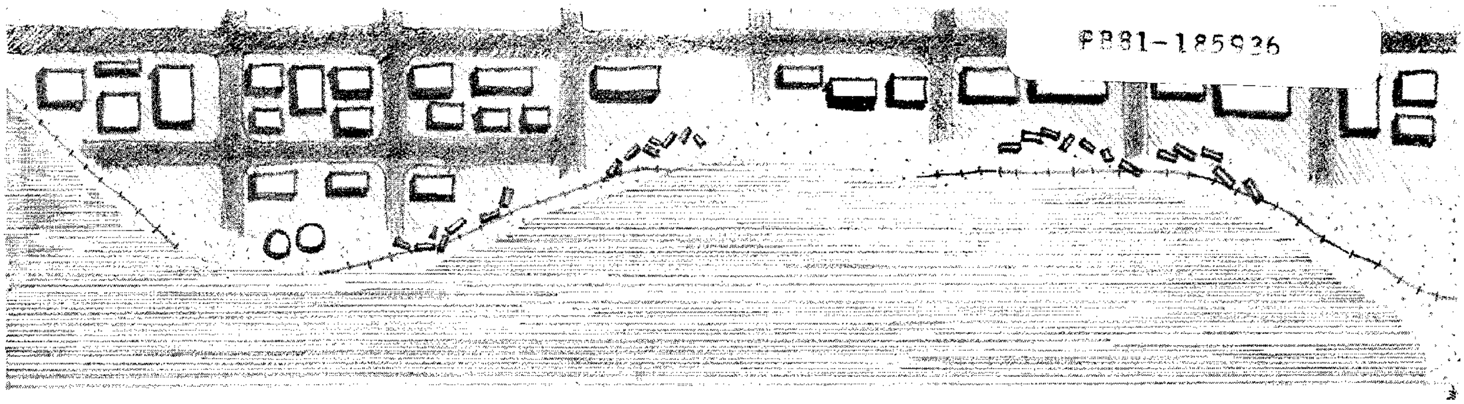

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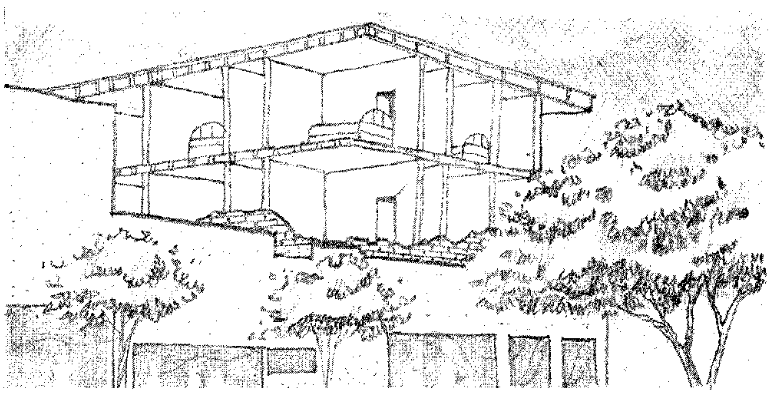

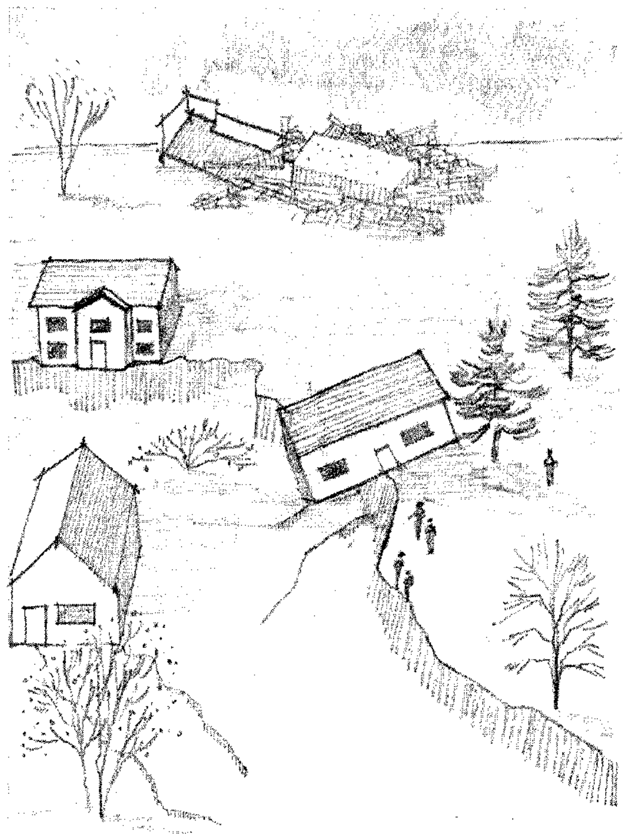

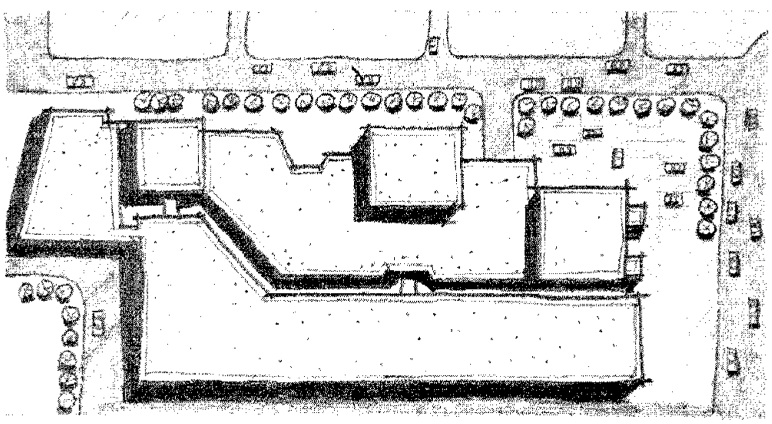

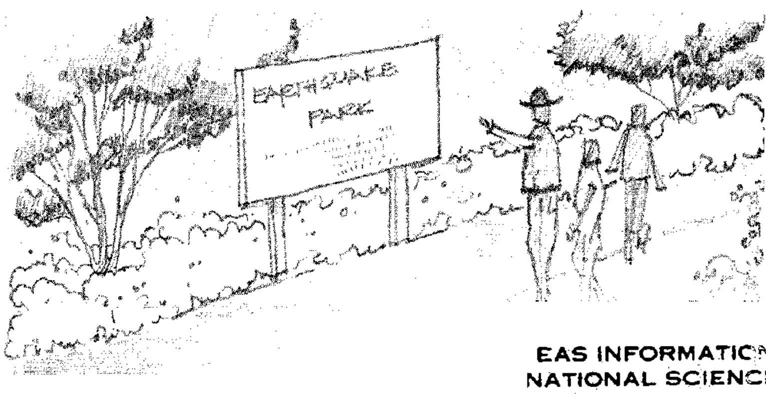

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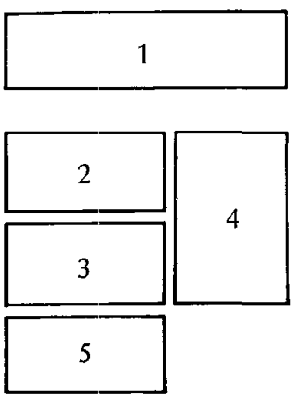

1. Tsunami-damaged waterfront of Seward, Alaska, 1964
2. Earthquake-damaged masonry hotel, San Fernando, California, 1971
3. Redevelopment plan for portion of Santa Rosa, California, damaged in 1969 earthquakes
4. Earthquake damage, L Street slide, Anchorage, Alaska, 1964
5. Park established on Turnagain landslide after 1971 earthquake, Anchorage, Alaska

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16. Abstract (Limit: 200 words)

This study identifies and analyzes factors in post-earthquake land use planning which can effectively reduce further earthquake risk in urban areas. Case studies are evaluated for earthquakes in San Fernando, Santa Rosa, Laguna Beach, and Alaska. A wide variety of responses to earthquake hazards was observed, ranging from a cavalier disregard for future risk, to a long-term concerted effort to improve seismic safety. Effectiveness of land use planning in post-earthquake reconstruction is influenced by four major factors: (1) cause and extent of damage; (2) hazard and risk evaluation; (3) capabilities of local government to respond to an earthquake; and (4) role of the Federal government in post-earthquake decisions. Recommendations concern changes needed in Federal disaster assistance procedures to resolve some of the identified problems. The Federal role is paramount since allocation of Federal funds is the most important factor governing reconstruction decisions. Formation of two teams is recommended, one for hazard evaluation and the other for reconstruction planning after an area has been declared a major disaster site following an earthquake.

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Land Use Planning After Earthquakes

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David Beatty, Attorney, McDonough, Holland, Schwartz & Allen, formerly with the League of California Cities, Sacramento

Robert D. Brown, Jr., geologist, U.S. Geological Survey, Menlo Park

Dale James, Regional Environmental Officer, Department of Housing and Urban Development, San Francisco

Theodore H. Levin, formerly Chief Economist, Federal Insurance Administration, Washington, D.C.

Frank Manda, Assistant Director, Federal Emergency Management Agency, Region 9, San Francisco

Norman Murdoch, Planning Director, County of Los Angeles

John C. Rosenthal, Planner, International Paper Company, Instructor in reconstruction planning, Pratt Institute

E. Jack Schoop, Director of Urban Planning, Dallas, Planning Director of Anchorage at time of the Alaska earthquake

Robert A. Stallings, Associate Professor, Sociology, University of Southern California

These people met with us four times during the course of the study to review work in progress and lend their special expertise in commenting on emerging conclusions and recommendations. We are grateful for the assistance of this group.

In August 1979, following completion of the first draft of this report, a workshop was held in Boulder, Colorado to discuss the report. The American Society of Consulting Planners, Association of Engineering Geologists, Earthquake Engineering Research Institute, and the Natural Hazards Research and Applications Information Center of the University of Colorado served as co-sponsors of the workshop, lending their support to the effort to ensure adequate discussion of and dissemination of findings from the study. We are especially indebted to the Natural Hazards Research and Applications Information Center which assisted us in arranging for the workshop to be held immediately following its Annual Natural Hazards Workshop, thus making it convenient for people to participate in both workshops. Susan Tubbesing of the Center was unfailingly helpful in making arrangements in Boulder. Through her efforts, problems of arranging a workshop from a distance never arose.

Participants in the workshop included people who had special experience in problems of post-disaster reconstruction or who were in positions to make use of the study recommendations. Many helpful suggestions for improving the report were gleaned from the workshop and from written comments submitted by several of the participants. We are pleased to extend our appreciation to the following people who attended the workshop:

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John D. MacLeod, Associate Program Analyst, California Seismic Safety Commission, Sacramento, California

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Susan K. Tubbesing, Natural Hazards Research and Applications Center, University of Colorado, Boulder, Colorado

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Many individuals, too many to mention here, contributed to the case study reports. These people are separately acknowledged in the case study reports included as appendices to this report.

The quality of this report has been immeasurably improved by the assistance of the people noted. We are deeply appreciative of their contribution. However, the project team assumes full responsibility for the final product. The many comments helped us to focus on problems and possible solutions, but the final decisions as to emphasis and content were made by the team.

The project team did in fact work as a team. Regular monthly meetings were held throughout the project and there were many other meetings between team members. One of the real pleasures of this study was the opportunity to work with Henry Degenkolb of H.J. Degenkolb & Associates and Richard Meehan and Sally Bilodeau of Earth Sciences Associates. Also, our consultants, George S. Duggar and Norman Williams, Jr. made many valuable contributions. A special note should be made of the key role Martha Blair played in pulling diverse information together in coherent reports and for her major role in research. Also, as the report neared completion, Stephanie Stubbs-Hogan of our office took on the major task of preparing graphics and readying the report for publication.

If we have failed to give credit to some who assisted during the course of the study, we regret the omission. We do, however, appreciate all of the assistance we have received.

William E. Spangle, Project Manager
George G. Mader, Principal Investigator

Summary

Is it inevitable that the city reconstructed after a major damaging earthquake be a virtual carbon copy of the pre-earthquake city? Can and should land uses be changed in the course of reconstruction to reduce future earthquake losses? What changes in governmental procedures are needed to improve the prospects for effectively planning post-earthquake reconstruction? This study stems from a need to find answers to these and related questions.

The underlying hypothesis of this study is that post-earthquake land use planning can effectively reduce future earthquake risk in an urban area. Land use planning after recent earthquakes, however, has not reduced future risk to the extent possible. In an effort to determine why the record after earthquakes has not been more encouraging, an interdisciplinary team composed of representatives from the fields of urban planning, geology, civil engineering and structural engineering, assisted by consultants in public administration and law, studied the experiences following selected recent major earthquakes and other disasters. The objective of the team was, through investigation of past experiences, to recommend ways to improve post-earthquake land use planning.

The research focused on the 1971 San Fernando, 1964 Alaska, and 1969 Santa Rosa earthquakes. Information from this research was supplemented by monitoring of decisions as they occurred following the October 1978 Bluebird Canyon landslide in Laguna Beach and the review of reconstruction decisions following selected other disasters including the Xenia and Omaha tornadoes, Rapid City flood, Hilo tsunami and Managua and Skopje earthquakes.

A wide variety of responses to earthquake hazards were observed in the case studies ranging from a cavalier disregard for the future risk to a long-term, concerted effort to improve seismic safety. From these observations, many findings emerged from the research that appear to have a crucial bearing on the effectiveness of land use planning in post-earthquake reconstruction. The findings cover a wide range of subjects, but can generally be grouped under four headings: cause and extent of damage; hazard and risk evaluation; capabilities of local government; and the role of the federal government.

The *cause and extent of damage* influences the need to change land use as a part of post-earthquake reconstruction. The need for land use changes is usually confined to those areas where ground failure or earthquake induced flooding occurred and where damage, especially to older buildings, was particularly concentrated. In other damaged areas, future seismic risk can ordinarily be reduced to acceptable levels through improved structural design and construction.

Hazard and risk evaluation is important in determining the appropriateness of land use changes. After an earthquake, it is relatively easy to identify particularly hazardous areas. Whether land uses should be changed to reduce seismic risk in such areas depends on the probability of recurrence of the hazard and the nature of the land use or occupancy with respect to the risk. The assessment of risk needs to be as explicit as technically possible to facilitate public judgments concerning the level of risk considered acceptable.

The *capabilities of local government* to respond to a damaging earthquake vary widely. The post-earthquake performance of local government is largely determined by pre-earthquake conditions. Those with a well-established planning function, a competent planning staff and recent experience with publicly-funded redevelopment tend to handle reconstruction planning most effectively. The feasibility of changing land uses is influenced by the size of a community, degree of isolation, existing land use pattern, economic health and a variety of social and cultural factors.

The *role of the federal government* in post-earthquake decisions, through its disaster assistance functions, is of overriding importance. Essentially, it was found that land use changes are made when the costs are borne primarily by the federal government, especially through redevelopment projects. However, federal procedures and regulations pose problems in using land use change to reduce future risk. These problems include: 1) the lack of specific authorization and funding for redevelopment projects in disaster assistance programs, 2) lack of requirements, procedures and specific funding for planning and implementing plans for long-term reconstruction, 3) disincentives for relocating public facilities or repairing and reconstructing facilities to improved standards not in force at the time of the earthquake, 4) lack of guidelines for determining price to be paid for properties to be acquired as part of a post-disaster redevelopment project or planned relocation, 5) little consideration of long-term hazard mitigation in administering disaster assistance, 6) lack of explicit consideration of opportunities to achieve other federal community development objectives in administering disaster assistance, 7) lack of flexibility in administering disaster assistance sometimes leading to federal/local conflict.

The recommendations focus on changes needed in federal disaster assistance procedures to resolve some of the identified problems. The recommendations deal with the federal role because how federal funds are allocated is the single most important alterable factor in determining reconstruction decisions. Specifically, the formation of two teams, one for hazard evaluation and the other for reconstruction planning, is recommended when the President declares a major disaster for an earthquake.

The *Hazard Evaluation Team,* appointed and funded by FEMA, would be composed of geologists, seismologists, engineering geologists, structural engineers and other professionals as needed. The team would be responsible

for identifying and mapping hazardous areas in two stages. Within two to three weeks, the team would designate Provisional Hazard Areas, broadly defined areas of ground failure, flooding or concentrated structural damage. Repair and reconstruction outside of these areas would proceed while further investigation of the Provisional Hazard Areas was undertaken. Based on further investigations, the Hazard Evaluation Team would narrow the areas of concern by designating High Hazard Areas — those portions of Provisional Hazard Areas considered likely to be most hazardous in future earthquakes. The team would further recommend any changes in community-wide design and construction standards needed in light of the earthquake experience, a range of acceptable uses and building restrictions for each High Hazard Area considering risk exposure, and any stabilization or engineering works needed.

The *Reconstruction Planning Team,* appointed by each affected local government, would be composed of local staff members and other experts as deemed necessary. FEMA would fund the work of the team and provide any needed technical assistance. The team would have three major tasks: revise the community-wide plan as necessary to provide a realistic guide for reconstruction decisions and specific planning for hazardous areas, work with the Hazard Evaluation Team to define options for reuse or reconstruction in the High Hazard Areas, and prepare specific plans for the reuse or reconstruction in the High Hazard Areas. The specific plans for the High Hazard Areas should be consistent with the Hazard Evaluation Team's recommendations, and adopted by the local legislative body. Consistency of the specific plans with the Hazard Evaluation Team's recommendations should be determined by the federal funding agency prior to allocation of any federal funds for repairs or reconstruction within the High Hazard Areas.

These recommendations are intended to provide a mechanism for systematic planning for the long-term use or reuse of hazardous areas to reduce a community's vulnerability to future earthquake losses and, at the same time, protect the federal investment in reconstruction. Significant public benefit should accrue over the long run from carefully planned and implemented reconstruction after damaging earthquakes.

Introduction

History has shown that, after a damaging earthquake, economic, psychological and political pressures foster rebuilding as rapidly as possible. The prevailing attitude after an earthquake is a desire to help those who have suffered injuries, disruption of their lives and property damage. Given this attitude, actions to reduce future risk might be seen as interfering with rapid recovery. The overriding concern is with immediate needs, not with future disasters. However, planning for reconstruction can result in significant reduction in future risk and, possibly, an improved urban pattern without unreasonable delay or hardship.

Improved safety in reconstruction after earthquakes has come primarily from rebuilding and repairing structures to better withstand shaking from future earthquakes. No doubt, the increase in safety from improved structural characteristics is very significant. However, little attention has been given to avoiding or restricting development or reconstruction in areas revealed by the earthquake as especially hazardous. An underlying concept of this project is that well-planned land use changes following an earthquake can effectively reduce risk from future earthquakes. The question is how to achieve these changes. An interdisciplinary research team was formed to investigate the problems and potentials of post-earthquake land use planning. The team includes members from the firms of Earth Sciences Associates, a geotechnical firm, H.J. Degenkolb and Associates, structural engineers, and William Spangle and Associates, Inc., city and regional planners. In addition, special consultants in public administration and law were retained. The team met frequently during the two-year project to shape the evolving content of the study. It was an exciting undertaking with a constantly unfolding story — many original assumptions proved unfounded, each case yielded its surprises, and in the give and take among the team members new perspectives on the problems and solutions emerged.

Perhaps the most notable lesson from the study is that ordinary land use planning procedures and regulation have not been very effective in shaping the course of reconstruction except where there has been unusual political agreement on their use. What have shaped reconstruction decisions are the massive infusion of federal funds following major natural disasters and requirements for the use of such funds. The success of a reconstruction program in reducing risk appears to require a unique blend of federal, state and local efforts in the aftermath of an earthquake.

SCOPE

The study focuses on actions and decisions taken after an earthquake which lead to permanent reconstruction. To a considerable extent, these actions are different from the hazard mitigation measures that are appropriately and often adopted before an earthquake. At some point after an earthquake, however, the mitigation measures begin to focus more on the next event than the prior one. In the sense that post-earthquake decisions are viewed in terms of their impact on future seismic safety, they can be considered pre-earthquake hazard mitigation efforts. There is no clear distinction between post- and pre-earthquake hazard mitigation.

The study deals with those aspects of reconstruction involving land use planning. Much has been written about the engineering aspects of seismic safety, but the role of land use planning in mitigating earthquake hazards has been largely ignored. Possible land use responses include changes in land use plans and regulations, changes in land use or occupancy, relocation of facilities, redevelopment, and land acquisition. A major effort was made to identify situations in which a land use response, as opposed to the more commonly invoked engineering or strictly structural response, is appropriate.

The study draws primarily on information from past U.S. earthquakes in order to arrive at recommendations appropriate to the governmental, economic, social, and institutional character of the United States. However, there have not been any recent major earthquakes which caused heavy destruction in metropolitan areas in the United States. Therefore, the project team reviewed two recent major foreign earthquakes to observe reconstruction problems in areas with extremely high damage. Information from the review of these foreign earthquakes was useful in analyzing the problems of organization and timing in handling reconstruction after a large-scale disaster in a major metropolitan area.

While the study is concerned principally with reconstruction after earthquakes, reconstruction after selected other natural disasters was reviewed. The objective of this review of other disasters was to identify lessons applicable to the post-earthquake situation. Findings from the review of other disasters confirm many conclusions derived from the study of earthquake disasters and provide additional insight into the problems of planning for reconstruction.

METHODOLOGY

A major part of the study consisted of case studies of reconstruction after three recent U.S. earthquakes. The three case studies were selected to illustrate as broad a range of earthquake effects and response as possible. The selection of recent earthquakes made it possible to interview people who participated in the post-earthquake reconstruction efforts, gave reasonable assurance that information on geologic and seismic effects and structural damage was at or close to the state-of-the-art, and set the investigations in the context of modern planning practices and procedures. In fact, the choice was very limited. From 1959 to 1978, eleven earthquakes occurred in the United States which caused damage in excess of $1 million (dollars at the time of the earthquake). Of these, only three (Alaska 1964, Puget Sound 1965, and San Fernando 1971) were federally-declared major disasters. As by far the largest and best documented recent earthquakes, Alaska and San Fernando were obvious choices for study. In addition, Santa Rosa, 1969, was chosen because of the interesting local effort to abate existing structural hazards throughout the city after the earthquake. For each case, the project team reviewed available background material related to the earthquake, geologic and structural effects, and reconstruction efforts. Key people involved with the reconstruction were then interviewed to learn further what actions were taken and, to the extent possible, the factors that influenced the decisions made.

Each case study was handled somewhat differently. Each succeeding study built on the lessons learned from the prior studies. Each earthquake evaluated was different with distinctive seismic and geologic effects, structural damage and damage patterns. The affected areas also differed in the extent of urbanization, degree of isolation, resources to cope with recovery, and socio-economic characteristics.

Each case study report describes the geologic and seismic effects of the earthquake, the extent and nature of damage, the probability for future damaging earthquakes, the actions taken in reconstruction and the reasons for the actions. Finally, each report contains conclusions drawn from that particular case study. Judgments are made in terms of whether or not actions and decisions led to a reduction in future seismic risk.

Reconstruction experience following selected other domestic and foreign earthquakes and natural disasters was reviewed and summarized. This part of the study involved reviewing published accounts and other records of reconstruction following the tornadoes in Xenia, Ohio in 1974 and Omaha, Nebraska in 1975; the flood in Rapid City, South Dakota in 1972; the tsunami in Hilo, Hawaii in 1960; and the earthquakes in Managua, Nicaragua in 1972 and Skopje, Yugoslavia in 1963. The information was used to confirm or to raise questions about conclusions from the detailed case studies and to explore possible similarities between reconstruction problems after earthquakes and other disasters.

While the study was in process, a major landslide destroyed twenty-two homes in the City of Laguna Beach, California. Because some reconstruction problems were similar to those of a post-earthquake situation, the study was expanded to include Laguna Beach as a case study area. This case allowed observation of actions taken and problems encountered in the period immediately following a disaster and a first-hand tracing of reconstruction decisions. It is the only detailed case study of disaster response under present (1978-79) federal disaster relief legislation and regulations included in the project and, thus, provided an opportunity to evaluate the effectiveness of existing disaster response procedures.

A Discussion Group Panel composed of recognized experts in various aspects of post-disaster response met with the study team four times during the two-year study providing comments on the work program, case study reports, and the conclusions and recommendations emerging from the study. After completing the case studies, the project team assembled the comments of the Discussion Group Panel and other reviewers of the case study reports, reviewed the material on other earthquakes and disasters, and reassessed the conclusions and recommendations drawn from the case studies. From this evaluation, recommendations were developed for improving post-earthquake reconstruction, particularly with respect to land use planning.

The project team recognizes that the three case studies are a small sample to illustrate the wide variety of possible conditions and problems pertaining to post-earthquake reconstruction. However, common threads are identified and reinforced by the review of reconstruction following other natural disasters and earthquakes. These commonalities form the basis for the conclusions and recommendations to improve post-earthquake land use planning.

Summaries of Investigations

The results of the investigations of the three U.S. earthquakes, the Laguna Beach landslide and other disasters are summarized in this section. The full reports are included as appendices.

SAN FERNANDO CASE STUDY

Shortly before dawn on February 9, 1971 an earthquake struck the San Fernando Valley in Los Angeles County, California. Registering 6.4 on the Richter scale, this moderate earthquake resulted in 64 deaths and $1/2 billion (1971 dollars) in property damage throughout the affected area of Southern California. Eighteen schools, four hospitals, 465 single-family homes, 62 apartment houses, and 372 commercial structures were posted as unsafe for occupancy. Highway bridges and utility lines were extensively damaged and the Lower San Fernando Dam nearly collapsed, necessitating the emergency evacuation of 80,000 people from the downstream area. Federal aid including Small Business Administration loans, temporary housing, unemployment benefits as well as funds for reconstruction of public facilities totaled over $540 million.

For purposes of this study, an area centering on the City of San Fernando and encompassing the most severely damaged structures was selected (Figure 1). Within this area, damage patterns were related to a variety of geologic and structural factors. Old masonry buildings, particularly in downtown San Fernando, suffered extensive damage. Damage occurred to buildings, roads and utility lines in the area where the San Fernando fault ruptured at the

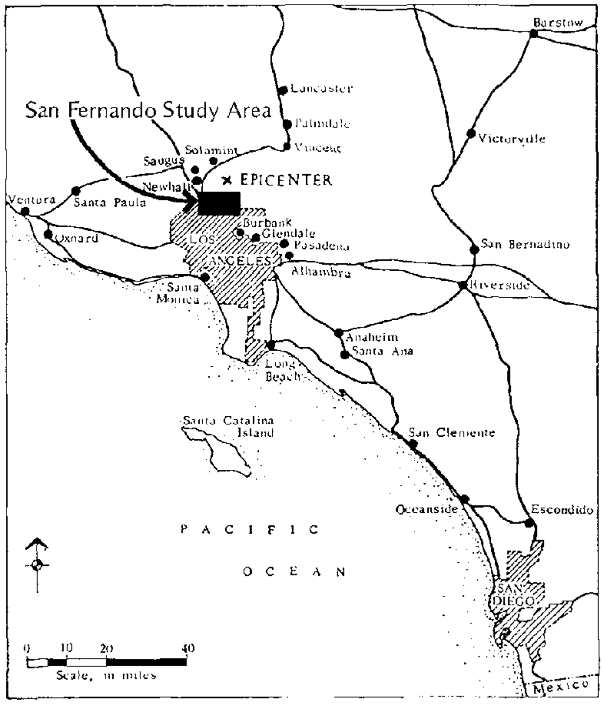


Figure 1. Map showing San Fernando study area, epicenter of the 1971 San Fernando earthquake, and relationship to Southern California cities

surface. The San Fernando Valley Juvenile Hall, Olive View Hospital, Veterans Administration Hospital and other buildings, located in a zone along the base of the foothills on the north side of the valley where ground shaking was especially intense, collapsed or were severely damaged. In the foothills, landslides, rockfalls and shattered ground on ridgetops were common, but caused little damage because the area was largely undeveloped. Soil liquefaction contributed to the failure of Juvenile Hall and the partial failure of Lower San Fernando Dam.

Following the earthquake, Los Angeles County and the cities of Los Angeles and San Fernando were declared a major disaster area by the President, releasing the flow of federal dollars for emergency work and reconstruction. Virtually every property owner whose building was damaged applied for and received Small Business Administration low-interest loans for repair. The U.S. Office of Emergency Preparedness funded the repair of public facilities and compensated local governments for property tax revenues lost because of lowered property values. The Department of Housing and Urban Development provided funds for temporary housing and grants for open space, historic preservation and comprehensive planning. In the City of San Fernando, the Army Corps of Engineers cleared debris, replaced the sewer and water systems and repaired streets.

Most reconstruction was completed, largely with federal funds, within two years of the earthquake. The only land use change made as a direct result of the earthquake was the relocation of the Veterans Administration Hospital and conversion of its former site to a county park. Other potential options for land use changes were either not considered or were rejected in favor of structural measures. No restrictions on development were considered in the inundation area below the Upper and Lower San Fernando Dams. A new dam has been constructed which is designed to withstand the effects of future earthquakes. Damaged single-family homes astride the San Fernando fault were repaired and reoccupied without restriction and the City of San Fernando's general plan, revised after the earthquake, retains the pre-earthquake single-family residential designation of most of the fault zone within the city. Repair and reconstruction of public facilities and homes in the heavily damaged Kagel Canyon area proceeded without restriction, although the area is vulnerable to damage from floods and wildfire as well as from future earthquakes.

Where safety was increased, it was largely through improved structural design and construction. As a result of the damage experienced in this earthquake, the state adopted new design standards for construction of hospitals and highway bridges. Collapsed and severely damaged masonry buildings in downtown San Fernando were replaced with buildings constructed to meet current standards. The city had started a redevelopment project for a two and one-half block area of downtown in 1966. At the time of the earthquake, street work and landscaping had been completed. The availability of SBA loans after the earthquake spurred the redevelopment of private property in the area.

Relocation of the San Fernando Valley Juvenile Hall and Olive View Hospital complex was considered but rejected after intensive geologic and engineering studies indicated that proper site preparation and foundation and building design could provide for reasonably safe reconstruction on the original sites. Juvenile Hall was rebuilt on its old site and a new Olive View Hospital building was under construction in 1978 on its original site. Under provisions of the Disaster Relief Act of 1970, the federal government was authorized to pay for the repairing, restoring, reconstructing, or replacing of public facilities, but was not authorized to pay for acquiring new sites for relocation. This provided a strong incentive for rebuilding on the original sites.

