REDUCING EARTHQUAKE HAZARDS—AN INTRODUCTION

By William J. Kockelman[1]

Any effective program having earthquake-hazard reduction as a goal requires (1) scientific and engineering studies identifying and assessing the hazards; (2) translation of such studies for nontechnical users; (3) transfer of this translated information to those who will or should use it; (4) use of appropriate hazard-reduction techniques; and (5) review and revision of such techniques to ensure their effectiveness. Each is a prerequisite for its successor.

The preceding articles under the headings "Tectonic Setting" (volume 1 of this report) and "Earthquake Hazards" (this volume) are a major contribution to scientific and engineering studies and their translation. The publication and widespread distribution of this professional paper will contribute substantially to the transfer of this information. The following articles are a part of this transfer component, namely, an introduction to and discussion of hazard-reduction strategies and techniques. These reports are addressed to the potential users listed in table 9 of the Introduction to the report (Rogers and others, volume 1, p. 40).

May (this volume) addresses the prospects and strategies for reducing earthquake hazards. The article is based upon interviews with State and local officials in the Puget Sound and Portland areas and on analysis of current hazard-reduction policies and techniques. The author, a political scientist, observed that officials are generally aware of earthquake risk but that their concern is limited because of more pressing problems. He takes a closer look at the local political and economic factors that relate to reduction of earthquake hazards in the future. The relatively vulnerable cities are divided into "pacesetter," "resourceful," and "restrained" groups and the less vulnerable cities into "new sophisticate," "measured," and "nonplayer" groups. Counties are divided into "leader," "transitional," and "rural" groups. The understanding of these diverse groups provides a basis for considering the following four strategies whose strengths and limitations are discussed:

- Disseminating translated scientific information.
- Seeking improvements in State-level building codes or land-use mandates.
- Improving the practices of local building and planning departments.
- Improving the practices of the private engineering and design communities.

Preuss and Hebenstreit (this volume) develop a method for assessing multiple hazards created by tsunamis and apply that method to estimating impacts on coastal communities. The method includes (1) identifying the tsunami hazard using numerical simulation of wave direction and height; (2) analyzing the vulnerabilities of populations and land uses; (3) identifying secondary hazards—subsidence, battering, fire, and air contamination; and (4) delineating the hazard zones of tsunami impact, flooding, and subsidence, including the coastal highway system. Identifying the hazards and delineating the zones is difficult and requires specialized technical treatment. The authors, a planning consultant and an oceanographer, then relate these hazard zones to various impacts—casualties, damage, and socioeconomic disruption—and possible mitigation, response, and recovery techniques. Their work uses Grays Harbor, Washington, as a case study and is applicable to other areas and hazards.

Booth and Bethel (this volume) discuss four regulatory techniques for reducing earthquake hazards on undeveloped land: comprehensive land-use and development plans and policies, functional land-use plans, building codes, and zoning overlays. The authors, King County, Washington, geologists, identify and discuss five elements needed for any regulation to reduce earthquake hazards:

- Defining the hazard.
- Evaluating specific hazardous site conditions.
- Mapping of the hazard zones.
- Screening of development proposals.
- Adding appropriate conditions to the basic ordinance requirements.

King County used all four reduction techniques, and the authors were able to evaluate the effectiveness of these five elements. They conclude that the mapping and site-specific evaluations are particularly weak and are likely to

[1]Deceased.

be so in other jurisdictions. They then make pertinent recommendations to improve each of the above elements.

Perkins and Moy (this volume) examine the potential liability of local governments in Washington for losses in an earthquake. The Washington Tort Claims Act is analyzed, as well as legal concepts such as "act of God," negligence, discretionary immunity, and the public-duty doctrine. Pertinent case law is cited. The authors, a regional planner and an attorney, observe that the most likely source of liability for a local government is losses caused by the dangerous condition of its own property—hospitals, city hall, jails, and other public works. They make the following recommendations to local governments:

- Comply with all State and Federal regulations.
- Inspect, repair, and maintain public buildings and facilities.
- Use local government risk managers as allies in promoting safety.
- Do not assume that public liability exists for programs affecting private property.
- Act reasonably to promote public safety and welfare.

Kockelman (this volume) introduces 36 types of earthquake-hazard-reduction techniques and describes the following six, citing examples: preparing redevelopment plans, creating regulatory zones, securing nonstructural building components, informing the public, strengthening unreinforced masonry buildings, and making loss estimates. The specific objectives of these techniques are to create an awareness of, avoidance of, resistance to, response to, or recovery from the effects of an earthquake on people and their land uses, structures, and socioeconomic activities. The author, a planner, emphasizes that scientific and engineering studies are a prerequisite to the use of these reduction techniques. Thus, it is not prudent for urban planners to develop land-use regulations for civil engineers when designing structures and for lenders and public-works directors when adopting policies reducing earthquake hazards without scientific and engineering studies that assess the hazards.

TECHNIQUES FOR REDUCING EARTHQUAKE HAZARDS

By William J. Kockelman[1]

ABSTRACT

Six earthquake-hazard-reduction techniques are discussed: preparing redevelopment plans, creating regulatory zones, securing nonstructural building components, informing the public, strengthening unreinforced-masonry buildings, and making loss estimates. An overview of these techniques is useful to planners who prepare hazard-reduction programs, engineers who serve as advisors to local or State governments, and decisionmakers who select the most appropriate technique for a given situation.

INTRODUCTION

Many techniques for reducing earthquake hazards are available to planners, engineers, and decisionmakers. This report identifies 36 techniques and describes 6 in detail using examples. Some of these techniques, such as public acquisition of hazardous areas, are well known to the planning profession. Others, such as design of resistant structures, are commonly used by engineers. Still others, such as installation of warning systems and emergency preparedness, are obvious and practical but require maintenance and persistence in their implementation.

As an overview, the various techniques are listed in table 39. They are divided into six groups related to specific objectives; however, they can also be grouped in other ways, such as the following chronological order:

- Pre-earthquake mitigation techniques, which may take 1–20 years;
- Preparedness measures, which may take 1–20 weeks;
- Response during and immediately after an earthquake;
- Recovery operations after an earthquake, which may take 1–20 weeks; and
- Postearthquake reconstruction activities, which may take 1–20 years

These estimated time periods would vary depending upon the postulated or actual size of the earthquake, the damage it causes, and the resources available to a State, its communities, its corporations, and its citizens.

The specific objectives of the techniques listed in table 39 are to create an awareness of, avoidance of, resistance to, response to, or recovery from the effects of earthquake phenomena on people and their land uses, structures, and activities. The general goal of these objectives is to reduce human casualties, property damage, and socioeconomic interruptions. Many of the reduction techniques are complex, interconnected, and require special skills—legal, financial, legislative, design, economic, communications, educational, political, and engineering.

Many of the hazard-reduction techniques have been discussed and illustrated by Blair and Spangle (1979), Kockelman and Brabb (1979), Brown and Kockelman (1983), Kockelman (1985, 1986), Jochim and others (1988), Mader and Blair-Tyler (1988), Blair-Tyler and Gregory (1988), and the United Nations Office of the Disaster Relief Coordinator (Lohman and others, 1988).

Prerequisite to the use of these reduction techniques are scientific and engineering studies. Such studies are vital because, in the words of former U.S. Geological Survey director Walter C. Mendenhall, "There can be no applied science unless there is science to apply." Experience has shown that it is not prudent for urban planners to develop land-use regulations, civil engineers to design structures, and lenders and public-works directors to adopt policies reducing earthquake hazards without reliable scientific and engineering assessments.

The following six earthquake-hazard-reduction techniques and examples of how they are applied are detailed in this report:

1. Preparing redevelopment plans
2. Creating regulatory zones
3. Securing nonstructural building components
4. Informing the public
5. Strengthening unreinforced-masonry buildings
6. Estimating casualties, damage, and interruptions

[1]Deceased.

Table 39. Examples of various techniques for reducing earthquake hazards.

[(*), technique described in this report]

Incorporating hazard information into studies and plans:	Discouraging new development in hazardous areas:
Community-facilities inventories and plans	Adopting utility and public-safety service-area policies
Economic-development analyses and plans	Clarifying the liability of developers and government officials
Emergency and public-safety plans	Creating financial incentives and disincentives
Land-use and transportation inventories and plans	*Informing and educating the public
*Redevelopment plans (pre-earthquake and postearthquake)	Posting public signs that warn of potential hazards
Utility inventories and plans	Requiring nonsubsidized insurance related to the level of hazard
Regulating development:	**Strengthening, converting, or removing unsafe structures:**
*Creating special hazard-reduction zones and regulations	Condemning and demolishing unsafe structures
Enacting building and grading ordinances	Reducing land-use intensity or building occupancy
Enacting subdivision ordinances	Relocating community facilities and utilities
Requiring engineering, geologic, and seismologic reports	Repairing unsafe dams or lowering their impoundments
Requiring investigations in hazardous areas	Retrofitting bridges and overpasses
Reviewing annexation, project, and rezoning applications	*Strengthening unreinforced-masonry buildings
Siting, designing, and building safe structures:	**Preparing for and responding to emergencies and disasters:**
Evaluating specific sites for hazards	Conducting emergency or disaster training exercises
Reconstructing after a disaster	*Estimating casualties, damage, and socioeconomic interruptions
*Securing nonstructural building components and contents	Initiating community and corporate education programs
Selecting the most resistant building system and configuration	Operating monitoring, warning, and evacuation systems
Siting and designing critical facilities	Preparing emergency response and recovery plans
Training building designers and inspectors	Providing for damage inspection, repair, and recovery

These techniques are discussed and illustrated for nontechnical readers. The references cited for each technique will provide both scholars and practitioners with more details and examples.

