMPLEMENTATION FEASIBILITY: HAZARDOUS BUILDING ABATEMENT ORDINANCE

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can the hazardous buildings be identified?	Potentially hazardous buildings must be precisely identified, although fairly general criteria can be used to isolate buildings requiring an inventory.
2. Is it possible to prepare retrofitting standards?	Inability to define standards would make ordinance preparation difficult.
B. How likely is compliance?	
1. What is the economic or other incentive for property owners to comply?	Potential liability would make compliance more likely.
2. What are the size and value of buildings affected?	The higher the building value the more likely the owner can afford the retrofitting cost.
3. Is there a mix of private/ public building ownership in affected areas?	Retrofitting of public buildings demonstrates the city's commitment to the program. If most of the buildings are private, city has less leverage and greater difficulty in showing benefits of program.
C. How difficult is enforcement?	
1. How difficult will it be to assess property owner conformance with retrofitting requirements?	Enforcement effectivenss related in part to ease of detecting non-conformance.

TABLE C-5 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
2. What is the willingness to reduce retrofitting requirements for specific buildings?	Willingness to reduce requirements could weaken the program; however, flexibility might also be necessary to gain political support.
3. What is the economic value to the city of buildings and/or uses subject to retrofitting requirements?	Jurisdiction may be more willing to negotiate requirements for high value buildings.
D. Other considerations?	
1. Political support.	Ease with which a tool can be adopted and enforced may depend on political endorsement and support.

TABLE C-6 IMPLEMENTATION FEASIBILITY: CRITICAL FACILITY AND SPECIAL USE PERMIT

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can hazardous areas generally be defined?	Establishes the geographic area for which the requirements would apply.
2. Can uses and facilities be identified that would be subject to permit?	Establishes whether or not such requirements can be used.
3. What future facilities are anticipated?	This tool only applies to future development of facilities.
B. How likely is compliance?	
1. What is the economic incentive of the facilities to comply?	If compliance is costly, facility may not be built or may be put elsewhere. If a public facility, may involve rate increases/approval.
2. What is the availability of alternative facility sites in nonhazardous areas?	If other sites are available, facility may use them. May lead to development shifting to another jurisdiction.
C. How difficult is enforcement?	
1. Does local capability exist to specify requirements for individual facilities?	Negotiating requirements for each facility requires staff skilled in such negotiations.
2. What is the economic value of future facilities to local jurisdiction.	Jurisdiction may be more willing to weaken requirements for high value facilities.

TABLE C-6 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
3. What type of ownership will potential facilities have?	Mix of public/private complicates negotiating. May not have authority for some types of facilities.
4. How difficult will it be to detect nonconformance with requirements for each facility.	Enforcement effectiveness related in part to ease of detecting nonconformance.
D. **Other considerations**	
1. Political Support.	Ease with which the tool can be adopted, and willingness to negotiate specific requirements are related to the level of political support.

Table C-7 IMPLEMENTATION FEASIBILITY: ENVIRONMENTAL IMPACT STATEMENT

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Are large-scale developments expected in hazardous areas?	This establishes the need for this tool.
2. Can hazardous areas be delineated?	This is necessary for requiring on-site geologic investigations. Mapping can be expensive and time consuming.
B. How likely is **compliance?**	
1. What is the economic incentive of the property developer to undertake special seismic studies?	If compliance is costly, developers will go elsewhere or provide only minimal coverage.
2. What is the availability of alternative development sites?	If other sites are available, the developer is likely to use them. If not, development may be shifted to other areas.
C. How difficult is enforcement?	
1. Is there expertise to determine necessity for evaluating the earthquake risk?	More than minimal information will not be provided, unless it is clear that it is required.
2. What is the economic value of future developments to the local jurisdiction?	For more profitable developments the jurisdiction may be less willing to require and/or act on earthquake hazard information.
3. What is the number of future developments likely to be by affected a special seismic review?	As the number of developments increases, more administrative staff/expertise may be required.

TABLE C-7 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
4. What is the seriousness which EIS review agencies attach to seismic hazards?	If agencies not concerned about the hazard, the EIS information will have little impact on agency actions/design requirements.
D. Other considerations	
1. What is the compatibility of the EIS seismic safety provision with other provisions?	Greater compatibility makes adoption more feasible and likelihood of acting on information higher.
2. What is the expertise of the review agency?	Information will be taken more seriously and legal challenges to decisions based on earthquake information will be fewer if agency staff has earthquake expertise.

TABLE C-8 IMPLEMENTATION FEASIBILITY: TAX CREDITS

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can hazardous areas be delineated?	Establishes geographic area in which credits would be available so number and types of potentially affected properties can be determined.
2. What is the existing use of properties in these areas?	Existing nonconformance with eligible uses affects suitability of program to area (because program geared at avoiding future nonconforming uses).
3. What is the ownership of property in the affected areas?	Complex public/private mix of ownership increases adoption and implementation difficulties.
4. Is such a program legal?	In some states, for example, some forms of tax credit (e.g., current use taxation) are against the state constitution.
B. How likely is compliance?	
1. What is the economic incentive for property owners to opt for current use taxation?	If opportunity cost of use restriction is great, participation will be low.
2. What is the economic value of property in future unregulated uses to local jurisdiction?	Jurisdiction may be less willing to restrict use (to open space or other less hazardous uses) of high value property.
3. What is the turnover of property in affected areas by likely participants?	Higher turnover creates less incentive to take credit, adds to the administrative burden of running the program.

TABLE C-8 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
C. **How difficult is enforcement?**	
1. How difficult will it be to detect nonconformance with use restrictions among those taking tax credit?	Constant checking may be required to determine compliance.
2. What is the willingness to impose penalties for non-conformance?	If not imposed, compliance with use restrictions is less likely.
D. **Other considerations**	
1. Political support.	Affects the ease with which program can be adopted.

TABLE C-9 IMPLEMENTATION FEASIBILITY: REAL ESTATE DISCLOSURE

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can hazardous areas be delineated?	The more difficult and expensive the mapping effort is, the more difficult adoption of such a tool will be.
2. Are property sales in seismic areas anticipated?	Real estate turnover is the point at which the policy has its impact. This also indicates the amount of potential impact.
B. How likely is compliance?	
1. What is the willingness of real estate agents to disclose hazardous area information?	This willingness is the key to implementation of this tool, affected by turnover of agents, sales patterns, sanctions, enforcement and mapping quality and availability.
C. How difficult is enforcement?	
1. What is the ability to detect failure to disclose?	Compliance is less likely if conformance is difficult to detect.
2. What are the sanctions for failure to disclose?	Compliance is less likely if the sanctions are weak; yet if they are too strong, the tool may not be enforced.
3. What is the volume of real estate transactions and does it vary?	As the volume of transactions goes up, more enforcement/administrative apparatus may be required.

TABLE C-9 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
D. **Other considerations**	
1. How likely are buyers to consider the earthquake hazard to be serious?	If potential buyers are not concerned about the hazard, disclosure will have little impact on purchase or mitigation behaviors.
2. What is the endorsement and support of real estate/ regulatory authorities?	Since real estate agents are the critical implementation link, endorsement is important.

TABLE C-10 IMPLEMENTATION FEASIBILITY: PROPERTY ACQUISITION

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. **Can it be adopted?**	
1. Can hazardous areas be delineated?	This establishes the appropriateness of this tool and would indicate the number and type of potentially affected properties.
2. Can the jurisdiction establish a financing mechanism for such a program?	Without funding the jurisdiction cannot acquire properties, and the extent of funding (as well as cost of property) determines number that can be acquired.
3. What is the ownership of property in affected areas?	A complex public/private mix of ownership makes it more difficult to adopt and implement.
B. **How likely is compliance?**	
1. What is the economic incentive of the property owner to sell the property?	If cost and other concessions are not suitable, acquisition cannot be made.
2. What is the economic value of property in its existing use to the local jurisdiction?	Jurisdiction may be less willing to downgrade use of high value property.
C. **How difficult is enforcement?**	
1. Is there likely to be follow-through on implementation by the local jurisdiction?	If the jurisdiction acquires a property fee simple, there should be no enforcement issue. If only the development rights are purchased, the jurisdiction would want legal recourse in the event a property is developed at a different density or for a use than allowed.