Findings

From the San Fernando case study the study team drew the following conclusions:

1. Realistic options for land use change in post-earthquake reconstruction are limited by both the extent of damage and damage patterns. In this moderate earthquake in a metropolitan area, damage was scattered and, in most cases, related to building rather than site characteristics. The high public and private investments in the urban infrastructure and the established land use pattern tend to preclude major changes unless an area is virtually destroyed and demonstrably unsafe for its pre-earthquake uses.
2. Federal funds are an essential element in reconstruction after an earthquake. Few property owners have earthquake insurance and local governments,

faced with loss of revenue, are unlikely to be able to fund reconstruction of public facilities without outside assistance. Most decisions to reconstruct or relocate structures are made on the basis of the availability of federal funds.

3. It is frequently thought that in the crisis atmosphere that prevails in the immediate aftermath of a damaging earthquake, important decisions are made too quickly without adequate consideration of the consequences. This does not seem to be the case in San Fernando. True, reconstruction did proceed rapidly in most damaged areas. But the decisions most important to future safety – those concerning reconstruction of critical or high-occupancy facilities in seemingly hazardous areas – were made only after careful study.

4. The most important actions reducing future risk of earthquake damage were replacement of damaged buildings with better designed and constructed structures and the adoption of more earthquake resistant design standards by the state for hospitals and highway bridges.

5. Rebuilding wood-frame, single-family homes in areas subject to surface fault rupture may be defensible if the recurrence interval of damaging earthquakes on the fault is considered to be very long and/or the potential movement quite small. In making this finding, it is pointed out that loss of life has rarely been caused by the collapse of a single-family, wood-frame house due to surface fault rupture. Also, if surface fault rupture is expected only once in a 200 year period, the annual risk of damage to a single-family house is very low and might be considered acceptable. Hence, reconstruction of houses along the San Fernando fault, expected to produce an earthquake comparable to the 1971 event once every 200 years or so, was not necessarily unreasonable. However, no evidence was found that decisions to rebuild were based on such an explicit consideration of risk.

ALASKA CASE STUDY

Late in the afternoon of Good Friday, March 27, 1964, the largest North American earthquake of the century (8.4 on the Richter scale) struck southeastern Alaska. At that time, Alaska was sparsely populated, only a few years into statehood and afflicted with a shaky public and private economy. The earthquake dealt a staggering blow to the fledgling state, killing 114 people, causing over $300 million (1964 dollars) in property damage and crippling the economy of several towns. Federal assistance to public agencies and victims in Alaska after the earthquake totalling over $400 million, exceeded the amount of property damage.

Because of the extent of the damage relative to Alaska's resources for rebuilding, the federal government assumed the primary responsibility for reconstruction. Soon after the earthquake, President Johnson appointed the Federal Reconstruction and Development Planning Commission, chaired by Senator Clinton P. Anderson, to coordinate the rebuilding effort and plan for the long-term reconstruction

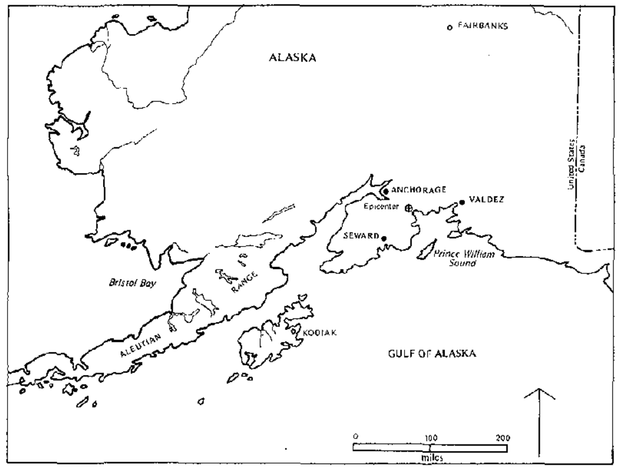


Figure 2. Map of Alaska showing location of Anchorage, Seward and Valdez and the epicenter of the 1964 Alaska earthquake

and economic development of the state. Nine task forces were established to assist the Commission in its mission. The most important of these from a land use planning standpoint was the Scientific and Engineering Task Force, also called Task Force 9. Composed of structural engineers, engineering geologists and seismologists from the U.S. Geological Survey, U.S. Army Corps of Engineers and U.S. Coast and Geodetic Survey, Task Force 9 was established to advise the Commission where federal funds should be spent for stabilization, repair and complete reconstruction or relocation of facilities. The Task Force organized a field team to direct the geologic and engineering studies, recommend areas suitable for reconstruction and establish interim design criteria to guide construction.

The efforts of the Task Force resulted in a series of maps for several Alaska communities showing areas of unstable ground in which federal funds were not to be used for reconstruction unless stabilization was achieved. These maps and the recommendations of the Task Force regarding construction standards, possible stabilization measures and further studies were adopted by the Federal Reconstruction Commission and guided the allocation of federal funds for reconstruction.

The study focuses on the reconstruction experience in three areas of Anchorage, Alaska's largest city and heart of its economy; Seward, a small port and southern terminus of the Alaska Railroad; and Valdez, a fishing and shipping port at the time of the earthquake and now terminus of the Alaska pipeline (Figure 2).

Anchorage

A large portion of the damage in Anchorage was caused by seismically-triggered landslides. The biggest and most damaging landslides were the Fourth Avenue, L Street and Turnagain slides – all along the bluff of Knik Arm (Figure 3).

The Fourth Avenue slide occurred in a commercial area near the heart of downtown Anchorage. The slide consisted of a 36 acre block of ground which moved

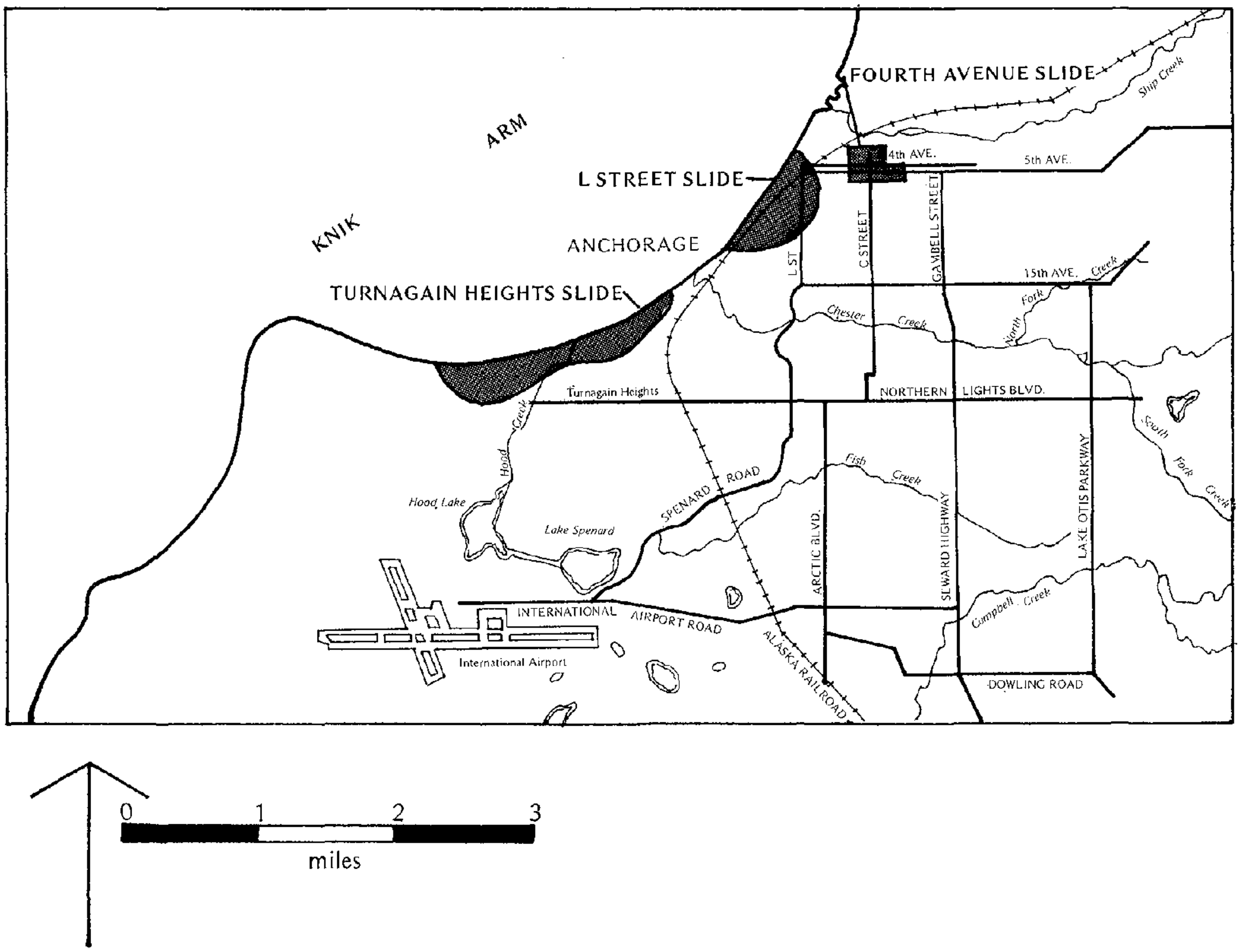


Figure 3. Map of a portion of Anchorage showing the location of the Fourth Avenue, L Street, and Turnagain landslides

horizontally about 17 feet toward the Arm leaving a graben (a depressed swath of land) up to 11 feet deep, 100 feet wide and 1,800 feet long along Fourth Avenue. Buildings along the north side of Fourth Avenue collapsed into this graben.

The Scientific and Engineering Task Force (Task Force 9) designated the slide area as unstable and recommended construction of an earthen buttress to achieve stabilization. Specific limitations on the depth of excavations and fills and the weight and height of buildings to be permitted on the stabilized slide were also recommended. Construction of the buttress was carried out as part of a federally-financed urban renewal project and completed in 1967. Private property needed for constructing the buttress was acquired and after the buttress was complete, parcels were sold for development of two shopping malls, a hotel and related development at the top of the buttress. The recommended grading and building restrictions were incorporated into the urban renewal plan and were followed in construction of the project. The urban renewal project was completed in August 1978 at a total federal cost of about $9 million.

The L Street slide to the west of downtown occurred in an area of mixed residential and small office uses. It was a block slide involving 72 acres (30 city blocks) which moved, quite intact, 14 feet toward the bluff leaving a graben up to 250 feet wide and 7 to 10 feet deep. Buildings on the block were largely undamaged but those at the edges of the block were destroyed.

The Scientific and Engineering Task Force designated the slide and adjacent areas as unstable and recommended further engineering and economic studies of stabilization measures. It further recommended that, even if the area were stabilized, construction should be limited to light structures no more than two stories high. Plans, drawn up soon after the earthquake, to include the L Street area in an urban renewal project along with the Fourth Avenue were not adopted by the Anchorage City Council. No additional studies were undertaken and no restrictions on rebuilding were enacted. In fact, about a year after the earthquake, the Anchorage City Council rezoned the area to higher density residential and office use. New construction in or next to the area began soon after the earthquake, starting with the high-rise Captain Cook Hotel.

Offices, apartment buildings, and even government buildings, many of them high-rise, soon followed and today the L Street slide area, although not stabilized, is far more intensively developed than at the time of the earthquake. The construction has been financed by private financial institutions. The Federal Housing Administration (FHA) and other federally-insured mortgage funds have not been used for construction in the unstable areas designated by Task Force 9.

The Turnagain slide was the largest and most spectacular of the Anchorage landslides, involving about 130 acres of land and destroying 75 homes. It extended for 8,500 feet along Knik Arm and as much as 1,200 feet inland. The bluff essentially disintegrated as successive blocks peeled off – some moving seaward up to 500 feet. The slide mass and a considerable area inland of the new bluff line was designated unstable by the Scientific and Engineering Task Force.

The Urban Renewal Administration authorized $633,872 for the Army Corps of Engineers to study methods of stabilizing the Turnagain slide as part of the feasibility study for a proposed urban renewal project. In 1966, the Corps concluded that the slide mass was stabilizing itself and forming a natural buttress against further bluff failure. In the opinion of the Corps, the natural buttress would be effective in preventing additional bluff failure in an earthquake of magnitude and duration similar to the 1964 earthquake, if erosion of the toe of the slide were controlled. Even with erosion control, however, the natural buttress would experience differential movements and would be unsafe for building. An urban renewal plan calling for park and recreation uses of the slide area, a road along the shoreline and erosion control measures was prepared, but rejected by the Anchorage City Council in 1967.

The western portion of the slide, which was in public ownership at the time of the earthquake, was left in its post-earthquake condition as a city park, appropriately named Earthquake Park. To the east, the slide mass was bulldozed to bury debris from the destroyed houses. No replatting has occurred and, although most owners received lots elsewhere on state land at a nominal cost after the earthquake, the state failed to acquire title to the Turnagain lots in exchange.

By 1978, new houses had been constructed on the edge of the new bluff and a duplex was under construction on the slide itself. No erosion control measures had been taken and as much as 400-500 feet of the toe of the slide had eroded away exposing previously buried debris from houses destroyed in 1964. The Anchorage Municipal Assembly (formerly the City Council) was wrestling with the question of whether to permit development on the slide. In April 1978, the Assembly passed an ordinance permitting development on the slide, if property owners are willing to pay for extension of roads and utility services into the area.

Seward

At the time of the earthquake, Seward was a city of about 2,300 people with a seasonal and declining economy based on shipping, fishing and tourism. Its importance as a port depended on links to the interior provided by the Anchorage-Seward Highway and the Fairbanks-Seward Alaska Railroad line, both of which were severed in the earthquake. The Seward waterfront was virtually destroyed by massive landsliding followed by a series of slide-induced waves and tsunamis. Thirteen people were killed, five injured and damage to public and private facilities surpassed $22 million (in 1964 dollars).

Much of the damaged waterfront was designated unstable by the Scientific and Engineering Task Force and stabilization was deemed infeasible. An urban renewal plan encompassing the entire city was prepared but later revised to include only the waterfront area in order to bring the cost of the project into line with funding authorized by Congress for post-earthquake urban renewal projects in Alaska. The revised plan called for relocation of the city dock, railroad dock and small boat harbor and use of much of the unstable waterfront for parks and recreation.

The Federal Housing Administration (FHA), in accord with the Federal Reconstruction Commission recommendations, did not insure loans for construction in the high-risk area and, because of declining economic opportunity and population, there was little incentive for local financial institutions to fund development in the area. As of 1978, the dock and harbor facilities had been relocated and the waterfront was largely free of structures. The city was hoping to get U.S. Coastal Energy Impact funds to develop recreational facilities along the waterfront.

Valdez

Valdez is Alaska's northernmost ice-free port and southern terminus of the Richardson Highway linking the city to Fairbanks and Alaska's vast interior. At the time of the earthquake, about 1,000 people lived in Valdez and were supported primarily by shipping and commercial and sport fishing. During the earthquake a large submarine slide and slide-induced waves destroyed Valdez' port facilities and much of its commercial area. Damage to port facilities alone exceeded $3.5 million (in 1964 dollars).

Almost immediately after the earthquake, geologists recognized that Valdez occupied a particularly hazardous site, subject to further sliding, ground cracking, wave damage and flooding. The Federal Reconstruction Commission, after considering abandonment of the city altogether, finally decided to relocate the city to a safer site about four miles away. In the process, the local people were offered the choice of relocating with most of the cost borne by the federal government or rebuilding at the old site at their own expense. The relocation of Valdez was essentially completed in late 1967 under two separate urban renewal projects – one to acquire land and clear the old site at a federal cost of about $2.9 million; the other for public improvements at the new site at a federal cost of about $1.8 million.

In 1978, little evidence of the former city remained at the old site. The city's sewage treatment facility was there and part of the site was leased to Alyeska (the pipeline corporation) as a staging area for truck and ship transport. The long term use of the area appeared uncertain. The new city was expanding beyond its original boundaries, having grown dramatically during the boom years of the pipeline construction. Fiscally, the city was in unusually good shape with tax revenues from the pipeline terminal facilities, but with the completion of construction activities on the pipeline, the private economy was depressed. The city was actively seeking development to bolster and stabilize the local private economy.

Findings

1. The experience following the 1964 Alaska earthquake strongly reinforces the conclusion from the San Fernando case study that federal funds dominate post-earthquake reconstruction. The public actions taken to reduce the risk were those that the federal government agreed to fund. Renewal projects were scaled to the available funds as were projects to rebuild public facilities, especially port, highway and the railroad facilities. The reliance on federal funds was heightened in Alaska because of the high proportion of government-owned property and consequent high proportion of damage to public facilities.
2. In Alaska, in contrast to San Fernando, several opportunities for land use changes to reduce future seismic risk were obvious immediately after the earthquake. Much of the damage was concentrated in areas of landsliding or wave runup which were vulnerable to future damage. Some land use changes were made, but many were not. The changes that were made were accomplished through publicly-funded redevelopment projects; changes were not made through conventional rezoning or other land use controls.
3. In most cases, the timing of reconstruction in heavily damaged areas was determined by the commitment of federal funds. Initial plans for reconstruction or redevelopment were prepared within a few months of the earthquake. However, the plans were followed only to the extent that federal funds were committed to implement them.
4. The Federal Reconstruction Commission was effective in coordinating federal aid and quickly obtaining commitments to fund particular projects. When its recommendations were backed up with federal funds, they were followed. However, the Commission disbanded 6 months after the earthquake before firm decisions on the future of the Turnagain and L Street slide areas had been made.
5. The Scientific and Engineering Task Force accomplishments demonstrate the feasibility of bringing together scientists and engineers to quickly evaluate hazardous areas as a guide to reconstruction. The fact that Task Force 9's technical recommendations remain largely unchallenged to this day is a tribute to its success.
6. Redevelopment is an effective way to achieve land use change in heavily damaged areas.
7. Within an urbanized area which is experiencing even modest growth, pressures will eventually mount for rebuilding even in the most obviously hazardous areas, particularly if the land is left in private ownership and without adequate land use restrictions.
8. Decisions which effectively reduce seismic risk are most likely to be made when they are consistent with other community objectives. Even after an earthquake, reducing seismic risk appears to have fairly low priority — certainly lower than quickly restoring the normal functioning of the community.
9. Major land use changes, such as the relocation of Valdez, are unlikely to occur without a strong federal hand — stronger than local governments normally consider acceptable.

SANTA ROSA CASE STUDY

Santa Rosa is located about fifty miles north of San Francisco in a valley underlain by deep alluvium (Figure 4). In the evening of October 1, 1969, this city of about 50,000 people was hit within two hours by two earthquakes with Richter magnitudes of 5.6 and 5.7. Almost all the $6 million (in 1969 dollars) or so in resulting property damage was caused by intense ground shaking. Many buildings, including numerous old, unreinforced masonry buildings in downtown Santa Rosa, were damaged;

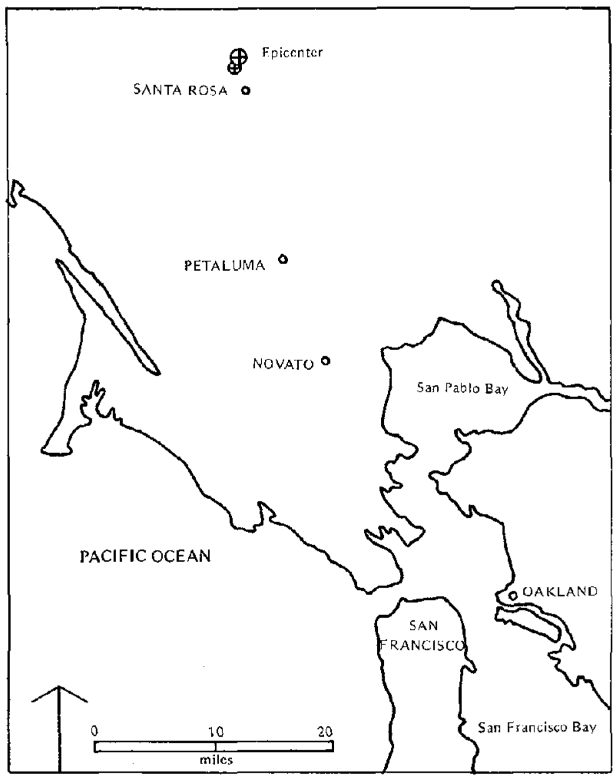


Figure 4. Map of a portion of the San Francisco Bay area showing location of Santa Rosa and epicenters of the 1969 earthquakes

however, none collapsed. The city was not declared a major disaster area, but, under a federal declaration of emergency, Small Business Administration low-interest loans were available to property owners for repairs. Because damage to most structures was relatively light and because some property owners felt the application procedures were too cumbersome, few owners applied for this assistance.

The major hazard revealed by the earthquakes was that of old buildings, inadequately constructed to withstand the strong ground shaking that can be expected in the area. To address this hazard, the city used two approaches -- redevelopment and requirements to abate existing structural hazards.

In 1961, Santa Rosa embarked on a redevelopment project covering part of the downtown area. Just prior to the earthquake, the city had adopted a central business district plan which covered an area adjacent to the redevelopment area. After the earthquake, this area, with a high percentage of damaged buildings, was added to the original redevelopment area. With a federal contribution of about $5 million, properties were acquired and cleared for development of a major regional shopping center integrated with the rest of downtown. Construction of the shopping center began in late 1978 after the project survived a number of legal challenges.

Requirements to abate structural hazards evolved over the two years following the earthquakes. In October 1971, the city council adopted Resolution 9820 requiring a preliminary structural inspection, at city expense, of 1) all buildings in the city constructed before 1958 except public schools (which are governed by state requirements) and one- and two-family dwellings; 2) all buildings with unreinforced masonry walls; and 3) all wood-frame buildings located in Fire Zone 1. A priority system for review was set forth emphasizing high-occupancy structures and facilities needed for emergency response. Buildings were to be inspected for conformance with the 1955 Uniform Building Code. The 1955 Code, rather than the current code, was chosen to limit the economic burden on property owners and to encourage rehabilitation rather than demolition of old buildings, some of which had historical value. The owner of a building found to be substandard was required to engage a structural engineer to design and oversee structural modifications to meet the required standards.

In 1978, Resolution 9820 was slightly revised and added to the City Code as part of the building regulations. Since 1971, 200-250 buildings have been reviewed and many have been rehabilitated or replaced. The process, still on-going, is a lengthy one requiring tenacity, patience and flexibility on the part of the city staff to maintain political support for the program and encourage voluntary compliance of property owners.

Findings

1. The Santa Rosa experience illustrates that a moderately damaging earthquake can spur redevelopment of obsolescent or deteriorating areas and confirms the value of redevelopment as a method of improving seismic safety in conjunction with meeting other community objectives.
2. The Santa Rosa study points up the importance of experienced and dedicated staff and a sound ongoing planning program.
3. Abatement of structural hazards in undamaged or slightly damaged buildings is possible, but it is a long-term, slow process requiring dedication, flexibility and professional expertise.

LAGUNA BEACH CASE STUDY

On October 2, 1978, a 3.5 acre landslide occurred in a fully developed residential area of Bluebird Canyon in the City of Laguna Beach, California. Twenty-two houses, major portions of three roadways and all utilities within the landslide area were destroyed or damaged beyond repair, resulting in approximately $15 million in damages. Fortunately, no deaths and only minor injuries resulted from the early morning slide. In addition to the houses on the slide, some twenty houses next to the slide were evacuated, and remained unoccupied as of July 1979, because of the threat of renewed earth movement, nonexistent or unsafe access, or disrupted utility services. Furthermore, two additional houses were destroyed in a failure of the headscarp on April 23, 1979.

The Bluebird Canyon landslide is a reactivated portion of a larger, five acre, prehistoric landslide. Geologists retained by the city concluded the October movement was triggered by runoff from the heavy rains of February 1978 which infiltrated the slide mass and caused a creek to erode the toe of the ancient landslide.

On October 9, at the Governor's request, the President declared Laguna Beach a major disaster area making federal disaster assistance available. The declaration and subsequent federal-state agreement limited the federal assistance to emergency work needed to protect public and private property from further damage from sliding. Assistance to the landslide victims consisted of temporary housing assistance and low-interest Small Business Administration loans of up to $55,000 to rebuild destroyed homes.

Almost immediately after the landslide, the city hired an engineering geology firm to determine the cause of the landslide, chances for further movement and possible stabilization measures. Repeated movement of the slide in the days following the initial slide made it apparent that immediate stabilization actions were needed to prevent the loss of additional homes and public improvements. The engineering geologists recommended that a drainage pipe be installed in the canyon at the bottom of the landslide to handle runoff from the expected winter rains, and that the destroyed houses be removed and the slide mass graded to control runoff and erosion. These emergency measures were complete in December 1978.

The engineering geologists evaluated several alternative methods of achieving "emergency" stabilization of the slide, that is, stabilization sufficient to prevent further damage to properties next to the slide. The most effective and least expensive alternative was the construction of two earth buttresses -- one at the top and one at the bottom of the slide. At the top, a "shear-key" buttress would prevent further failure of the slide's headscarp. At the bottom, a gravity buttress would prevent further movement of the slide mass and prevent damage to the drainage pipe and the access road to the area. The cost of the two buttresses was estimated at $650,000. After the design was completed, the project was calculated to provide a safety factor of 1.2, meaning that the forces holding the slide in place would exceed the force of gravity by 20%. According to the geologists, additional grading and stabilization work would be needed to achieve a safety factor of 1.5 — the normal design factor for stabilizing an area for development.

The recommendation for buttressing the slide initiated discussion between officials of the Federal Disaster Assistance Administration (FDAA) and the City of Laguna Beach over whether the proposed buttresses constituted emergency work or work which would lead to permanent reconstruction in the area. Under terms of the disaster declaration, FDAA could fund only emergency work. On this basis, the agency questioned the emergency nature of the shear-key buttress and refused to fund additional work that would provide a safety factor of 1.5. Finally, in February 1979, FDAA agreed to fund construction of both buttresses at the 1.2 safety factor levels and, as of July 1979, the work had been completed. No formal planning effort was undertaken to explore options for the future use of the area destroyed by the slide, and decisions regarding the design of the stabilization work were not directly linked to decisions on the future use or uses of the stabilized area. FDAA, in a July 1979 letter, stated opposition to the construction of homes on the site. By this time, the stabilization work and rough grading for roads and utilities had been completed. The landslide victims strongly supported rebuilding, in part, because of the lack of economically feasible alternatives. The engineering geology firm indicated that the 1.2 safety factor was conservatively derived and that the stabilized slide was as safe to build on as most slopes stabilized to a factor of 1.5. Given this position, the California Office of Emergency Services and the City of Laguna Beach agreed to share the cost, estimated at $300,000, of constructing public improvements on the slide.

As of July 1979, construction of roads and installation of utilities were scheduled for completion in October 1979. The city was accepting applications from property owners for building permits to reconstruct homes on the landslide site. Lot lines and road right-of-way will be in exactly the same location as before the disaster. However, the topography of the hillside is somewhat different as a result of the stabilization work.

Findings

1. Disagreement between FDAA and the city over whether the proposed buttressing project was emergency or permanent work appears to have been the major issue in the aftermath of the slide. Federal funds were eventually authorized for both buttresses on the basis that they were necessary to protect property next to the slide from damage from additional sliding.

2. Hazard evaluation was not a problem. Geologists quickly determined the cause of the slide, evaluated the potential for additional land failure and recommended measures to prevent further failures.

3. Those who lost their homes in the slide became a cohesive, and politically effective, group supporting federal, state and local actions that would permit rebuilding of homes on the site. The desire of the victims to rebuild, based, in part, on the lack of other options, and community sympathy for their plight appear to be factors in limiting consideration by local government of land use changes or restrictions on rebuilding.

4. The timing of both emergency and reconstructive actions depended on federal decisions. During the debate over stabilization, no federal representative was assigned to the local area and local officials had difficulty reaching federal officials with the authority to make decisions.

5. The experience in Laguna Beach points up the need for a mechanism to plan for use of a hazardous area before decisions are made regarding stabilization. Stabilization projects should be designed to provide an acceptable level of safety for the expected use of the stabilized area.

OTHER DISASTERS

Published accounts and readily accessible records of rebuilding after other selected disasters were reviewed to identify possible similarities between reconstruction after earthquakes and other kinds of disasters and the contrasts between reconstruction after large, foreign earthquakes and that following the less damaging U.S. earthquakes. In some cases, review of literature and records was supplemented by personal contacts with individuals who had key roles in the post-disaster planning. Disasters studied included the Omaha, Nebraska and Xenia, Ohio tornadoes, the Rapid City, South Dakota flood, the Hilo, Hawaii tsunami, and the Managua, Nicaragua and Skopje, Yugoslavia earthquakes. Key facts of each disaster are summarized in Table 1. The review of rebuilding after these disasters reinforced many of the findings emerging from the more detailed case studies but pointed up the need for substantially different planning approaches where destruction was nearly total as in the cases of Skopje and Managua.