ACKNOWLEDGMENTS

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PREPARING REDEVELOPMENT PLANS

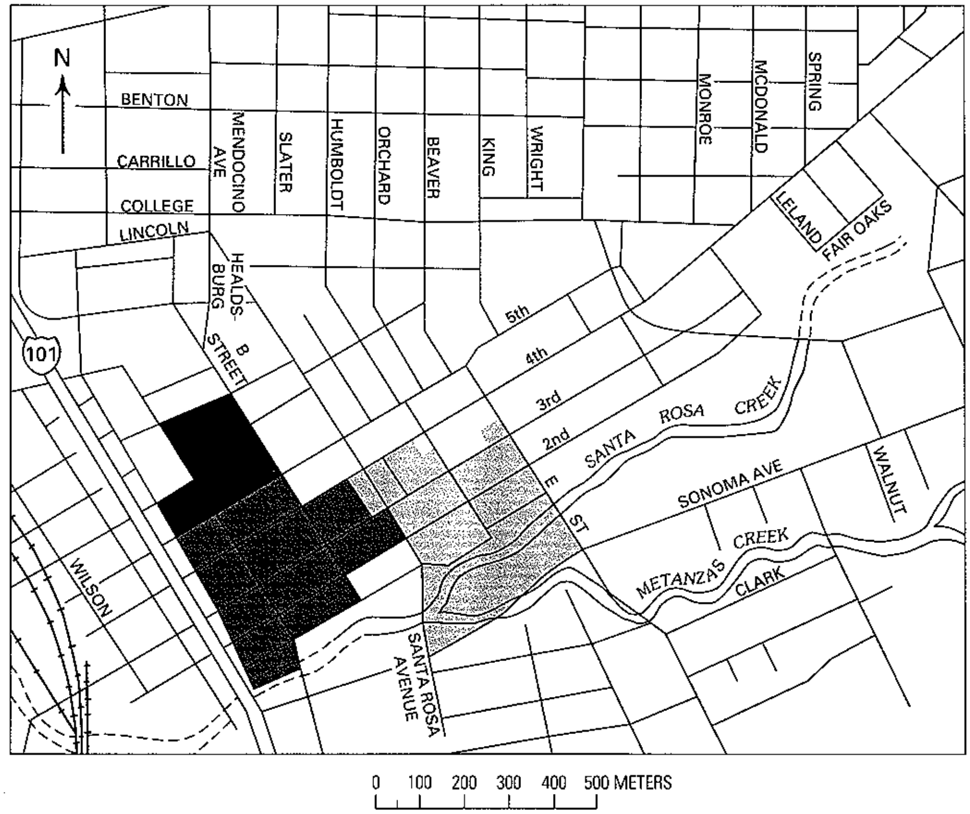
Incorporating earthquake-hazard information into designs for the development or redevelopment of a community's land use, housing, transportation, and other public facilities is a common natural-hazard-reduction technique. One of the designs is the redevelopment plan. Most States authorize the creation of public redevelopment agencies that provide for the preparation and adoption of redevelopment plans; the acquisition, clearance, disposal, reconstruction, and rehabilitation of blighted (including damaged) areas; and the relocation of persons. These redevelopment agencies usually are empowered to issue bonds, receive part of the taxes levied on property included in the project, and use grants or loans available under various State and Federal programs. Redevelopment plans may be divided into three categories:

1. Those that incorporate damaged areas into redevelopment plans that had been created prior to damaging earthquakes
2. Those that include vulnerable structures (identified prior to an earthquake) in the redevelopment plans
3. Those that include damaged areas in redevelopment plans that are created after an earthquake

Santa Rosa, Calif., a city of about 50,000 people, has a redevelopment plan that illustrates the first category. Two earthquakes struck within 2 hours in 1969, and many old unreinforced-masonry buildings were damaged. Mader and others (1980, p. C1–C15) reported the following:

> In 1961, Santa Rosa embarked on a redevelopment project covering part of the downtown area. Just prior to the earthquakes, the city had adopted a central business district plan which covered an area adjacent to the redevelopment area. After the earthquakes, this area, with a high percentage of damaged buildings, was added to the original redevelopment area.

Figure 226. Part of the Santa Rosa, Calif., urban-renewal project area. Light shade, Phase I—the original project area; medium shade, Phase II—the area added following two 1969 earthquakes; black, Phase III—the area surveyed for additional land required for a regional shopping center. Modified from Mader and others (1980, p. C–8, fig. 7).



The time and effort required to get the revised redevelopment project funded and underway after the earthquakes was significantly shortened because of the existence of an up-to-date plan (fig. 226) adopted prior to the earthquakes.

Spangle and others (1987, app. A) described the second category—incorporating vulnerable structures identified prior to an earthquake into the redevelopment plan. It is a new technique called pre-earthquake planning for postearthquake rebuilding (PEPPER). It includes four pre-earthquake activities: evaluation of vulnerability to damage; organization for preparedness and response; mitigation of hazards; and planning for postearthquake response. Spangle and others (1987) believed it possible to develop damage estimates sufficiently accurate for pre-earthquake programming of postearthquake recovery activities and to define the nature of the postearthquake recovery organization needed.

The Whittier City Redevelopment Agency (1987) adopted a plan for Whittier, Calif., that represents the third category—redevelopment plans created after an earthquake. The plan provides for redevelopment powers to be used for projects to maintain, repair, restore, demolish, or replace property or facilities damaged or destroyed as a result of an earthquake in 1987. The earthquake damage in Whittier exceeded $70 million in 1987 dollars.

Preparing and implementing redevelopment plans that recognize and reduce earthquake hazards is very important because postearthquake reconstruction commonly takes place in the same hazardous areas. Youd and others (1978, p. 1111), for example, observed that after the 1971 San Fernando earthquake, "***buildings had been repaired, new buildings have been built, and a freeway interchange has been constructed across the trace of the 1971 fault rupture."

CREATING REGULATORY ZONES

Various types of land-use and land-development regulations meant to reduce earthquake hazards are available to State and local governments. Controlling use and development with regulatory zones can be one of the most economical and effective means available to government agencies. The regulations can be used to reduce damage from earthquake hazards such as a surface-fault rupture, ground shaking, liquefaction, landslides, and tsunamis. They may be divided into four categories:

1. Regulations requiring site investigations and building setbacks
2. Regulations reducing the density of development or the number of occupants
3. Regulations permitting only less vulnerable land uses and land development
4. Regulations requiring special seismic-design and construction standards

The first category can be illustrated by the Alquist-Priolo Special Studies Zone Act enacted by the California

Legislature (1972). The act provides for public safety by restricting development near or over the surface traces of active faults (fig. 227). In addition, the act requires or provides for geologic reports, approval of projects by cities and counties, and the charging of reasonable fees for administrative costs. The California State Geologist delineates appropriately wide zones that include "all potentially and recently active traces" of faults that "he deems sufficiently active and well defined to constitute a potential hazard to structures from surface faulting or fault creep" (Hart, 1988, app. A).

Before approval of any project in these zones, cities and counties must require "a geologic report defining and delineating any hazard of surface fault rupture." The legislature defines a project as including structures for human occupancy and subdivisions that contemplate the eventual construction of structures for human occupancy. The legislature exempts single-family wood-frame buildings (including mobile homes) not exceeding two stories when not part of a development of four or more dwellings. The approval of a project must be in accord with the policies and criteria established by the California Mining and Geology Board. The board prohibits a project from crossing the trace of an active fault (Hart, 1988, app. B), requires a geologic report if a project lies within 15 m of an active fault trace, and requires a registered geologist retained by the city or county to evaluate such reports. The act also allows cities and counties to establish more restrictive policies and criteria. Some local jurisdictions, such as the Portola Valley Town Council (1973), require multifamily buildings to be set back 40 m or more from fault traces.

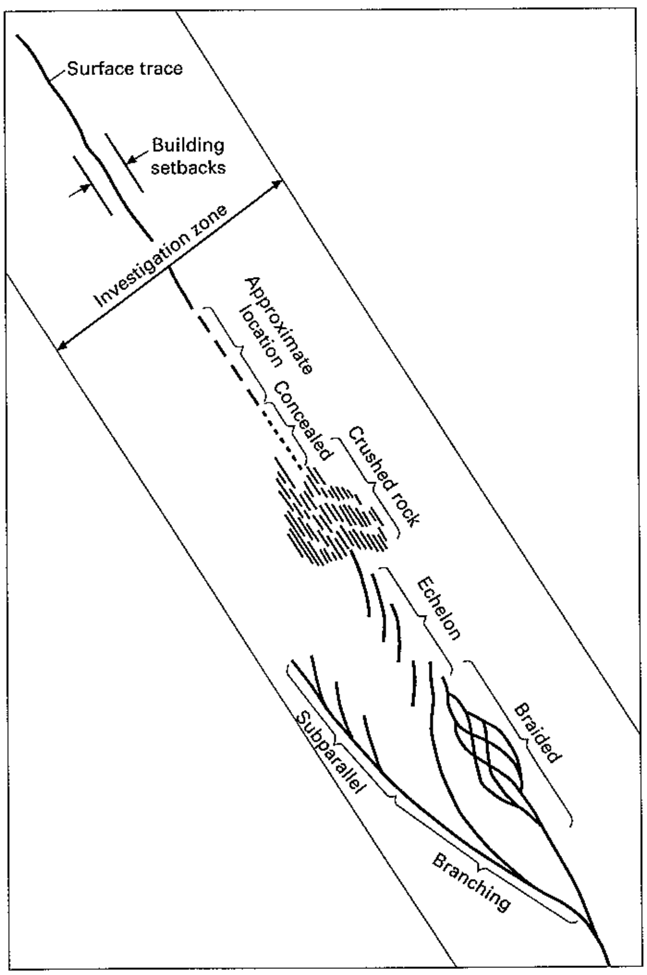


Figure 227. Hypothetical surface-fault-rupture regulatory zone in California showing different ways that the ground may break. The figure shows the complex faulting (solid, dashed, and dotted lines), the minimum 300-m-wide investigation zone required by the Alquist-Priolo Special Studies Zones Act, and the 15-m building setbacks required by the California Mining and Geology Board. From Brown and Kockelman (1983, p. 8, fig. 30).