TABLE C-10 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
D. **Other considerations**	
1. Public concern for the earthquake risk.	This will affect willingness of the voters to support referenda approving public financing of the acquisition program.
2. Endorsement and support of elected officials.	Affects ease with which tool can be adopted.

TABLE C-11 IMPLEMENTATION FEASIBILITY: LIFELINE LOCATION/DESIGN

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
A. Can it be adopted?	
1. Can hazardous areas be delineated?	Establishes geographic area where tool would apply. Delineates (potential) location of lifelines.
2. Can design/development standards be prepared for infrastructure development?	Inability to define reasonable standards would make adoption impossible.
3. Will existing or future lifelines be affected by these standards?	Locational standards only apply to future lifelines. As number of affected lifelines increases more negotiations required.
4. Can negotiated agreements be made between the local government and the lifeline owners (service providers)?	Open communication required to negotiate a memorandum of understanding or other agreements. Multiple public/private ownership complicates negotiation.
B. How likely is compliance?	
1. What is the need for these lifelines to support growth demands?	High need for new lifelines increases difficulty of redirecting service extensions.
2. Are alternative locations in nonhazardous areas available?	Lack of alternative sites may lead to development being shifted to other cities if cannot be redirected in local area.
3. Is there any economic incentive to comply?	May be possible to demonstrate to service provider that better design of facilities will reduce future losses due to earthquakes (and other natural disasters). Increases willingness to comply.

TABLE C-11 (cont'd)

FEASIBILITY CONSIDERATION	HOW IT AFFECTS IMPLEMENTATION
C. How difficult is enforcement?	
1. Can design and/or locational plans be developed for each lifeline?	Requires a staff with knowledge of technical problems and the capabilities to negotiate requirements.
2. Can the jurisdiction maintain negotiated agreements with the service provider?	Jurisdiction needs tools to ensure that service provider follows through with memorandum of understanding.
3. What is the economic value of future lifelines to the city?	The value of the lifelines to jurisdiction may affect willingness to do without relocation.
D. Other considerations	
1. Political support.	Affects the ease with which tool can be adopted as well as the willingness to negotiate relocation specifics.

APPLICATION

Following is an example from the field test done in Bellingham, Washington. The potential for adopting a sensitive area ordinance, obtaining compliance with it, and enforcing it are examined (see table C-3). The sensitive area ordinance is considered in the specific context of Bellingham.

A. Can a sensitive area ordinance be adopted?

1) Can these areas be delineated?	**Yes.** Possible sensitive areas, including seismic hazards, are already mapped. Professional judgement is needed to determine which areas should be labeled sensitive.
2) Is it possible to specify the types of reports to be required for different developments?	**Yes.** In essence, this is already generally defined in the existing ordinance and through current practice. The requirement needs formalization.
3) Is it possible to develop "performance standards"?	**It would be difficult,** and perhaps detailed standards are not necessary. Assuming a qualified professional reviewed the site-specific studies, conditions can be tailored on a case-by-case basis.
4) Are there undeveloped areas where this ordinance would apply?	**Yes.** The city is expanding into fringe areas of the county and continues to be infill development within the city. However, a better calculation of the amount of land potentially affected is needed.

B. How likely are developers to comply with such an ordinance?

1) How much existing development is there in the potential sensitive areas?	**A moderate amount.** Areas over the old coal mines are extensively developed and it may be difficult to place very strict on projects. In addition, there is some residential development along shoreline bluffs.

2) What is the economic incentive to comply?	There will be a **strong incentive** to comply since the local government will not issue the appropriate permit unless there is compliance. However, if the study and potential mitigation costs appear too high, there may be a tendency to avoid development. Generally, study costs are scaled to development size.
3) Are there alternative development sites available?	**Yes.** A developer could choose to go elsewhere, but that is less likely since this ordinance leads to modifications, not total restrictions.

C. How difficult is enforcement likely to be?

1) Is it possible to assess the adequacy of special site reports and to prepare development standards or mitigation requirements on a case-by-case basis?	Only to a **limited degree**, given present staffing in the city and county. Implementing a sensitive area ordinance would require either hiring an engineering geologist or having one on retainer. This would be an added cost.
2) What is the economic value to the jurisdiction of future developments in these areas in terms of tax revenues or employment?	**This will vary**, and may have an effect on how willing the city or county is to approve development proposals. However, most of the affected development will be for residential uses. Development may be conditioned, but probably not prohibited.
3) What is the willingness to reduce development standards for particular projects?	This is difficult to predict, but it is **likely there will be some.** The county and city will want to avoid placing an undue burden on developers, especially if that would make an economically valuable project unfeasible.
4) Is it possible to detect non-conformance with specific project requirements?	**Yes,** there are multiple checks. Most of the requirements will be reflected in the project design, which must be approved prior to the issuance of a building permit. There are also three site inspections prior to occupancy.

5) Is there likely to be follow-through on implementation?	**Yes,** although there may be a breakdown when it comes to imposing sanctions since this takes place through the county prosecutor.

D. Are there other considerations that affect implementation feasibility?

1) Primarily who will be affected by the ordinance?	**Private developers,** generally those engaged in residential projects or a few industrial and commercial/retail endeavors.
2) Is there likely to be political support for this ordinance?	**That is unclear.** Any regulation tends to generate opposition in the area, and the county staff indicated that the time might not be right. However, this ordinance is similar to existing standards and formalizing it will provide development predictability.
3) How compatible is the sensitive area ordinance with other goals or programs?	**Very.** As mentioned earlier, it is similar to the concept of "unsuitable lands" which is now used by both the city and county. Such an ordinance could also be jointly administered since the city and county already have such an arrangement with certain codes.

TABLE C-12 CONSIDERATIONS IN DETERMINING IMPLEMENTATION FEASIBILITY

PLANNING TECHNIQUE	TARGET GROUP	CONTROL OF IMPLEMENTATION	PROGRAM DEVELOPMENT AND ADOPTION	ADMINISTRATION AND ENFORCEMENT	IMPLEMENTATION BARRIERS
1) ZONING	Developers • individual builders • large-scale developments	Local entity has direct control through its zoning authority)	Revisions or possible new ordinance • zoning maps • performance standards	Conformance with zoning standards	Undermined by granting of variances; may not be able to detect nonconformance for some standards
2) SUBDIVISION ORDINANCE	Developers • large-scale developments	Local entity has direct control; negotiates standards for each subdivision	Development of subdivision ordinance	Conformance with negotiated requirements	May not be able or willing to negotiate strong seismic provisions because of economic interests
3) SENSITIVE AREA ORDINANCE	Developers • individual builders • large-scale	Local entity has direct control (through administration of ordinance)	Development of ordinance and standards	Conformance with ordinance standards	Undermined by granting of variances; may not be able to detect nonconformance for some standards
4) BUILDING CODE SEISMIC REQUIREMENTS	Owners/managers of future buildings in seismically vulnerable areas	Local entity has direct control through building department	Can adopt UBC seismic standards and/or develop own standards	Conformance with seismic safety standards as part of construction and permit process	Undermined by weak enforcement/exemptions; may be difficult to detect nonconformance for some standards
5) HAZARDOUS BUILDING ABATEMENT ORDINANCE	Owners/managers of existing buildings in seismically vulnerable areas	Local entity has direct control through building department	Can adopt previously developed standards and/or develop own standards	Must identify nonconforming buildings; enforce conformance as part of building inspection process	Undermined by weak enforcement/exemptions; may be difficult to detect nonconformance for some standards