Non-Local Funding

Funding from non-local sources was a very important factor in shaping reconstruction decisions following all of the disasters studied. In the U.S. disasters, federal grants and loans and private insurance payments profoundly influenced post-disaster reconstruction decisions. In Rapid City, federal funds supported post-disaster planning and made possible the acquisition of land and buildings in the flood plain and the conversion of the area to open space and recreational uses. Following the Xenia and Omaha tornadoes, private insurance payments allowed many owners to reconstruct rapidly and without special constraints. In Xenia, substantial funds from several federal sources aided in rebuilding but, with the exception of one rather small renewal project, did not lead to changes in land uses contemplated in the adopted post-disaster plan for the devastated area. Two major objectives of the plan were not achieved: 1) creation of a green belt in the

Table 1
Key Facts about Selected Natural Disasters

Disaster	Population at Time of Disaster	Casualties and Damages	Property Damage ($ at Time of Disaster)	Federal Assistance (loans and grants)
Xenia, Ohio 1974 Tornado (1/3 of town devastated – an area 1 mi. wide and 4 mi. long)	27,500	34 deaths 500 injuries 1,300 buildings destroyed	$100,000,000	$ 4,300,000
Omaha, Nebraska 1975 Tornado (devastated area 1/4 mi. wide and 9 mi. long)	350,000	3 deaths 150 injuries 278 buildings destroyed 2,650 damaged	$120,000,000	$ 4,000,000
Hilo, Hawaii 1960 Tsunami (a 400 acre area devastated)	26,000	61 deaths 288 buildings destroyed	$ 22,000,000	$ 6,680,000 (urban renewal)
Rapid City, South Dakota 1972 Flood (area flooded extended along creek for 12 mi. ranging from 1/2 to 1-1/2 mi. wide)	44,000	238 dead & missing 1,600 buildings damaged or destroyed	$ 80,000,000	$150,000,000
Skopje, Yugoslavia 1963 Earthquake (devastation extensive throughout city)	200,000	1,000 deaths 3,000 injuries 150,000 homeless 42% dwellings destroyed 36% repairable	*	*
Managua, Nicaragua 1972 Earthquake (city center totally destroyed; devastation extensive in balance of city)	500,000	11,000 deaths 20,000 injuries 200,000 homeless	$500,000,000	*

* comparable information not available from sources reviewed

flood-prone area along a local creek, and 2) construction of low-moderate income housing near the downtown area. Rebuilding in Hilo after the 1960 tsunami was accomplished with federal and state funds in accordance with a land use plan designed to reduce exposure to tsunami hazards.

These U.S. cases also confirm the finding from the case studies that publicly-financed redevelopment is a particularly effective tool to achieve land use changes after a disaster where damage is concentrated. Redevelopment was used to change land uses in the Rapid City flood plain and in Hilo to relocate residences, businesses, and public buildings to higher, less tsunami-vulnerable ground. In Xenia, redevelopment to build a shopping mall as an integral part of the downtown area is likely to result in significant improvement of the Central Business District. The success of redevelopment in these cases hinged largely upon the ability of the federal government to rapidly commit funds and to expedite review including that related to land acquisition. At the time of the Hilo tsunami, the federal Disaster Review Program provided an established framework for redevelopment as a part of federal disaster assistance.

In the two foreign earthquakes aid from other nations and international bodies was very important to post-disaster rebuilding, but there were substantial differences in the effectiveness of the aid in reducing and in improving the quality of the urban environment. Skopje benefited from an integrated post-earthquake planning-reconstruction process designed to maintain a flow of decisions on critical components of rebuilding. Managua suffered from lack of agreed-upon guiding policy for reconstruction and failures to make critical decisions in a timely fashion. For example, the future use of the large devastated central area was still undecided seven years after the earthquake.

Use of Governmental Powers

Effective use of local governmental powers contributed substantially to the success of rebuilding in Rapid City, Hilo, and Skopje. In these cities, the devastated areas were almost immediately placed under effective controls limiting occupancy and repair or rebuilding of damaged structures while policy was being developed regarding future land use. In addition, effective procedures and programs were quickly set in motion for permanent relocation of site occupants that would be displaced by changes in land use. Some opportunities to achieve public purposes were lost in Xenia and Omaha through failure to make effective use of governmental powers. In Omaha, delays in starting negotiations for acquisition of lands needed for a proposed street widening led to private rebuilding of tornado-devastated properties needed for the project. In Xenia, exceptions to a moratorium on building were granted while the rebuilding plan was being prepared and, following adoption of the plan, many exceptions to the plan were made through an appeal process. These actions altered major features of the plan for the Central Business District, the flood plain of Shawnee Creek, and an area designated for low and low-moderate income housing.

Effectiveness of Post-Disaster Land Use Planning for Hazard Mitigation

In all of the communities studied, a degree of risk reduction was achieved in the rebuilding. For some of the communities other major benefits also accrued. Both Hilo and Rapid City achieved hazard reduction as well as other community objectives through relocation of businesses and homes out of the devastated areas and redevelopment of these areas for needed open space-recreation uses. In these cities, awareness of hazards was probably greater than usual, because both had experienced similar disasters within the memory of many residents. Some hazard reduction accompanied rebuilding in Omaha and Xenia, particularly where older structures were replaced by structures meeting building code requirements for wind resistance and the provision of tornado life-safety areas. In addition, Omaha, following the tornado, thoroughly reviewed its building code and identified specific improvements needed to increase safety from tornadoes.

Several differences are apparent between recovery from earthquakes and other disasters. Chances to reduce risk from future disasters through land use changes are greatest after floods and tsunamis in which the damage is concentrated and the damaged areas are clearly susceptible to future damage. Severe tornadoes, causing concentrated damage in large areas, offer opportunities for land use changes during reconstruction, but the objective of such changes is not to reduce risk from future tornadoes. However, land use changes in areas damaged by tornadoes can sometimes reduce risk from other hazards, such as flooding, which impact specific identifiable areas.

The reconstruction experience following the two foreign earthquakes, Managua and Skopje, is interesting because the extent of destruction vastly exceeded that of the three U.S. earthquakes studied. However, caution is needed in extrapolating this experience to the United States because of different characteristics of buildings and political and economic institutions. Both earthquakes illustrate the need for a competent planning effort. Skopje provides an example of planning for and achieving substantial improvements in safety, function and urban design in reconstruction of an almost totally destroyed city. Managua underscores the feasibility of quick assessment of seismic hazards and the difficulty of preparing and implementing plans and regulations in a situation where there has been little effective planning and regulation prior to a disaster. Major hazard reduction was, however, achieved through major improvements in the Managua building code standards and permit and inspection procedures. However, procedures adopted to control new construction on identified active faults were less successful because administrative officials allowed many exceptions in response to pressure from applicants for favorable treatment.

Conclusions — Major Factors Affecting Post-Earthquake Land Use Planning

A central objective of this study has been to identify the factors influencing land use decisions following a damaging earthquake. A key finding is that realistic options for land use change after an earthquake are more limited than the study team expected at the outset of the study. Usually improved safety can be more easily achieved through improved structural design and construction than through changing land use. However, in specific instances, changing land use is the best response. The major findings regarding whether land use changes are appropriate and likely to be carried out can be grouped under four headings:

- cause and extent of damage
- hazard and risk evaluation
- capabilities of local government
- role of the federal government

CAUSE AND EXTENT OF DAMAGE

The need for land use change following an earthquake depends, in part, on the cause and extent of damage. Depending on the earthquake effects, the need can range from virtually nil to very great. Rarely, if ever, will a U.S. city be leveled; areas are not equally hazardous and most damage is likely to be scattered. Every major earthquake seems to yield its photograph of the totally collapsed building next to a seemingly similar one standing unscathed. The greatest loss of life, injury and property damage in North American earthquakes result from the failure of man-made structures. Most structural failures are caused by ground shaking and the results can be extraordinarily capricious, related in some degree to variations in ground conditions, but more importantly, to building design and condition. In addition, different earthquakes produce different ground shaking characteristics such as intensity, predominant frequency, and duration of motion, which result in correspondingly different effects on different types of structures. Damage from ground shaking alone rarely justifies a change in land use, because improving structural design and construction can usually reduce risk to an acceptable level.

An exception arises when heavy damage from ground shaking is concentrated in areas of older and poorly constructed buildings, particularly where unreinforced masonry is a widely used building material. Often such areas are deteriorating, functionally obsolescent, and in need of redevelopment before an earthquake. The earthquake presents the chance to move ahead with redevelopment as an integral part of reconstruction. However, even in such cases, reducing seismic risk is usually achieved through improvements in structural characteristics and not necessarily because of changes to less vulnerable land uses or occupancies.

Land use change is most likely to be appropriate in areas where ground failure has occurred, whether from surface fault rupture, landsliding, soil liquefaction, or other causes, and in areas where flooding has occurred, whether from seiche or tsunami runup or dam or dike failure. Achieving reasonably safe reconstruction in such areas is often difficult and usually expensive. Where there is a high risk of future ground movement, either the area must be stabilized to prevent further movement or structures must be designed and constructed to overcome adverse site conditions. Adequate protection against future flood damage requires construction of flood control works, flood-proofing or elevation of structures. In both cases, restricting land use and occupancy may be the most economical and effective method of reducing future risk.

Changing land uses in areas of ground failure and flooding may not only reduce future seismic risk, but also contribute to other community objectives. Ground failure often occurs in steep hillsides, on coastal bluffs and in low-lying areas along rivers, streams, lakes and other bodies of water. Low-lying areas may also be subject to flooding. These areas can often be beneficially used for park, or other low-intensity open space uses. Some seismically hazardous areas may also be subject to other natural hazards such as wild fires, high winds, non-seismic flooding or storm surges. Reducing intensity of land use in these areas after a damaging earthquake may not only avert future needs for disaster assistance because of earthquake damage, but also reduce exposure to damage from other natural hazards.

HAZARD AND RISK EVALUATION

Efforts to reduce risk from natural hazards through land use planning and regulation depend on the ability to delineate hazardous areas and evaluate the level of risk pertaining to potential uses in those areas. Delineating hazardous areas is often easier after an earthquake than before. For example, it is possible to delineate areas where the ground failed, flooding occurred, a fault ruptured at the surface, and ground shaking was unusually intense or damaging. In all of the earthquakes studied, hazardous areas were readily identified in studies made soon after the earthquake. The most systematic hazard evaluation after a U.S. earthquake was that conducted by the federal Scientific and Engineering Task Force after the Alaska earthquake.

Although delineating hazardous areas after an earthquake is fairly readily accomplished, evaluating risk is far more difficult. Risk is exposure to loss of life, injury and property damage. Its level depends on the probability of a hazard recurring and the use and occupancy of the hazardous area.

In the cases studied, risk was assessed by engineers. In San Fernando, risk was explicitly considered in the structural design for rebuilding Juvenile Hall and Olive View Hospital. The objective was to design buildings to overcome hazardous site conditions and to meet commonly accepted engineering standards for the safety of high-occupancy and critical structures. In Alaska, the Scientific and Engineering Task Force delineated hazardous areas, determined that the areas could be unstable in future earthquakes and made recommendations for stabilization and/or use limitations to reduce risk. No explicit consideration was given to the probability of recurrence and risk was expressed in relative terms (high risk, nominal risk, etc.). Explicit assessment of risk was made by engineers in the design of the Fourth Avenue buttress and in the development of specific building restrictions.

A determination of risk expressed as the annual probability of loss of life, injury or damage is unlikely to be available after an earthquake to guide land use decisions. However, decisions will still be made and should be based on the best information and professional judgment available. Information regarding the level of risk can significantly help public decision makers make the necessary value judgments concerning the acceptable level of risk.

It would be helpful to have some standard or guideline as to acceptable risk, such as the 100 year flood standard, to serve as a basis for federal decisions to fund reconstruction projects. It is not likely that as specific a standard for acceptable earthquake risk can be set. The many variables affecting acceptable risk make wide agreement very doubtful.

Improved techniques of hazard evaluation and risk assessment, including advances in earthquake prediction, will help in making decisions. As presently defined by the earthquake research community, an earthquake prediction reduces uncertainty about when an earthquake can be expected and its location and magnitude. This allows more precise definition of risk in areas known to be hazardous and more accurate assessment of the benefits or results of public actions to reduce those risks. Still, for the foreseeable future, except in the area of structural standards, federal funding decisions will likely have to be based on imprecise judgments of risk.

CAPABILITIES OF LOCAL GOVERNMENT

Through grants of authority from the states, local governments appear to have adequate authority under the police power to respond to a damaging earthquake. However, local public attitudes may strongly inhibit the full use of this authority, especially to plan and regulate land use. After an earthquake (or other disaster) local public officials and political bodies are understandably anxious to do everything possible to help disaster victims. Although local government has the power to impose limitations on rebuilding in hazardous areas, public sentiment, in the absence of adequate public information and strong leadership, is more likely to favor relaxing restrictions rather than increasing them. The desire to return quickly to normal usually overrides concerns about future safety unless strong incentives for change are present. These incentives are usually of two kinds – first, strongly held community objectives which are consistent with actions to reduce seismic risk, and second, conditions attached to the use of disaster relief funds. Understanding community objectives helps predict where changes to achieve risk reduction are likely to be most acceptable to a local community. The use of disaster relief funds offers the major opportunity to accomplish greater safety through reconstruction.

The post-earthquake performance of local government is largely determined by pre-earthquake actions. If a community has acted before an earthquake to adopt and enforce adequate building codes, abate structural hazards, locate critical facilities on safe sites, and prevent or appropriately control development in hazardous areas, then clearly it will suffer less damage and face less of a problem in recovery after an earthquake. These actions are of primary concern and have been gradually taken by many local governments. Less obvious are the pre-earthquake actions which, although they do not in themselves reduce damage from the next earthquake, assist a local government in managing reconstruction. These actions include:

1. *preparing and keeping up-to-date realistic land use, circulation and public facilities plans.* The community which has a well-established planning function, experienced planners and realistic plans is more likely to recognize and seize opportunities for community improvements during reconstruction than other communities. Having well-defined community development objectives helps federal, state and local officials set reconstruction priorities and judge the public acceptability of potential land use changes or restrictions.
2. *enacting and enforcing land use regulations, building codes and project review procedures.* Experience in plan implementation and appreciation of the importance of consistent and equitably applied regulations can help a local government cope with the usual overload in building permit applications, requests for exemptions, and pressures to alter established procedures after an earthquake.
3. *establishing a redevelopment agency and carrying out redevelopment or rehabilitation projects.* Such experience is invaluable after an earthquake if redevelopment is to be used in reconstruction. Pre-existing powers and familiarity with techniques of redevelopment planning, project execution and funding requirements make it easier for a local agency to use redevelopment in reconstruction after an earthquake. A community with up-to-date redevelopment plans or specific plans for older areas likely to be damaged in an earthquake is in an excellent position to move quickly into redevelopment, if needed, after the earthquake.
4. *obtaining and using geologic and other natural hazard related information.* Familiarity with the techniques and products of hazard evaluation will greatly assist the local government staff and public officials in making use of the technical information that will be forthcoming after a major earthquake. Less time will be needed to explain the nature of seismic hazards and the range of appropriate responses.

The effectiveness of local response will also be affected by factors such as the size of community, degree of isolation, existing land use pattern, economic health and a variety of social and cultural factors. These are factors that cannot be readily altered before a disaster, but which help define the options and problems of reconstruction. Changes of land use may be more difficult to achieve in a large metropolitan area with its complex and interdependent land uses and infrastructure than in a relatively small and isolated community. Opportunity for major relocation of all or part of a community is greater if the community is small and isolated than if it is an integral part of a metropolitan area. Isolation implies vacant land that may be available for relocation and the chance to contain the disrupting impacts of relocation. Relocation was a feasible option for the town of Valdez after the 1964 earthquake and for a portion of Hilo after the 1960 tsunami. The impacts of large-scale relocation multiply with the size of the community and its degree of interdependence with surrounding communities.

The existing land use pattern, largely determined by local actions, is very important in defining options for land use change after an earthquake. The feasibility of relocating uses or structures is affected by the availability of suitable alternative sites and by the presence of reasonable alternative uses for the damaged site. The possible cost of engineered solutions to hazardous site conditions has to be weighed in terms of the importance of the location for a particular use or structure and realistic options for changing location.

A community with a growing economy may even benefit economically in the long run from a damaging earthquake with the stimulation provided by federal disaster relief funds, increased construction activity and, sometimes, the modernization of previously obsolete industrial and commercial operations. The fish processing plants destroyed in the Alaska earthquake were replaced by more modern and efficient facilities.

The effect of economic conditions on opportunities for land use change after an earthquake is mixed. In a growing economy, political pressures and the economic means to reconstruct quickly can act against efforts to reduce land use intensity in hazardous areas. This is seen in the privately-funded reconstruction and new high-density construction in the L Street slide area in Anchorage. In a declining economy, the private economic incentive to rebuild is far less intense. In Seward, where Standard Oil, Texaco and a fish processor chose not to rebuild their destroyed facilities in the town, little economic pressure has developed for new building in the waterfront area. In spite of public investments in the Alaska Railroad terminal and small boat harbor, Seward's economy continues its pre-earthquake decline.

The Santa Rosa case illustrates another potential effect of economic conditions on response to an earthquake. The city's healthy and growing economy with concomitant increases in property values has made redevelopment an attractive and economically viable option and has provided a climate conducive to the abatement of structural hazards through privately-funded rehabilitation.

The contrast between the accomplishments of Anchorage and Santa Rosa, both with growing economies, illustrates an important point. With insufficient funds for stabilization or purchase of the L Street and Turnagain slide areas, Anchorage's only real option for reducing future risk was to prohibit or severely limit new development in these areas. In a growing economy with strong development pressures, this is difficult to achieve. In Santa Rosa, however, future risk could be reduced by gradually upgrading structural safety. This approach presents no direct challenge to development and can be aided rather than undermined by economic growth.

ROLE OF THE FEDERAL GOVERNMENT

The major conclusion derived from the study is that the availability of, and conditions for the use of, federal funds for post-earthquake recovery largely determine the actions and decisions of local governments. Financing recovery from a major earthquake is likely to be beyond the fiscal capacity of state governments and almost certainly of the affected local governments. Private funds may be available for reconstruction of private property, but such reconstruction is often dependent on repair or restoration of public facilities, especially streets and utilities. Relatively few property owners carry earthquake insurance. The federal role in financing reconstruction has been crucial in past earthquakes and is likely to continue to be crucial in the foreseeable future.

The scope and limitations of federal aid to disaster victims and state and local governments are set forth in the Federal Disaster Relief Act of 1974 and regulations issued May 28, 1975. The major provisions of the Act are, as of July 1979, administered by the Federal Emergency Management Agency (FEMA). Observations of the strengths and weaknesses of the federal role under prior legislation has provided a basis for evaluating the adequacy of the present legislation and regulations as they apply to earthquake disasters. Seven problems are identified.

1. *Lack of specific authorization and funding for redevelopment projects*

   Where used for reconstruction, publicly-funded redevelopment proved to be a particularly effective tool for achieving changes in land use and safe reconstruction in heavily damaged areas. However, the Federal Housing and Community Development Act of 1975 dismantled previous federal programs for urban renewal or redevelopment and replaced them with the Community Development Block Grant program. Block Grant funds are now allocated on a formula basis to communities of over 50,000 people and urban counties for eligible projects. Limited funds are available for distribution to smaller cities. These funds may be used for redevelopment projects, but the emphasis in recent years has been on rehabilitation programs. Funds must be spent for projects benefiting mainly low and moderate income persons. It is unclear how this restriction would affect the use of Block Grant funds for post-earthquake redevelopment projects. A special fund has been set aside for use at the discretion of the Secretary of Housing and Urban Development for disaster-related projects. However, the present appropriation is a small percentage of this discretionary fund and likely to be inadequate to cover needed projects following a major earthquake in a metropolitan area.

2. *Lack of requirements, procedures and funding for planning and implementing plans for long-term reconstruction*

   Title V of the Disaster Relief Act provides for establishment of a Recovery Planning Council to prepare a 5 year "recovery investment plan" recommending "revision, deletion, reprogramming, or additional approval of Federal-aid projects and programs within the area. . ." (Sec. 802). The main objective of the Title is to assist a disaster area in achieving long-term economic recovery. The Title has not been implemented and no federal agency has been assigned responsibility for carrying out its provisions. Title V imposes no planning requirement for use of federal funds in reconstruction of heavily damaged areas and fails to authorize funding for such planning and implementation of plans. Project applications for repair and reconstruction of public facilities are considered individually and there is no requirement for coordinating the restoration of public facilities and services with private repair and reconstruction.

   In many of the U.S. communities studied, plans for reconstruction were quickly prepared after the disaster. Most of the plans were for redevelopment projects and dealt with the most severely damaged areas. Redevelopment plans for areas with hazardous site conditions effectively addressed those conditions. However, several problems were observed in the planning efforts: 1) SBA loans were often approved for repair or rebuilding of privately-owned structures without regard for planned uses or decisions of other federal agencies to fund rebuilding of public facilities, 2) limitations on federal funds for redevelopment led to restriction of the scope of some projects and abandonment of others, and 3) projects that required adoption of local land use and building regulations or acquisition of significant amounts of private property for public uses seemed to generate strong local opposition. There appears to be a need after a disaster, for preparation of a plan for long-term reconstruction, and also for procedures to ensure that federal and local decisions affecting rebuilding are consistent with the plan.

3. *Disincentives for relocating public facilities or repairing and reconstructing facilities to improved standards not in force at the time of the earthquake*

   Section 2205.54 of the Rules and Regulations states that the federal contribution for permanent repair or restoration of public facilities "shall not exceed the net eligible cost of restoring a facility based on the pre-disaster design of such facility and on the current codes, specifications, and standards in use by the applicant for similar facilities in the locality." The regulations permit 100% federal funding for the repair or reconstruction of public facilities. The Regional Director of FEMA may authorize relocation of a facility to a less hazardous site; however, any additional cost must be borne by state or local government. If a jurisdiction chooses to relocate, modify or not replace any facility, the regulations give local governments the option of receiving 90% of the total cost of repairing or rebuilding all damaged public facilities in its jurisdiction. The funds may then be used to repair or restore, relocate or build new public facilities which the applicant deems necessary.

   The effect of this provision is to discourage relocation of damaged facilities to less hazardous sites unless suitable, publicly-owned sites are available. After a damaging earthquake, local governments rarely have the financial resources to purchase new sites for relocation of public facilities and the tendency is to seek engineering solutions to hazardous site problems with little consideration of possible advantages of relocation.

4. *Lack of guidelines for determining price to be paid for properties to be acquired as part of a post-earthquake redevelopment project or a planned relocation*

   Establishing criteria for determining the price to be offered for properties to be acquired for public purposes after an earthquake is a major issue. In several cases studied, the failure to come to terms on property value resulted in rejection of projects which would have significantly improved future safety. Reasonable criteria for establishing compensation are needed. Property values after an earthquake are usually lower. A recurring question is to what extent an owner should be compensated for pre-earthquake value.

5. *Little consideration of long-term hazard mitigation in administering disaster assistance*

   Although explicit consideration of hazard mitigation is required in Sec. 406 of the Act, no rules have been adopted to implement this section. Section 406 states:

   > As a further condition of any loan or grant made under the provisions of this Act, the State or local government shall agree that the natural hazards in the areas in which the proceeds of the grants or loans are to be used shall be evaluated and appropriate action shall be taken to mitigate such hazards, including safe land-use and construction practices, in accordance with standards prescribed or approved by the President after adequate consultation with the appropriate elected officials of general purpose local governments, and the State shall furnish such evidence of compliance with this section as may be required by regulation.

   In April 1979, the Federal Disaster Assistance Administration, now the Office of Disaster Response and Recovery in FEMA, issued proposed rules for implementing this section of the Act following a major disaster declaration. The rules call for a Survey Team to be formed by Hazard Mitigation Coordinators (HMC's) from federal, state and local governments to identify significant hazards, evalute the impacts of the hazards and possible mitigation measures, and recommend appropriate mitigation measures. The recommended measures would be required by FEMA as a condition of receiving federal funds, authorized under Sec. 402 of the Act, for the repair, restoration, reconstruction or relocation of public facilities. The state would be responsible for verifying compliance of local governments with hazard mitigation requirements.

   These proposed rules, if finally adopted, will help correct the present lack of consideration of hazard mitigation in reconstruction decisions after natural disasters. Because of the importance of federal funds in post-earthquake reconstruction, the proposed federal requirements are likely to be particularly effective in encouraging safer reconstruction after earthquakes. However, local ability to meet hazard mitigation requirements after an earthquake is likely to depend on the availability of funds.

6. *Lack of explicit consideration in administering disaster assistance of opportunities to achieve other federal community development objectives*

   Federal community development objectives as set forth in the Housing and Community Development Act of 1977 (Sec. 101) are:

   > (1) the elimination of slums and blight and the prevention of blighting influences and the deterioration of property and neighborhood and community facilities of importance to the

welfare of the community, principally persons of low and moderate income;

(2) the elimination of conditions which are detrimental to health, safety, and public welfare, through code enforcement demolition, interim rehabilitation assistance, and related activities;

(3) the conservation and expansion of the Nation's housing stock in order to provide a decent home and a suitable living environment for all persons, but principally those of low and moderate income;

(4) the expansion and improvement of the quantity and quality of community services, principally for persons of low and moderate income, which are essential for sound community development and for the development of viable urban communities;

(5) a more rational utilization of land and other natural resources and the better arrangement of residential, commercial, industrial, recreational, and other needed activity centers;

(6) the reduction of the isolation of income groups within communities and geographical areas and the promotion of an increase in the diversity and vitality of neighborhoods through the spatial deconcentration of housing opportunities for persons of lower income and the revitalization of deteriorating or deteriorated neighborhoods to attract persons of higher income;

(7) the restoration and preservation of properties of special value for historic, architectural, or esthetic reasons, and

(8) the alleviation of physical and economic distress through the stimulation of private investment and community revitalization in areas with population outmigration or a stagnating or declining tax base.

Often after a major earthquake, reconstruction can be carried out in a way that significantly furthers one or more of these objectives, typically through redevelopment of heavily damaged areas. Such opportunities need to be considered in federal decisions to fund recovery projects. Successful projects are likely to be those clearly related to damaged areas and consistent with community needs and objectives. However, trying to accomplish too much or extending projects significantly beyond damaged areas is likely to be rejected locally unless the public is convinced the projects will not interfere with the return to normal and will lead to substantial benefits. Some redevelopment (or development) projects may be needed to accommodate uses displaced from high hazard areas.

7. *Lack of flexibility in administering disaster assistance sometimes leading to federal/local conflict*

   In spite of the presumably altruistic nature of disaster relief efforts, there are elements of conflict in the relationship between federal and local officials in the post-disaster situation. Local people are striving to maximize assistance to victims and local governmental agencies, while the federal officials are anxious to minimize the cost of relief, insure that funds are spent only for authorized purposes and avoid any possible irregularities that might bring criticism at a later date. Even when officials have broad authority, there is a tendency to interpret it narrowly. The effect of this conflict is to slow down the reconstruction effort and create uncertainties which can lead to private actions undercutting public attempts to reduce future risk. Procedures are needed to encourage sufficient flexibility in administering disaster assistance to take account of variations in local conditions and minimize chances for conflict.

Recommendations for Land Use Planning Following a Major Earthquake

Land use planning after a damaging earthquake can be an effective tool to reduce future seismic risk. It can and should be a significant part of the total intergovernmental response to a major earthquake. Presently, when a large damaging earthquake occurs, the governor of the affected state requests that the President of the United States declare a major disaster — by definition a catastrophe of such severity and magnitude that effective response is beyond the capability of the state and the affected local governments. The request must include:

(1) An estimate of the amount and severity of damage broken down by type, such as private non-agricultural, agricultural, and public.

(2) A statement of actions pending or taken by the State or local legislative and governing authorities with regard to the disaster.

(3) A certification that, for the current disaster, State and local government obligations and expenditures (of which State commitments must be a significant proportion) will constitute the expenditure of a reasonable amount of the funds of such State and local governments for alleviating the damage, loss, hardship, or suffering resulting from such disaster. . .

(4) An estimate of the extent and nature of Federal assistance needed within the State, broken down by category of public or individual assistance for each disaster affected area for which Federal assistance is requested and the estimated Federal funds required for each category.

(5) As appropriate, other justification in support of the request.

(Federal Disaster Assistance Administration, May 28, 1975, Rules and Regulations, Sec. 2205.41)

If the President declares a major disaster, a federal/state agreement, specifying the categories of federal assistance to be made available for recovery, is signed by federal and state representatives. Federal funds may be available for: temporary housing assistance, mortgage and rental payments, unemployment assistance, individual and family grants, food commodities, relocation assistance, emergency public transportation, repair and restoration of public (and certain private) facilities, debris clearance and loans to cover substantial losses of local tax revenues. Less extensive assistance may be authorized for federally-declared "emergencies" — disasters of less severity and magnitude than the "major disasters."

The Presidential declaration formally inaugurates coordinated federal, state and local efforts in response to a disaster. The organization and procedures governing these efforts are geared primarily to handling emergency response. However, review of actions following several disasters reveals a need for more explicit consideration of hazard mitigation in actions related to long-term recovery. Thus, the recommendations are presented in the form of suggested federal regulations and procedures to incorporate hazard evaluation, land use planning for hazardous areas, and funding for plan implementation into the present framework for federal disaster assistance. State legislation and regulations may be needed to authorize the participation of state agencies and local governments in the activities recommended.

As recommended, the regulations would pertain only to recovery from earthquakes; however, some of the suggested actions may be applicable to recovery from other disasters. In addition, the recommended regulations apply only to recovery from earthquakes sufficiently damaging to be declared major disasters by the President. Smaller and less damaging earthquakes are admittedly more frequent and may be disruptive enough to warrant state, and in some cases, limited federal assistance for emergency work and repairs. However, significant opportunities for land use changes in post-earthquake recovery are much more likely to be found after major damaging earthquakes.

The recommendations define key elements of land use planning as a part of the total post-earthquake reconstruction process. These elements are: 1) identifying and evaluating hazardous areas which should be given particular attention in planning for post-earthquake land use changes, 2) revising community land use plans as needed to reflect changed conditions brought about by the earthquake, 3) preparing specific plans for reuse or reconstruction of hazardous areas, and 4) implementing plans for the hazardous areas. The study indicates that, after an earthquake, hazards are ordinarily identified and evaluated, plans prepared, and federal funds made available for reconstruction. The major problem has been in the linkages — that is, assuring that plans are responsive to the hazard evaluation, that funds are allocated on the basis of the plan, and that appropriate mechanisms are in force to assure reconstruction in accordance with the plans.

Figure 5 outlines the sequence and interrelationships of the governmental activities essential to land use planning in a post-earthquake context. The key functions, as shown on the left side of the diagram, are hazard evaluation and plan preparation, review and approval of maps and plans by officials at the appropriate governmental levels, and federal, state and local implementation of land use plans for hazardous areas.

Figure 5 shows the sequence of steps needed to provide hazard area information for use in preparing plans and for developing plans for reuse or reconstruction of hazardous areas within the framework of a community-wide plan. As shown, the functions of hazard evaluation and plan preparation are interrelated, but, carried out by two teams each with specifically assigned responsibilities. The functions of each team are described separately in the text which follows. Nonetheless, the two teams would work together during reconstruction. Procedures for review and approval and implementation actions are described for each map or plan which emerges from the actions shown in the figure.