The San Mateo County Board of Supervisors (1973) is using the second category—reducing the density of development. San Mateo County, Calif., has a resource-management zoning district that also carries out the objectives and policies of the county's open-space and resource-conservation plans. The district regulations limit the number of dwellings in zones with a surface-fault-rupture hazard, flood hazard, or unstable slopes to one unit per 16 hectares (40 acres) and require geologic site investigations to ensure that the reduced development is in nonhazardous areas (fig. 228). The lower net number of dwellings permitted may then be clustered at a higher density in the nonhazardous areas.

An example of the third category—permitting only less vulnerable land uses—can be seen in Colorado, where geologic hazards have been declared by the State legislature to be matters of State interest. To assist communities in designing land-use regulations, the Colorado Geological Survey prepared model geologic-hazard-area control regulations for adoption by local governments. The regulations permit only the following uses in areas designated geologically hazardous: (1) agricultural uses such as general farming, grazing, truck farming, forestry, sod farming, and wild-crop harvesting; (2) industrial/commercial uses such as loading areas, parking areas not requiring extensive grading or impervious paving, and storage yards for equipment or machinery easily moved or not subject to geologic-hazard damage; and (3) public and private recreational uses not requiring permanent structures designed for human habitation such as parks, natural swimming areas, golf courses, driving ranges, picnic grounds, wildlife and nature preserves, game farms, shooting preserves, target ranges, trap and skeet ranges, and hunting, fishing, skiing, and hiking areas, if such uses do not cause concentrations of people.

The fourth category is illustrated by a Redwood City Council (1974, 1977) ordinance in California that requires special seismic design and construction standards. These standards supplement those recommended by the International Conference of Building Officials (1991) for structures in seismic zone 4 under the Uniform Building Code—the code adopted by Redwood City as its own building code.

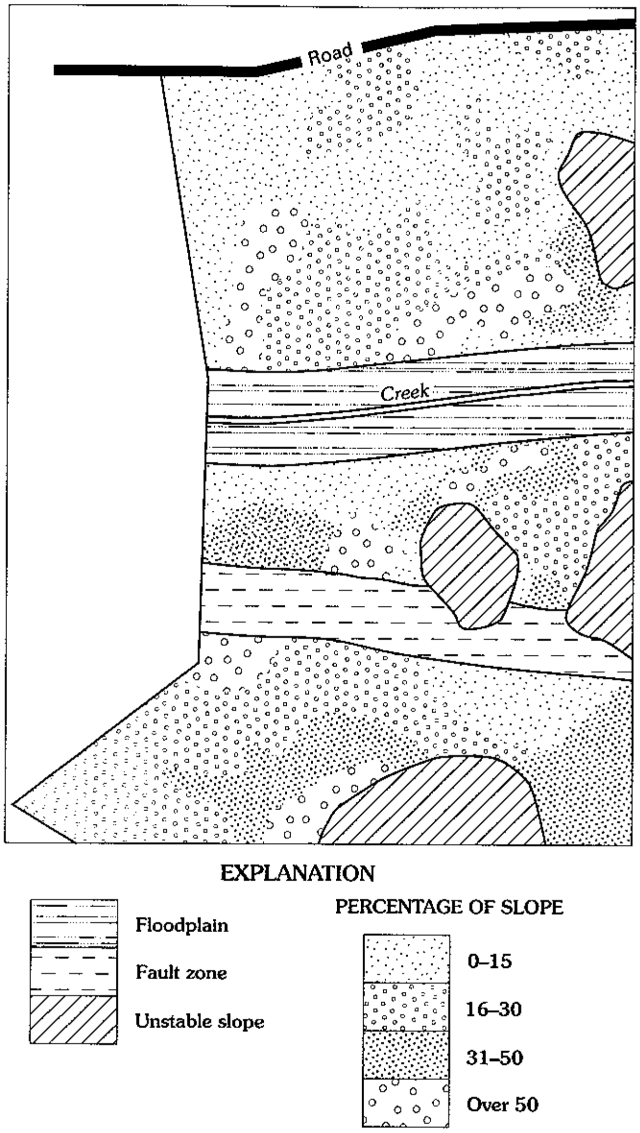


Figure 228. Regulatory zones in a hypothetical area of seismic and other geologic constraints. In San Mateo County, Calif., dwellings in floodplain, fault, and unstable slope zones are limited to one per 16 hectares (40 acres) by the San Mateo County Board of Supervisors (1973). Modified from Kockelman and Brabb (1979, p. 82, fig. 6).

The ordinance is consistent with the city's initial Seismic Safety Element (Redwood City Planning Department, 1974), which had placed the mud around the margins of San Francisco Bay in a moderately high-seismic-risk zone and recommended that the Uniform Building Code be reviewed and amended as "frequently as may be prudent." The supplemental standards called for in the city's ordinance relate to special foundation-design criteria, design provisions for greater lateral force, foundation systems to resist settlement, wood-frame sheathing, moment-resisting frames, response spectrum, reinforced-masonry construction, elements of structural redundancy, and reinforcement of structural members. These standards apply only to those lands within the city that are underlain by bay mud, as shown on a map adopted for the ordinance (fig. 229).

SECURING NONSTRUCTURAL BUILDING COMPONENTS

Proper siting, design, and construction of structures are well-known techniques for reducing earthquake casualties and damage, but often the contents and other nonstructural components of buildings are overlooked. People have been injured by falling light fixtures, flying glass, overturned shelves, and spilled chemicals. The Federal Emergency Management Agency (1981, table 2) (FEMA) estimates that one-third of the property lost in future earthquakes will be building contents. Such contents are only one part of the nonstructural components of buildings.

Nonstructural damage is caused by object inertia or distortion of the structure. For example, if an office computer is shaken, only friction will restrain it from sliding toward its user. As a structure bends or distorts, its windows, partitions, and other items are stressed, causing them to shatter, crack, or spring out of place. There are measures that can be taken to protect nonstructural components, among which are the following:

- Attaching sharp or heavy office equipment and fixtures to the floor or walls
- Attaching artwork securely to walls
- Connecting filing cabinets at their tops and to a wall
- Arranging free-standing, movable partitions in a zigzag pattern
- Installing locks on cupboards
- Boxing large containers that contain hazardous chemicals
- Strapping hot-water heaters to wall studs

An excellent guidebook on reducing the risk of nonstructural earthquake damage was prepared by Reitherman (1983). He described typical conditions found in office, retail, and government buildings. Measures are suggested for restraining more than 20 nonstructural building components such as office machines, electrical equipment, file cabinets, partitions, suspended ceilings, exterior ornamentation, elevators, piping, stairways, and parapets. Each component is rated for existing and upgraded vulnerability to life-safety hazards, percent of replacement-value damaged, and postearthquake outages for three levels of shaking intensity (fig. 230).

A second guidebook (Washington State Superintendent of Public Instruction, 1989) focuses on procedures for reducing nonstructural hazards in schools. This guidebook, issued by the Washington State Superintendent of Public Instruction, contains drawings of methods for securing hazardous objects commonly found in schools. The objects include ceiling panels, chemicals, doors, exterior chimneys, exterior