TABLE C-12 (cont'd)

PLANNING TECHNIQUE	TARGET GROUP	CONTROL OF IMPLEMENTATION	PROGRAM DEVELOPMENT AND ADOPTION	ADMINISTRATION AND ENFORCEMENT	IMPLEMENTATION BARRIERS
6) CRITICAL FACILITY AND SPECIAL USE PERMITS	Operators/owners of seismically vulnerable special facilities (e.g., schools, nuclear facilities)	Local entity control depends on authority to regulate facility; negotiates specific requirements for each facility	Design of requirements for each class of facility	Conformance with negotiated requirements	May not be able or willing to negotiate strong seismic provisions because of cost to facility and need for the facility
7) EIS REQUIREMENTS	Developers of large-scale developments	Local entity has indirect control (through administration of EIS, required by state)	State develops EIS requirements	Conformance with requirements	Undermined by weak enforcement/exemptions
8) TAX CREDIT for land uses which are compatible with seismic hazards	Owners of property in seismically vulnerable areas	Local jurisdiction provides incentives (assuming has tax levy authority); participation is voluntary	Ordinance specifying eligibility for tax credits	Must identify eligible properties; monitoring of land use as part of assessment practices	Property owners may not find the tax credit amount sufficient to induce land use changes
9) REAL ESTATE DISCLOSURE of seismic vulnerability	Purchasers of property in seismically vulnerable areas	Local entity control is indirect; requires cooperation of real estate agents and target group response to information	Local entity must delineate seismic zones, prepare maps, establish disclosure requirements	Requires monitoring of disclosure practices (presumably by real estate board)	Undermined if agents/boards not willing to disclose and monitor disclosure; disclosure itself means little unless purchaser concerned with hazard

TABLE C-12 (cont'd)

PLANNING TECHNIQUE	TARGET GROUP	CONTROL OF IMPLEMENTATION	PROGRAM DEVELOPMENT AND ADOPTION	ADMINISTRATION AND ENFORCEMENT	IMPLEMENTATION BARRIERS
10) PROPERTY ACQUISITION for property in seismically vulnerable areas	Owners of property in seismically vulnerable areas	Local jurisdiction provides incentives; participation is voluntary	Requires identification and authority to purchase property; may require special public financing/approvals	No enforcement required other than normal policing of acquired property	Property owners may not be willing to sell at price offered; voters may not authorize/financing hard to obtain
11) LIFELINE LOCATION AND DESIGN FOR SEISMIC SAFETY	Agencies which own/operate lifelines (e.g., water mains, sewers, gas lines)	Local entity control depends upon ownership of lifeline; must negotiate specific requirements for each lifeline	Design of acceptable locations for siting lifelines and/or performance	Conformance with negotiated locational or performance requirements	Ability to control lifeline decisions may be limited; may not be willing to have strong seismic provisions because of ratepayer cost

This
page
is
intentionally
blank

PART D: CONSIDERING DEVELOPMENT CONTEXT AND OTHER COMMUNITY OBJECTIVES

Contents

page

Tables

This
page
is
intentionally
blank

PART D: CONSIDERING DEVELOPMENT CONTEXT AND COMMUNITY OBJECTIVES

The appropriateness of a particular land use planning technique and the likelihood that it can be implemented must be judged against the situation in the community for which it is proposed. The relationship of the existing development pattern to the hazard area is one important contextual factor. Another is the social, economic, and political environment of the community--that is, any community decision, such as implementing one of the land use planning techniques discussed in this handbook, is a reflection of what is acceptable to various interests and compatible with other community objectives. Both the development context and the political context must be taken into account, along with the nature of the earthquake hazard, when selecting an appropriate land use planning technique for reducing losses from future earthquakes.

The Context of Development Pressures

There are five features of the development context that affect the selection of relevant land use planning techniques:

- the physical nature of the hazard,
- the intensity of development in hazardous areas,
- the community growth rate,
- the availability of alternative development sites outside hazardous areas, and
- technical considerations.

The nature of the area's hazard affects the appropriateness of land use planning techniques. Areas with geographically definable hazards are more likely to be able to adopt more precise techniques. For instance, if the geographic area of the hazard has been precisely delimited, then it is possible to adopt techniques such as zoning or subdivision ordinances that have explicit prohibitions or performance standards for development. Geographically definable hazardous areas include those assessed as likely to be subject to faulting, landsliding, or flooding (from tsunamis or dam failure).

If, however, the nature of the hazard is defined as ground shaking from earthquakes, and the hazard is diffused over the entire area of the community (developed and undeveloped), it is not feasible to adopt zoning ordinances to mitigate earthquake loss potential. In such an instance, construction standards for all new development would be easier to institute.

With respect to existing development in high-hazard areas, certain portions might come to be viewed as particularly vulnerable, either because of their location (e.g., on areas prone to liquefaction or subsidence) or because of their construction characteristics (e.g., unreinforced masonry). In such instances, regulations might require the relocation of certain types of existing development (e.g., hospitals or schools) to a less hazardous area, or at least the reinforcement of buildings or lifelines.

In areas where there is already extensive development in identified seismic risk zones, jurisdictions are likely to be wary of restricting new development for fear of litigation over equal protection. In addition, those areas with a high concentration of development and services tend to attract additional development. Economic and political pressure may be brought to bear for access to those areas, making land use restrictions difficult to apply and enforce.

A related issue is whether there are available development sites in the surrounding area. In jurisdictions where few new sites remain, economic demand will make it difficult to restrict new development, even if hazardous conditions exist. While restricting development through zoning may not be feasible, enforcing stricter building standards may be acceptable.

Large, rapidly growing areas may be willing to consider the adoption of land management controls to reduce future earthquake hazards. Areas subject to rapid growth often are more receptive to applying controls because the problems associated with unregulated development are generally exacerbated during boom times. Again, however, the availability of developable sites is important in a community's receptivity to land use management controls.

Finally, the complexity of the hazard in a particular area may require considerable technical expertise for its definition or mitigation. As was noted in the preceding section on implementation feasibility, a jurisdiction may lack the economic resources or staff capability to provide the precisely defined boundaries of a particular hazard area. For example, considerable technical expertise may be needed to designate areas particularly prone to intensified shaking, liquefaction, or subsidence. A community must have or acquire the technical expertise to determine the exact location of such areas before it can adopt and enforce land use planning controls.

Where it is known that particularly hazardous areas are likely to be present, but large-scale and precise mapping of them has not been accomplished, it is also possible to shift the burden of identifying the hazardous areas to the developer. This is done through the adoption of management techniques requiring that certain performance standards be met, rather than by specifying what type of development is or is not permitted in a specific area. In this instance, the jurisdiction still must have the necessary technical expertise to review the plans, but will be spared the cost of the hazard study.

Earthquake Hazard Mitigation and Other Objectives

The need to attend to the threat of an earthquake has, for may communities, little sense of urgency. Often political support is minimal for earthquake mitigation and preparedness activities and, in a list of priority activities for local officials, earthquake preparedness might rank in the lower third. On the other hand, even when a community has decided to address earthquake concerns, it may be possible to sell the idea of earthquake risk reduction only as it enhances another community objective, such as reducing potential damage from flooding or landsliding. Thus, the interaction between earthquake mitigation and other community objectives can sometimes be both positive and negative.

It is important for planners to remember that such interactions exists and can be important to the ultimate implementation of any particular technique. It is also important to realize that implementation of any planning technique in a community often involves a series of trade-offs and compromises. The series of questions asked in Part C on the feasibility of implementing a selected technique aims, in part, at this point. Political acceptability is particularly important. This section serves as a further reminder that other interests and objectives exist in each community, and that they can, in some cases, enhance or compete with the goal of earthquake hazard mitigation.