The recommendations are presented as ideas for suggested federal regulations in order to illustrate as realistically as possible how they might be implemented. Considerable detail has been provided to stimulate discussion and focus attention on the issues that need to be resolved in order for the general ideas embodied in the recommendations to be translated into a regulatory framework. Specific terms are used to designate areas and groups pertinent to post-earthquake land use planning. They are used for convenience only; the concepts and activities associated with the terms should be the focus of attention. Because the recommendations are stated as suggested regulations, the terms "shall" and "should" are liberally used. The intent is to distinguish actions the project team feels ought to be mandatory from those which, while desirable, ought to be discretionary. Each section of the suggested regulations is followed by a commentary describing some of the thinking that led to the recommendations, questions still to be resolved and areas of uncertainty.

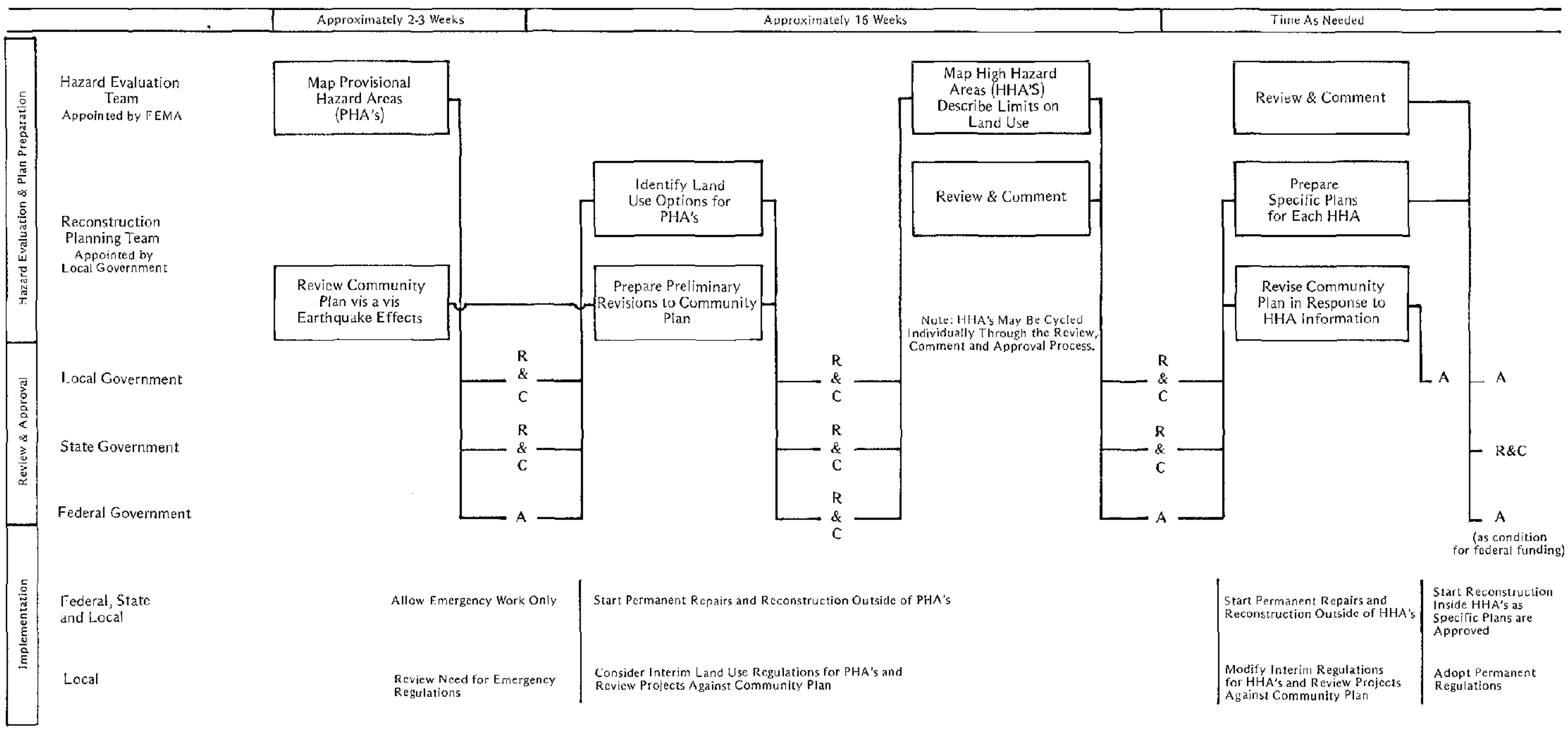
HAZARD EVALUATION

The need for timely and credible evaluation of hazards after a damaging earthquake is clear. The following section outlines procedures for accomplishing this as an integral part of the federal response to an earthquake disaster. The function is viewed as essentially a federal responsibility to insure that federal funds for reconstruction are allocated in a way that reduces damage potential in future earthquakes and, in particular, reduces the likelihood of repeated federal assistance in areas which have already experienced earthquake damage.

Hazard Evaluation Team

Immediately after a major earthquake disaster is declared, the Director of the Federal Emergency Management Agency (FEMA) shall appoint a Hazard Evaluation Team (HET). The purpose of the HET shall be to provide scientific and technical information and recommendations needed to plan for the safe reuse or reconstruction of hazardous areas. Members of the HET should be selected from a list previously prepared by federal and state agencies and professional organizations. Professionals with experience in, and familiarity with, the local area should be

Figure 5. Post-Earthquake Land Use Planning
Recommended Governmental Actions and Interactions



A = APPROVAL
R&C = REVIEW & COMMENT

This sequence of actions provides a framework for coordinating the efforts of federal, state and local governments to plan and implement plans after major earthquakes. Of major concern is the identification of Provisional and High Risk Areas. The identification results in control of reconstruction in these areas and in release of federal funds for reconstruction projects outside these areas.

included on the team. In most cases, the team would include geologists, engineering geologists, geotechnical engineers, structural engineers and seismologists, but the composition should be determined by the characteristics of the earthquake hazards involved. Expenses of the team shall be paid by FEMA.

Commentary. This idea is drawn from the successful experience of the Scientific and Engineering Task Force after the 1964 Alaska earthquake. The Task Force was composed of personnel from federal agencies. However, here it is suggested that the team be formed of qualified people from governmental agencies and private firms. The important point is that the team be accorded official status and have sufficient expertise to lend credibility to its recommendations.

After an earthquake, scientists and engineers typically gather to conduct on-site investigations in order to expand scientific understanding of earthquakes and their effects. Others undertake the technical function of inspecting buildings to determine those to be demolished or posted as unsafe. The function of the Hazard Evaluation Team is distinct from the foregoing activities, and is to delineate hazardous areas for the purpose of guiding reconstruction planning.

Provisional Hazard Areas

Within two to three weeks of appointment, the HET shall prepare a report including maps showing Provisional Hazard Areas (PHA's). PHA's shall include areas of ground failure, flooding and concentrated structural damage. The PHA's should be drawn large enough so that refinement of data is more likely to result in a decrease in size than an increase. The report shall describe the reasons for the designation of PHA's and recommend design and construction standards for federally-assisted repair and reconstruction throughout the earthquake damaged area. The report should be released simultaneously to the federal and state disaster relief personnel, officials of affected local governments, property owners, local financial institutions and the news media for review and comment. Following approval of the maps and recommended standards by the Regional Director of FEMA, federal funds to assist property owners and public agencies with permanent repairs in areas outside the PHA's should be made available. The maps and recommended standards should be used by special districts and the state government to guide post-earthquake planning activities.

Commentary. The rapid designation of PHA's is intended to make federal assistance available for immediate repair and reconstruction of damaged buildings and facilities outside of PHA's. Repairs and reconstruction to be federally-assisted should be required to meet design and construction standards which insure reasonable safety in future earthquakes. In many cases, local codes and ordinances will be adequate, but in some cases, the earthquake will reveal inadequacies which need to be corrected to ensure rebuilding to an acceptable level of safety.

Only a small part of the earthquake damaged area is likely to be included in the PHA's. PHA's are specifically limited to those areas in which reuse, relocation, special structural restrictions, stabilization measures, or redevelopment might be called for to achieve reasonable safety. Available information concerning other major natural hazards that occur in the PHA's such as non-earthquake related flooding, should be considered in making the designations. Federal assistance for permanent repair or reconstruction in these areas should be withheld pending further study and planning.

The PHA's should include both developed areas and undeveloped areas in or near an urbanized area where ground failure, whatever the cause, occurred during the earthquake and where flooding occurred from tsunami or seiche runup or the failure of dams or dikes. It is important to include undeveloped areas where the ground failed or flooding occurred to prevent the relocation of buildings or location of temporary housing in these areas. The information is also needed by local governments to plan and regulate future growth in such areas.

All areas of concentrated structural damage should be designated as PHA's whether or not the cause of damage can be quickly determined. Designating PHA's requires consideration of the amount and severity of structural damage and the age and condition of buildings. The initial designation should be largely the responsibility of structural engineers on the HET working cooperatively with local building officials.

The suggested time limitation of two to three weeks to designate PHA's is intended to emphasize the importance and the feasibility of rapid initial assessment of earthquake hazards. Obviously, provisions are needed to provide flexibility to extend this time period, if needed, possibly at the discretion of the Regional Director.

The suggestion that PHA's be conservatively drawn is important in preserving the credibility and public acceptability of the process. It will be difficult to later expand the areas to include sites where repairs or reconstruction may have already been started. More important, however, is the overriding objective of the procedure to ensure safe reconstruction. If the safety of an area is in doubt based on preliminary evaluation, decisions concerning construction in the area should be deferred until further study confirms or contradicts the initial evaluation.

The release of the maps to all potentially affected public and private agencies, property owners and the general public is extremely important. Nothing destroys the credibility of a technical effort more effectively than the suspicion that results are being determined behind closed doors. Openness, clarity and completeness of communication to the public of the process and its results are absolutely essential. The reasons for the designations, probable accuracy, expected schedule for release of the final map, and specific constraints on rebuilding in the designated areas should be clearly stated. Non-federal agencies should use the maps as bases for their own actions. Local governments, for instance, could enact emergency legislation to limit reconstruction in PHA's pending further investigation. Also, the maps should be given to the Reconstruction Planning Team for use in its work.

High Hazard Areas

After completion of the provisional hazard area maps, the Hazard Evaluation Team shall conduct, or call in appropriate experts to conduct, more detailed evaluations of the PHA's to determine: 1) potential for damage in future earthquakes, 2) potential means of mitigating the hazard and estimated costs, 3) appropriate building design and construction standards, and 4) more exact boundaries of areas subject to high seismic hazard. In evaluating uses for the PHA's, the HET shall consider those uses identified by the Reconstruction Planning Team (RPT) as potentially appropriate. Following the detailed evaluation, the HET shall issue maps delineating High Hazard Areas (HHA's) and final recommendations. This should be accomplished within 16 weeks of the disaster declaration. HHA's shall include the PHA's or those portions of the PHA's in which there is 1) a high probability for recurrence of ground failure or flooding, and 2) a need for redevelopment or reconstruction to improved building standards to achieve reasonable safety. Results shall be fully communicated to the public and to affected public and private agencies. Following review and comment by affected state and local governmental agencies, the Regional Director shall approve, with any modifications deemed necessary, the maps and the HET final recommendations. No federal funds shall be allocated for permanent repairs or reconstruction in the HHA's until plans for reuse or reconstruction, consistent with the recommendations of the HET, have been adopted by local government. The federal funding agency should be responsible for determining consistency of the locally adopted plan with the HET recommendations.

Commentary. The HET should investigate each PHA designated on the basis of ground failure or flooding to determine more exactly the boundaries of the areas likely to fail or be flooded in future earthquakes. For each area, the team should recommend appropriate uses, any needed remedial measures and design and construction standards to achieve an acceptable level of risk. The HET should attempt, to the degree possible, to be explicit in its definition of acceptable risk. One possible set of criteria relating probability of occurrence of damage to categories of land use is shown in Table 2. Other criteria are possible and additional study is needed on this subject.

Particular attention should be given to the options for future uses of the PHA's identified by the Reconstruction Planning Team. In many cases, the most important information needed from the HET will be an evaluation of the appropriateness of pre-earthquake uses in the areas revealed as hazardous by the earthquake.

Those PHA's designated solely on the basis of concentrated structural damage should be considered separately from those designated on the basis of ground failure or flooding. With adequate building design and construction, these areas can be safely reconstructed. The decision to designate these areas as HHA's should be reached jointly by the HET and the Reconstruction Planning Team (RPT). The designation essentially is a decision to seek redevelopment of the area and involves consideration of planning factors in addition to potential future risk. Once a redevelopment or reconstruction plan has been approved and carried out the High Hazard Area designation would no longer pertain to the area.

The time span of 16 weeks for the HET to issue the maps of HHA's and final recommendations seems to be achievable, but undoubtedly situations can arise warranting an extension. The Regional Director could be authorized to grant such extensions. In many cases, it may be possible and desirable to issue HHA designations sequentially as the evaluation is completed. It is important that the work of the HET be completed as quickly as possible to avoid unnecessary delays in recovery and forestall private actions to repair or rebuild in unsafe areas. The acceptability of the process will be enhanced if time schedules for important steps and decisions in the reconstruction effort are publicized and adhered to.

The maps and final recommendations of the HET should be released simultaneously to all affected governmental agencies and to the news media with recommendation for state and local governmental approval.

The HET is assigned a basically technical task and it can be argued that the team should be insulated from political pressures. However, the recommendations of the HET could have far-reaching consequences, particularly in the allocation of federal funds for reconstruction projects, and some mechanism for approval of the recommendations is needed. It is suggested that the Regional Director be authorized to approve, disapprove or modify the HET recommendations taking into consideration comments and objections raised by affected governmental agencies and property owners and other individuals. Local or state government approval should be encouraged but not required, because the major purpose of the maps is to guide the federal funding for reconstruction. In the case of major disagreement, appeal procedures already in place within FEMA could be used.

RECONSTRUCTION PLANNING

Planning for long-term reconstruction after a damaging earthquake is an important responsibility of local governments. However, because of the wide variability in local capabilities, federal and state assistance is often needed in planning and in providing information on federal and state assistance programs. The following sections outline procedures for reconstruction planning and ways to link such planning to the hazard evaluation and, ultimately, the funding of reconstruction projects.

Formation of the Reconstruction Planning Team

Following a Presidential declaration of a major disaster for an earthquake, each affected local government shall appoint a Reconstruction Planning Team (RPT). The team should be headed by the planning director or the staff member responsible for planning and include staff members from key departments such as public works, building inspection, engineering. Other professionals, such as experts in land use and redevelopment planning, land appraisal, property acquisition, finance, social planning, housing and economic development, should be called in to work with the team as needed to provide the expertise to address the particular situation. FEMA shall fund the work of the RPT and provide technical assistance either by assigning federal personnel to work with the RPT or

TABLE 2
POSSIBLE RISK CRITERIA FOR LAND USES

<table>
<tr><th rowspan="2">ANNUAL PROBABILITY</th><th colspan="2">COMMON PERCEPTION OF RISK</th><th rowspan="2">POSSIBLE CORRELATION OF LAND USES WITH THE ANNUAL PROBABILITY OF LOSS OF FUNCTION AND DAMAGE EXCEEDING 10% OF VALUE (2)</th></tr>
<tr><th>FOR SIGNIFICANT ECONOMIC LOSS</th><th>FOR FATALITY (1)</th></tr>
<tr><td rowspan="2">1:10</td><td rowspan="2">HIGH</td><td rowspan="5">HIGH (4)</td><td rowspan="4">5. OPEN SPACE, NON-STRUCTURAL USES</td></tr>
<tr></tr>
<tr><td rowspan="2">1:100</td><td rowspan="2">MODERATE (3)</td></tr>
<tr></tr>
<tr><td rowspan="2">1:1,000</td><td rowspan="2">LOW</td><td rowspan="2">4. CONVENTIONAL RESIDENTIAL, COMMERCIAL</td></tr>
<tr><td rowspan="4">MODERATE (5)</td></tr>
<tr><td rowspan="2">1:10,000</td><td rowspan="6">NEGLIGIBLE</td><td rowspan="2">3. HIGH OCCUPANCY STRUCTURES</td></tr>
<tr></tr>
<tr><td rowspan="2">1:100,000</td><td rowspan="2">2. EMERGENCY FACILITIES</td></tr>
<tr><td rowspan="3">LOW (6)</td></tr>
<tr><td rowspan="2">1:1,000,000</td><td rowspan="2">1. NUCLEAR REACTORS, LARGE DAMS, ETC.</td></tr>
<tr></tr>
</table>

DECREASING RISK (arrow pointing down the Annual Probability column)

NOTES:

(1) Starr, 1972, "Benefit-Cost Studies in Sociotechnical Systems", in *Perspectives on Benefit-Risk Decision Making:* National Academy of Sciences.

(2) Use categories 1-4 from California State Legislature, Joint Committee on Seismic Safety, 1974, *Meeting the Earthquake Challenge*

(3) The "100 year flood" is a criterion of an acceptable risk level for many types of land development. Exposure of capital to this risk level represents a self-insurance cost of 1%, which is probably tolerable to most investors in today's economic climate.

(4) 1:100 is the average disease mortality; activities involving this level of risk are considered dangerous by most people.

(5) The risk of death from automobile accidents is about this level.

(6) Fatality risks at this level are commonly perceived as "acts of God" – e.g., getting hit by lightning.

by funding contracts with private firms to provide the needed expertise.

The purpose of the RPT shall be to guide and assist local governments in 1) revising community land use plans which recognize altered conditions brought about as a result of the earthquake, and 2) preparing specific reuse or reconstruction plans for the HHA's designated by the HET, including relocation plans, if needed. The RPT shall work closely with the HET in preparing plans for the HHA's.

Commentary. The role of the RPT and the expertise needed will vary with the nature and extent of damage and local ability to respond. In communities with a well-established planning function and capability to plan for reconstruction, the need for technical assistance would be minimal. In some situations, outside experts, at the request of the local legislative body, would assume full responsibility for the technical work needed to prepare the plan, in effect, becoming the RPT.

Federal and state advisors to the RPT are needed for liaison and technical assistance. The composition of the RPT recognizes that planning is a local government function. Federal funding of the planning effort and provision of technical assistance recognizes the importance to the federal government of spending disaster recovery funds wisely.

Revised Community Land Use Plan

The first task of the RPT is to review existing land use and circulation, community plans and regulations and the location of critical or high-occupancy facilities in relation to the initial damage assessment. This review should be completed within two to three weeks of the disaster declaration. Following issuance of the maps of Provisional Hazard Areas, the RPT shall make preliminary revisions in the community land use plan to provide a community-wide perspective and framework for planning for the reconstruction or reuse of the PHA's, identify areas suitable for relocation of major facilities or for the location of temporary housing, identify specific problems related to reconstruction, particularly of critical and high-occupancy facilities and lifelines outside the PHA's, and evaluate the land use and circulation relationships between the PHA's and the rest of the community.

The preliminary revisions should be reviewed by the HET, appropriate federal and state agencies and local legislative bodies and serve as a guide to further planning. Comments from the public and, in particular, property owners in the PHA's should be solicited. Reconstruction projects outside of the PHA's should be reviewed for consistency with the preliminary revisions to the plan. The plan should be considered a working document to be progressively modified and refined as a guide to the reconstruction effort and specific planning for the PHA's. Following release of the maps of the HHA's and initial planning for the PHA's, the community land use plan should be revised as needed and such revisions adopted by the appropriate local government legislative bodies.

Commentary. The preparation or revision of a community land use plan is viewed as a local responsibility with federal and state agencies providing technical assistance and advice as needed. The effort required to revise the community land use plan will depend on the quality of existing plans and their relevance to post-earthquake conditions. The extent of revision needed will also depend on the location, extent and causes of damage and the likelihood of future earthquake damage. If a local jurisdiction does not have a land use plan, the RPT will essentially have to start from scratch. In most cases, however, it is likely that a land use plan or a zoning map or even a map of pre-earthquake land uses will be available and can serve as a starting point in providing a framework to relate specific reconstruction or reuse options to the entire community.

A preliminary plan or revisions to the existing plan should be prepared as quickly as possible so that impacts of potential changes in use of the PHA's on the areas outside, such as relocation of structures or realignment of lifelines or streets, can be anticipated before permanent repairs or new installations are made. However, it is not the intent of this recommendation that all repairs or reconstruction outside of the PHA's be held up until the plan is revised. Procedures should be established to assure coordination between the RPT and operating agencies at federal, state and local levels to assure that decisions will be made in accord with emerging information. Continuous interchange between the HET and RPT is needed to provide for early identification of potential problems. The local government should impose such restrictions on construction and repair as may be appropriate based on the plan.

Work on the community land use plan could continue in successive stages as appropriate with progressive refinements throughout the reconstruction process, particularly in response to the final recommendations of the HET and specific planning for the HHA's. As revisions to the plan are completed, they should be adopted by the local government. Specific reconstruction projects should then be consistent with the plan.

Options for PHA's

On release of maps of the PHA's, the RPT shall prepare a preliminary report outlining the options for reuse or reconstruction of each designated PHA. The preliminary community land use plan shall serve as a guide in defining the range of possible land use options. The report shall be used by the HET in determining the range of land uses which should be evaluated for potential reuse of the PHA's. It should also be used in establishing final boundaries of PHA's designated because of concentrated structural damage. The report shall also be used in preparing or revising the community land use plan.

Review and comments on the report shall be sought from the FEMA Regional Director, state government, local government, affected special districts, property owners, and the general public.

Commentary. The major purpose of the report outlining options for the PHA's is to provide needed planning information to the HET in designating HHA's and to obtain federal, state, local and general public review and comment on ideas for reuse or reconstruction on the PHA's. The review process should serve to focus subsequent planning for the PHA's on realistic options.

Specific Plans for HHA's

As maps are released designating HHA's, the RPT shall prepare a specific plan for the reconstruction or reuse of each HHA. Each specific plan should include:

1. Map of the High Hazard Area.
2. Recommended land uses, regulations and building standards for each HHA.
3. Description of any recommended engineering or stabilization measures for each HHA.
4. Location, capacity and design standards for any public facilities, lifelines, critical or high occupancy structures to be repaired, reconstructed or relocated in a HHA.
5. Identification of properties to be acquired, demolished or rehabilitated.
6. Owner-participation options and relocation plans as needed.
7. Cost estimates and specification of federal, state and local share of costs for implementing each plan.
8. A time schedule for implementing each plan.

Each plan shall be adopted by the appropriate local legislative bodies and, if federal funding is proposed for implementation, shall be consistent with the recommendations of the HET. The federal funding agency shall make the determination of consistency. No federal funds for permanent repair of public facilities or non-emergency aid to private property owners in a High Hazard Area shall be committed until a plan has been locally adopted and determined by the funding agency to be consistent with the recommendations of the HET. Adoption and determination of consistency shall represent a federal commitment to provide the specified share of funds needed for implementation. In redevelopment projects, covenants should be placed in deeds to ensure continuity of the restrictions contained in the plan.

Commentary. Specific plans for the HHA's should be prepared in as much detail as necessary and should reflect the recommendations of the HET. Considerable interchange between the HET and RPT will be needed, particularly in relating possible stabilization or other engineering measures to the proposed uses of the HHA's. The specific plans should be generally consistent with the community land use plan.

The requirement for a federal determination of consistency of the plans with the recommendations of the HET pertains only if federal funds are to be used to achieve reuse or reconstruction of the HHA's. Local governments may choose to ignore the HET recommendations and seek non-federal sources of funds for reconstruction.

No time limit has been set for the completion and local adoption of the specific plans. The withholding of federal funds for any permanent reconstruction in these areas until the plans have been adopted is expected to provide sufficient incentive for expeditious action. Following local adoption of a specific plan, time limits should be placed on the federal determination of consistency.

A central issue in the implementation of the specific plans for the HHA's is likely to be the basis for compensation of property owners for property recommended for acquisition for public purposes. The local acceptability of proposed redevelopment or relocation projects is highly sensitive to whether or not affected property owners feel they will be fairly compensated. In some recent cases HUD has paid pre-flood property values to property owners being relocated out of the flood plain. Compromises between using full pre-earthquake values and post-earthquake values as a basis for negotiating with property owners need to be devised to recognize different conditions in each earthquake.

LONG-TERM MONITORING

Both the HET and RPT should be responsible for recommending procedures to ensure that their recommendations are followed after the teams are officially disbanded. The HET should recommend procedures to ensure that its design and construction standards are complied with, to authorize changes in the boundaries of HHA's based on new information, to arrange for the installation and monitoring of any instruments needed in the HHA's, and to advise local officials concerning other potential hazards in future earthquakes. The RPT should recommend procedures to ensure that plans for reuse or reconstruction of the HHA's are carried out and to authorize changes in the plans consistent with changes in the HET recommendations.

Commentary. The need for long-term follow-up of land use and construction practices in HHA's and procedures to make use of new data is apparent. How this is handled will vary depending on local capabilities. If a local government has good geologic and engineering expertise available on a regular basis, it may easily assume this role, with the provision that important deviations from the HET's final recommendations are subject to federal approval. State assistance or more direct federal follow-up may be needed in other cases. Some mechanism, possibly like A-95 review, could be used to ensure that federal and state assisted community development and related projects are consistent with the HET recommendations and the locally-adopted specific plans for the HHA's. HHA's designated on the basis of concentrated structural damage and having undergone redevelopment would not be subject to long-term monitoring.

Summary

These recommendations are offered as a basis for study, discussion and action. The suggested requirements are intended to set the stage for effective federal, state and local decisions with respect to land use after a major damaging earthquake. Land use planning and regulation in the United States is primarily a local government function. The suggestions are designed to preserve local prerogatives and state responsibilities while recognizing the federal dominance in financing post-disaster reconstruction and the consequent need to protect the federal investment in reconstruction. However, the overriding objective is to protect public safety and reduce the potential impact of future earthquakes.

San Fernando Case Study

appendix a

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Acknowledgments

No case study can be done without the cooperation of many people. We relied heavily on information and recollections from local government officials who participated in reconstruction decisions after the San Fernando earthquake.

We especially appreciate the cooperation of the following persons with whom we talked either by phone or in person.

City of San Fernando

- Joseph E. Comstock, City Administrative Officer
- Rudy Gunnerson, Director, Department of Building and Planning
- David Watt, Director, Department of Parks and Recreation

City of Los Angeles

- Frank Lombardi, Executive Officer, Department of City Planning
- Glenn Blossom, City Planning Officer
- J.M. Wool, Senior Waterworks Engineer, Department of Water & Power
- Jack M. Sweetman, Waterworks Engineer, Department of Water & Power

County of Los Angeles

- Norman Murdoch, Director, Department of Regional Planning
- Robert Hoie, Supervising Regional Planner, Department of Regional Planning
- Kenneth R. Putnam, Division Engineer, Department of County Engineer, Waterworks Division

Wherever possible we tried to verify information obtained in the interviews by reference to other sources; however, this was not possible in all cases. The authors assume full responsibility for any misstatement or misinterpretation of fact.

Under the guidance of George Mader and William Spangle, Martha Blair was responsible for assembling the contributions of the study team into a cohesive report and for writing the sections on planning response. Sally Bilodeau and Richard Meehan wrote the sections on geologic effects, and Henry Degenkolb the section on structural damage. Interviews in the San Fernando area were conducted by Martha Blair and George Duggar on May 11 and 12, 1978. The report was edited and prepared for reproduction by William Spangle and Associates, Inc. Pamela Holt and Stephanie Stubbs-Hogan prepared the original graphic material.

Introduction

The objective of the San Fernando case study was to determine the main factors influencing reconstruction decisions following the 1971 San Fernando earthquake. The study was carried out by a team from the disciplines of city and regional planning, geology, civil engineering, structural engineering, public administration and planning law. During the course of the study, the team met frequently to evaluate work in process and define and reach agreement on tasks. The study was carried out in three distinct phases. First, a literature search was conducted to record and describe the geologic effects of the earthquake and to predict effects from future earthquakes. Second, damaged homes and major facilities or structures were mapped and compared with the geologic effects to determine which structural failures were associated with ground failure and which were the result of design and construction inadequate to withstand ground shaking. Following completion of this work, the study team met to identify where geologic conditions and structural damage indicated the possible need for a change in land use, as opposed to a purely structural response during reconstruction. Questions and issues were identified for use in the third phase – interviewing local officials to determine what decisions were made in those cases identified and the major factors influencing those decisions.

The earthquake, registering 6.4 on the Richter scale, caused significant damage in the San Fernando Valley on the fringes of the Los Angeles metropolitan area. Figure 1 shows the location of the epicenter in relation to major Southern California cities. The location of the area chosen for study is also shown in Figure 1. The study area encompasses about 50 square miles – a small part of the Los Angeles metropolitan area. This area was chosen because most of the earthquake damage occurred here and the area experienced a variety of seismic effects – strong ground motion, surface fault rupture, liquefaction, landslides, and rock falls.

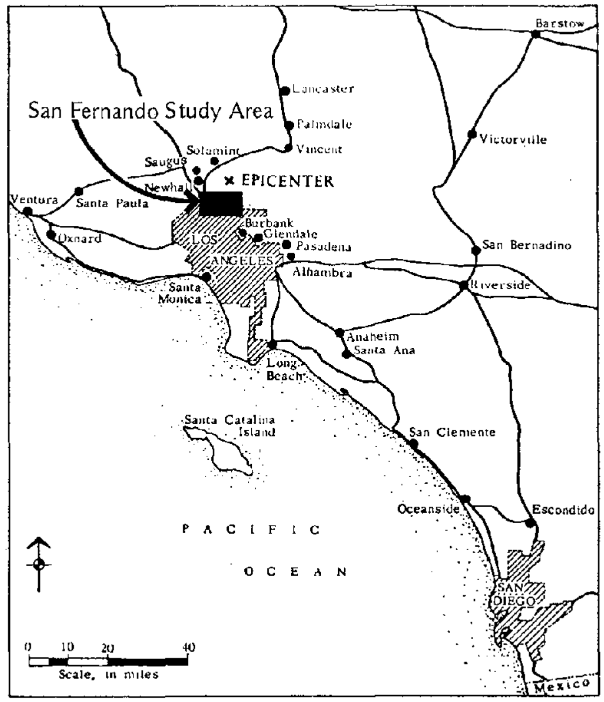

Figure 1. San Fernando study area, epicenter of San Fernando earthquake, and relationships to Southern California cities
(Source: Steinbrugge and others, 1971, pg. 1, modified by William Spangle and Associates, Inc.)