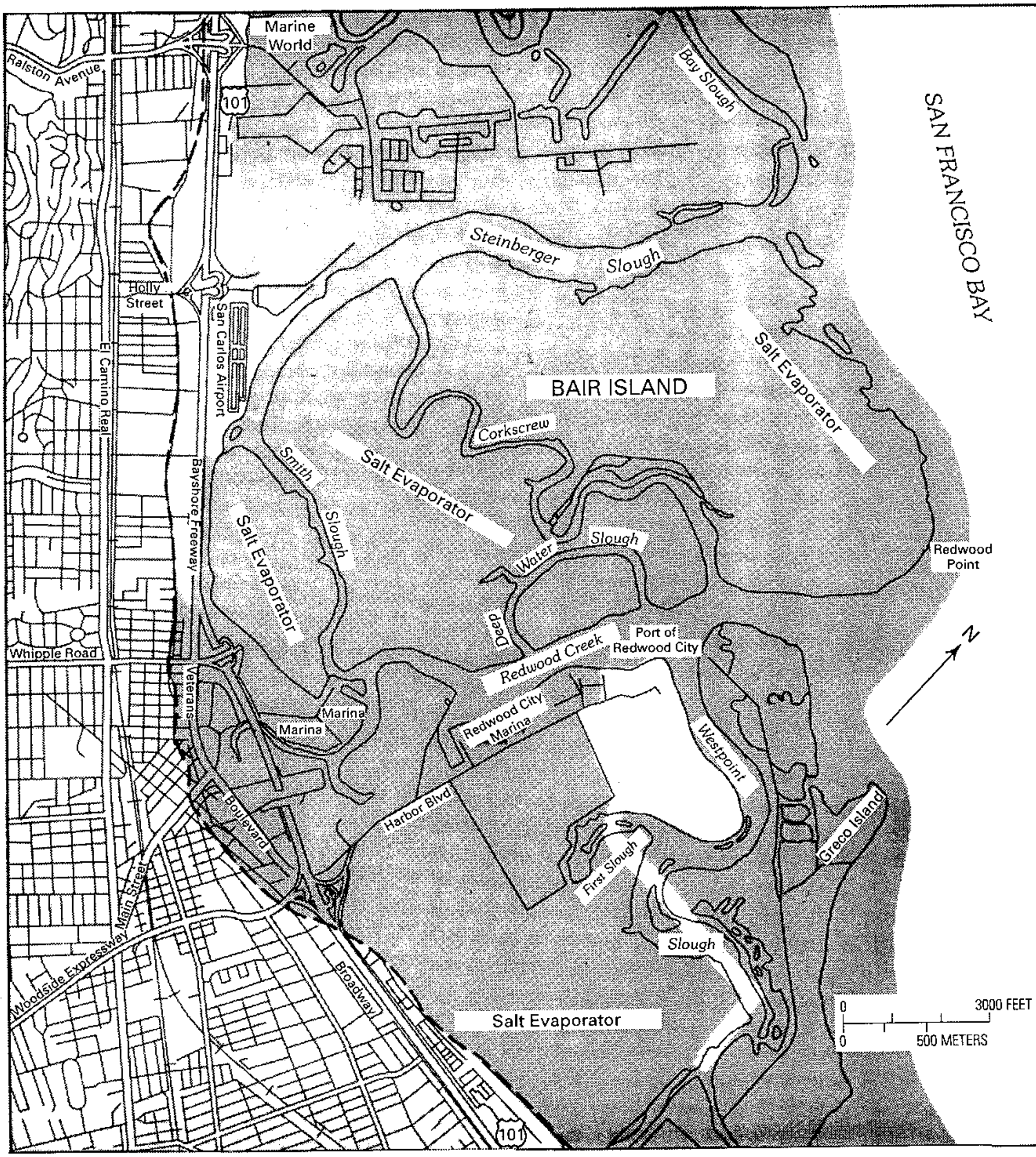
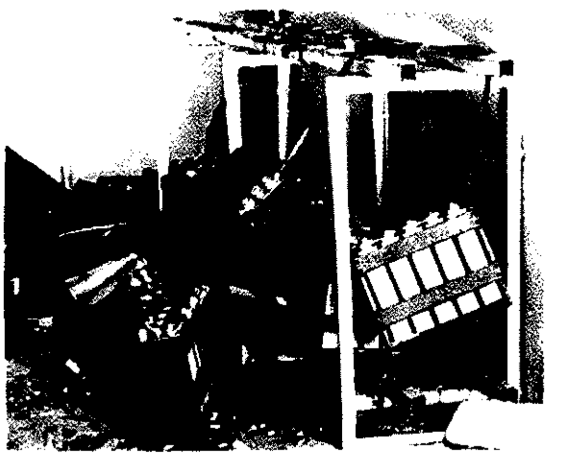
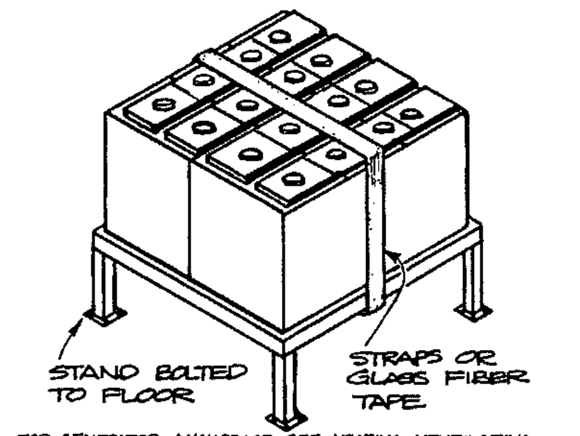


Figure 229. Map included with the Redwood City, Calif., ordinance that requires special seismic-design and construction standards for all new development on San Francisco Bay mud deposits. Bay mud is indicated by shading; its southwestern boundary is the dashed line. The unshaded areas lie outside the city's jurisdiction. From Redwood City Council (1977).

masonry, parapets, furniture, file cabinets, windows, mirrors, skylights, heaters, light fixtures, partitions, and water heaters. A general estimate of the earthquake risk for each object and the cost to secure each are provided. In addition, checklists for school administrators and custodians' are included for both interior hazards, such as ceilings, floors, walls, boiler rooms, cafeterias, halls, stairways, and laboratories, and exterior hazards such as chimneys, ornaments, and parapets.

The application of such techniques to another type of public building was made by the city of Mountain View, Calif. Blair-Tyler and Gregory (1988, p. 19) observed that

EMERGENCY POWER GENERATORS

DAMAGE EXAMPLE	PROTECTIVE COUNTERMEASURE
	
earthquake: 1971 San Fernando credit: John F. Meehan	APPROXIMATE COST: $10 per rack for strapping $50 for bolting

EXISTING VULNERABILITY

SHAKING INTENSITY	EFFECTS	✚	$	▦
LIGHT	slight chance of piping connection break	low	0–5%	mod
MODERATE	slight shifting of equipment; batteries slide	low	5–20%	high
SEVERE	lurching of generator off supports; batteries fall	mod	20–50%	high

UPGRADED VULNERABILITY

SHAKING INTENSITY	EFFECTS	✚	$	▦
LIGHT	no damage	low	0%	low
MODERATE	no damage	low	0%	low
SEVERE	damage to rest of electrical system more likely than generator damage	low	0–5%	low

✚ LIFE SAFETY HAZARD $ % OF REPLACEMENT VALUE DAMAGED ▦ POST–EARTHQUAKE OUTAGE

Figure 230. An example of how to reduce the risk of earthquake damage to one type of nonstructural building component. From Reitherman (1983, p. 39).

the city had consultants prepare a room-by-room inventory of nonstructural hazards in the Emergency Operations Center—an alternate City Hall that would be used in the aftermath of an earthquake. Blair-Tyler and Gregory (1988) reported the following:

Communications equipment was braced and interior glass is being replaced with safety glass or covered with a safety film. The City's maintenance staff is providing the estimated 320 man-hours to complete the nonstructural work during the next year. Any structural strengthening will be done by an outside contractor. Information gained from this experience will be used to reduce nonstructural hazards in the design of Mountain View's new Library and City Hall.

INFORMING THE PUBLIC

A fourth earthquake-hazard-reduction technique involves bringing earthquake-hazard information to the attention of the public. Both pre-earthquake and postearthquake hazard-reduction programs depend on the understanding and support of an informed public. Responsible developers and prudent citizens, when told of possible earthquake hazards, would not wish to risk property losses or expose their clients or families to danger and trauma. Preparing, announcing, and disseminating information on possible earthquake damage, risk, and hazard-reduction techniques can be accomplished in many ways (see examples in tables 40 and 41).

STRENGTHENING UNREINFORCED-MASONRY BUILDINGS

Many techniques for strengthening, converting, or removing unsafe structures are available to State and local governments. One practice, strengthening unreinforced-masonry buildings, has been used by several communities. California has begun the first phase of this process, the identification of unsafe buildings by cities and counties.

These structures include unreinforced-masonry bearing-wall buildings and steel- and concrete-frame buildings with infill walls of unreinforced masonry. According to the California Seismic Safety Commission (1987, p. 2), these structures typically have four weaknesses:

1. Masonry walls, lacking reinforcement, cannot resist earthquake shaking without degrading, which sometimes leads to collapse.
2. The practice of not structurally tying the walls to the roof and floor can allow excessive movements in the walls, which may lead to collapse.
3. Ground floors with open fronts and little crosswise bracing may allow excessive movement and twisting motions, damaging the building.
4. Unbraced parapets may fall into the street.

An ordinance adopted by the Los Angeles City Council (1981) outlines procedures and standards for identifying and classifying buildings having unreinforced-masonry bearing walls; these procedures and standards are based on a building's present use and occupancy (fig. 231). Priorities, deadlines, and standards are also established under which buildings are required to be structurally analyzed and anchored. Whenever analysis determines deficiencies, the ordinance requires that the building be strengthened or removed. The ordinance applies to all buildings having bearing walls of unreinforced masonry that were constructed before 1933 or those structures for which a building permit was issued prior to 1933, the effective date of the city's first seismic building code. The ordinance does not apply to detached one- or two-story single-family dwellings and detached apartment houses containing less than five dwelling units and used solely for residential purposes.

Affected buildings are classified according to type of function and occupancy as essential, high risk, medium risk, and low risk (see SEC. 91.6803 in fig. 231). The strengthening standards and time schedules for notification and compliance vary with the risk category. A structural analysis of each building is also required in order to determine the remedial measures necessary to meet the appropriate standards. The city provides a specific time schedule.

An alternative compliance schedule, intended to lessen the financial and social impacts of the ordinance, gives a building owner the option of performing part of the remedial work within 1 year of notification in exchange for a longer time in which to reach full compliance. The work to be performed within that year involves the anchoring of all unreinforced-masonry walls to roof and floor with bolts and washers. According to the Los Angeles City Planning Department (1979, p. 5), this procedure yields an immediate and substantial improvement in safety for perhaps one-fifth the cost of full compliance.

Using the knowledge and experience gained from the procedures used in Los Angeles, the California Legislature (1986) requires all cities and counties in seismic zone 4 to identify hazardous unreinforced-masonry buildings, notify the building owners, and establish a mitigation program. Local building departments are authorized to establish fees to recover the costs of identification. The California Legislature (1986) specifies that the mitigation program may include the following:

> The adoption by ordinance of a hazardous buildings program, measures to strengthen buildings, measures to change the use to acceptable occupancy levels or to demolish the building, tax incentives available for seismic rehabilitation, low-cost seismic rehabilitation loans, * * * application of structural standards necessary to provide for life safety above current code requirements, and other incentives to repair the buildings which are available from federal, state, and local programs.

Compliance with a hazardous-buildings ordinance or mitigation program is the responsibility of building owners. Nothing in the law makes any local government responsible for paying the cost of strengthening a privately owned structure, reducing the occupancy, demolishing a structure, preparing engineering or architectural analyses, conducting investigations, or other costs associated with compliance of locally adopted mitigation programs.

A guidebook addressing the hazards of unreinforced-masonry buildings has been developed by the California Seismic Safety Commission (1987). The guidebook contains a series of steps for both identifying potentially hazardous buildings and developing and implementing a hazard-mitigation program, including a model ordinance that provides for strengthening or removal of unsafe buildings. Other discussions include costs to local government, costs to building owners, incentives, and sources of information.