Table D-1, which follows, provides examples of the ways in which the specific planning techniques may enhance or conflict with other community objectives. A primary concern is how compatible the proposed program of risk reduction is with existing community goals and programs. Where goals compete, it will be necessary to decide priorities in the political arena. Where the actions necessary to reduce the damage potential from earthquakes might well enhance other community objectives, the creative design of planning initiatives to capitalize on this is in order.

In any policy decision, the community social, economic and political context will be a factor. While the physical development context can be defined in fairly general terms, the social, economic and political context of a community is more idiosyncratic. For example, the amount of effort needed to implement an earthquake-related land use policy in a particular community will be influenced by such things as the general predisposition locally for or against regulation, time-specific budget constraints, current rulings on legal liability, or the overall importance placed on seismic hazards as one of many community agenda items. These factors cannot be quantified and entered into a formula, but they will be influential in the ultimate decision to adopt--or not to adopt--an earthquake loss reduction program. The insight of a community's planners and administrators is necessary for identifying how these factors will affect attempts to implement any land use planning techniques.

HOW TO USE TABLE D-1

1) This table offers, for each of the 11 planning techniques identified in Part C, an example of how the technique might enhance or conflict with another community objective. The examples provided here are illustrative, and not necessarily exhaustive. Users of this handbook, familiar with their own community situations, undoubtedly will be able to identify other possible interactions between a technique to reduce earthquake damage and other community objectives.

2) The planning techniques are listed in the left-hand column, and possible ways in which each technique might enhance or conflict with other objectives are listed in the next two columns.

TABLE D-1 INTERACTION OF PLANNING TECHNIQUES WITH OTHER COMMUNITY OBJECTIVES

Planning Technique	Could **enhance** another community objective such as:	Could **conflict** with another community objective such as:
ZONING ORDINANCE	Reduction of the flood hazard	Economic development
SUBDIVISION ORDINANCE	Reduction of the landslide hazard	Private developers' provision of low-cost housing
SENSITIVE AREA ORDINANCE	Preservation of open space	Minimize government regulations
BUILDING CODE	Improved public safety	Minimize government regulations
HAZARDOUS BUILDING ABATEMENT ORDINANCE	Improved emergency preparedness	Historic preservation
CRITICAL FACILITY PERMIT	Improved public safety	Minimize government regulations
ENVIRONMENTAL IMPACT STATEMENT	Growth management	The encouragement of development projects
TAX CREDIT	Preservation of agricultural land	Economic development
REAL ESTATE DISCLOSURE	Protection of sensitive areas	Real estate agents' right to practice
PROPERTY ACQUISITION	Preservation of open space	Maintenance of existing development patterns
LIFELINE LOCATION/DESIGN	Growth management	Maintenance of existing development patterns

*The examples given here are meant to be illustrative, not exhaustive.

This
page
is
intentionally
blank

PART E: DETERMINING THE COSTS OF TECHNIQUES

Contents

Tables

This
page
is
intentionally
blank

PART E: DETERMINING THE COSTS OF TECHNIQUES

The costs associated with implementing a particular planning technique are an important consideration in an overall assessment of its risk reduction potential. Costs can be estimated for each of the three implementation stages--adoption, compliance, and enforcement. Costs can also be broken down according to how much is borne by government and by the private sector. Any way you look at it, however, there are both front-end and future costs.

It is always most useful to be able to identify dollar figures, although that can be difficult. There is some value in estimating only level of cost (high-moderate-low). A final detailed evaluation of a planning technique in a particular community does, however, require dollar amounts for the costs of implementation.

HOW TO USE TABLES E-1 THROUGH E-11

The following 11 tables identify the categories of costs associated with the implementation of each of the techniques.

1) The left-hand column identifies types of costs for adoption, compliance, and enforcement.
2) The middle column describes the costs in terms of who bears the cost and when.
3) The far right-hand column provides a brief description of how each cost can be assessed.

TABLE E-1 COST CONSIDERATIONS: ZONING ORDINANCE

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to identify and map the hazardous areas?	Front-end cost to be borne by city and/or county.	Will field work be required? Additional staff expertise? Consulting expertise?
2) Will new zoning maps be required, and what would their costs be?	Front-end cost to city or county.	New maps? Overlay?
3) How much will it cost to develop the ordinance (or modification) and standards?	Front-end cost to city or county.	Staff time to write ordinance? Review time?
How much does it cost to comply?		
1) What are the design and development costs for future developments resulting from new standards or zoning provisions?	Engineering and site preparation costs (front-end) to developer.	Nature of site and construction project will determine.
2) Would there be changes in revenues (particularly property taxes) resulting from changes in future land use?	Future, across time, cost to local jurisdiction.	Will substantial change in nature of development occur?
3) Are there potential increases in permit costs?	Front-end cost (in a review time) to local jurisdiction and in permit fees to developer.	Will additional review necessitate consulting with engineer or geologist?
How much does it cost to enforce?		
1) What are the costs of reviewing compliance with new zoning standards?	Front-end and future cost to local jurisdiction.	Will additional expertise be required (staff or consulting)?
2) What are the costs of conditioning development (e.g., requiring certain performance standards)?	Ongoing cost to local jurisdiction.	Will additional review capability be required?

TABLE E-2 COST CONSIDERATIONS: SUBDIVISION ORDINANCE

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to map the hazardous areas?	Front-end cost to local jurisdiction (unless regional, state or federal agency can undertake the project).	Additional information required? Expert-consultant estimates. Comparison with similar efforts.
2) How much will it cost to prepare basic standards?	Front-end cost to local jurisdiction.	Comparison with past and/or similar efforts. Expert judgment.
How much does it cost to comply?		
1) Changes in design and development costs for future developments resulting from new standards or requirements?	Front-end cost to developer.	Preliminary site-specific study will determine need.
2) Changes in revenues resulting from changes in future uses (opportunity costs)?	Ongoing cost to local jurisdiction.	Significant only if expect substantial change in the nature of development.
3) Costs of negotiating specific requirements for each development (e.g., special staff review, extra legal fees, consultants)?	Ongoing cost to local jurisdiction and/or developer.	Additional staff time for review?
How much does it cost to enforce?		
1) Cost of reviewing compliance with requirements?	Ongoing cost to local jurisdiction.	Additional expertise (structural engineer)?
2) Increases in permit costs resulting from new requirements?	Ongoing cost to developer.	Nature of development can determine.
3) What are the costs of conditioning development?	Ongoing cost to local jurisdiction.	Types of site-specific studies required? Additional expertise required on site?
Other costs		
1) Delays in development resulting from compliance with or disputes over new requirements?	Ongoing cost to local jurisdiction and developer.	Additional time to comply? Degree of acceptance of changes (interviews with developers)?
2) Potential loss of development because of unwillingness to comply with new requirements?	Future cost to local jurisdiction.	Assess willingness to comply through interviews with potential developers.