As shown in Figure 2, the study area includes all of the City of San Fernando, and portions of the City of Los Angeles and Los Angeles County. By focusing the study on this area, the decisions of three local jurisdictions concerning reconstruction of most of the major facilities damaged in the earthquake and in dealing with the full range of seismic hazards could be explored. With the exception of the Angeles National Forest and some hilly areas to the north, most of the study area was quite extensively urbanized at the time of the earthquake. The extent of urbanization is illustrated in Figure 3, an aerial photograph of a portion of the study area taken soon after the earthquake.

Geologic and Structural Effects

Shortly before dawn on February 9, 1971, residents of the San Fernando Valley were awakened unexpectedly by sharp ground vibrations that represented the beginning of an earthquake that records later showed to be a modest 6.4 on the Richter scale. Less than a minute later, the last of the tremors had died away. Nonetheless, in spite of the moderate size of the earthquake, the destruction was considerable. It included near collapse of a major dam, collapse of some modern hospital buildings supposedly designed to resist earthquakes, destruction of 126 and

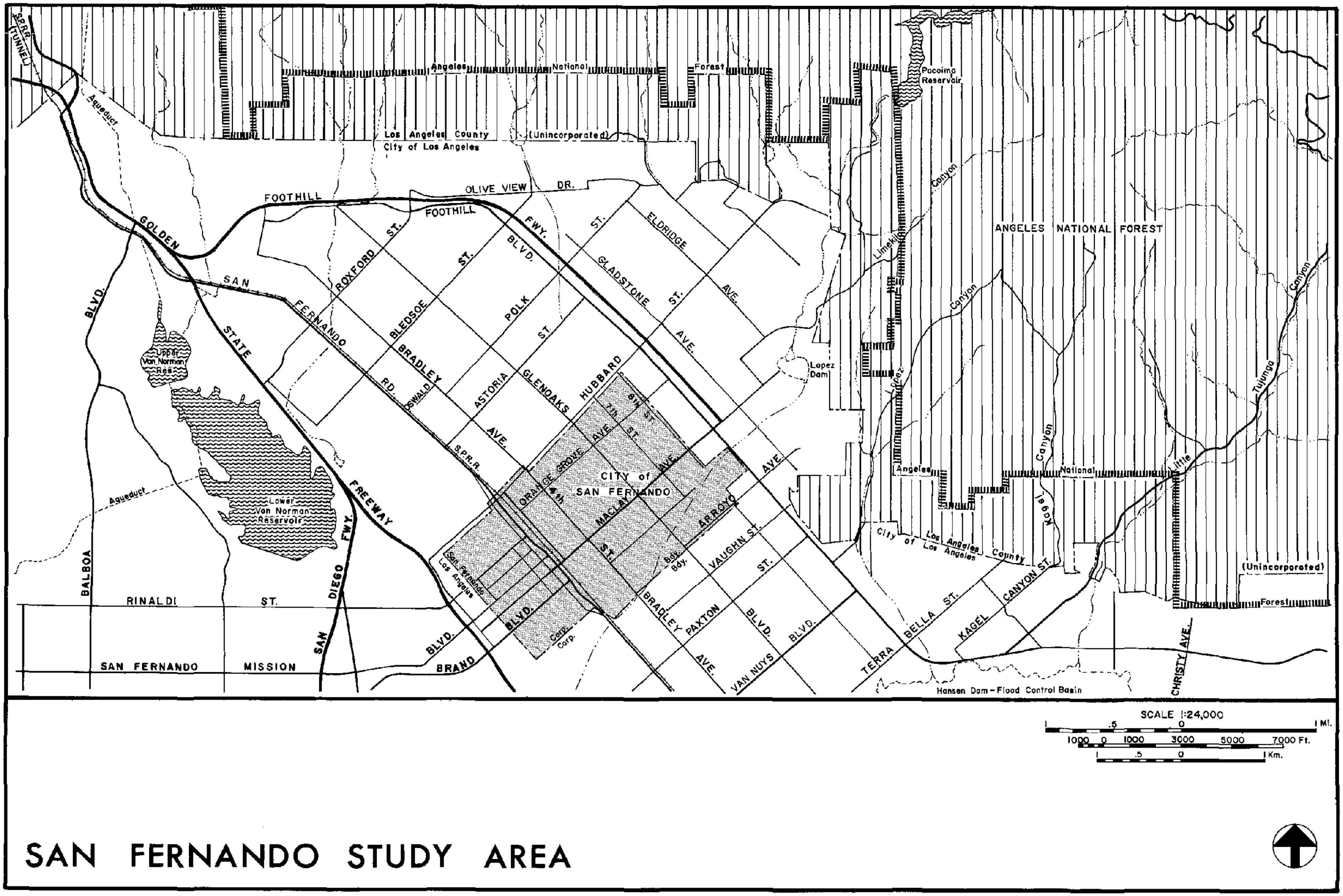

Figure 2. San Fernando study area

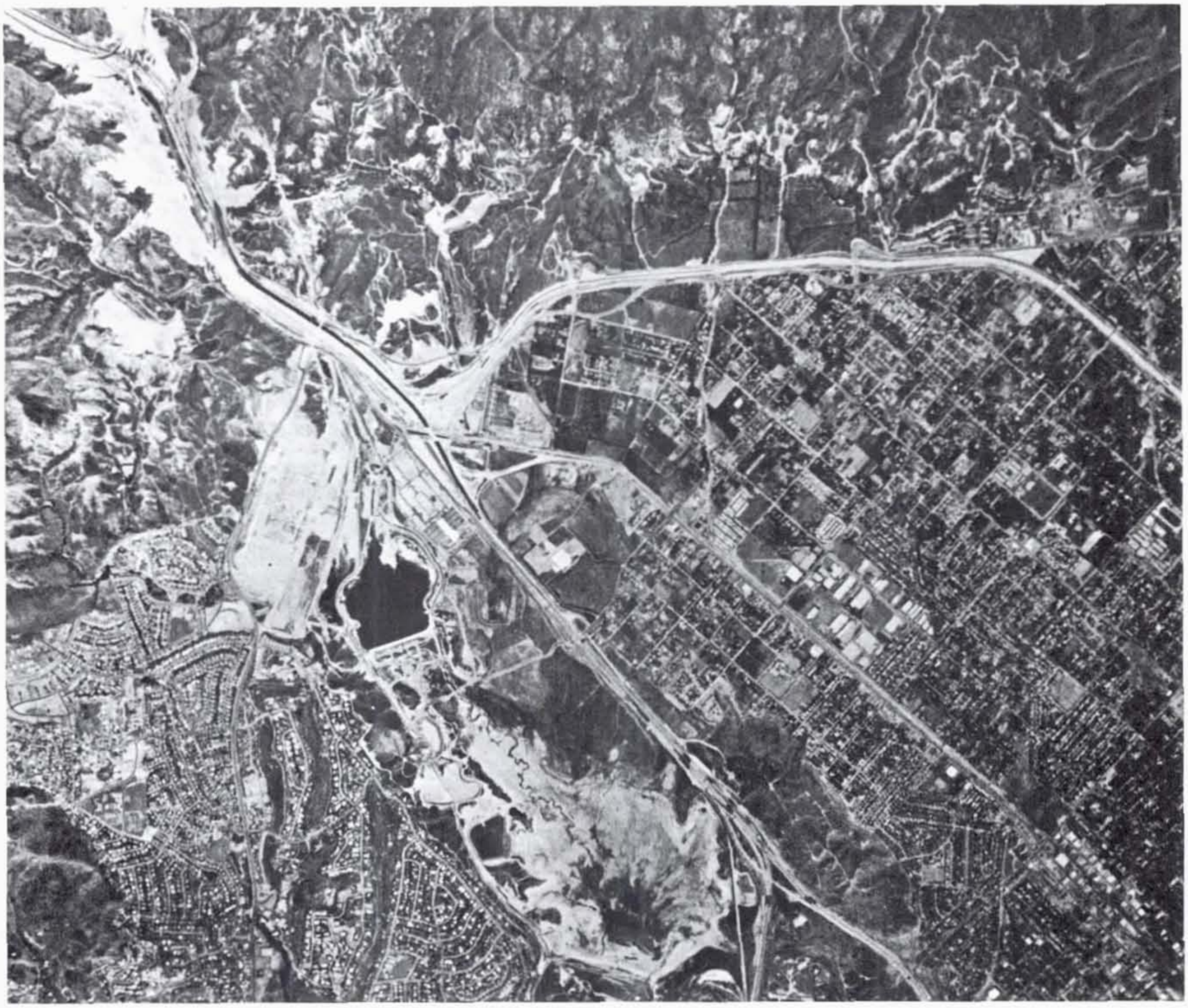

Figure 3. Aerial photo taken in May 1971, of western portion of study area showing highly urbanized valley floor and relatively undeveloped hills to the north. The drained Lower Van Norman Reservoir is in the lower center of the photograph. (Source: Jennings, P.C., Ed., 1971, p. 473)

damage to 12,000 residences – some $500 million in property damage all told. Sixty-four people lost their lives in the earthquake, although experts believe that the number might have been closer to tens of thousands if the shock had occurred a few hours later, during rush hour, and if the Lower San Fernando Dam had failed completely sending a deadly flood wave through the heavily populated downstream area.

The San Fernando earthquake produced a variety of geologic effects – damaging ground shaking, landslides, soil liquefaction, and surface fault rupture. It was located in a modern North American urban area characterized by a relatively sophisticated, scientific understanding of earthquakes and a high level of education among residents. These factors, coupled with rapid dissemination of information, offered the chance for the Los Angeles metropolitan area and other earthquake-prone areas to take full advantage of the lessons taught by the earthquake. Engineers and geologists consider the earthquake to be an unprecedentedly valuable laboratory for studying such diverse problems as the predictability of earthquakes, the safe design of structures ranging from houses to high-rise buildings, and the disaster management of lifelines and services. Since the earthquake, a vast amount of technical data on the location and characteristics of geologic and seismic hazards in the San Fernando area have been collected, providing a reasonably sound basis for forecasting the geologic and seismic effects of future earthquakes in the area. This technical information – the geologic and seismic setting of the study area, the principal effects of the 1971 earthquake, and some reasonable expectations of the effects of future earthquakes – are briefly described in the following sections of the report. Special emphasis is given to those conditions which can

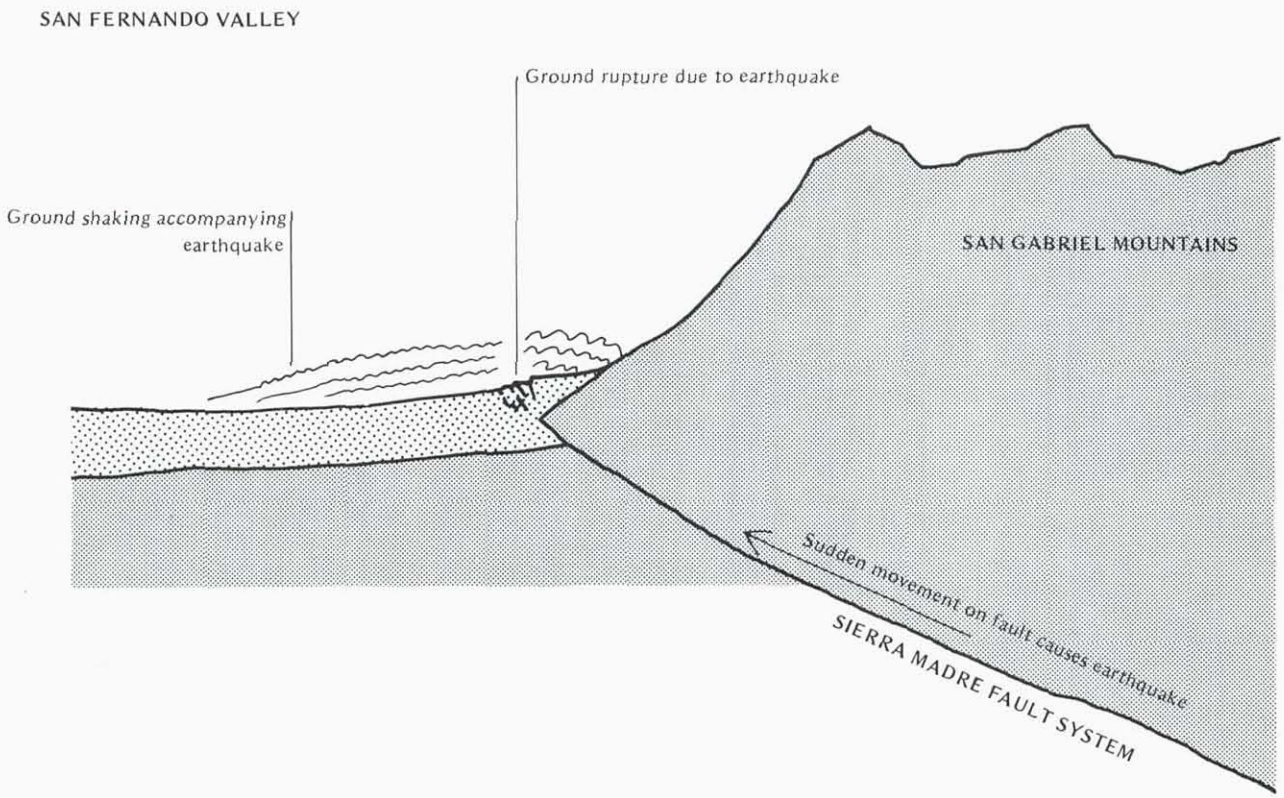

Figure 4. The 1971 San Fernando earthquake was caused by movement on the Sierra Madre fault system. Continuing past movement on this fault has lifted the San Gabriel Mountains to their present height. The same process, which produces periodic earthquakes, is certain to occur in the future.

be predicted in advance and which seem to be of special interest in land use planning.

GEOLOGIC AND SEISMIC SETTING

The San Fernando earthquake is one of the most thoroughly studied earthquakes in history. Since its occurrence in early 1971, extensive geotechnical research has been conducted in an effort to better understand the regional geologic and tectonic environment which produced the shock. Particular emphasis has been placed on regional geologic conditions and precursor events that might have provided advance warning that an earthquake would occur in this area.

Regional Setting

The fault which caused the February 9, 1971 San Fernando earthquake is located at the foot of the San Gabriel Mountains on the sloping floor of the Upper San Fernando Valley. In fact, recurrent movements along this fault contributed to the uplift creating the San Gabriel Mountains. The sudden slippage of rock that caused the earthquake originated on the fault about five miles deep beneath the mountain range, some 8 miles north-northeast of the City of San Fernando. The fault plane itself slants back underneath the San Gabriel Mountains at an angle of 45° to 50° and is part of a complex group of faults collectively called the Sierra Madre fault system (Figure 4).

The San Gabriel Mountains are a major east-west trending mountain range which is part of the Transverse Range Province of Southern California. They have long been recognized as geologically young and tectonically active. Structurally, they consist of a tectonically uplifted block, approximately 60 miles long and 20 miles wide, bounded by major fault zones on the north, south, and southwest. Their present elevation of over 10,000 feet has been achieved with periodic, earthquake-producing episodes of uplift over the past two million years. This uplift has been accompanied for millions of years by faulting along the southern front of the range along the Sierra Madre fault system. The Sierra Madre fault system is actually more

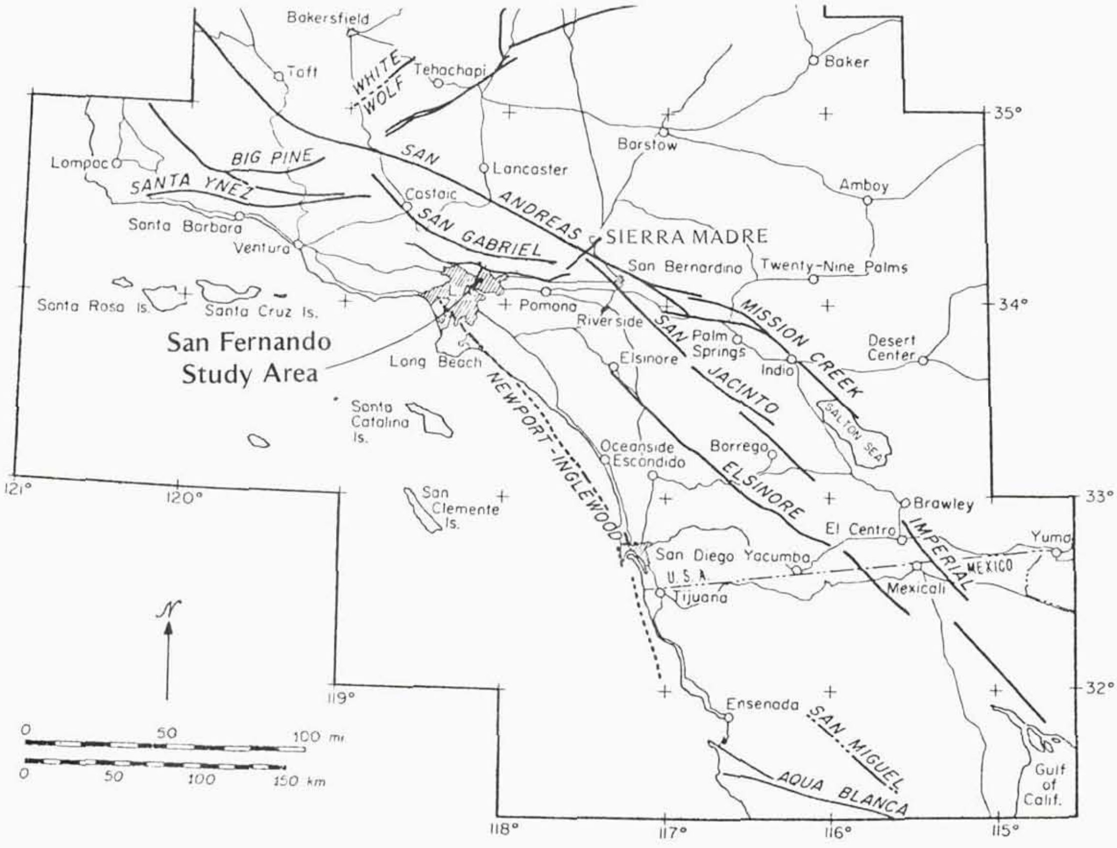

Figure 5. Major faults of Southern California region (Source: Hileman, et al., 1973, modified by William Spangle and Associates, Inc.)

complicated than the relatively simple, bold, southern face of the range shown in Figure 4 might suggest. Faulting appears to be broken up into five or six independent segments, each 10 to 15 miles long and each composed of numerous individual faults. The San Fernando fault is one such segment. Although many segments of this system had been mapped and interpreted prior to the February 9 earthquake, the San Fernando fault had not been widely recognized. It had not appeared on the majority of geologic maps in use at the time.

Besides the Sierra Madre fault, many other active faults are known to exist in Southern California. In this report, an active fault is defined as a fault that has slipped in recent geologic time (about 11,000 years), and is likely to move again (Slemmons, 1977). The frequency of fault activity varies from very low to very high. The study area is literally surrounded by active faults as shown in Figure 5. Earthquakes on any of these faults could affect the study area and other parts of Southern California. The San Andreas fault, which is the largest fault in California and which is capable of producing great earthquakes, is located about 35 miles northeast of the San Fernando Valley. Between 1912 and 1972, twelve earthquakes of Richter magnitude 6.0 or greater were experienced within a 100 mile radius of the San Fernando study area (Figure 6).

Evaluation of the historic record suggests that the Southern California region can expect an earthquake of a magnitude comparable to the 1971 earthquake on the average of once every four years. Because the fault producing the San Fernando earthquake shows geologic evidence of countless past movements, and also because the historic record shows that San Fernando-type earthquakes occur regularly in Southern California, the 1971 earthquake can be considered a relatively normal occurrence.

Local Setting

The study area considered here is approximately 50 square miles and encompasses the Upper San Fernando Valley and the immediately surrounding hills and mountains. The Upper San Fernando Valley is a horseshoe-shaped, gently sloping, alluvial basin bordered to the north and east by the foothills of the San Gabriel Mountains and to the west by the Mission Hills. The basin has been filled by sands, gravels, and clays derived from the adjacent hills. These alluvial, or water-deposited, sediments range in thickness from 100 to 200 feet over most of the valley floor. The San Fernando fault lies along the southern margin of the basin. Other faults of the Sierra Madre system known to be present in the basin include the Hospital and Mission Hills faults.

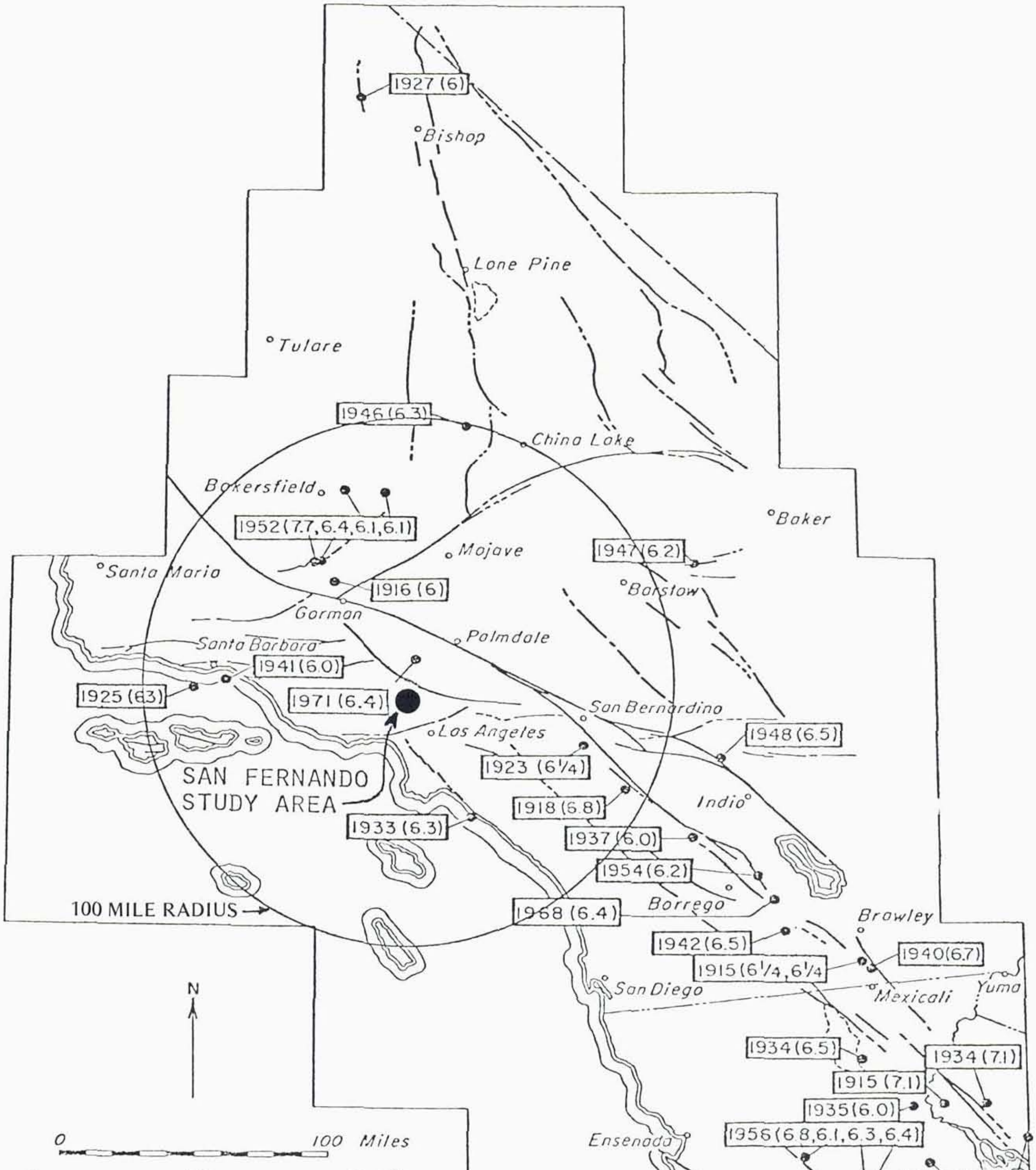

Figure 6. Earthquakes of Richter magnitude 6.0 and greater in Southern California 1912-1972 (Source: Hileman, et al., 1973)

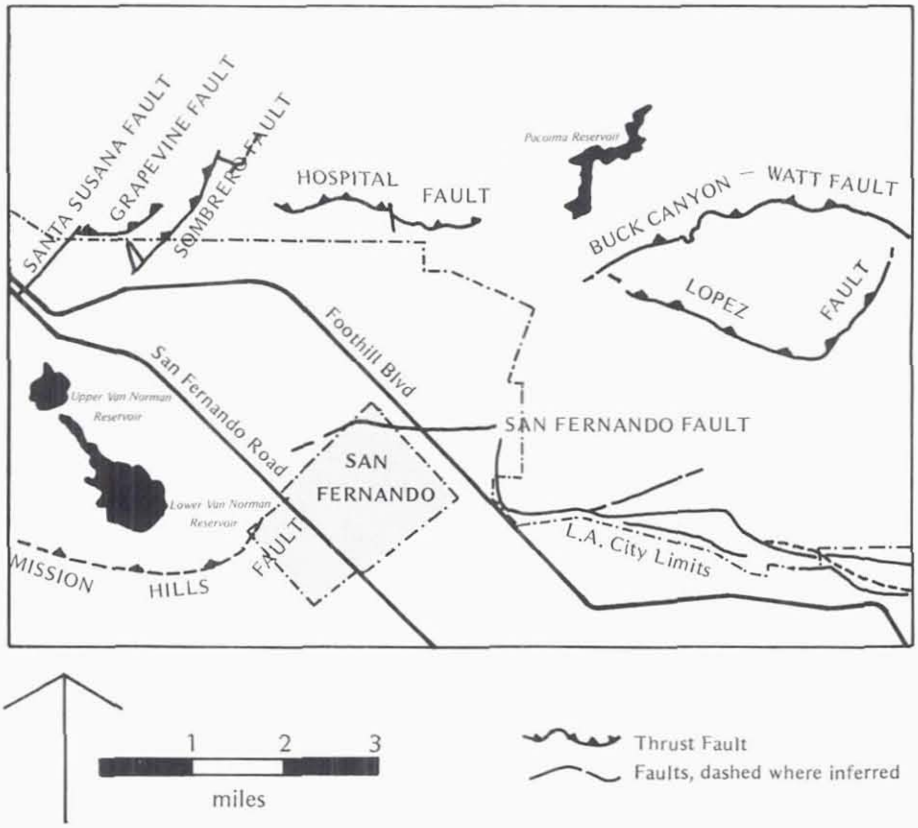

Figure 7. Major faults in the area of the San Fernando Valley

The hills that border the valley are composed of extensively folded and faulted sedimentary rock. Faults present in these hills belong to the Sierra Madre system and include, from west to east, the Santa Susana, Grapevine, Sombrero, Buck Canyon-Watt and Lopez faults (Figure 7). These faults, which are primarily of the thrust type, trend generally northwest to southeast and dip to the north at angles between 30° to 60° to the horizontal. They represent the response of the rocks to the north-south compressional forces in the earth's crust in this part of California.

GEOLOGIC EFFECTS OF THE SAN FERNANDO EARTHQUAKE

The San Fernando earthquake was the first earthquake in recorded history known to have caused tectonic ruptures of the ground surface in the metropolitan Los Angeles area. Permanent surface effects included fault rupture in a zone crossing the urbanized valley floor; uplift, tilting, and southwestward shifting of the San Gabriel Mountains; minor subsidence of the valley floor, and numerous landslides and rockfalls. Transitory effects included the highest ground accelerations ever instrumentally recorded and the temporary liquefaction of some sediments.

Immediately after the earthquake, field investigations by geologists, seismologists, and structural engineers were initiated. Extensive documentation of the earthquake's geologic and seismic effects and damage to man-made structures is available in the published literature (see Selected References). The following summary highlights the effects which can be significant in land use planning and reconstruction. Figure 8 is a map of the surface geologic and seismic effects of the earthquake.

Ground Shaking

The earthquake was felt over approximately 80,000 square miles of California, Nevada, and Arizona. The most severe effects were in the San Fernando Valley. Scott (1973) has tentatively assigned a maximum Modified Mercalli Intensity of XI to the area of the Olive View Hospital, although others consider Intensity X to be the maximum (Figure 9).