Some of the advantages of such ordinances are that deaths and injuries will be substantially reduced, economically obsolete buildings may eventually be removed, land will be reused more efficiently, and repair or demolition will provide work for the construction industry. Some of the disadvantages of such ordinances are that some low-income housing may be lost, tenants probably will have to be relocated, and businesses could be interrupted.

ESTIMATING CASUALTIES, DAMAGE, AND INTERRUPTIONS

Several techniques to assist State and local governments in preparing for, responding to, and recovering from earthquake emergencies and disasters are available. One of the techniques is commonly called a loss estimate. A National Research Council (1989) panel defines an earthquake loss estimate as "a forecast of the effects of a hypothetical earthquake. Depending on its purpose, a loss study may include estimates of deaths and injuries; property losses; loss of function in industries, lifelines, and emergency facilities; homelessness; and economic impacts." These estimates are effective techniques in creating public awareness of hazards and support for preparedness measures and response and recovery operations. Three examples of loss estimates follow.

Table 40. Examples of information and dissemination techniques for informing the public about earthquake hazards.

General, introductory, and index materials
"Washington State Earthquake Hazards" (Noson and others, 1988)
"Facing Geologic and Hydrologic Hazards—Earth-Science Considerations" (Hays, 1981)
A newspaper home-guide section on how a house withstands an earthquake, by Kerch (1988)
"Getting Ready for a Big Quake" (Sunset Magazine, 1982)
"Seismic Hazards of Western Washington and Selected Adjacent Areas—Bibliography and Index" (Manson, 1988)
"Policy Recommendations" (Washington State Seismic Safety Council, 1986)
Serial publications
Oregon Geology (published bimonthly by the Oregon State Department of Geology and Mineral Industries)
Earthquake hazard-reduction booklets published by the Federal Emergency Management Agency (see table _3_)
Earthquakes and Volcanoes (formerly the Earthquake Information Bulletin, published by the U.S. Geological Survey beginning 1971)
Washington Geologic Newsletter (published quarterly by the Washington State Division of Geology and Earth Resources)
Wasatch Front Forum (published quarterly by the Utah Geological and Mineral Survey beginning 1984)
Guidebooks and guidelines
"The Next Big Earthquake in the Bay Area May Come Sooner Than You Think" (U.S. Geological Survey, 1991)
"Geologic Principles for Prudent Land Use—A Decisionmaker's Guide for the San Francisco Bay Region" (Brown and Kockelman, 1983)
"An Earthquake Advisor's Handbook for Wood-Frame Houses" (University of California Center for Planning and Development Research, 1982)
"Reducing Earthquake Risks—A Planner's Guide" (Jaffe and others, 1981)
"Preparing a Safety Element of the City and County General Plan" (Mintier, 1987, p. 146–153)
"California at Risk—Steps to Earthquake Safety for Local Government" (Mader and Blair-Tyler, 1988)
"Landslide Loss Reduction—A Guide for State and Local Government Planning" (Wold and Jochim, 1989)
Conferences and workshops
"Governor's Conference on Geologic Hazards" (Utah Geological and Mineral Survey, 1983)
"Proceedings of Conference XLVIII—3d Annual Workshop on Earthquake Hazards in the Puget Sound, Portland, Area" (Hays, 1989)
"Proceedings of Conference XLIIV—A Workshop on Evaluation of Earthquake Hazards and Risk in the Puget Sound and Portland Areas" (Hays, 1988)
"Workshop on Future Directions in Evaluating Earthquake Hazards of Southern California, Proceedings of Conference XXXII, Nov. 12–13, 1985, Los Angeles, Calif." (Brown and others, 1986)
"Third International Earthquake Microzonation Conference, Proceedings, June 28-July 1, 1982, Seattle, USA" (Sherif, 1982 [particularly sessions 3, 6, and 10])
Outreach programs
"The Circuit-Rider Geologist in the State of Washington" (Thorsen, 1981)
"Engineering Geology at the Local Government Level—Planning, Reviewing, and Enforcement" (McCalpin, 1985)
"Advisory Services [of the California Division of Mines and Geology]" (Amimoto, 1980)
Educational, advisory and review services provided by the Southeastern Wisconsin Regional Planning Commission
Emergency Management Institute's mitigation and natural hazards curriculum (Federal Emergency Management Agency, 1991, p. 37–43)
"Perspectives on Public Information and Awareness Programs in the Puget Sound, Washington, Area" (Martens, 1988)
"Final Technical Report—Wasatch Front County Hazards Geologist Program" (Christenson, 1988)
Discussions of adopted reduction techniques
"Anticipating Earthquakes—Risk Reduction Policies and Practices in the Puget Sound and Portland Areas" (May, 1989)
"Washington State School Earthquake Emergency Planning" (Noson and Martens, 1987)
"Hazardous Buildings—Case Studies" (Bay Area Regional Earthquake Preparedness Project, 1988)
"Using Earth-Science Information for Earthquake-Hazard Reduction" (Kockelman, 1985)
"Putting Seismic Safety Policies to Work" (Blair-Tyler and Gregory, 1988)
"Examples of Seismic Zonation in the San Francisco Bay Region" (Kockelman and Brabb, 1979)

Table 41. Federal Emergency Management Agency (FEMA) earthquake-hazards-reduction reports available to the public.

[Modified from an Earthquake-Hazards-Reduction Series (EHRS) list prepared by the Federal Emergency Management Agency (1989). Publications are free of charge; copies may be obtained by writing to Federal Emergency Management Agency, P.O. Box 70274, Washington, D.C. 20024]

EHRS number	Title	FEMA number
1	Reducing the risks of nonstructural earthquake damage: A Practical guide (June 1985, 87 p.)	74
2	Comprehensive earthquake preparedness planning guidelines: City (May 1985, 94 p.)	73
3	Comprehensive earthquake preparedness planning guidelines: County (May 1985, 107 p.)	72
4	Comprehensive earthquake preparedness planning guidelines: Corporate (May 1985, 57 p.)	71
5	Earthquake preparedness information for people with disabilities (May 1985, 16 p.)	70
6	Pilot project for earthquake hazard assessment (May 1985, 108 p.)	69
7	Earthquake insurance: A public policy dilemma (May 1985, 67 p.)	68
8	Earthquake public information materials: An annotated bibliography (September 1986, 92 p.)	67
12	Guidelines for local small businesses in meeting the earthquake threat (September 1985, 16 p.)	87
13	Societal implications: A community handbook (June 1985, 54 p.)	83
14	Societal implications: Selected readings (June 1985, 148 p.)	84
15	Proceedings: Workshop on reducing seismic hazards of existing buildings (December 1985, 214 p.)	91
16	An action plan for reducing earthquake hazards of existing buildings (December 1985, 75 p.)	90
17	NEHRP (National Earthquake Hazard Reduction Program) recommended provisions for the development of seismic regulations for new buildings, part 1: Provisions (January 1992, 199 p.)	222
18	NEHRP recommended provisions for the development of seismic regulations for new buildings, part 2: Commentary (February 1986, 200 p.)	96
19	NEHRP recommended provisions for the dèvelopment of seismic regulations for new buildings, part 3: Appendix (February 1966, 142 p.)	97
20	Improving seismic safety of new buildings: A nontechnical explanation of NEHRP provisions (March 1986, 64 p.)	99
21	Guidelines for preparing code changes based on the NEHRP recommended provisions (March 1986, 120 p.)	98
22	Preparedness in apartments and mobile homes (September 1986, 15 p.)	L–143
23	A guide to marketing earthquake preparedness: Community campaigns that get results (September 1986, 39 p.)	111
24	Marketing earthquake preparedness: Community campaigns that get results (September 1986, 39 p.)	112
25	Guide to application of the NEHRP recommended provisions in earthquake-resistant building design (July 1987, 360 p.)	140
26	Abatement of seismic hazards to lifelines, Volume I: Water and sewer (July 1987, 185 p.)	135
27	Abatement of seismic hazards to lifelines, Volume II: Transportation (July 1987, 163 p.)	136
28	Abatement of seismic hazards to lifelines, Volume III: Communications (July 1987, 103 p.)	137
29	Abatement of seismic hazards to lifelines, Volume IV: Power (July 1987, 79 p.)	138
30	Abatement of seismic hazards to lifelines, Volume V: Gas and liquid fuels (July 1987, 135 p.)	139
31	Abatement of seismic hazards to lifelines, Volume VI: Papers on political, economic, social, legal, and regulatory issues (August 1987, 237 p.)	143
32	Abatement of seismic hazards to lifelines: An action plan (August 1987, 241 p.)	142
33	Comprehensive earthquake preparedness planning guidelines: Large city (September 1987, 61 p.)	146
34	Seismic considerations: Elementary and secondary schools (April 1988, 105 p.)	149
35	Seismic considerations: Health-care facilities (May 1990, 102 p.)	150
36	Seismic considerations: Hotels and motels (May 1990, 106 p.)	151
37	Seismic considerations: Apartment buildings (November 1988, 120 p.)	152
38	Seismic considerations: Office buildings (November 1988, 110 p.)	153
39	Typical costs for seismic rehabilitation of existing buildings, Volume I: Summary (July 1988, 65 p.)	156
40	Typical costs for seismic rehabilitation of existing buildings, Volume II: Supporting documentation (September 1988, 150 p.)	157
41	Rapid visual screening of buildings for potential seismic hazards: A handbook (July 1988, 185 p.)	154
42	Rapid visual screening of buildings for potential seismic hazards: Supporting documentation (September 1988, 137 p.)	155
43	Earthquake damaged buildings: An overview of heavy debris and victim extrication (September 1988, 95 p.)	158
44	Differences between the 1985 and 1988 editions of the NEHRP recommended provisions for the development of seismic regulations for new buildings (October 1988, 46 p.)	162
45	Establishing programs and priorities for the seismic rehabilitation of buildings: A handbook (May 1989, 122 p.)	174

Table 41. Federal Emergency Management Agency (FEMA) earthquake-hazards-reduction reports available to the public—Continued.