TABLE E-3 COST CONSIDERATIONS: SENSITIVE AREA ORDINANCE

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to identify and map the hazard?	Front-end cost to be borne by local jurisdiction, unless regional, state or federal agency willing to undertake project.	Will field link be required? Additional staff expertise? Consulting expertise?
2) How much will it cost to develop the ordinance and standards?	Front-end cost to local jurisdiction.	Staff time to write ordinance? Review time? Coordination with other departments, programs?
How much does it cost to comply?		
1) What are the costs of preparing site investigations?	Front-end cost to the developer.	Nature of site and size and type of construction project will determine.
2) What are the design and development costs associated with these new standards?	Front-end cost to developer.	Nature of project will determine.
3) Are there potential increases in permit costs?	Front-end cost (permit fee) to developer. Front-end cost (staff review of permit) to jurisdiction.	Will additional review necessitate additional expertise?
4) What, if any, will be the change in revenues as a result of the new ordinance?	Future, across time, to local jurisdiction.	Will there be a significant change in development pattern?
How much does it cost to enforce?		
1) What are the costs of reviewing site studies and conditioning development?	Front-end and future cost to local jurisdiction.	Will additional expertise be required?
2) What are the increased costs of reviewing project compliance?	Ongoing cost to local jurisdiction.	Will additional review capability be required?
Other costs		
1) What are the effects on other regulatory programs?	May increase/decrease ongoing costs to local jurisdiction.	Can separate regulatory programs be streamlined by this?

TABLE E-4 COST CONSIDERATIONS: BUILDING CODE SEISMIC REQUIREMENTS

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to map hazardous area?	Front-end cost to local jurisdiction and/or another public agency.	Will field link be required? Additional expertise?
2) How much will it cost to prepare seismic building requirements	Front-end cost to local jurisdiction.	Will additional, specialized expertise be required? Staff time to prepare requirements?
How much does it cost to comply?		
1) What are the changes in design and building costs for new construction because of seismic standards?	Front-end cost to developer, building owner (could be passed on to buyer, occupants)	Additional engineering work required?
How much does it cost to enforce?		
1) What are the costs of reviewing compliance with requirements?	Front-end cost to local jurisdiction.	Additional staff time, expertise required?
2) What are the increases in permit costs resulting from new requirements?	Front-end cost to developer (could be passed on to buyer, occupant)	Nature of project will determine.
Other costs		
1) Will there be a potential loss of development because of inability to meet seismic requirements?	Ongoing cost to local jurisdiction.	Assess likelihood that new requirements will prevent new development.
2) Will there by delays in building construction resulting from compliance with or disputes over new requirements?	Front-end cost to local jurisdiction and developers.	How much additional time will be required for compliance.

TABLE E-5 COST CONSIDERATIONS: HAZARDOUS BUILDING ABATEMENT ORDINANCE

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) What is the cost of mapping hazardous areas?	Front-end cost to local jurisdiction (if it doesn't already exist)	Will field work be required?
2) What is the cost of identifying hazardous buildings?	Front-end cost to local jurisdiction.	Will it just be screening criteria or detailed survey? Staff time necessary? Additional expertise?
3) What is the cost of preparing seismic building requirements?	Front-end cost to local jurisdiction.	Staff time to prepare ordinance? Review time?
How much does it cost to comply?		
1) What is the cost of design and building renovations in order to comply with standards?	Front-end cost to developer or building owner.	What is the necessary additional engineering structural work required?
What are the enforcement costs?		
1) What are the inventory costs?	Front-end cost to local jurisdiction.	Additional expertise (structural engineer) required?
2) What are the costs of reviewing compliance with the retrofitting standards?	Ongoing cost to local jurisdiction.	Additional staff (inspectors) required?
3) Are there likely to be other enforcement costs?	If compliance is not 100% there may be legal and demolition costs to the local jurisdiction.	
Other costs		
1) What is the potential loss of redevelopment because of the inability to meet seismic requirements? Or potential increase in tax base?	Ongoing cost to local jurisdiction.	Over time, high rehabilitation costs likely to translate into higher rents.

TABLE E-6 COST CONSIDERATIONS: CRITICAL FACILITY AND SPECIAL USE PERMIT

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) What does it cost to map the areas?	Front-end cost to local jurisdiction.	How much information is required? Additional expertise?
2) What are the preparation costs to establish a basic set of requirements?	Front-end cost to local jurisdiction.	Additional expertise? Will revisions be required?
How much does it cost to comply?		
1) What are the likely changes in design and development costs for special facilities resulting from new requirements?	Front-end cost to facility owners/operators.	Change in materials or additional equipment?
2) What are the costs of negotiating specific requirements for each new facility?	Front-end cost to local jurisdiction and facility owner.	Staff time required? Negotiation tools?
How much does it cost to enforce?		
1) What are the costs of reviewing compliance with requirements?	Front-end cost to local jurisdiction.	Additional staff time?
2) Is there likely to be increased permit costs resulting from new requirements?	Front-end cost to facility operator (may be passed on to citizens/ratepayers)	Nature of facility will determine.
Other costs		
1) Possible delays in facility construction resulting from compliance with or disputes over new requirements?	Potential front-end cost to facility operator and local jurisdiction	Additional staff time? Additional expertise required (legal, technical)?
2) Potential loss of development because of lack of facilities?	Future cost to local jurisdiction.	Likelihood that new requirements would prevent building of facility?

TABLE E-7 COST CONSIDERATIONS: ENVIRONMENTAL IMPACT STATEMENT

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to map hazardous areas?	Front-end cost to local jurisdiction.	Level of detail required? Additional expertise?
2) What will it cost to prepare guidelines for an EIS?	Front-end cost to local jurisdiction or permitting agency.	Additional staff time? Additional expertise?
How much does it cost to comply?		
1) What is the cost of preparing an EIS seismic component?	Front-end cost to future developers	Additional time and/or information required?
2) Will there be changes in revenues if EIS provisions lead to land use changes?	Ongoing cost to local jurisdiction.	Significant only if expect substantial change in the nature of development.
3) Costs of negotiating specific EIS requirements for applicants?	Ongoing cost to local jurisdiction.	Extra legal fees? Consultants/additional expertise required?
How much does it cost to enforce?		
1) What are the costs of reviewing EIS compliance (may be considered a negotiation cost)?	Ongoing cost to local jurisdiction or permitting agency.	Additional expertise required? Additional staff time?
2) What are the increases in review fees resulting from new requirements?	Front-end cost to future developers.	Nature of project will determine.
Other considerations		
1) Might there be delays in development resulting from compliance with or disputes over need for EIS?	Ongoing cost to local jurisdiction and future developers.	Additional time to comply? Degree of acceptance of changes?
2) Is there a potential loss of development because of unwillingness to comply with EIS preparation?	Ongoing cost to local jurisdiction.	Assess willingness of potential developers to comply.

TABLE E-8 COST CONSIDERATIONS: TAX CREDITS

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to identify and map hazardous	Front-end cost to local jurisdiction.	Level of detail? Additional expertise required?
2) What will it cost to identify eligible properties?	Front-end cost to local jurisdiction.	Staff time to prepare inventory? Knowledge of existing property descriptions?
How much does it cost to comply?		
1) Cost of tax credit to the jurisdiction?	Ongoing cost to the local jurisdiction.	Foregone tax revenues? Value of credit?
2) Opportunity cost to the property owners?	Future cost to property owners.	Present discounted value of the difference between income from land if no credit is taken and value of the credit.
3) Cost of administering program?	Ongoing cost to local jurisdiction.	Additional staff? Legal fees?
How much does it cost to enforce?		
1) Costs of reviewing compliance with land use restrictions required to be eligible for the program?	Ongoing cost to local jurisdiction.	Additional time to review?
Other costs		
1) Potential disputes over conditions under which credit is granted.	Ongoing cost to local jurisdiction and property owners.	