Peak ground accelerations of 1.25g were recorded in the vicinity of Pacoima Dam and widespread areas experienced accelerations of .2g. The duration of strong shaking was approximately 12 seconds and the majority of damages occurred within about 15 seconds of the initial shock. The San Fernando earthquake was only moderate in magnitude, but the ground motion was

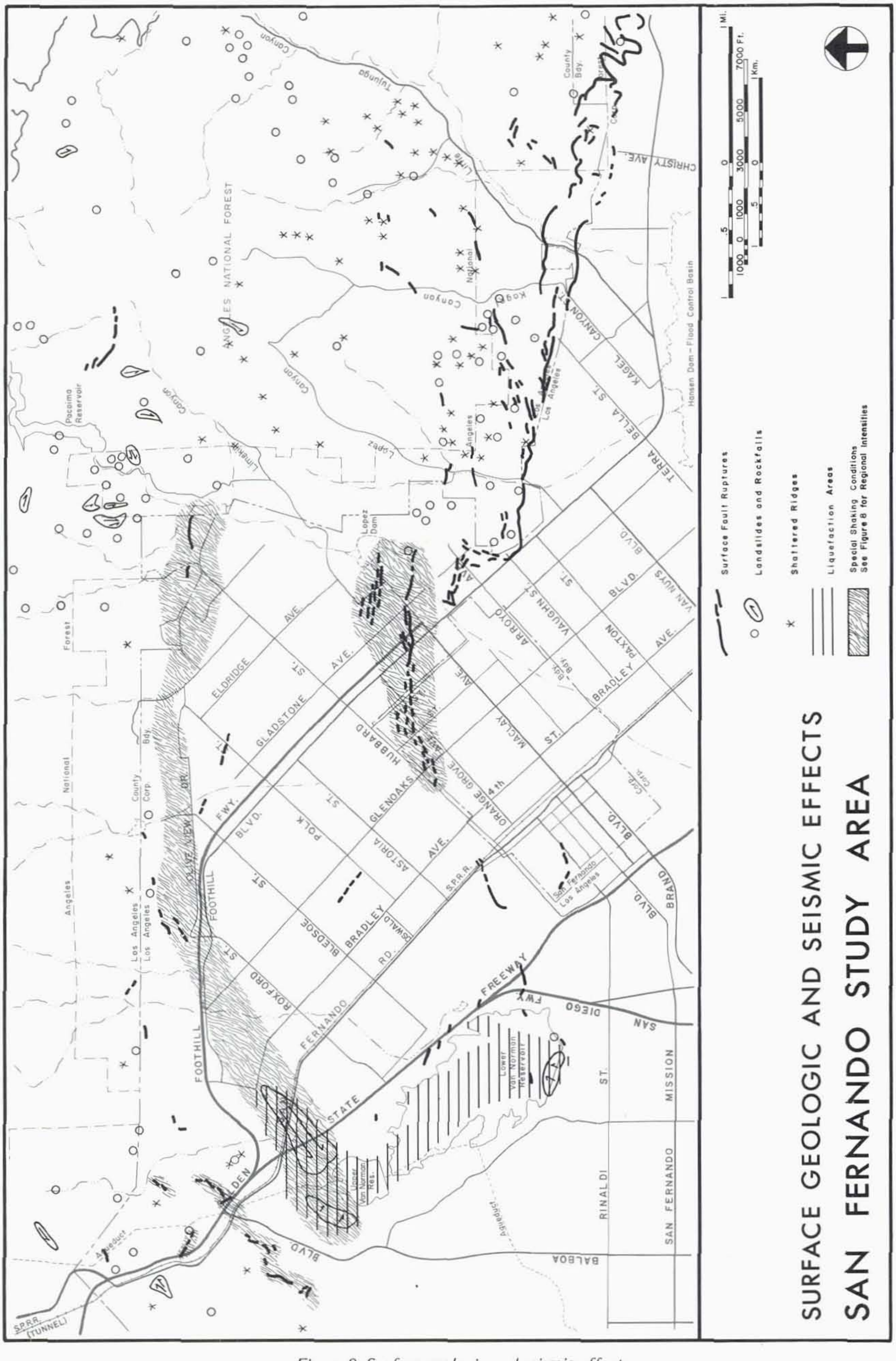

Figure 8. Surface geologic and seismic effects

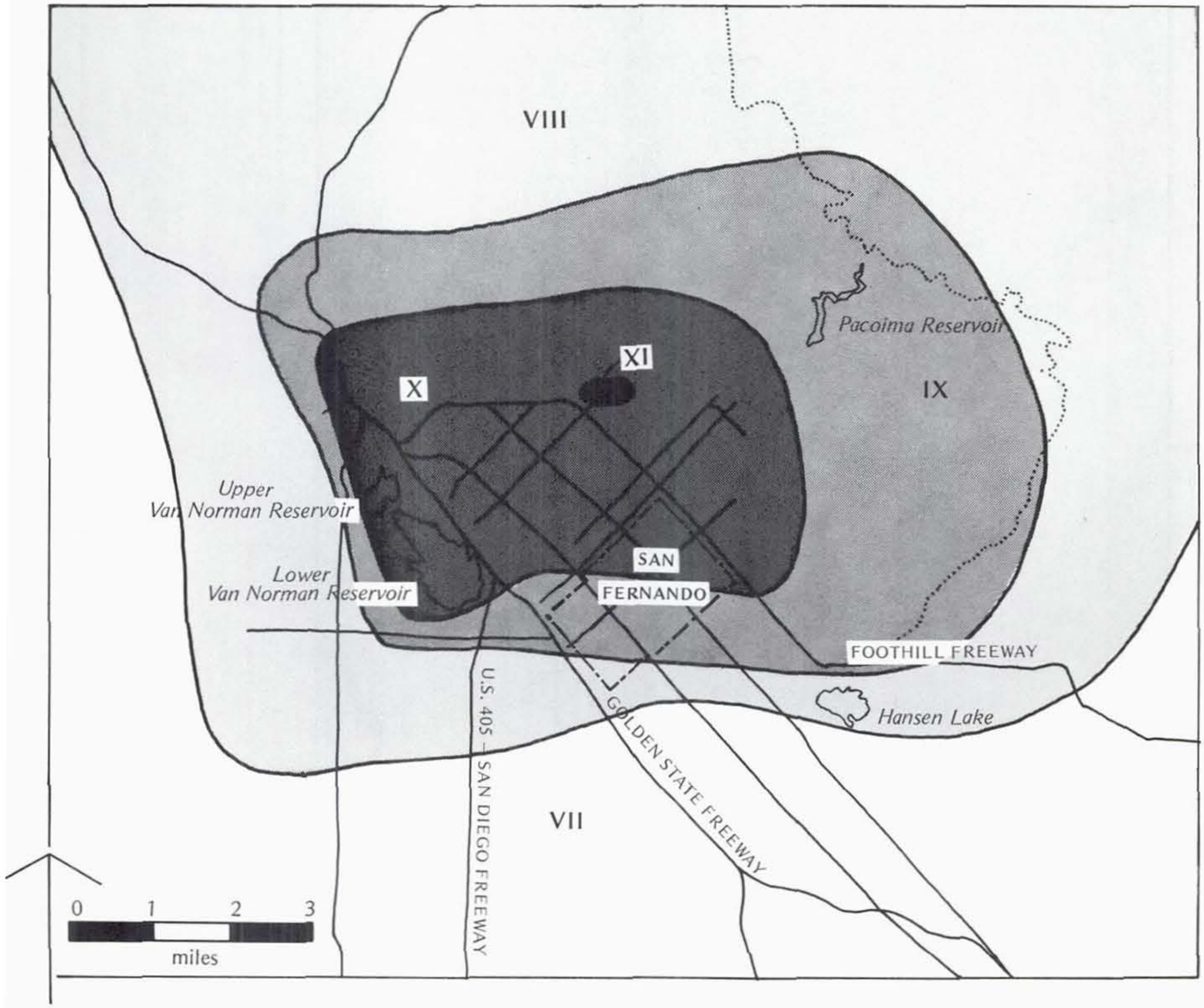

Figure 9. Approximate Modified Mercalli Intensity of San Fernando Earthquake 1971 (Source: Scott, 1973, modified by William Spangle and Associates, Inc.)

probably locally as strong as would be produced by a larger magnitude earthquake. However, in a greater earthquake, damage would occur throughout a larger area, and the longer duration of shaking would damage more buildings.

Some scientists and engineers have noted that a zone of unusually severe shaking was concentrated in a relatively narrow strip of land along the front of the mountains (National Oceanic and Atmospheric Administration, 1973). There is also evidence that seismic shaking was worse near the boundaries of alluvial areas at the margins of the basin. Intensified shaking also seems to have occurred along portions of the Santa Susana fault and along the Sylmar fault segment. These areas of "special shaking conditions" are shown in Figure 8. A number of explanations have been advanced to explain these various locally severe zones of shaking, such as enhancement of seismic waves along subsurface fault planes or refraction and reflection of seismic waves along the mountain front. Although the causes of these local "hot spots" are not entirely clear, it is generally agreed that the damage pattern from the earthquake was somewhat irregular.

Surface Fault Rupture

Almost all of the fault movement experienced in the area is believed to be related to a single master bedrock fracture at depth striking N72°W and dipping about 45°N. Surface fault rupture during the earthquake traversed a

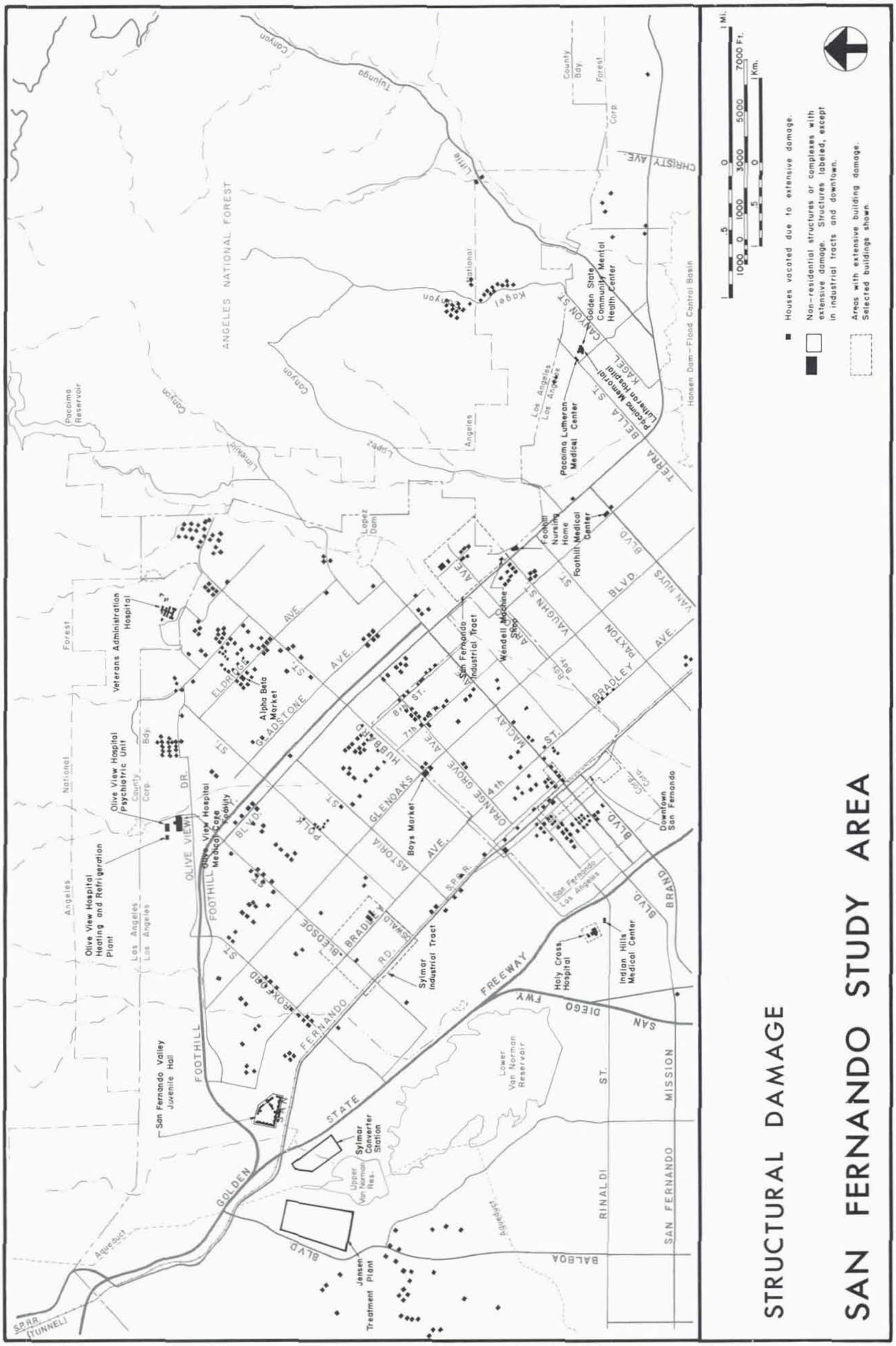

Figure 10. Structural damage

linear distance of over 12 miles. Ruptures are shown in Figure 8. The major surface breaks are expressions of thrust faulting whereby land on the northern side was lifted and thrust obliquely toward the southwest. Surface fault rupture occurred in portions of the Santa Susana and San Fernando fault zones. The Santa Susana fault is thought to be inactive. Nonetheless, during the February 9 earthquake, the fault experienced a small amount of surface rupturing at its eastern end, probably as a result of vibrations actually originating on the San Fernando fault (Oakeshott, 1975).

Surface rupture along the San Fernando fault occurred on a number of fault segments. Along these segments surface rupture was irregular and discontinuous (Figure 8). Although maximum oblique displacement along the San Fernando fault has been calculated to be 7.9 feet, displacements recorded on most fault segments did not exceed 3 feet (Oakeshott, 1975). Surface rupture was mostly confined to a zone ranging from about 10 feet to 1,500 feet wide, although secondary fault rupture occurred as far as three miles away.

Other Ground Failures

Landsliding, liquefaction, ground cracking, ridge shattering, settlement, subsidence, and uplift are various other types of ground failure which occurred during the San Fernando earthquake. Areas of landsliding, liquefaction, and shattered ridges are shown in Figure 8. Landsliding was limited mainly to the hilly and mountainous terrain of the study area. Soil liquefaction (the temporary transformation of wet, sandy soils into a fluid mass) was experienced in the Van Norman Reservoir area. Ground cracking was evident in the vicinity of the fault zones, but was also somewhat randomly distributed within the Upper San Fernando Valley. Shattered ridges generally expressed by a chaotic disruption of the upper few feet of soil, occurred throughout the mountainous portion of the study area along the tops of steep ridges. Compaction of loose soils and poorly consolidated alluvium caused settlement in scattered areas within the valley, often disturbing pipelines and other rigid linear elements. Local and regional subsidence and uplift were also experienced throughout the area. North of the fault, the ground rose as much as 6.5 feet, and parts of the area south of the fault subsided about .3 foot.

DAMAGES AND CAUSES

The San Fernando earthquake lasted less than a minute. Within this brief span of time the San Fernando-Los Angeles area suffered damage exceeding $500 million. A total of 18 schools, 4 hospitals, 465 single-family dwellings, 62 apartment houses, and 372 commercial structures were so severely damaged that they were declared unsafe. Figure 10 shows the pattern of damage to single-family homes and the location of other important damaged facilities in the study area. Highway structures and utility lines were also extensively damaged in several locations.

Numerous studies of the damage were conducted to evaluate the causes of the structural failures. In some cases the failures were found to relate to building design inadequacies; in other cases, they were found to be a result of failures of the ground beneath the buildings. The most common forms of ground failure which caused structural damage were surface fault rupture, landslides, and liquefaction.

As shown in Figure 8, surface fault rupture crossed Foothill Boulevard in an east/west direction at two places. One location was between Orange Grove Avenue and Maclay Avenue and the other at the Foothill Nursing Home northwest of Paxton Street. Almost all buildings overlying the areas of surface rupture were extensively damaged due to permanent vertical and horizontal movements of the ground. Freeway and street pavements were shattered, and gas, sewer, and water pipes were broken and compressed.

The second form of ground failure was landsliding. Landslides caused severe damage to several major transportation routes both through blockage with debris and disruption by slipouts (Figure 11). Many small slides occurred in the hillside areas, but, because these areas were largely undeveloped, little structural damage resulted. However, the areas where the slides did occur may be developed in the future.

The third form of ground failure was liquefaction. Liquefaction caused slide movements at the Jensen Water Treatment Plant, the Juvenile Hall and Sylmar Converter Station. These movements, coupled with severe shaking, caused extensive damage to these facilities.

The relationship of these forms of ground failure and patterns of damage is shown in Figure 10 – a composite of structural damage and Figure 8. As can be seen, much of the damage was not directly related to ground failure. In this earthquake, the major damage was caused by ground shaking and inadequate building design and construction. Categories or classes of structures experiencing damage include older buildings, split-level, wood frame dwellings, industrial buildings with tilt-up construction, critical or high occupancy facilities, dams and utilities.

Figure 11. Landslide near the interchange of the Golden State Freeway and Foothill Freeway (Source: Jennings, P.C., ed., 1971, p. 315)

Old "Hazardous" Buildings

Forty-seven people lost their lives in the collapse of buildings, constructed between 1925 and 1939, at the Veterans Administration Hospital. Isolated instances of damage to old buildings occurred as far away as downtown Los Angeles. However, most construction in the impacted area was post-World War II and fared quite well. In the downtown area of San Fernando, many pre-1940 unreinforced masonry buildings failed (Figures 10 and 12). Walls and parapets, not adequately tied to roofs and floors, fell out and caused the floors and roofs to collapse. Where walls did not fall out, they were cracked and broken.

Table 1 illustrates the vulnerability of this type of structure. Of 180 mercantile buildings examined in downtown San Fernando, the 19 considered severely damaged were constructed before 1940 and 18 of the 19 were constructed of unreinforced brick or hollow concrete block. Only 10 of the 74 pre-1940 unreinforced brick buildings were undamaged. In this case, damage is clearly related to structural deficiencies and ground shaking. No surface fault rupture or other forms of ground failure occurred in downtown San Fernando. Buildings constructed to modern codes in the area survived well.

Figure 12. Damaged masonry building in downtown San Fernando. The brick walls collapsed leaving floors supported on interior wood and plaster partitions.
(Source: Jennings, P.C., ed., 1971, p. 281)

Table 1

Mercantile Building Damage in Downtown San Fernando

Wall construction	Number of buildings					Loss in fair market value[1]
	No damage	Slight damage	Moderate damage	Severe damage	Total examined	
Brick:						
Pre-1940	10	25	25	14	74	$247,000
1940-1949	3	1	0	0	4	1,000
Post-1949	4	0	1	0	5	5,000
Hollow concrete block:						
Pre-1940	9	7	6	4	26	72,000
1940-1949	6	0	0	0	6	0
Post-1949	25	1	0	0	26	1,000
Reinforced concrete:						
Pre-1940	5	1	0	0	6	500
1940-1949	1	1	0	0	2	500
Post-1949	3	0	0	0	3	0
Wood frame and other:						
Pre-1940	13	4	2	1	20	9,000
1940-1949	3	0	0	0	3	0
Post-1949	4	1	0	0	5	500
Total	86	41	34	19	180	$336,500

[1]Where assessor information unavailable, authors estimated.
NOTE. – Roof and floors were wood.

(Source: NOAA, 1973, p. 723)

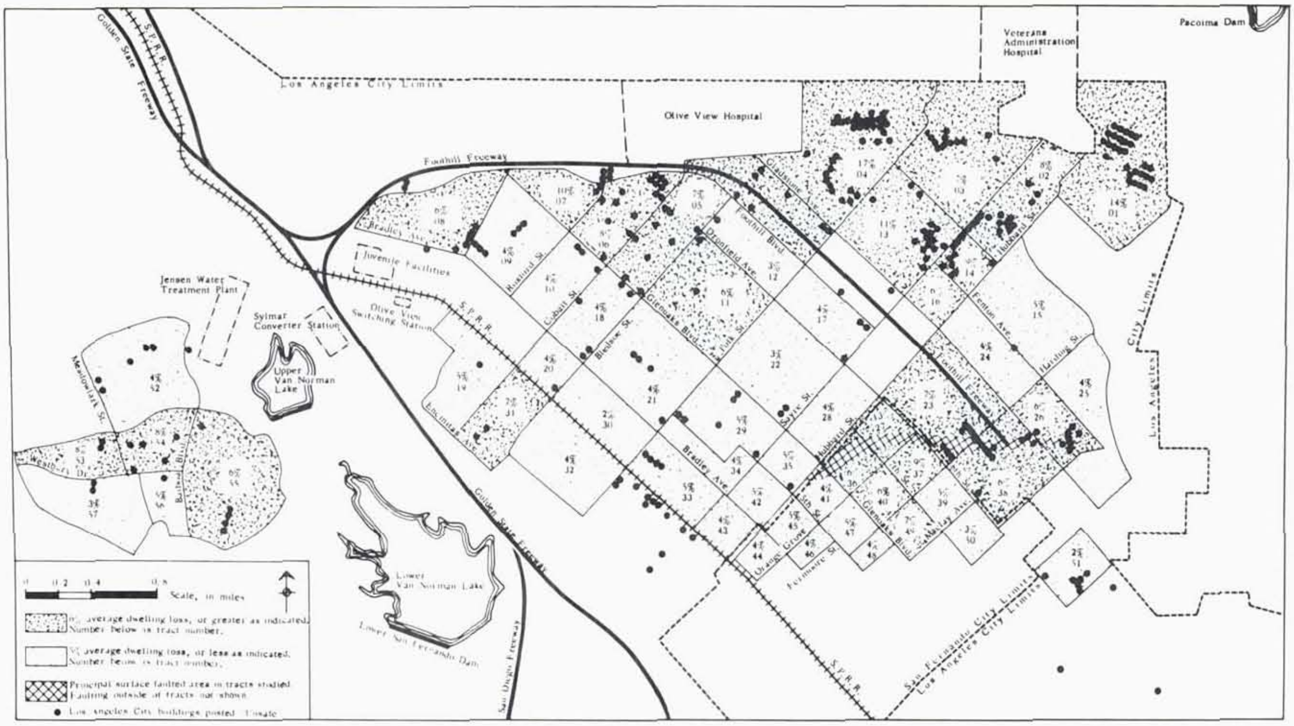

Figure 13. Damage distribution of wood frame dwellings (Source: Steinbrugge and others, 1971, p. 19)

Wood Frame Dwellings

Most of the houses in the study area were less than 20 years old and, therefore, constructed under modern building codes. As shown in Figure 10, dwelling damage was scattered. In the City of San Fernando, much of the damage was to older homes – some of unreinforced brick and stone. Figure 13 shows the distribution of damage to wood frame dwellings as the percent loss of dwelling value in each of 57 tracts. In the tracts affected by surface fault rupture, the highest percentage of damage is 13% with the average much lower than that. However, considering just the areas within the tracts where surface rupture occurred, the percentage is much higher (U.S. Geological Survey and U.S. National Oceanic and Atmospheric Administration, 1971, p. 75).

Dwelling loss of 17% occurred just east of Olive View Hospital in an area of special shaking conditions. However, much of the damage was because of structural deficiencies and pointed up certain inadequacies of building codes pertaining to split-level construction. Split-level houses were poorly tied together; unsuitable materials and systems were used for exterior wall bracing; reinforced chimneys were inadequately tied to the roof system, and attached garages were inadequately braced. As a result they suffered unusually severe damage (Figure 14). The Uniform Building Code has been revised to correct most of these design problems.

Damage to single-family homes was particularly pronounced in Kagel Canyon (see Figure 10). A large number of failures were attributed to the poor quality of filled ground. Almost all of the fill was placed prior to enforcement of modern grading codes which were adopted in Los Angeles in 1963 and soon thereafter in Los Angeles County. Few failures occurred in areas where properly engineered fill was used (Oakeshott, 1975, p. 239). Many of the homes in the canyon were originally summer homes which have been modified for year-around use. Undoubtedly a number of the houses did not meet current building code standards.

Industrial Buildings

There were two industrial tracts in the heavily damaged area: the Sylmar industrial tract near Bradley and Bledsoe Streets and the San Fernando industrial tract near Gladstone and Arroyo Streets. All buildings had been built recently under the regulations of modern codes – some were not yet occupied. Most were one story with tilt-up concrete walls, although some had walls of reinforced grouted brick or reinforced concrete block. All had plywood roof sheathing with either steel beam supports or glued laminated wood beams.

Damage was extensive – so extensive in fact that one engineer termed this the "earthquake of the rear walls" because of the large number that fell out. The principal cause of structural damage was the strong ground shaking. Soil breakage was negligible except in the case of the Wendell Machine Shop at the west end of the Tujunga segment of the fault where vertical displacements occurred. Essentially, all failures were caused by inadequate anchorage of the walls to the roof system, the poor

Figure 15. Collapsed stairwell and elevator shaft, main building, Olive View Hospital
(Source: Steinbrugge and others, 1971, p. 45)

Figure 14. Two severely damaged split-level houses
(Source: Jennings, P.C., ed., 1971, p. 289)

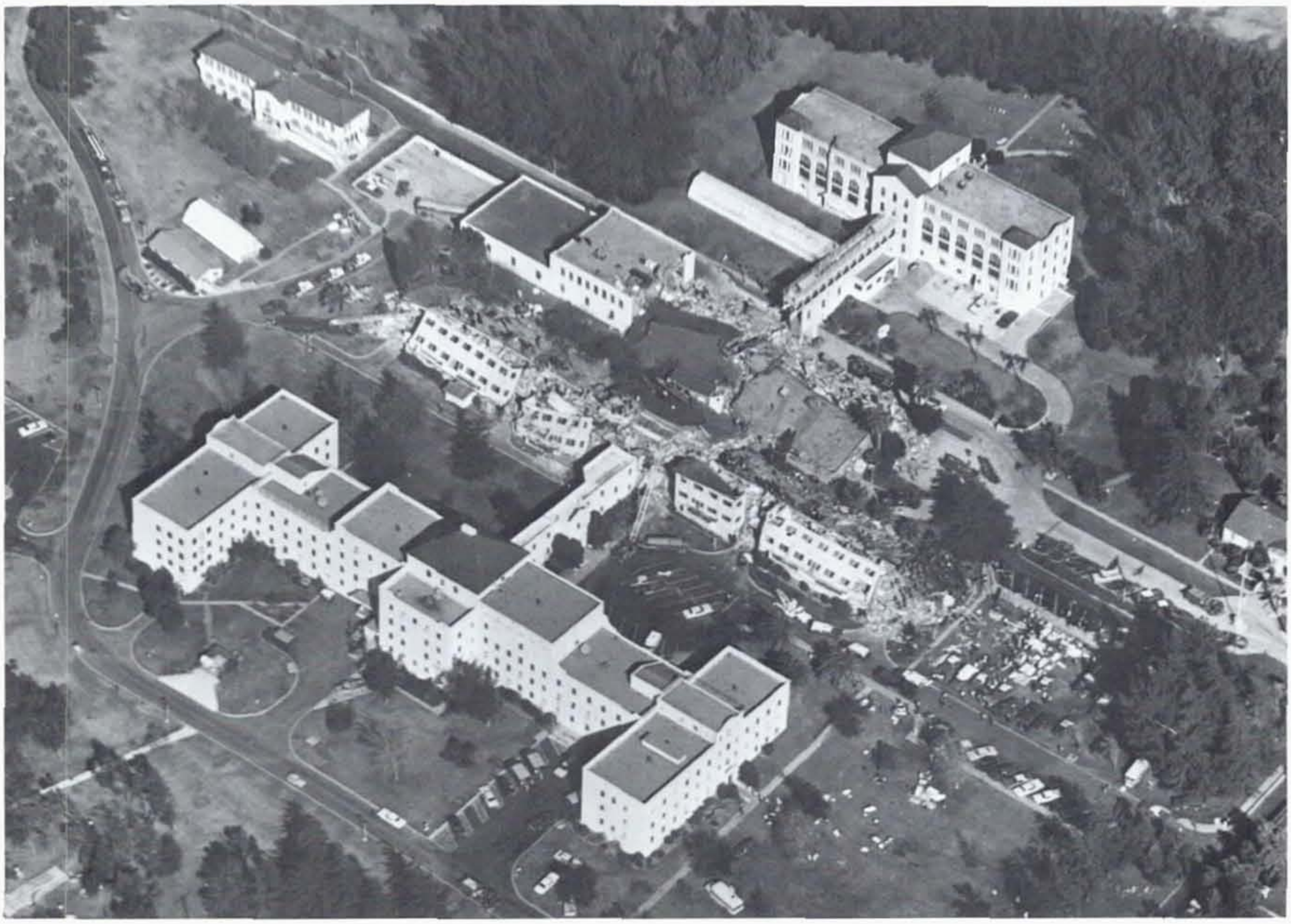

Figure 16. Aerial view of destruction at Veterans Administration Hospital
(Source: Steinbrugge and others, 1971, p. 55) Photo credit: Los Angeles Times

interconnection of the tilt-up wall segments, and the lack of tension capacity in the roof system. Uniform Building Code requirements have been changed since the earthquake in an attempt to improve performance.

Critical or High Occupancy Structures

Buildings at all four major hospital complexes in the area, Olive View, Holy Cross, Pacoima Memorial Lutheran and Veterans Administration, were severely damaged by the ground shaking and had to be evacuated. In no case was surface ground rupture or other ground failure responsible for the damage. Olive View Hospital and the Veterans Administration Hospital were located in the area of special shaking conditions (Figure 10). Several buildings, some recently constructed, were destroyed at Olive View Hospital. Figure 15 shows a collapsed stairwell and elevator shaft of the new main building in the hospital complex. Figure 16 is an aerial view of the devastation, mainly of older buildings, at the Veterans Administration Hospital. This experience indicated problems with design and construction standards for hospitals and led to action by the State Legislature requiring the Department of Health and the Office of the State Architect to adopt and enforce more restrictive regulations pertaining to the earthquake resistant capabilities of hospitals.

The Jensen Water Treatment Plant, Sylmar Converter Station and San Fernando Juvenile Hall were all extensively damaged. As shown in Figure 10, these facilities are all located in an area of liquefaction-induced landsliding and special shaking conditions. Because of excessive costs to relocate these facilities, they were reconstructed at their original locations. However, extraordinary measures were taken to cope with the adverse site conditions and to build earthquake resistant structures.

Dams

Five dams were damaged. Of particular importance was the near collapse of the Lower San Fernando Dam, a relatively old structure built by primitive hydraulic fill methods. During the earthquake, liquefaction of portions of the dam's upstream face occurred and initiated a major landslide which took out the crest of the dam and the upper 30 feet of earth fill (Figure 17). Fortunately, at the time of the earthquake, the water level in the reservoir was 35 feet below the crest. After the earthquake, a scant four feet of freeboard was left, leaving the dam on the brink of total failure and necessitating the evacuation of the 80,000 people who lived downstream.

Immediately upstream of this dam and draining into its reservoir is the Upper Van Norman Reservoir formed behind the Upper San Fernando Dam. This dam is also of older hydraulic fill design and also experienced partial failure. The dam itself moved about five feet downstream and settled about three feet during the earthquake. Had this dam failed completely, the resulting inflow of water to Lower Van Norman Reservoir would have caused overtopping of the severely damaged Lower San Fernando Dam.