EHRS number	Title	FEMA number
46	Establishing programs and priorities for the seismic rehabilitation of buildings: Supporting report (May 1989, 190 p.)	173
47	A handbook for seismic evaluation of existing buildings [preliminary] (June 1989, 169 p.)	178
48	Seismic evaluation of existing buildings: Supporting documentation (May 1989, 160 p.)	175
49	Techniques for seismically rehabilitating existing buildings [preliminary] (May 1989, 172 p.)	172
50	Estimating losses from future earthquakes: Panel report [a nontechnical summary] (June 1989, 82 p.)	176
51	Estimating losses from future earthquakes [panel report and technical background] (June 1989, 231 p.)	177
52	Landslide loss reduction: A guide for state and local government planning (August 1989, 50 p.)	182
53	Estimated future earthquake losses for St. Louis city and county, Missouri (June 1990, 204 p.)	192
53A	Estimated future earthquake losses for St. Louis city and county, Missouri: Executive summary (June 1990, 10 p.)	192A
54	Financial incentives for seismic rehabilitation of hazardous buildings, An agenda for action, Volume I: Findings, conclusions, and recommendations (September 1990, 102 p.)	198
55	Financial incentives for seismic rehabilitation of hazardous buildings, An agenda for action, Volume II: State and local case studies and recommendations (September 1990, 128 p.)	199
56	Earthquake resistant construction of electric transmission and telecommunication facilities serving the Federal government: Report (September 1990, 41 p.)	202
57	Financial incentives for seismic rehabilitation of hazardous buildings, An agenda for action, Volume III: Applications workshops report (July 1991, 187 p.)	216
58	Seismic vulnerability and impact of disruption of lifelines in the conterminous United States (September 1991, 439 p.)	224
59	Colocation impacts on the vulnerability of lifelines during earthquakes with applications to Cajon Pass, California: Study overview (October 1991, 20 p.)	221
60	Inventory of lifelines in the Cajon Pass, California (February 1992, 92 p.)	225
61	Colocation impacts on the vulnerability of lifelines during earthquakes with applications to the Cajon Pass, California (February 1992, 103 p.)	226
62	A benefit-cost model for the seismic rehabilitation of buildings, Volume I: A user's manual (April 1992, 115 p.)	227
63	A benefit-cost model for the seismic rehabilitation of buildings, Volume II: Supporting documentation (April 1992)	228
64	NEHRP recommended provisions for the development of seismic regulations for new buildings and NEHRP map, part 1 (January 1992, 199 p.)	222
65	NEHRP recommended provisions for the development of seismic regulations for new buildings, part 2: Commentary (January 1992, 237 p.)	223

The Federal Emergency Management Agency (1981) estimated the number of dead and hospitalized, the number of injured but not hospitalized, and losses to buildings and their contents resulting from postulated earthquakes in four California locations (table 42). In addition, damage to or impact on selected facilities was discussed as were post-seismic needs; these included temporary housing, key communication facilities, military command circuits, all transportation modes, businesses, and industries. FEMA and the California Office of Emergency Services then conducted an analysis of readiness for each of these categories and discussed Federal, State, and local responses and response planning.

The second example of a loss estimate was prepared by Davis and others (1982). They created a planning scenario for a postulated earthquake in the Los Angeles region that can be used to gauge the severe impact on this urban area by assessing the effects on principal lifelines for emergency planning purposes. An analysis of readiness can then be used to provide planning insights, recommend further work, and serve as a basis for making or improving emergency preparedness, response, recovery, and reconstruction plans.

Davis and others (1982) included individual scenarios that show damage to lifelines such as highways, airports, railroads, marine facilities, communication lines, water-supply and waste-disposal facilities, and electrical power, natural gas, and petroleum lines. The scenarios are based on evaluation of earthquake-engineering literature, comments

Figure 231 (overleaf). Part of the Los Angeles, Calif., earthquake-hazard-reduction ordinance requiring owners of buildings having unreinforced-masonry bearing walls constructed before 1933 to obtain a structural analysis. If the building does not meet the minimum standards, the owner is required to strengthen or remove it according to a specific time schedule. From Los Angeles City Council (1981).

Ordinance No. 154,807

An ordinance adding Division 68 of Article 1 of Chapter IX of the Los Angeles Municipal Code relative to earthquake hazard reduction in existing buildings.

Section 1. Article 1 of Chapter IX of the Los Angeles Municipal Code is hereby amended to add a Division 68 to read:

DIVISION 68 — EARTHQUAKE HAZARD REDUCTION IN EXISTING BUILDINGS

SEC. 91.6801. PURPOSE:

The purpose of this Division is to promote public safety and welfare by reducing the risk of death or injury that may result from the effects of earthquakes on unreinforced masonry bearing wall buildings constructed before 1934. Such buildings have been widely recognized for their sustaining of life hazardous damage as a result of partial or complete collapse during past moderate to strong earthquakes.

The provisions of this Division are minimum standards for structural seismic resistance established primarily to reduce the risk of life loss or injury and will not necessarily prevent loss of life or injury or prevent earthquake damage to an existing building which complies with these standards. This Division shall not require existing electrical, plumbing, mechanical or fire safety systems to be altered unless they constitute a hazard to life or property.

This Division provides systematic procedures and standards for identification and classification of unreinforced masonry bearing wall buildings based on their present use. Priorities, time periods and standards are also established under which these buildings are required to be structurally analyzed and anchored. Where the analysis determines deficiencies, this Division requires the building to be strengthened or demolished.

Portions of the State Historical Building Code (SHBC) established under Part 8, Title 24 of the California Administrative Code are included in this Division.

SEC. 91.6802. SCOPE:

The provisions of this Division shall apply to all bullings constructed or under construction prior to October 6, 1933, or for which a building permit was issued prior to October 6, 1933, which on the effective date of this ordinance have unreinforced masonry bearing walls as defined herein.

EXCEPTION: This Division shall not apply to detached one or two story-family dwellings and detached apartment houses containing less than five dwelling units and used solely for residential purposes.

SEC. 91.6803. DEFINITIONS:

For purposes of this Division, the applicable definitions in Sections 91.2301 and 91.2305 of this Code and the following shall apply:

Essential Building: Any building housing a hospital or other medical facility having surgery or emergency treatment areas; fire or police stations; municipal government disaster operation and communication centers.

High Risk Building: Any building, not classified an essential building, having an occupant load as determined by Section 91.3301(d) of this Code of 100 occupants or more.

EXCEPTION: A high risk building shall not include the following:

1. Any building having exterior walls braced with masonry crosswalls or wood frame crosswalls spaced less than 40 feet apart in each story.
2. Any building used for its intended purpose, as determined by the Department, for less than 20 hours per week.

Historical Building: Any building designated as an historical building by an appropriate Federal, State or City jurisdiction.

Low Risk Building: Any building, not classified an essential building, having an occupant load as determined by Section 91.3301(d) of less than 20 occupants.

Medium Risk Building: Any building, not classified as a high risk building or an essential building, having an occupant load as determined by Section 91.3301(d) of 20 occupants or more.

Unreinforced Masonry Bearing Wall: A masonry wall having all of the following characteristics:

1. Provides the vertical support for a floor or roof.
2. The total superimposed load is over 100 pounds per linear foot.
3. The area of reinforcing steel is less than 50 percent of that required by Section 91.2418(e) of this Code.

SEC. 91.6804. RATING CLASSIFICATIONS:

The rating classifications as exhibited in Table No. 68-A are hereby established and each building within the scope of this Division shall be placed in one such rating classification by the Department. The total occupant load of the entire building as determined by Section 91.3301(d) shall be used to determine the rating classification.

EXCEPTION: For the purpose of this Division, portions of buildings constructed to act independently when resisting seismic forces may be placed in separate rating classifications.

TABLE NO. 68-A
RATING CLASSIFICATIONS

Type of Building	Classification
Essential Building	I
High Risk Building	II
Medium Risk Building	III
Low Risk Building	IV

SEC. 91.6805. GENERAL REQUIREMENTS:

The owner of each building within the scope of this Division shall cause a structural analysis to be made of the building by a civil or structural engineer or arthitect licensed by the State of California; and, if the building does not meet the minimum earthquake standards specified in this Division, the owner shall cause it to be structurally altered to conform to such standards; or cause the building to be demolished.

The owner of a building within the scope of this Division shall comply with the requirements set forth above by submitting to the Department for review within the stated time limits:

a. Within 270 days after the service of the order, a structural analysis. Such analysis which is subject to approval by the Department, shall demonstrate that the building meets the minimum requirements of this Division; or

b. Within 270 days after the service of the order, the structural analysis and plans for the proposed structural alterations of the building necessary to comply to the minimum requirements of this Division; or

c. Within 120 days after service of the order, plans for the installation of wall anchors in accordance with the requirements specified in Section 91.6808(c); or

d. Within 270 days after the service of the order, plans for the demolition of the building.

After plans are submitted and approved by the Department, the owner shall obtain a building permit, commence and complete the required construction or demolition within the time limits set forth in No. Table 68-B. These time limits shall begin to run from the date the order is served in accordance with Section 91.6806(a) and (b).

TABLE NO. 68-B
TIME LIMITS FOR COMPLIANCE

Required Action By Owner	Obtain Building Permit Within	Commence Construction Within	Complete Construction Within
Complete Structural Alterations or Building Demolition	1 year	180 days*	3 years
Wall Anchor Installation	180 days	270 days	1 year

*Measured from date of building permit issuance.