TABLE E-9 COST CONSIDERATIONS: REAL ESTATE DISCLOSURE

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to identify hazardous areas?	Front-end cost to local jurisdiction (or other governmental agency).	Level of detail? Additional expertise required?
2) How much does it cost to prepare disclosure requirements?	Front-end cost to local jurisdiction	Additional expertise required?
How much does it cost to comply?		
1) Training of real estate brokers about disclosure?	Front-end cost to local jurisdiction and/or real estate industry.	Numbers to be trained, training frequency, cost of each session and materials will determine.
2) Economic impact of disclosure resulting in purchase changes: lost commissions, decreased property value?	Ongoing cost to real estate industry, property owners, and local jurisdiction (lost property values).	Assessment of impact of disclosure upon purchases from past experience and/or expert judgment.
How much does it cost to enforce?		
1) What are the costs of reviewing real estate agent compliance with disclosure requirements?	Ongoing cost to real estate industry.	Method and frequency of monitoring will determine.
Other costs		
1) Disputes over location of disclosure zone.	Ongoing cost to local jurisdiction.	Additional expertise required? Legal fees?
2) Potential loss of development because of seismic zoning.	Ongoing cost to local jurisdiction.	Assess likelihood that new requirements will discourage new development (experts and experiences of other jurisdictions).

TABLE E-10 COST CONSIDERATIONS: PROPERTY ACQUISITION

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to identify and map hazardous areas?	Front-end cost to be borne by local jurisdiction.	Will field work be required? Additional staff expertise? Consulting experience?
2) What will it cost to identify properties for acquisition?	Front-end cost to local jurisdiction.	Staff time to prepare inventory? Knowledge of existing property descriptions?
3) Voter approval required (e.g., for bonds)?	Front-end cost to local jurisdiction.	What financing will be employed? Authority of local officials to issue debt?
How much does it cost to comply?		
1) Cost of acquisitions to legal jurisdiction?	One-time purchase cost borne by jurisdiction.	Acquisition cost of properties? Financing costs? Legal costs?
2) Opportunity cost to local jurisdiction?	Ongoing cost to local jurisdiction.	Lost property tax revenues from previously private property.
3) What property management is required?	Ongoing cost to local jurisdiction.	What use will be made of the property? Costs of maintaining property?
How much does it cost to enforce?		
SELF-ENFORCING		
Other costs		
1) Potential disputes over acquisition process.	Local jurisdiction and/or property owners.	Method of financing.

TABLE E-11 COST CONSIDERATIONS: LIFELINE LOCATION/DESIGN

COST CONSIDERATION	WHO BEARS COST/WHEN	HOW TO ASSESS COST (Major Considerations)
How much does it cost to adopt?		
1) How much will it cost to map the areas?	Front-end cost to local jurisdiction	Level of detail necessary? Additional expertise?
2) What are the preparation costs to establish development standards?	Front-end cost to local jurisdiction	Additional expertise required?
How much does it cost to comply?		
1) What are the likely changes in design and development costs for lifelines resulting from new requirements?	Front-end cost to lifeline owners and/or operators?	Change in materials? Additional equipment?
2) What are the costs of negotiating specific requirements for each lifeline?	Front-end cost to local jurisdiction and lifeline owners/operators.	Additional legal fees? Consultants required?
How much does it cost to enforce?		
1) What are the costs of receiving compliance with requirements?	Ongoing cost to local jurisdiction.	Will additional expertise (special consultant) be required?
2) Are there likely to be increased permit costs resulting from these new requirements?	Ongoing cost to lifeline owners/operators.	Nature of the project and the local jurisdiction will determine.
Other costs		
1) Delays in lifeline construction resulting from compliance with or disputes over new requirements.	Future cost to local jurisdiction and lifeline owners/operators.	Additional staff time? Additional expertise? Legal fees?
2) Potential loss of development because of inability to build lifeline or relocation of development away from local jurisdiction.	Future cost to local jurisdiction.	Assess likelihood that new requirements will prevent building new facilities experts and experiences of other jurisdictions).

APPLICATION

Below is an example from the field test done in Bellingham, Washington. This example illustrates the questions posed and the estimate made of costs for the adoption, compliance, and enforcement of a sensitive area ordinance for that community (see Table E-3). In this example, costs were identified by level rather than by actual dollar cost.

How much does it cost to adopt?

1) How much will it cost to identify and map the hazard?	Low. Information exists; only a small amount of review is needed.
2) How much will it cost to develop the ordinance and standards?	Moderate. This consists primarily of staff time to write an ordinance draft and take it through the adoption process (this will likely take 6-9 months for a part-time planner). Requires coordination or modification with other existing standards.

How much does it cost to comply?

1) What are the costs of preparing site investigations?	Variable, depending on development scale. It can range from as low as several hundred dollars for a residence to thousands for a large scale nonresidential development. The developer bears the cost.
2) What are the design and development costs associated with these new standards?	Variable. The developer bears the cost which is decided on a case-by-case basis.
3) Are there potential increases in permit costs?	Yes, but these are usually reflected in higher permit fees. Fees generally cover costs of the extra review at the local government level.
4) What, if any, will be the change in revenues as a result of the new ordinance?	Low-Moderate. No major change in development patterns is anticipated.

How much does it cost to enforce?

1) What are the costs of reviewing site studies and conditioning development?	Moderate. Probable means adding a staff geotechnical engineer ($30,000-$50,000/yr.). This cost could be shared by the city and county.
2) What are the increased costs for reviewing project compliance?	Low. This can be incorporated into existing review processes.

Are there other cost considerations?

1) What are the effects on other regulatory programs?	The program may permit streamlined management of sensitive areas in the two jurisdictions that are now covered by several, separate programs.

PART F: ASSESSING THE EFFECTIVENESS OF EACH TECHNIQUE

Contents

Tables and Figures

This
page
is
intentionally
blank

PART F: ASSESSING THE EFFECTIVENESS OF EACH TECHNIQUE

The Concept of Effectiveness

Considering the effectiveness of a particular technique in reducing a community's risk from an earthquake is an important part of the selection process. Although it is desirable to estimate effectiveness in terms of dollars saved through averted property damage or the number of lives saved, it is rather difficult. Officials in the community must know: 1) probable location and intensity of a design earthquake and the distribution of effects; 2) expected damages based on a structural/demographic analysis; and 3) the possible damages and deaths both with and without the proposed new policy.

However, this information does not exist for most communities at risk to earthquakes and, even in the few communities where there is such information, experts frequently disagree over the estimates. Additionally, if a local jurisdiction develops costly damage scenarios, they may be controversial enough to preclude any policy decision being based on them. This handbook takes a somewhat different approach to assessing effectiveness. If a community does have access to damage scenarios, they should be used to refine the broad-brush procedure suggested here.

Elements of Effectiveness

To establish the relative effectiveness of a planning technique in a particular community, each technique must be examined in terms of its coverage, potential impact, and implementation success. **Coverage** refers to how much of the total area (the structures therein) at risk will be affected, or "covered," by the application of the planning technique. **Potential impact** describes the relative amount of loss reduction that can be expected if the technique is fully implemented. For example, a zoning ordinance which prohibits development reduces the loss potential completely, or 100%, whereas improved structural standards will reduce some damage, but not all of it. This measure does not allow for the fact that implementation may not be complete. **Implementation success** describes the likelihood that an ordinance will be fully complied with and enforced. This measure is somewhat subjective, based on the knowledge of the characteristics of each community and the expected level of enforcement, sanctions, incentives and support. This element can also be considered a "discount factor" to be applied to potential impact.

Coverage
Coverage is the estimate of the area of the community affected by the planning technique, expressed as a percentage of the total hazard area (see Figure 2). It can be estimated using the following steps:

1) To determine A, identify all areas within the jurisdiction that are exposed to earthquake hazards.

2) Identify as B the area within A that will be affected by the planning technique.

3) Calculate B as a percentage of A, assuming 100% policy implementation (or it can be expressed as an estimate: high-medium-low).