Professor H. Bolton Seed of the University of California, who directed a detailed post-earthquake study of the behavior of these dams, reported at the conclusion of his study that . . . "had any one of a number of possible conditions been slightly less favorable, such as the duration of shaking or the water level in the reservoir, the Lower Dam could have failed resulting in the sudden release of 10,000 acre-feet of water over a heavily populated residential area" (Seed, 1973).

Other dams which were damaged include Pacoima Dam, Lopez Dam and Hansen Dam. The concrete, gravity-arch Pacoima Dam suffered about $1.5 million damage at its abutments but remained operational after the earthquake. Minor damage occurred at the rolled-fill Lopez and Hansen dams. Numerous other dams of all types located nearby remained operational during the San Fernando earthquake. With the exception of those dams mentioned above, dams within a 40-mile radius of the epicentral area performed well.

Utilities

The San Fernando earthquake caused extensive damage to utilities. Throughout the area affected by the earthquake, there were 363 breaks in water mains, 1155 breaks in sewer lines and 189 breaks in gas mains as well as numerous breaks in service lines (Steinbrugge and others, 1971). Damage was especially severe in the City of San Fernando and in Kagel Canyon. Underground utility systems suffered most, especially where the ground shifted or the soil was poor. Breaks often occurred at the joints, particularly those with rigid connections. It was found that where service connections had some slack, fewer breaks resulted.

PREDICTED EFFECTS OF FUTURE EARTHQUAKES

The San Fernando earthquake was not a unique or unusual event from a seismological standpoint. Earthquakes of this magnitude (or larger) are part of the natural environment of this area. Although precise earthquake prediction is not possible at this time, it is generally accepted that the San Fernando area, along with other major urban areas of California, will experience moderate to great earthquakes in the coming decades. The damage within the study area resulting from future earthquakes could vary considerably, depending on the size of the earthquake and the location of its epicenter with respect to the study area. The damage associated with the San Fernando earthquake as well as other earthquakes shows that future damage will be a consequence of one or more of the following phenomena: ground shaking, surface fault rupture, or other form of ground failure.

Two planning documents which attempted to deal with these hazards were available within a year or two after the earthquake – the San Fernando Seismic Safety Element and the Los Angeles County Seismic Safety Element. In the San Fernando Seismic Safety Element, an area 1000 feet either side of the fault ruptures was identified as a zone of potential ground breakage. In addition, three different zones of potential ground shaking response were defined on the basis of subsurface soil profiles and computer analysis of potential source earthquakes on and off site. The Los Angeles County Seismic Safety Element identified an area 1000 feet either side of

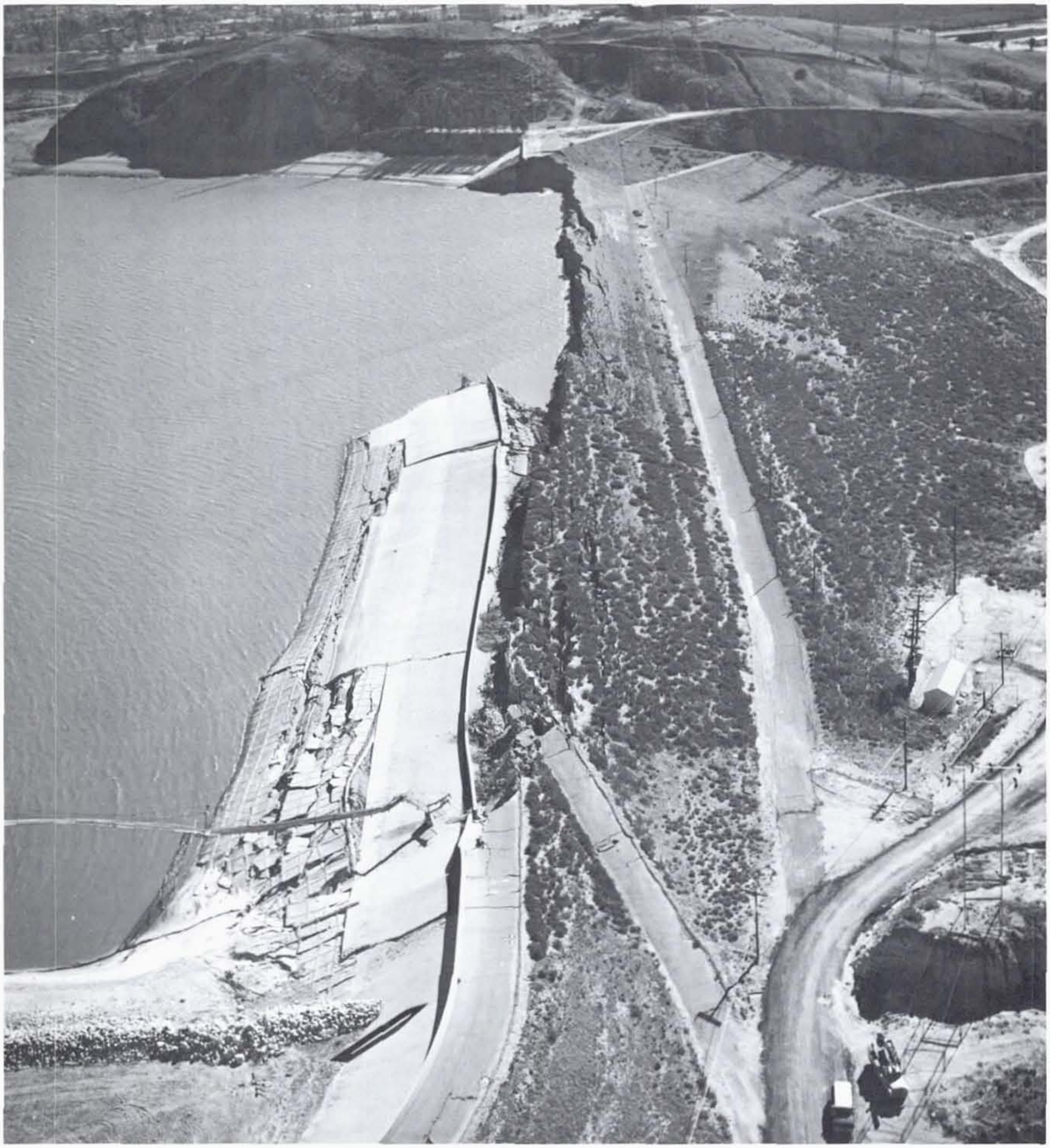

Figure 17. Slide damage to Lower San Fernando Dam
(Source: U.S. Geological Survey, photo library, Menlo Park, CA) Photo credit: California Department of Water Resources

any fault as a zone of potential ground breakage. Areas of potential liquefaction, as well as existing landslides, were defined. However, areas of potential landsliding were not delineated. Four potential ground shaking zones were identified on the basis of subsurface soil profiles and computer analysis of potential source earthquakes in and outside of the County boundaries. Through analysis of the observed earthquake effects and evaluation of these documents the effects of future earthquakes in the study area have been predicted as shown in Figure 18.

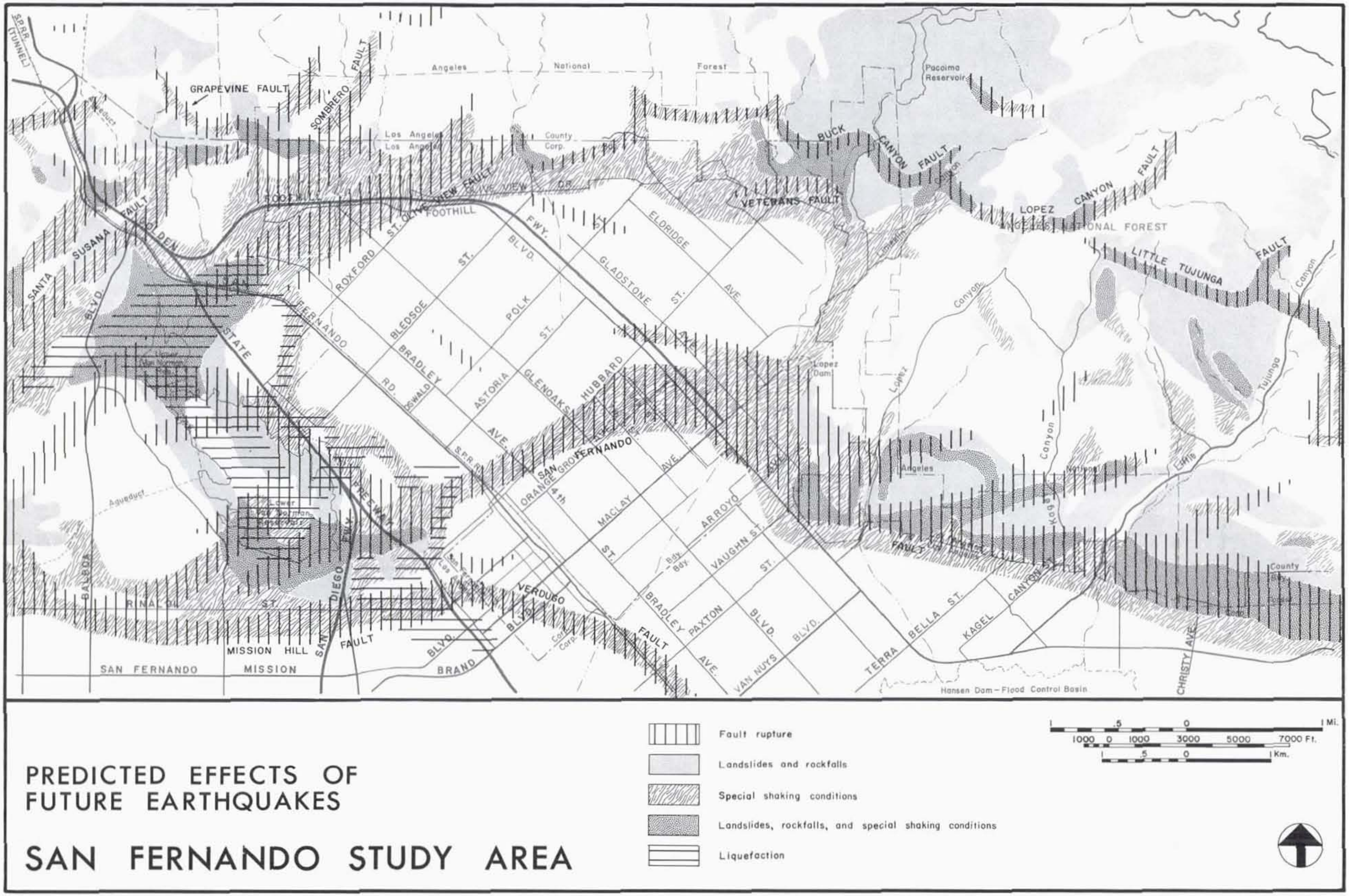

Figure 18. Predicted effects of future earthquakes

Surface Fault Rupture

Disturbance of the ground due to surface fault rupture is likely to occur in the study area during future earthquakes of significant magnitude and originating on faults in the area. In general, ground movements can be in vertical or horizontal directions and are usually evident at the surface within zones centering on the fault itself. These zones may be tens to occasionally hundreds of feet wide. Within the study area the only fault which is known to have ruptured during recorded history is the San Fernando fault. The San Fernando fault zone, as shown in Figure 18, varies in width from 50 to 5,000 feet and may be capable of generating movements up to 16 feet or so, although movements on the order of 0.5 to 5 feet are more likely (Yerkes and others, 1974). Other related active faults within the study area, as discussed under local geologic setting, may also be capable of similar movements.

Dr. Clarence Allen has suggested a recurrence interval of approximately 200 years for a Richter magnitude 7.5 earthquake on the Sierra Madre fault system, which stretches from Ventura to San Bernardino (Lamar and others, 1973). Earthquakes of lesser magnitude have and could occur more frequently. Trenches excavated across the San Fernando fault have revealed evidence of earlier movements along this fault. One scarp, in particular, was radiometrically determined to be approximately 200 years old. Evaluation of the tectonic environment combined with geotechnical analysis of the history of the fault movement suggests that a 200 to 300 year recurrence interval for a San Fernando-type earthquake is reasonable for this area.

Studies of repeated fault offsets indicate that active faults tend to break the ground surface along or near to areas of ground which have broken previously. Therefore, specific areas of the ground which actually broke in 1971 are likely to break again in the future, as are areas along other faults with a history of recent activity. The likelihood of surface rupture decreases proportionally with distance from the broken ground perpendicular to the strike of the fault. The California State Mining and Geology Board considers the area within 50 feet of an active fault trace to be subject to fault rupture unless substantial evidence indicates otherwise (Hart, 1976). Because thrust faults are known to rupture across broader zones than strike slip faults, Figure 18 shows a wider 100 to 500 foot zone. However, the probability of rupture in the areas 50 to 500 feet from the fault is less than it is within 50 feet of a past surface rupture.

Ground Shaking

Ground shaking causes the most widespread damage in most earthquakes. Many active faults in the area are capable of generating earthquakes and ground shaking as is discussed in the regional geology section of this report. The intensity and character of the ground motion depends on the location and characteristics of the source earthquake and on the local subsurface conditions. All of the study area is subject to future ground shaking. However, Figure 18 shows only those areas possibly subject to local special shaking conditions. These areas include the alluvial/bedrock contact, the ridge tops, and the fault planes. The recurrence interval for moderate to strong ground shaking (Intensity VI or greater) within the study area is on the order of once every decade.

Ground Failures

Ground failures including slope failures, liquefaction-induced failures, and other failures associated with strong ground shaking (lurching, shattered ridge tops, etc.) are also to be expected. Areas subject to slope failure are confined to the hillsides and are generally concentrated within those slopes composed of weakly cemented bedrock, with adversely dipping structure, and along steep sided canyons. Liquefaction-induced failure requires a certain set of specific natural conditions for its occurrence, including the presence, at a reasonably shallow depth, of saturated sandy soils. The only place within the study area that is known to have these conditions is the Van Norman Reservoirs area. Areas subject to failures such as lurching and shattered ridge tops tend to be confined to areas close to the fault zones and along the tops of steep sided ridges. Recurrence of these types of ground failures would most likely be related to movements along the Sierra Madre or other nearby fault systems and might occur on the order of once a century, mainly in areas where they have been previously observed.

Dam Failure

Another potential seismic hazard of significance is that of dam failure. California law now requires dam owners to map the area subject to flooding in the event of total dam failure with the reservoir filled to capacity. These maps are recommended for use in evacuation planning only and do not imply that the dams are unsafe. The possible inundation area for Pacoima Dam is shown, in part, in Figure 19. A new dam, the Los Angeles Dam, has replaced the damaged Lower San Fernando Dam. Because the previous Lower Van Norman Reservoir can contain all the water presently stored behind the Los Angeles Dam in the event it should fail, the California State Office of Emergency Services did not require that an inundation map be prepared for the new dam.

Multiple Hazards

Certain portions of the study area are susceptible to more than one of the hazards discussed above as shown by overlapping patterns in Figure 18. Some portions of the study area are susceptible to as many as four different earthquake hazards (for example, surface fault rupture, special ground shaking, liquefaction-induced failure, and landsliding near the San Fernando Valley Juvenile Hall area). The location of man-made structures in areas of multiple hazard should be carefully evaluated. While, in many cases, risk can be reduced to acceptable levels through design and structural measures; in other cases, this is not feasible. In these cases, avoidance or control of development in high hazard areas is the only viable solution.

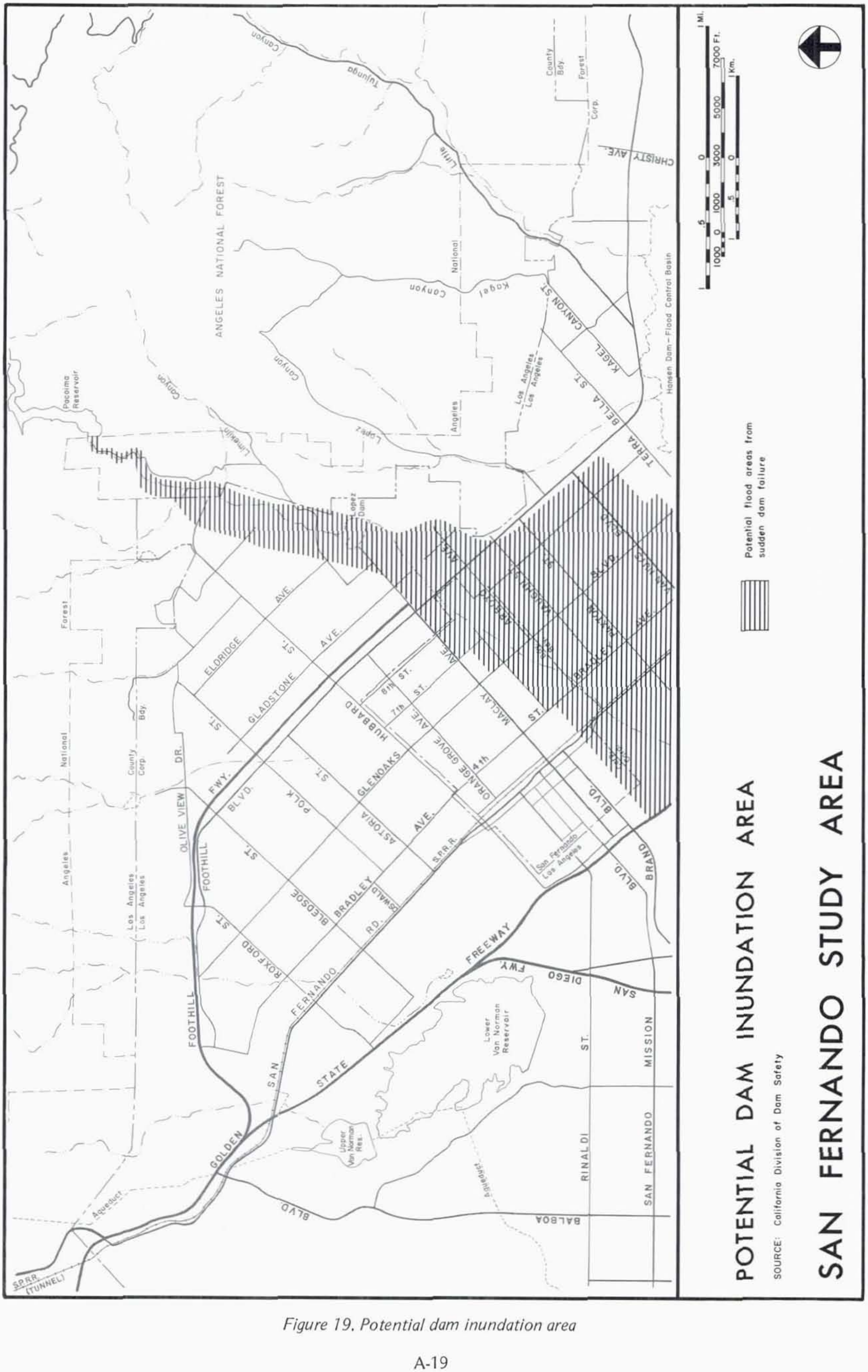

Figure 19. Potential dam inundation area

Response of Local Governments to the San Fernando Earthquake

The San Fernando Valley can expect to experience moderate to strong ground motion every ten years or so from earthquakes originating on one of the many Southern California faults. Potential damage can be largely averted by proper building design and construction, and by land use planning sensitive to seismic hazards. In the flurry of reconstruction activity following an earthquake, decisions are made which significantly affect future seismic safety. This study of post-earthquake land use planning stems from the premise that unique opportunities exist following an earthquake to make land use changes which will increase seismic safety and improve the urban environment.

In examining the San Fernando experience, the study team tried to identify opportunities for land use change whether or not they were recognized locally. The basic tool used in the initial identification of opportunities was the composite map of geologic effects and structural damage (Figure 10). Those areas where structural damage appeared to be related to ground failure were noted. Safe construction in such areas, if possible, is more difficult and expensive than in areas subject only to ground shaking. Changes in land use might be warranted. Areas were also noted where concentrated damage occurred because of ground shaking. Depending on the reasons for the damage and the importance of the uses to the overall land use pattern, these areas might be appropriate for redevelopment or special treatment during reconstruction. Most of this type of damage, however, can be averted by better building design and construction.

A particular problem of interpretation is presented by the areas of "special shaking conditions." A large amount of the damage occurred in these areas. Yet, for the most part, reasonable safety can be achieved through careful design and construction. Land use changes might be called for to avoid construction of critical or high occupancy facilities in these areas.

Carrying the process a step further, specific "issues" were listed which the study team felt might have been handled with a land use change. For each issue, possible options for response were hypothesized. The list of issues and options provided the framework for interviews with public officials in the City of San Fernando, City of Los Angeles and Los Angeles County. For each issue, the action taken during reconstruction and the apparent reasons for the action were determined. The purpose of this review was not to criticize the actions of the public agencies, but to identify those factors that most strongly affected decisions during the reconstruction period.

In the following sections, the responses of the three local jurisdictions, with emphasis on the City of San Fernando, to specific reconstruction issues are described. Decisions to reconstruct or relocate damaged facilities are explored as well as changes in land use plans primarily affecting future development. It was found that, although many key and determining decisions were made in the months immediately after the earthquake, other issues are still not finally resolved. Opportunities still exist, seven years after the earthquake, to reduce risk from future earthquakes.

RESPONSE OF THE CITY OF SAN FERNANDO

The City of San Fernando is a 2.4 square mile enclave surrounded by the City of Los Angeles. It is the oldest community in the San Fernando Valley and, prior to the earthquake, contained many buildings constructed before seismic design requirements were included in building codes. The city of about 16,500, a majority of whom have Spanish surnames, has one of the lowest average household incomes in the valley.

Losses

In the February 9, 1971 earthquake, about $70,000,000 (1971 dollars) in property damage occurred within the City of San Fernando. Of this, damage to privately-owned buildings exclusive of land and contents amounted to about $35,500,000, and losses to local government exceeded $34,000,000 (Steinbrugge, 1973, p. 695). Over 1,500 buildings were damaged; 437 posted unsafe; and 214 demolished including 165 homes, 26 apartment units, 20 commercial buildings and 3 industrial buildings (City of San Fernando, Department of Building and Planning). Local financial resources to recover from such a staggering loss were limited. Thanks to a massive infusion of federal funds, the city has recovered and now looks upon the earthquake as providing the impetus for a number of important community improvements.

Following the earthquake, property values dropped sharply. The County Assessor reduced total assessments in the city from $30 million to just over $20 million as shown in Table 2. The loss was recouped within two years and by 1974 assessed value had reached $35,745,616. During the period of lower than normal assessed value, the federal government reimbursed the city for this loss in property tax revenue.

Assistance

The City of San Fernando received extensive assistance from many federal agencies in recovering from the earthquake. Assistance from agencies most strongly affecting reconstruction planning is described below.

Table 2

Losses to Assessed Value of Taxable Property[1]
City of San Fernando

	Pre-Earthquake Assessed Value	*Loss in Assessed Value*	*% Loss*
Land	$14,223,594	$6,925,983	49.5
Improvements	14,970,538	2,635,904	17.6
Fixtures	131,700	1,825	1.38
Personal Property	197,178	2,790	1.51
Business Inventory	571,580	1,605	.28
	$30,094,590	$9,568,107	32%

Source: Steinbrugge, 1973, p. 719

[1] Assessed value equals one-fourth of fair market value.

U.S. Army Corps of Engineers

The Corps of Engineers was called upon by the U.S. Office of Emergency Preparedness to undertake demolition and debris removal, restore water and sewer service, and repair streets, sidewalks, curbs and street lighting. The Corps contracted with Morrison-Knudsen and work was underway by Saturday, February 13. Building demolition and debris removal was accomplished by mid-June. Water service was restored on a temporary basis by February 21 and the distribution system permanently reconstructed by June 1971. Additional work on the wells and reservoirs was completed soon after June.

The sewer system was operable by March 12 and reconstruction was completed about one year after the earthquake. Street repairs followed. By June 1971, the Corps had let 36 contracts for repair work throughout the valley valued at $4,320,349. Total Corps expenditures in earthquake related work exceeded $25 million (FDAA, 1978). Much of this work was done within the City of San Fernando.

U.S. Department of Housing and Urban Development (HUD)

Section 253 of the 1970 Disaster Relief Act allowed HUD to waive administrative requirements in order to give immediate consideration to applications from disaster affected communities for assistance under HUD's regular programs. Under this authority, HUD provided the following assistance to San Fernando:

1. Open Space Land Grant of $77,688 to add 2.87 acres to Las Palmas Park
2. Open Space Land Grant of $263,989 for the 5-acre Glenoaks Park
3. Historic Preservation Grant of $40,000 for a museum at La Casa de Geronimo Lopez
4. Comprehensive Planning Grant (701) of $41,137 for general plan revision

(U.S. Senate Hearings, 1971, p. 533)

In addition, HUD worked with the city in writing a Workable Program which was certified by HUD within three weeks of the earthquake. The program provided the basis for a city application for urban renewal assistance consisting of rehabilitation loans of up to $15,000 for owner occupants of damaged houses. The application was turned down by HUD, along with a similar one from the City of Los Angeles, as an inappropriate use of urban renewal funds, particularly in view of the availability of SBA loans for repair of damaged homes.

HUD also administered the temporary housing program and mortgage or rental payment assistance program. As of June 5, 1971, HUD had provided temporary housing for 248 San Fernando households and mortgage or rental payment assistance to 9 households (U.S. Senate Hearings, 1971, p. 549). Throughout the earthquake affected area, 1,288 households received temporary housing assistance totaling $2,405,318 or almost $2,000 per family (FDAA, 1978). Assuming this average, assistance to the 248 San Fernando households cost about $496,000.

Small Business Administration (SBA)

Most direct aid to businesses and home owners in San Fernando was provided in the form of loans and grants from the SBA. Nearly every household and business experiencing damage received SBA assistance and this was a critical factor in the reconstruction of private property. SBA made low interest loans (about 5% with $2,500 of the first $3,000 forgiven) to businesses and households throughout the damaged area totaling $258.6 million (FDAA, 1978). As of June 1971, about 95% of the number of loans were to homeowners for an average amount of $3,860 (U.S. Senate Hearings, 1971, p. 791). Because of the $2,500 forgiveness, most SBA assistance was in the form of outright grants.

Office of Emergency Preparedness (OEP) and State Office of Emergency Services (OES)

San Fernando formally requested federal assistance on February 11. As required under procedures of the Disaster Relief Act of 1970, the request was sent to the California OES which approved it and sent it to the OEP – on February 11. An additional request for assistance in restoring public buildings was made on March 3. OEP coordinated the assistance efforts of the Corps of Engineers and other public and private agencies. Direct assistance to San Fernando including compensation for lost property tax revenues totaled about one-half million dollars (FDAA, 1978).

State Department of Housing & Community Development (HCD) and State Office of Architecture and Construction

Before the earthquake, San Fernando's Department of Building and Planning was staffed by a director, two inspectors and one secretary. Overwhelmed by the task of assessing damage, posting unsafe buildings and handling building permits for reconstruction, the Department requested state assistance. Eight inspectors were sent by HCD and two structural engineers by the Office of Architecture and Construction. Within four to five days, this team inspected 5,000 buildings. The structural engineers assisted with checking plans for repair and new construction. This assistance lasted for about six months after the earthquake by which time the city staff was able to handle the work load.

Summary

Federal assistance following the San Fernando earthquake, including loans and unemployment benefits exceeded 1/2 billion dollars. The City of San Fernando and its residents received over $55 million in federal aid as shown in Table 3. This figure does not include disaster unemployment benefits, rental and mortgage payments assistance, funds to repair damaged schools, or aid from the State of California. Total outside assistance to earthquake victims and the City of San Fernando was probably in the range of $55 to $60 million. In 1970, 16,571 people lived in San Fernando in 5,428 households (U.S. Census). Thus, disaster assistance amounted to between $3,300 and $3,600 per person or over $10,000 per household.

Table 3

Estimated Federal Assistance to City of San Fernando

Army Corps of Engineers	$18,750,000(1)
HUD – projects	423,000
HUD – temporary housing	496,000
SBA	35,400,000(2)
OEP	500,000
	$55,569,000

(1) Assumes that 75% of Army Corps of Engineers' $25,000,000 in assistance to the entire damaged area went to the City of San Fernando.

(2) Losses to private property excluding land and building contents throughout the valley were estimated by Steinbrugge to be $259,300,000. Losses to private property in the City of San Fernando were $35,500,000 or 13.7% of total private losses (NOAA, p. 694). Assuming that SBA assistance was proportional to losses, homeowners and businesses in San Fernando would have received 13.7% of the $258,600,000 in SBA loans or $35,400,000. Because $2,500 of the first $3,000 of SBA loans did not have to be repaid, much of this total represents outright grants.

San Fernando General Plan

At the urging of federal and state disaster relief officials, San Fernando applied for and received a $41,137 HUD grant for a complete revision of its general plan. A major reason for the revision was to satisfy concerns of private lending institutions and federal agencies about funding reconstruction, particularly in the areas of obvious fault rupture. The consulting firm Newville-Meyer & Associates was engaged to prepare the plan and, in turn, contracted with Woodward-McNeill & Associates to prepare the background report for the seismic safety element. The *Report of Seismic Hazard for the City of San Fernando, Los Angeles County, California (1972)* includes a seismic hazard map showing potential ground breakage zones and three potential ground-shaking zones based on soil profiles. Response spectra are shown for each of the three ground-shaking zones. The map identified no areas of potential ground failure other than from fault-related ground breakage.

The background report sets the stage for a limited land use response to seismic hazards with the following caveat concerning the use of the Seismic Hazard Map:

> It is not the intention to eliminate certain types of structures from various areas through zoning, but instead to set the requirements for the level of earthquake consideration required prior to design and construction.
>
> (Woodward-McNeill & Associates, 1972, p. 2)

Based on the background report, the seismic safety element, adopted with the rest of the revised general plan in February 1973, describes a limited city role in seismic safety planning with the following introductory comments:

> It is important to understand, however, that to date, no *standards of safety have been agreed to* by engineers, scientists, legislators, or code officials. Furthermore, it must be understood that earthquake related land use and design standards will ultimately have to be established on a statewide basis: quakes and geology do not follow municipal boundaries. We, therefore, feel that all municipal codes should and eventually will follow a statewide-accepted standard of risk.
>
> We are, however, of the opinion that areas of high risk within a region should be known to buyers and developers of land. Our recommendations, therefore, are moderate but realistic and should be updated as scientific knowledge increases and regional standards of safety are accepted. (p. 1)

The element recommends use of the Seismic Hazard Map as a basis for requiring site investigations and structural design to reduce earthquake damage. Land use regulation is downplayed as a way to reduce seismic risk.