Owners electing to comply with Item c of this Section are also required to comply with Items b or d of this Section provided, however, that the 270-day period provided for in such Items b and d and the time limits for obtaining a building permit, commencing construction and completing construction for complete structural alterations or building demolition set forth in Table No. 68-B shall be extended in accordance with Table No. 68-C. Each such extended time limit, except the time limit for commencing construction shall begin to run from the date the order is served in accordance with Section 91.6806 (b). The time limit for commencing construction shall commence to run from the date the building permit is issued.

TABLE NO. 68-C
EXTENSIONS OF TIME AND SERVICE PRIORITIES

Rating Classification	Occupant Load	Extension of Time if Wall Anchors are Installed	Minimum Time Periods for Service of Order
I (Highest Priority)	Any	1 year	0
II	100 or more	3 years	90 days
III	100 or more	5 years	1 year
	More than 50, but less than 100	6 years	2 years
	More than 19, but less than 51	6 years	3 years
IV (Lowest Priority)	Less than 20	7 years	4 years

SEC. 91.6806. ADMINISTRATION:

(a) Service of Order. The Department shall issue an order, as provided in Section 91.6806(b), to the owner of each building within the scope of this Division in accordance with the minimum time periods for service of such orders set forth in Table No. 68-C. The minimum time period for the service of such orders shall be measured from the effective date of this Division. The Department shall upon receipt of a written request from the owner, order a building to comply with this Division prior to the normal service date for such building set forth in this Section.

(b) Contents of Order. The order shall be written and shall be served either personally or by certified or registered mail upon the owner as shown on the last equalized assessment, and upon the person, if any, in apparent charge or control of the building. The order shall specify that the building has been determined by the Department to be within the scope of this Division and, therefore, is required to meet the minimum seismic standards of this Division. The order shall specify the rating classification of the building and shall be accompanied by a copy of Section 91.6805 which sets forth the owner's alternatives and time limits for compliance.

(c) Appeal From Order. The owner or person in charge or control of the building may appeal the Department's initial determination that the building is within the scope of this Division to the Board of Building and Safety Commissioners. Such appeal shall be filed with the Board within 60 days from the service date of the order described in Section 91.6806(b). Any such appeal shall be decided by the Board no later than 60 days after the date that the appeal is filed. Such appeal shall be made in writing upon appropriate forms provided therefor, by the Department and the grounds thereof shall be stated clearly and concisely. Each appeal shall be accompanied by a filing fee as set forth in Table 4-A of Section 98.0403 of the Los Angeles Municipal Code.

Appeals or requests for slight modifications from any other determinations, orders or actions by the Department pursuant to this Division, shall be made in accordance with the procedures established in Section 98.0403.

(d) Recordation. At the time that the Department serves the aforementioned order, the Superintendent of Building shall file with the Office of the County Recorder a certificate stating that the subject building is within the scope of Division 68 — Earthquake Hazard Reduction in Existing Buildings — of the Los Angeles Municipal Code. The certificate shall also state that the owner thereof has been ordered to structurally analyze the building and to structurally alter or demolish it where compliance with Division 68 is not exhibited.

If the building is either demolished, found not to be within the scope of this Division, or is structurally capable of resisting minimum seismic forces required by this Division as a result of structural alterations or an analysis, the Superintendent of Building shall file with the Office of the County Recorder a certificate terminating the status of the subject building as being classified within the scope of Division 68 — Earthquake Hazard Reduction in Existing Buildings — of the Los Angeles Municipal Code.

(e) Enforcement. If the owner or other person in charge or control of the subject building fails to comply with any order issued by the Department pursuant to this Division within any of the time limits set forth in Section 91.6805, the Superintendent of Building shall order that the entire building be vacated and that the building remain vacated until such order has been complied with. If compliance with such order has not been accomplished within 90 days after the date the building has been ordered vacated or such additional time as may have been granted by the Board and the Superintendent may order its demolition in accordance with the provisions of Section 91.0103(o) of this Code.

SEC. 91.6807. HISTORICAL BUILDINGS:

(a) General. The standards and procedures established by this Division shall apply in all respects to an historical building except that as a means to preserve original architectural elements and facilitate restoration, an historical building may, in addition, comply with the special provisions set forth in this Section.

(b) Unburned Clay Masonry or Abode. Existing or re-erected walls of abode construction shall conform to the following:

1. Unreinforced abode masonry wall shall not exceed a height or length to thickness ratio of 5, for exterior bearing walls and must be provided with a reinforced bond beam at the top, interconnecting all walls. Minimum beam depth shall be 6 inches and a minimum width

Table 42. Estimated consequences of postulated catastrophic earthquakes occurring on four California faults at different times of the day.

[All estimates have an uncertainty factor of 2 to 3. Injuries not requiring hospitalization are estimated to be 15–30 times greater than the number of fatalities. Modified from Federal Emergency Management Agency (1981, p. 23, table 3)]

Fault	Time	Fatalities	Hospitalized
Northern San Andreas (near San Francisco).	2:30 a.m.	3,000	12,000
	2:00 p.m.	10,000	37,000
	4:30 p.m.	11,000	44,000
Hayward (near Oakland).	2:30 a.m.	3,000	13,000
	2:00 p.m.	8,000	30,000
	4:30 p.m.	7,000	27,000
Southern San Andreas (near Los Angeles).	2:30 a.m.	3,000	12,000
	2:00 p.m.	12,000	50,000
	4:30 p.m.	14,000	55,000
Newport-Inglewood (in Los Angeles).	2:30 a.m.	4,000	18,000
	2:00 p.m.	21,000	83,000
	4:30 p.m.	23,000	91,000

by numerous engineers and officials of public agencies, and judgments by the authors. The assessment evaluated the postearthquake performance of lifeline segments throughout the region. Figure 232 shows the communications map, which assesses telephone-system performance following the postulated earthquake. Other maps (water-supply and waste-disposal facilities, for example) show the locations and estimates of damage to specific facilities. Most of these planning maps contain notations that are explained further in their text, such as "Water deliveries through the MWD Upper Feeder will be temporarily interrupted by pipe rupture where this major transmission line crosses the Santa Ana River." The scenarios indicate that most of the lifelines will sustain significant damage that could require a major emergency-response effort. Each scenario map is accompanied by a discussion of the general patterns of earthquake effects, as in the following:

> Interstate 5 from the San Joaquin Valley and Interstate 15 through Cajon Pass will be closed, leaving U.S. 101 along the coast as the only major viable route open from the north. Highway connections with San Diego will remain open.

And,

> Not all of the [telephone] systems in the greater Los Angeles region are set up to process emergency calls automatically on previously established priority bases. Thus overloading of equipment still in service could be very significant.

Similar scenarios have been prepared for other postulated earthquakes, such as on the Hayward fault in the San Francisco Bay region, by Steinbrugge and others (1987).

The third example of a loss estimate was one prepared by the U.S. Geological Survey (1975). It postulated earthquakes for two locations in the Puget Sound, Wash., region and concluded that under the worst circumstances, there could be as many as 2,200 dead, 8,700 injured, and 23,500 homeless. Anticipated damage patterns for five counties in the region were also estimated for both events. The degree of impairment was assigned to selected critical facilities, equipment, or supplies (fig. 233). Detailed assessments are included, as in the following:

- Damage to hospitals having capacities of 50 or more beds
- Physician and nurse fatalities at nonhospital locations
- Losses of stock at retail drugstores and pharmacies
- Damage to railroad bridges and tunnels
- Probability of fatalities based upon siting of schools in areas of high damage intensities

These loss estimates, damage scenarios, and degrees of impairment are intended for planning purposes only, and some may consider them overly pessimistic. However, in emergency planning, it is important to plan for the most severe levels of casualties and socioeconomic disruption in order to be better able to prepare, respond, and recover.

PREREQUISITES FOR EARTHQUAKE-HAZARD-REDUCTION TECHNIQUES

Prerequisites for the selection and implementation of an appropriate earthquake-hazard-reduction technique from table 39 are as follows:

- Conducting scientific and engineering studies of the physical processes of earthquake phenomena—source, location, size, likelihood of occurrence, triggering mechanism, path, ground response, structure response, and equipment response
- Translating the results of such studies into reports and onto maps at an appropriate scale so that the nature and extent of the hazards and their effects are understood by nontechnical users
- Transferring this information to those who will need to use it and then assisting and encouraging them in its use

SCIENTIFIC AND ENGINEERING STUDIES

It is not prudent for planners to develop land-use regulations, engineers to design structures, and lenders and public-works directors to adopt policies reducing earthquake hazards without adequate and reliable scientific and engineering assessments. As an overview of some of these assessments, the nontechnical reader is referred to Hays (1989, p. 193–194, list 1). Many studies were envisioned and are described in the "Regional Earthquake Hazards Assessments" draft work plan for the Pacific Northwest by Hays (1988, p. 12–33).