Potential Impact
This measure is a constant measure of loss reduction potential for each planning technique. In other words, open space zoning, if fully implemented, will have a high maximum impact because development is limited, but the impact of a sensitive area ordinance will be less because development is still allowed as long as certain conditions are met. The maximum ability of a planning technique to reduce losses can be seen as the product of the three elements of effectiveness:

Coverage x Impact Potential x Implementation Success
= Maximum Risk Reduction Potential

Once estimated, the loss reduction ratings for several techniques can be compared to determine which of several options may have the greater potential ability to reduce losses. These estimates for each of the techniques in Figure 2 were developed in consultation with planners and public policy administrators. It is possible to change the estimates in other communities' calculations of loss reduction potential, but it is important to keep all these measures constant for each of the different techniques. (See also the accompanying example of using only general categories of high-medium-low rather than percentages.)

Implementation Success
This subjective measure is based on knowledge of characteristics in the local jurisdiction. It can be considered a "discount factor," applied to the potential impact, adjusting that measure to reflect the real possibilities of successful implementation. Calculating implementation success is site-specific and is likely to be issue-specific as well.

Comparing Technique Effectiveness

Some users of this handbook will be able to assign percentage figures to the estimate of coverage, potential impact, and implementation success. Other users will not have sufficiently detailed data to assign numbers, and will instead use the designations low, moderate, and high. Both approaches can be useful. It is less time-consuming and takes less specific data to estimate the loss reduction elements in non-quantitative terms, and can still facilitate a comparison among techniques (see the attached example).

Once effectiveness of a particular planning technique has been estimated, it should be possible for a local decision maker to set this against the costs of technique implementation (see Part E) and determine whether the technique is appropriate for use in the community.

HOW TO USE TABLE F-1

1) This table is somewhat different from the other tables in the handbook because it presents a structure for summing up information presented in the earlier parts of this handbook. A community official, evaluating one or more planning techniques, identifies coverage, potential impact, implementation success, and costs as follows:

   - **Coverage** is estimated using the technique described above in in Part F.
   - **Potential impact** is determined from Figure 2 in Part F.
   - **Implementation success** is a summary of information developed in Part C.
   - **Cost estimates** are taken from information developed in Part E.

2) This table is a summary tool, it can provide justification for the selection (or rejection) of a planning technique for community consideration. This table explicitly identifies the criteria used in such selection decisions.

EXAMPLE/APPLICATION

The table following F-1 is an example taken from the Bellingham, Washington, field test of the decision-making framework. It illustrates how Table F-1 can be filled out by a community considering several planning techniques. A local official more familiar with the specific situation in Bellingham, and able to spend sufficient time to gather specific cost figures, could fill out this table using percentages and dollar estimates. For our purposes in testing the framework we used the measures low-moderate-high.

The table does not provide a summary score or identify **the** technique most appropriate for Bellingham. The table is meant to be an aid, recognizing that decisions regarding the appropriateness of a planning technique have complexities that are not amenable to being boxed in on paper. Local officials in the jurisdiction are the most appropriate final interpreters of the information provided in the table.

TABLE F-1 EVALUATION OF LOSS REDUCTION POTENTIAL AND COSTS

	PLANNING TECHNIQUE		
	A	B	C
Coverage: The amount of buildings located in all sensitive areas which will be affected by the ordinance (assuming it is fully implemented).	existing development: future development:	existing development: future development:	existing development: future development:
Impact A rating of how much change in risk exposure would result from the full implementation of planning techniques. Implementation success: The likelihood of adoption, compliance, and enforcement of the planning techniques.			
Cost: to government to private sector	front-end future	front-end future	front-end future

APPLICATION

	PLANNING TECHNIQUE: Modification to Zoning Ordinance (hazard overlay map with performance standards) A		Modification to Subdivision Ordinance (site-specific geologic reports in areas of particular seismic hazard sensitivity) B		Development of a Sensitive Area Ordinance with Performance Standards C	
COVERAGE--the amount of buildings located in all sensitive areas which will be affected by the ordinance (assuming it is fully implemented).	Existing Development: NA Future Development: Low--only small and well-documented hazard areas are likely to be included in the ordinance.		Existing Development: NA Future Development: Moderate--technique would apply on a site-specific basis. Likely that developers would would steer away from hazardous area development anyway.		Existing Development: NA Future Development: extensive--an SAO will only "miss" those areas too smal to be picked up by other mapping procedures.	
IMPACT--a rating of how much change in risk exposure would result from the full implementation of planning techniques.	High--a well-enforced zoning ordinance can significantly restrict or condition development.		Low-moderate--a subdivision regulation does not affect the type of use or structural characteristics. Instead, it can only regulate the location of development on the site and some site preparation and foundation characteristics.		High--effectively used performance standards would emphasize end result and control land use.	
IMPLEMENTATION SUCCESS--the likelihood of adoption, compliance, and enforcement of the planning techniques.	Low--adoption likely to be a stumbling block because of map preparation and standards.		High--city & county have subdivision ordinance in place. Might require additional expertise to enforce. Similar requirements to existing procedures.		Moderate--burden of developing criteria for sensitive areas on city/county. Indication that political mood not right.	
COST--to adopt, comply, and enforce	Front-End	Future	Front-End	Future	Front-End	Future
To Government:	High--info gathering, map preparation.	High--could require hiring of additional expertise, updating of information.	High--some new information required to determine areas of particular seismic sensitivity.	Moderate to high--might need additional expertise to review/interpret studies. Large number of permits to be reviewed.	Moderate.	Moderate--could require hiring additional expertise.
To Private Sector:	Low.	Moderate--could require site and engineering changes.	High for residential developers--must provide information.	Moderate--could require design changes.	None.	Moderate--requires site studies & may necessitate development modifications.

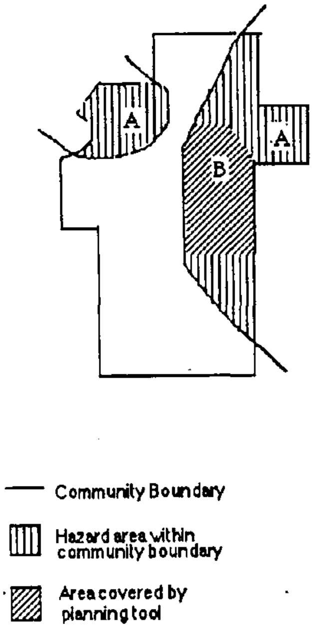
Coverage times	Impact Potential times	Implementation Feasibility	equals:
 A = Hazard Area B = Hazard area where planning tool will be in effect A/B = % of **total** community hazard area covered by the planning tool	(The ability of the planning technique to reduce loss potential if fully implemented) <u>FOR FUTURE DEVELOPMENT</u> Zoning ordinance 85% Subdivision ordinance 80% Sensitive area ordinance 80% Environmental impact statement 60% Building code 60% Special use and critical facility 70% Lifeline location/ standards 70% / 20% Tax credit 25% Property acquisition 90% <u>FOR EXISTING DEVELOPMENT</u>: Hazardous building abatement 60% Real estate disclosure 15%	An assessment made for each planning technique, given the specific community context (Can it be adopted? How likely is compliance? How difficult is enforcement?)	MAXIMUM LOSS REDUCTION POTENTIAL FOR A SPECIFIC PLANNING TECHNIQUE

FIGURE 2 CALCULATING MAXIMUM LOSS REDUCTION CAPABILITIES FOR PLANNING TECHNIQUES

This page is intentionally blank

REFERENCES

Algermissen, S.T., K.V. Steinbrugge, and H.L. Lagorio
1978 Estimation of Earthquake Losses to Buildings (Except Single Family Dwellings). U.S.G.S. Open File Report # 78-441. Reston, VA: U.S. Geological Survey.

Arnold, Christopher and Richard Eisner
1984 Planning Information for Earthquake Hazard Response and Reduction. San Mateo, CA: Building Systems Development Inc.

Ayre, Robert S. et al.
1975 Earthquake and Tsunami Hazards in the United States: A Research Assessment. Program on Technology, Environment and Man Monograph #5. Boulder: University of Colorado, Institute of Behavioral Science.

Blair, Martha. L. and W.E. Spangle
1979 Seismic Safety and Land-Use Planning--Selected Examples from the San Francisco Bay Region, California. Geological Survey Professional Paper #941-B. Washington, DC: U.S. Government Printing Office.

Bolt, Bruce A. et al.
1977 Geological Hazards (Revised, 2nd Edition). New York: Springer-Verlag.

Borcherdt, R.D. et al.
1975 "Response of Local Geologic Units to Ground Shaking." Pp. A52-A67 in R.D. Borcherdt (ed.), Studies for Seismic Zonation of the San Francisco Bay Region. Geological Survey Professional Paper #941-A. Washington, DC: U.S. Government Printing Office.

Cluff, Lloyd S.
1978 "Geologic Considerations for Seismic Microzonation." Pp. 135-152 in Proceedings of the Second International Conference on Microzonation, Vol. I. San Francisco, November 26-December 1, 1978.

Committee on Earthquake Engineering Research
1982 Earthquake Engineering Research-1982. National Research Council. Washington, DC: National Academy Press.

Dunne, Thomas and Luna B. Leopold
1978 Water in Environmental Planning. San Francisco: W.H. Freeman.

EERI Committee on Seismic Risk
1984 "Glossary of Terms for Probabilistic Seismic-Risk and Hazard Analysis." Earthquake Spectra 1 (#1), pp. 33-40.

Erley, Duncan and William Kockelman
1981 Reducing Landslide Hazards: A Guide for Planners. Planning Advisory Service Report #359. Chicago: American Planning Association.

Evernden, Jack F.
1982 "Comments on Seismological Input to Microzonation Maps." pp. 1171-1189 in Proceedings of the Third International Conference on Microzonation, Vol. III. Seattle, July 28-July 1, 1982. .

French, Steven P.
1983 Personal communication to the authors. San Luis Obispo: California Polytechnic State University.

French, Steven P. and Mark Isaacson
1984 "Applying Earthquake Risk Analysis Techniques to Land Use Planning." Journal of the American Planning Association (Autumn), pp. 509-522.

Gaus, M.P., and M.A. Sherif
1972 "Zonation and Microzonation." Pp. 3-11 in Proceedings of the First International Conference on Microzonation. Seattle, October 30-November 3, 1972.

Jaffe, Martin, JoAnn Butler, and Charles Thurow
1981 Reducing Earthquake Risks: A Planner's Guide. Planning Advisory Service Report #364. Chicago: American Planning Association.

Kohler, and G.D. Clow
1981 Seismic Intensities of Earthquakes of Conterminous United States--Their Prediction and Interpretation. U.S.G.S. Professional Paper #1223. Reston, VA: U.S. Geological Survey.

Laird, R.T. et al.
1979 Quantative Land-Capability Analysis: Selected Examples from the San Francisco Bay Region, California. Geological Survey Professional Paper #945. Washington DC: U.S. Government Printing Office.

Mader, George G.
1982 "Progress in Using Microzonation Data in Urban Planning--A Current Appraisal." Pp. 673-680 in Proceedings of the Third International Microzonation Conference, Vol. II. Seattle, June 28-July 1, 1982.

Mushkatel, Alvin H.
1982 "Land-Use Policy in the United States and the Potential Use of Microzonation." Pp. 1569-1578 in Proceedings of the Third International Conference on Microzonation, Vol. III. Seattle, July 28-July 1, 1982.

National Academy of Sciences
1975 Earthquake Prediction and Public Policy. Washington, DC: National Academy of Sciences.

Nichols, D.R. and J.M. Buchanan-Banks
1974 Seismic Hazard and Land-Use Planning. Geological Survey Circular #690. Reston, VA: U.S. Geological Survey.

Olson, Richard Stuart and Douglas C. Nilson
1982 "Microzonation as a Policy Tool: Factors for and Against Adoption." Pp. 1545-1556 in Proceedings of the Third International Microzonation Conference, Vol. III. Seattle, June 28-July 1, 1982.

Patri, T., D.C. Streatfield, and T.J. Ingmire
1970 Early Warning System: The Santa Cruz Mountains Regional Pilot Study. Berkeley: Department of Landscape Architecture, College of Environmental Design, University of California.

Preuss, Jane et al.
1982 Land Management Guidelines in Tsunami Hazard Zones. Seattle: Urban Regional Research.

Scawthorn, Charles
1982 "The Locational Approach to Seismic Risk Mitigation." Pp.729-740 in Proceedings of the Third International Microzonation Conference, Vol. II. Seattle, June 28-July 1, 1982.

Youd, T.L. et al.
1975 "Liquefaction Potential." Pp. A68-A74 in R.D. Borcherdt (ed.), Studies for Seismic Zonation of the San Francisco Bay Region. Geological Survey Professional Paper #941-A. Washington, DC: U.S Government Printing Office.

PUBLICATIONS OF INTEREST

from the

Natural Hazards Research and Applications Information Center
Institute of Behavioral Science #6
Campus Box 482
University of Colorado
Boulder, Colorado 80309
(303) 492-6818

Special Publications

#2. Regulation of Flood Hazard Areas to Reduce Flood Losses, Volume 3. Jon Kusler. 1982. 300 pp. $8.00

#3. Strengthening State Floodplain Management, Appendix A to Volume 3 (SP #2). Patricia A. Bloomgren. 1982. 123 pp. $8.00.

#4. Innovation in Local Floodplain Management, Appendix B to Volume 3 (SP #2). Jon Kusler. 1982. 262 pp. $8.00

#5. Floodplain Regulations and the Courts 1970-1981. Jon Kusler. 1982. 51 pp. $5.00.

#10. Evaluating the Effectiveness of Floodplain Management Techniques and Community Programs. Proceedings of a Seminar, Washington, DC, April 30-May 1, 1984. 1985. 143 pp. $8.00.

#12. Flood Hazard Management in Government and the Private Sector. Proceedings of the Ninth Annual Conference of the Association of State Floodplain Managers. 1985. 358 pp. $8.00.

#13. State and Community During the Aftermath of Mexico City's November 19, 1984 Gas Explosion. Kirsten Johnson. 1985. 48 pp. $4.00.

Working Papers

#47. Disseminating Disaster-Related Information to Public and Private Users. Claire B. Rubin. 1982. 32 pp. $4.50.

#50. Restoration and Recovery Following the Coalinga Earthquake of May, 1983. Steven P. French, Craig Ewing, and Mark Isaacson. 1984. 25 pp. $4.50.

#54. The Environmental Hazards of Colorado Springs. Eve Gruntfest. 1985. 58pp. $4.50.

$55. Disaster Preparedness and the 1984 Earthquakes in Central Italy. David Alexander. 1986. 98 pp. $4.50.

Monographs

#39. Terminal Disasters: Computer Applications in Emergency Management. Sallie Marston, ed. 1986. 225 pp. $10.00.

#40. When the Ground Fails: Planning and Engineering Response to Debris Flows. Martha Blair. 1985. 110 pp. $8.00.

#41. Community Recovery from a Major Disaster. Claire Rubin et al. 1985. 295 pp. $10.00.

#43. Unreinforced Buildings in Earthquakes: City Ordinances for Rehabilitation. Daniel Alesch and William Petak. 1986. 280 pp. $10.00.

Bibliographies

#11. Natural Hazards and Land Use Planning. Ann FitzSimmons. 1984. 107 pp. $5.50.

AB. A Selected, Partially Annotated Bibliography of Recent (1984-1985) Natural Hazards Publications. David Morton. 1986. 150 pp. $7.00.

Newsletter

The Natural Hazards Observer. Bi-monthly. 20 pp. No cost in USA.