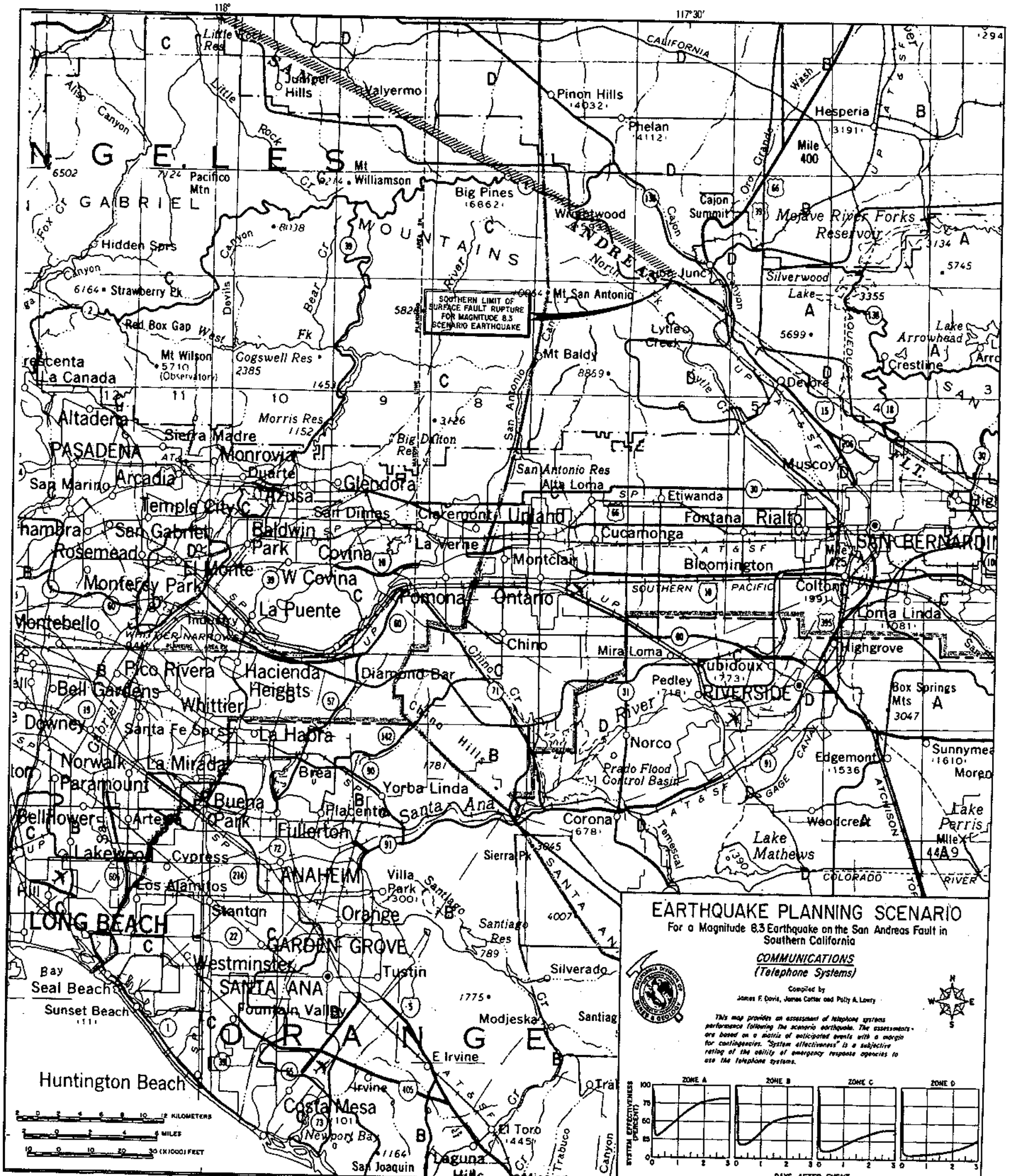
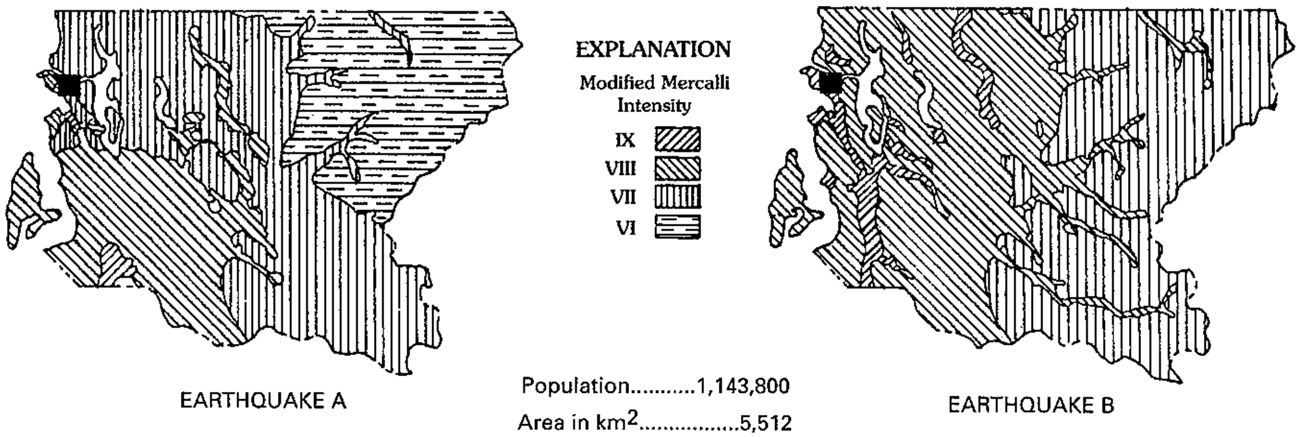


Figure 232. Planning-scenario map showing the impact of a postulated earthquake on the telephone system for part of the Los Angeles, Calif., metropolitan area. This compilation by Davis and others (1982) shows the percentage of telephone-system effectiveness in four zones (designated A, B, C, and D) as much as 3 days after the event. For example, in zone D near San Bernardino, only about 25 percent of the telephone system would be in operation 3 days after the earthquake.



Population..........1,143,800
Area in km²................5,512

	DEGREE OF IMPAIRMENT					
	EARTHQUAKE A			EARTHQUAKE B		
VITAL NEEDS	Minimal	Minor	Major	Minimal	Minor	Major
Communications		●				●
Fire		●				●
Police		●				●
Electric power			●			●
Water		●				●
Access roadways			●			●
Medical:						
Manpower			●			●
Hospitals			●			●
Ambulances		●				●
Blood bank		●				●
Supplies		●			●	
Food supplies	●				●	
Schools (as shelters)		●				●

	ESTIMATED LOSSES	
	EARTHQUAKE A	EARTHQUAKE B
Deaths	1,500	1,650
Serious injuries	6,000	6,600
Homeless	7,130	18,630

Figure 233. Anticipated damage and casualties from two postulated earthquakes in King County, Wash. The black square indicates the general location of Seattle. From U.S. Geological Survey (1975, p. 5, table 2).

TRANSLATION OF RESULTS FOR NONTECHNICAL USERS

Translating scientific and engineering data into formats that can be readily used by lay people provides those users with an awareness that a hazard exists that may affect them or their interests; gives them information that they can easily present to their superiors, clients, or constituents; and provides them with materials that can be directly used as hazard-reduction techniques. My experience with reducing potential natural hazards indicates that for the seismic-hazard information to be successfully used by nontechnical users, it must have the following three elements in one form or another:

1. The likelihood of occurrence of an earthquake that will cause casualties, damage, or disruption
2. The location and areal extent of ground effects by the earthquake

3. The estimated severity of the ground effects and effects on structures and equipment

These elements are needed because engineers, planners, and decisionmakers usually will not be concerned with a potential hazard if its likelihood is rare, its location is unknown, or its severity is slight, and neither will lenders, politicians, or citizens.

TRANSFER OF INFORMATION TO NONTECHNICAL USERS

The objective of transferring hazard information to nontechnical users is to assist in and encourage its use in order to reduce losses from future earthquakes. Translated hazard information is a prerequisite for transfer to nontechnical users. A comprehensive example of both the translation and transfer of geologic information for use by county planners and decisionmakers is provided by Brabb (1987).

Various terms are used to convey information transfer to users, including "dissemination," "communication," "circulation," "promulgation," and "distribution." These terms are often interpreted conservatively, such as when merely issuing a press release on hazards or distributing research information to potential users. This level of activity usually fails to result in the formulation of effective hazard-reduction techniques and may even fail to make users aware of the hazard. Therefore, I suggest that we use the term "transfer" to mean the delivery of a translated product (report, map, video, or poster) in a usable format at a scale appropriate to its use by a specific person or group interested in or responsible for hazard reduction. In delivering such a product, assistance and encouragement in its use must also be provided.

EVALUATION AND REVISION OF TECHNIQUES

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

Performing the studies and then translating and transferring the research information is expensive and difficult because of the limited number of scientists and geotechnicians, particularly when considering the number of communities faced with possible seismic hazards throughout the United States. The adoption and enforcement of an appropriate hazard-reduction technique is time consuming and requires many skills—planning, engineering, legal, and political—as well as strong and consistent public support.

Scarce financial and staff resources must be committed, and persistent and difficult actions must be taken to enact laws, adopt policies, or administer hazard-reduction programs for long periods of time. To discover later that the specific hazard-reduction technique selected is ineffective or unenforceable or its cost is greatly disproportionate to its benefits not only is disheartening but also may subject the persons involved to the criticism and loss of financial support!

CONCLUSIONS

The earthquake-hazard-reduction techniques presented in this report include preparing redevelopment plans, creating regulatory zones, securing nonstructural building components, informing the public, strengthening unreinforced-masonry buildings, and estimating casualties, damage, and interruptions. These techniques are designed to provide greater public safety, health, and welfare for individuals and their communities. The decision to adopt a technique is influenced by many factors—the nature of the earthquake hazard, public concern, strong community interest, State-enabling legislation, the availability of scientific and engineering information, and the ability of geologists, engineers, planners, and lawyers to incorporate the information into an effective hazard-reduction technique.

Some of the geologic and seismologic information needed for land-use and general planning in the Pacific Northwest region is available but generally not at the level of detail and scale needed for engineering and decisionmaking. Even greater detail at larger map scales ranging from 1:1,200 to 1:12,000 is needed for development planning, site investigation, ordinance administration, project review, and permit issuance.

Earthquake-hazard research is continuing, the information base is growing, new methods for evaluating hazards are being developed, and hazard-reduction techniques may be tested. Planners, engineers, and decisionmakers (both public and private) need to recognize these facts and use the latest information, methods, and techniques. However, they cannot be expected to have the training or experience necessary to understand and use untranslated scientific and engineering information. Therefore, if nontechnical users are to benefit from this information, it must be translated and transferred to them before effective hazard-reduction techniques can be adopted.

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