> The Seismic Hazard Map will aid the building official in determining the levels of earthquake consideration required for various types of structures according to their proposed use, geometry, and location within the City of San Fernando. It is not the intention of this element to eliminate certain types of structures from various areas through *zoning, but instead to set the requirements for the* level of earthquake consideration required prior to design and construction. (p. 2)

Site investigation requirements are modest and only mandatory with respect to high-rise buildings and critical facilities as shown in Table 4.

The following are the recommendations of the seismic safety element:

1. The City of San Fernando shall incorporate into its Building Code and Zoning Ordinance, the Seismic Hazard Zones map presented in this Element. Specifically, the potential ground breakage zones should be graphically indicated on the Zoning Map.
2. It is suggested that the Director of Building and Planning refer persons requesting building permits to the amended Zoning Map. In this way potential buyers or builders will be made aware of possible seismic hazards.
3. The Director of Building and Planning shall require special seismic hazard investigations for all critical site/structure combinations (as indicated in Table 4). For city-owned structures, the City should contract with qualified structural engineers, soil engineers and geologists to perform such work on new critical-use, City-owned facilities. For privately-owned critical facilities, we recommend that the Building Department require that a

TABLE 4

Seismic Hazard Site Investigation Requirements

Structure Type/Use	Potential Ground Shaking Zone[(a)]	Potential Ground Breakage Zone
1 1, 2 and 3 story single-family, light industrial and commercial	seismic hazard investigation not necessary	indicates risk due to potential ground breakage[(b)]
2 medium-rise (4-6 stories) and/or high density occupancy and/or unusual structural geometry[1]	special seismic hazard investigation recommended[3]	special seismic hazard investigation recommended
3 high-rise (7 stories and above) and/or critical use facilities[2]	special seismic hazard investigation mandatory	not advisable to site critical structures in this area unless a very extensive seismic hazard investigation provides information to the contrary

1 i.e. theatre, supermarket, church, industrial assembly plants, etc.
2 i.e. hospitals, schools, police station, fire station, etc.
3 Federal Government will require special seismic hazard investigation for all federally financed projects that fall within this category.

Notes by William Spangle and Associates, Inc.

(a) includes entire city.
(b) intended to alert property owners and developers to possible hazard.

Source: San Fernando General Plan, 1973, p. 10

seismic hazard investigation be submitted as part of the plan check procedure.

4. The City shall adopt a critical-use facilities list. A recently proposed change to the L.A. Building Code is the basis for the following list:
   - Hospitals, and other medical facilities having surgery or emergency treatment areas
   - Fire and police stations
   - Public utility service centers
   - Designated civilian emergency centers
   - Communication centers
   - Schools accommodating any grade through the 12th grade

   (The City of San Fernando should amend this listing to reflect local priorities.)
5. The City shall adopt the latest editions of the Uniform Building Code as they become available.
6. The City shall adopt a program requiring all critical structures, over a pre-determined period of years, to be brought up to Code or be demolished.

By the time the revised general plan was adopted in 1973, two years after the earthquake, the major reconstruction decisions had already been made and rebuilding was nearly complete. No changes in the land use plan were made based on considerations of seismic risk. The seismic hazard background report was available a year after the earthquake and served to allay fears of rebuilding in the area where fault rupture occurred. The previous designation of single-family residential use in most of the fault rupture area was continued. The city staff feels single-family use of this area is appropriate and that any move toward higher intensity use would be unwise. However, commercial designation of the heavily damaged area near Hubbard Street and Glenoaks Boulevard was maintained in the Plan (Figure 20).

Implementation of the modest recommendations of the seismic safety element has been spotty. The potential ground breakage zones shown on the Seismic Hazard Map are graphically shown on the existing city zoning map to alert potential buyers and builders to possible hazards. The city has not yet adopted a critical-use facilities list or a program to bring up to code or demolish all old or unsafe critical structures. The 1970 Uniform Building Code was adopted in April 1971 and subsequently the 1973 Code was adopted. The city is presently (1978) considering adoption of the 1976 Code.

Requirements for special seismic hazard investigations in the San Fernando fault zone were superseded by the more stringent State Alquist-Priolo Act requirements in 1976 when the area was designated as a Special Studies Zone (Figure 21). Within this zone, geologic investigations are required for all proposed projects involving structures for human occupancy except for single-lot, single-family, one or two story, wood-frame houses and single-family wood-frame residences in pro-

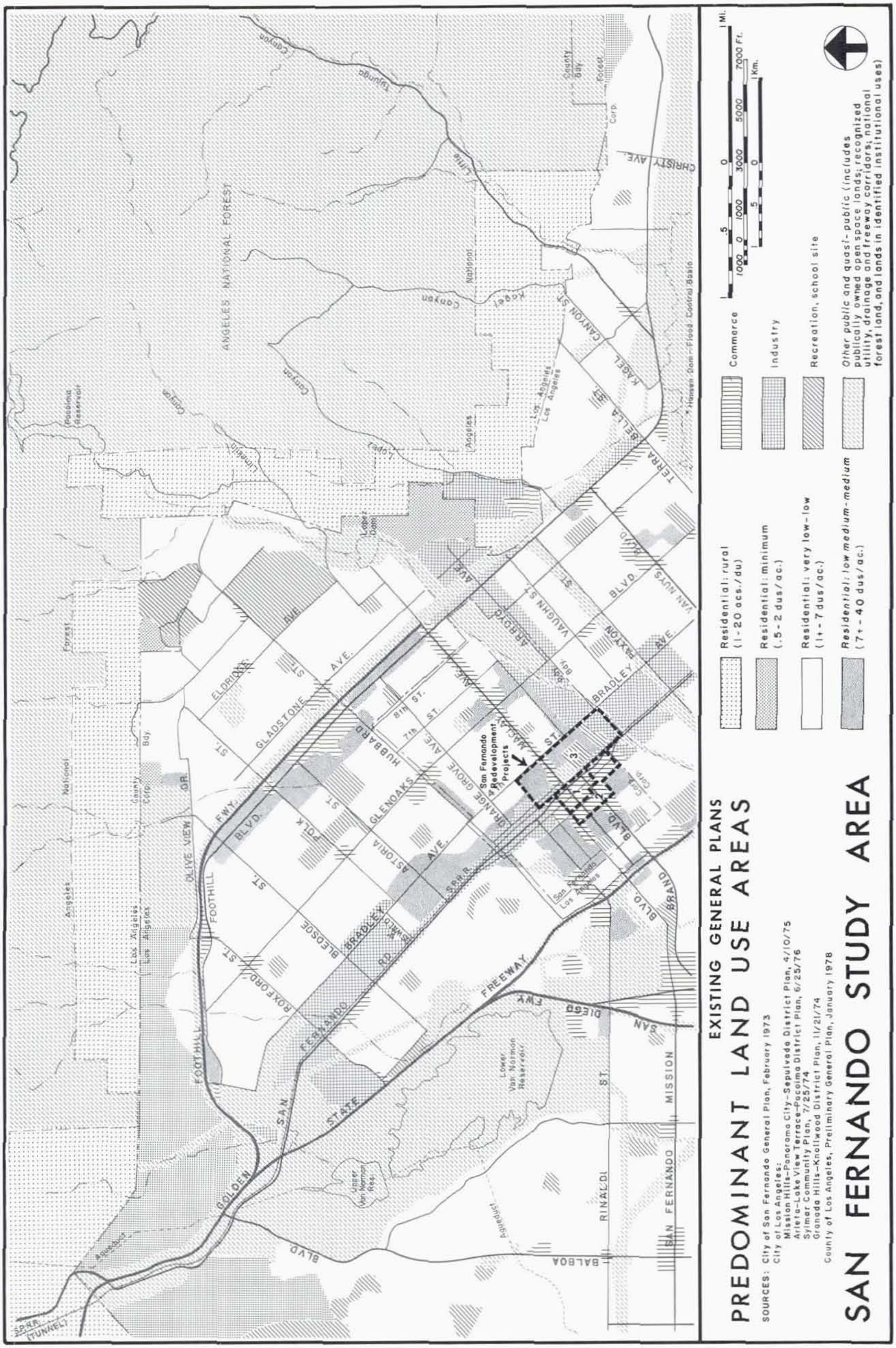

Figure 20. Predominant land use areas

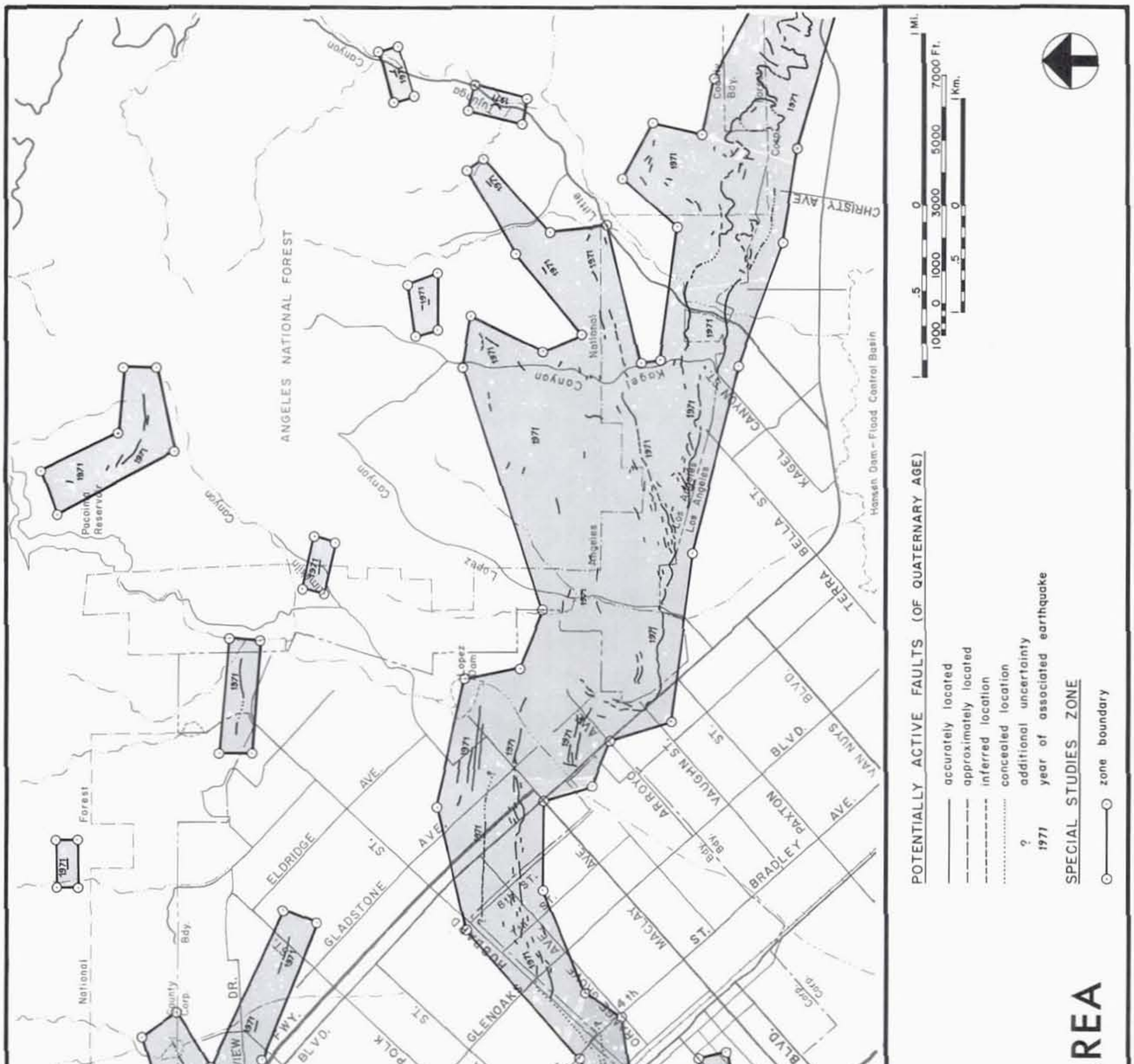

Figure 21. Special Studies Zones

jects of less than four lots. Responsibility to review the geologic reports and approve or deny development proposals rests with the city, although State Mining and Geology Board criteria prohibit building structures for human occupancy across an active fault trace.

Specific Issues, Options and Actions – City of San Fernando

Because the city was almost entirely developed at the time of the earthquake, options for land use changes were very limited. Also, the scattered pattern of structural damage, largely reflecting the age and type of construction, and the absence of large, clearly hazardous areas would seem to have further reinforced the city's decision to maintain the existing pattern of land use. Seismic risk was addressed almost entirely as a problem of building design and construction and the Uniform Building Code was relied upon to insure the safety of new construction. Although opportunities for major land use changes were limited in San Fernando, possibilities did exist. The following section outlines some specific issues which might have been addressed in land use plans, describes potential options and the city's action. Apparent reasons for the actions are hypothesized based on the review of public documents and interviews with government officials.

Issue: Rebuilding in the areas of surface fault rupture

It is very difficult, expensive and, in some cases, impossible to design and construct a building which can withstand surface fault rupture without serious structural damage. In the San Fernando earthquake, buildings astride faults which experienced surface rupture were severely damaged Figure 10 shows the relationship of damage to surface fault breaks. In the City of San Fernando, surface fault rupture occurred in a band across the northern end of the city. With the exception of a heavily-damaged commercial area at Glenoaks Boulevard and Hubbard Street, land use in the area of surface fault rupture consisted of single-family homes. Ninety-four houses between 7th and 8th Streets were in the fault zone. Of these, 21 (20%) received little or no damage; 43 (50%) received moderate to severe damage and 30 (30%) were posted as unsafe (U.S. Geological Survey, 1971, p. 75). Thus, 80% of the homes in this area sustained at least moderate damage – an unusually high concentration of damage. However, no lives were lost as a result of this damage.

In the commercial area, the Boys Market was destroyed and a bowling center and single-story shops were damaged (Figure 22). Although ground shaking and structural characteristics undoubtedly were responsible for much of the damage, the fact that surface fault rupture occurred in this area should be considered in rebuilding and determining future land uses.

Options. Possible land use responses for rebuilding in the surface fault rupture area include the following:

1. No restrictions on rebuilding or new building.
2. Allow rebuilding and new building if geologic investigations show no fault trace under building site.
3. Limit use to single-family homes.
4. Assuming an expected earthquake recurrence interval of about 200 years, allow reconstruction but plan to eventually remove structures using near future (10-30 years) for accumulation of local funds for acquisition and removal.
5. Allow reconstruction and new construction with special controls such as imposing seismic design and building standards.
6. Prevent reconstruction where other factors favor open space uses.
7. Prevent reconstruction or new construction in area of surface fault rupture.

Figure 22. Collapsed Boys Market, corner of Glenoaks Boulevard and Hubbard Avenue (Source: Jennings, P.C., ed., 1971, p. 475)

Action Taken. No restrictions on rebuilding or new building were contemplated or imposed by the city except that buildings which sustained damage exceeding 50% of market value had to be brought up to the current building code. The collapsed Boys Market was rebuilt within two years after the earthquake, but several other properties in the commercial area remain vacant. Proposals for two fast food outlets, a two-story office building and condominiums are pending for these properties. The rest of the surface fault rupture area is still occupied by, and planned for, single-family homes. Most of the severely damaged homes have been reconstructed.

Reasons. The availability of funds appears to have been the most important factor in San Fernando's decisions. SBA loans were readily available within a few months after the earthquake to assist home owners with repairs and reconstruction. These funds were allocated with no restrictions based on potential future risk of surface faulting. Demolition of severely damaged homes was carried out at public expense by contractors to the U.S. Army Corps of Engineers. With SBA assistance, damaged homes in the surface fault rupture area were repaired within a year and razed homes reconstructed within two. Some delays in reconstruction occurred because of initial uncertainty of private lending institutions about investing in the area and the difficulty of title companies establishing lot lines where ground movement had been most severe. The willingness of government agencies to fund reconstruction in the area and the generally optimistic tone of the seismic hazard study available a year after the earthquake, served to allay concerns of private lending institutions.

Issue: Concentrations of damaged, old, unreinforced masonry buildings in downtown San Fernando

In areas with predominately old buildings, damage caused by an earthquake may provide the opportunity for comprehensive redevelopment and revitalization. In downtown San Fernando 180 commercial buildings were examined after the earthquake by Pacific Fire Rating Bureau personnel. One hundred were pre-1940 unreinforced masonry structures. Of these, 18 were severely damaged, 31 moderately damaged, 32 slightly damaged and 19 undamaged (Table 1).

Options. Possible land use responses include the following:

1. Demolish severely damaged structures and permit rebuilding and repair of moderately and slightly damaged buildings on an individual basis to less than current code standards.
2. Demolish and rebuild all damaged buildings to improved or current code standards.
3. Use the opportunity to completely redevelop the damaged area.

Action Taken. Since 1966 a 2 1/2 block area of downtown called the "mall" had been planned for redevelopment (see Project Area #1 in Figure 20). Street work (reducing traffic lanes to two and installing diagonal parking) and landscaping had been completed before the earthquake. The earthquake hastened the redevelopment of private property which was proceeding slowly before the earthquake. Nine of about 30 buildings in the redevelopment area were razed; of these, six have been reconstructed. Figure 23 shows a portion of the mall as it appeared in 1978. Parking lots have been built at the periphery of the mall on sites where buildings were razed. The three remaining lots are in a single ownership. Negotiations with the owner to achieve reconstruction on these parcels are in process. The city chose not to exercise the right of eminent domain in this project which is being carried out under California State law with tax increment financing.

Figure 23. View of the mall, downtown San Fernando, Spring 1978

Prior to the earthquake, the city adopted an ordinance permitting total building coverage of commercial lots in exchange for an "in lieu" parking fee. The fees created a fund used by the city for parking lots. After the earthquake, the fee was rescinded for two years to encourage rapid rebuilding. All but one property owner took advantage of this. The one property owner who has not yet taken out a building permit to rebuild is now subject to this fee (about $80,000) which is a major issue in his present negotiations with the city.

In other downtown locations, some buildings which could have been repaired were demolished and rebuilt as the least expensive alternative. At least two old hotels were razed and the properties converted to other commercial uses. SBA loans in amounts necessary to restore operations were available to businesses to reconstruct and many took advantage of this.

Two additional redevelopment areas were defined in 1973. Project Area #2 is to the south and east of the mall and Project Area #3 is on the north side of the railroad tracks encompassing the Civic Center complex (Figure 20). A four-story Los Angeles County Courthouse is planned on a site near City Hall in Project Area #3 where single-family lots have been assembled and homes cleared by the City of San Fernando Redevelopment Agency. The difference in cost of the site and sale price is being absorbed by the Redevelopment Agency. The

County had previously selected a site outside of San Fernando, but decided on the San Fernando location, citing, in part, the absence of geologic hazards compared to the alternative site.

Reasons. As with the action taken with respect to rebuilding in the area of fault rupture, the major factor in the city's response to hazardous old buildings in the downtown area appears to be the availability of SBA loans for reconstruction. Many property owners took advantage of the opportunity to significantly upgrade the safety and appearance of their commercial buildings or to completely reconstruct. The city's previous investment in public improvements in the "mall," which were largely undamaged in the earthquake, and its rescinding the "in lieu" parking fee provided additional and important incentives for reconstruction and major upgrading of the commercial area.

Issue: Land use below Pacoima Dam

A portion of San Fernando extending from the Pacoima Wash to about Maclay Street is in the inundation area of Pacoima Dam as shown in Figure 19. The dam suffered damage in the earthquake and the water level was lowered, although there was apparently no danger of failure. The reservoir is strictly for flood control and the wash is a V-shaped concrete channel designed to contain the 100-year flood flow. The original drainage, considerably to the southeast of the present channel, was relocated to reclaim land and facilitate construction. Natural slope is to the southeast so that if the channel were to overflow, flooding in San Fernando is not expected to exceed one foot in depth. The Lopez Reservoir, on the Pacoima Wash below Pacoima Dam, serves only as a debris basin and has no ability to hold back flood waters in the event the Pacoima Dam were overtopped or failed. The question can be raised as to whether or not reconstruction or new development should have in any way been restricted in the inundation area because of flood risk.

Options. Possible land use responses include the following:

1. Repair the dam with no change in land use below the dam based on flood risk.
2. Repair the dam and limit the density of future development and location of critical facilities in inundation area below the dam and/or require flood-proofing or elevation of new structures in areas not subject to high velocity flow.
3. Remove the dam and use alternative means of flood control.

Action Taken. No action based on flood risk was taken by the city.

Reasons. The major factors leading to this inaction apparently were the established urban pattern and widely scattered damage in the inundation area. Considering the public and private investment in the existing land use pattern and the low likelihood of flooding from dam failure, land use changes or restrictions made little sense.

Issue: Lifelines – water system in San Fernando

The location of water supply and pipelines greatly affects the land use pattern. Prior to the earthquake, San Fernando operated its own water system supplied from several city wells located outside the city limits. The wells, reservoirs, and distribution system were extensively damaged in the earthquake due to faulting and other forms of ground failure leaving much of the city without water for some time. The opportunity existed for the city to develop a better and more earthquake-resistant water system.

Options. The following land use responses might have been considered:

1. Restore the water supply and distribution system to its pre-earthquake condition.
2. Restore the water system using more earthquake resistant design and materials.
3. Provide a secondary source of water.
4. If possible, redesign the water system to avoid major pipelines crossing an active fault.

Action Taken. The city's response consisted of a combination of Options 2 and 3. The water distribution system was rebuilt with federal funds, to modern standards under the auspices of the Army Corps of Engineers using earthquake resistant materials. The city wells and reservoirs were repaired.

Immediately after the earthquake, emergency water was provided through a hook-up to the Metropolitan Water District system (a district providing water from the California Water Project and Colorado River to a large portion of Southern California). The city voted to join the Metropolitan Water District in November 1971 and with the payment of a $20,000 hook-up fee, the connection became permanent. The annexation fee to join the District was about half what it would have been prior to the earthquake. The District, formed in 1929, charges an annexation fee roughly comparable to what would have been paid over the years by the jurisdiction if it had joined in 1929. A formula based on current assessed valuation is used to determine the fee. After the earthquake, San Fernando's assessed valuation dropped to about half the pre-earthquake level. Thus, the city was able to join the District for about $2,000,000 (rather than $4,000,000) payable over a 30-year period plus the $20,000 hook-up fee. The debt is being financed by a surcharge on the water rate.

The main water supply lines from the wells cross the San Fernando fault and the line from the Metropolitan Water District crosses the Verdugo fault. Unless both faults should rupture simultaneously, the city is likely to have a source of water following future earthquakes.

Reasons. The major improvements in the city's water supply and distribution system were made possible by federal disaster relief funds available for the reconstruction of public facilities. The fact that damage to the system was so extensive as to virtually preclude a "patch-up" approach also favored reconstruction resulting in a water system less vulnerable to earthquake damage.

Opportunities Seized

In retrospect the earthquake appears to have benefited the City of San Fernando. The city is safer, more functional and attractive now than before the earthquake, mainly because of the massive infusion of federal funds. Some of the long run benefits the community received were:

1. Many old, unsafe unreinforced masonry buildings were destroyed and rebuilt to 1967 or 1970 Uniform Building Code standards. The earthquake made possible instant code enforcement and rehabilitation at little or no cost to the city and without the typical political hassles.
2. The city water system was almost completely destroyed in the earthquake. New wells, more earthquake resistant reservoirs and tanks, and an improved distribution system were provided at federal expense. The hook-up to the Metropolitan Water District provides a secondary source of water.
3. At least one seedy hotel was severely damaged, razed and the property converted to another commercial use.
4. Redevelopment activities in the downtown area underway before the earthquake were given a spur with the instant demolition of some old, two-story brick commercial structures.
5. Funds were made available by HUD with a minimum of red tape for a revised general plan, additional parks and a museum.
6. With assistance from SBA loans, many home owners made substantial improvements to their homes in the course of repairing damage, and demolished homes and those with damage exceeding 50% of market value were rebuilt to current code standards.

Opportunities Missed

Although the net long-term effect of the earthquake appears to have been beneficial, some potential opportunities were missed:

1. Rebuilding in the fault zone has continued the level of risk existing before the earthquake. The most severely damaged area in the north part of the city is virtually without neighborhood park and recreation facilities. Use of the HUD funds for park acquisition and development in the area of greatest destruction between 7th and 8th Streets could have significantly increased seismic safety while at the same time meeting an important public need. Instead, the city used the funds to acquire land for the previously-planned Glenoaks park in the area of relatively low hazard Figure 20). About thirteen houses in sound condition were acquired and cleared to make way for the park which has yet to be developed.
2. The city may still have the opportunity to achieve low risk land use in the destroyed commercial area at Glenoaks Boulevard and Hubbard Street. The collapsed Boys Market was rebuilt within two years after the earthquake, but several other properties remain vacant. Proposals for two fast food outlets, a two-story office building and condominiums are pending for these properties. The area is now within a Special Studies Zone, but implementation of the State Act depends largely on local actions.
3. While the mall redevelopment area is undoubtedly safer than it was before the earthquake with the removal of 9 two-story unreinforced masonry buildings, unnecessary extra risk has been accepted with the widespread ornamental use of mission tile roofs overhanging the sidewalks throughout the redevelopment area.
4. Prior to the earthquake, there were about 100 pre-1940 (mostly pre-1933) unreinforced masonry buildings in downtown San Fernando. About 65 of these buildings presumably still remain (34 were razed) (Steinbrugge, 1973). The remaining buildings have not been reinforced and are no safer than they were before the earthquake. In fact, having been weakened by shaking in 1971, they may be more dangerous now than before the earthquake. Unless the damage exceeded 50% of market value, the city did not require that the whole building be brought up to code. It appears the earthquake solved only about one-third of the city's old, hazardous building problem.

ISSUES OUTSIDE THE CITY OF SAN FERNANDO

The earthquake affected such a small portion of the City of Los Angeles and Los Angeles County that the impact on normal governmental activities was much less noticeable than in San Fernando. Planners and planning departments appear to have had little involvement in reconstruction decisions. Operating divisions such as public works, water and power, and flood control played the major roles. There are few examples of deliberate changes in land use to reduce seismic risk. Private and public facilities, with the exception of critical facilities in particularly vulnerable locations, were reconstructed as quickly as possible. Where seismic risk was reduced, it was largely accomplished through structural measures. However, certain issues are sufficiently interesting from a land use planning point of view to warrant review in order to illustrate particular potentials or problems in the post-earthquake situation.

Issue: Land use in Kagel Canyon

Kagel Canyon is a small unincorporated community of predominately old single-family homes — many originally built in the 1920's and 1930's as vacation cabins and later modified and expanded for year-round occupancy. In the lower canyon, houses line the wooded banks of Kagel Creek and are scattered in the fairly steep hills rising along either side of the creek. Houses within the broader upper canyon are within the Angeles National Forest. The County's Dexter Park is to the east of the upper canyon and two cemeteries are to the north.

In the two years prior to the earthquake, the canyon was hit by flooding and brush fires. Fire insurance is only available through the California Fair Plan at about three times normal rates. The 1971 earthquake caused extensive damage: the county fire station at the intersection of the road to Dexter Park collapsed, water supply tanks on ridges on either side of the upper canyon ruptured and the water distribution system was destroyed, roads were extensively damaged, and 67 of the 200 or so homes in the area were condemned and razed (U.S. Senate Hearings, 1971, p. 632). Although most of the damage was caused by ground shaking and inadequate building and foundation construction, surface fault rupture occurred at two locations across the loop road serving the canyon. The magnitude of damage in this fairly isolated community which is also subject to floods and brush fires raises the question of possible relocation of the entire community.

Options. The following land use responses might have been considered:

1. Allow rebuilding and new building; bring fire, water, and other services up to urban standards.
2. Allow rebuilding; fund rebuilt water system sufficient to serve existing houses; prevent new development.
3. Allow rebuilding under restrictions such as imposing strict building standards, preventing new development, correcting foundation problems, providing redundancy in lifelines.
4. Prevent reconstruction; plan for eventual removal of undamaged structures.

Action Taken. SBA loans were available to repair and rebuild homes in the area. Some repairs took place without loans or building permits. Aside from requiring that the whole structure be brought up to code if damage exceeded 50% of market value, the county placed no restrictions on rebuilding in the area.

Emergency restoration of water service was accomplished by County Water District #21 in seven days. Permanent rebuilding was complete in nine months to a year after the earthquake (Putnam, interview). At the time of the earthquake, the water tanks failed to meet current standards of earthquake-resistive design and the water distribution system had inadequate capacity to provide protection against brush fires. After the earthquake, federal disaster relief funds were available to restore the system to its condition prior to the earthquake, but not to bring it up to current standards. The Water District chose to make some improvements over the pre-earthquake conditions without bringing the whole system up to present seismic standards. The federal government paid about 80% of the cost. Federal funds were also used to repair the roads, rebuild the fire station and repair damage in Dexter Park. Total federal expenditures to replace or repair public facilities alone amounted to $750,000 or over $3,500 per household (Putnam, interview).

Reasons. Kagel Canyon offers a distinctive living environment and life-style which residents have fought to maintain in spite of multiple natural hazards and high insurance costs. However, it could be argued from the public point of view that the cost of periodic disaster assistance to sustain this small community is excessive. Funds might have been spent for public acquisition of at least the most hazardous parcels, or those on which structures were demolished, as additions to either Angeles National Forest or the County's Dexter Park. The fact that this was not seriously considered underscores the very strong desire on the part of individuals and institutions to return as quickly as possible to pre-disaster conditions. It is very difficult to achieve major land use changes which require disruption or dissolution of a functioning community.

Issue: Reconstruction of critical and high occupancy facilities

The San Fernando earthquake might well be termed the "hospital" earthquake. The extensive damage to many hospitals (VA hospital, Olive View, Pacoima-Lutheran, Holy Cross), including buildings constructed under modern codes, came as a shock to the structural design and engineering professions. After the earthquake, California adopted legislation imposing substantially stricter hospital design and construction standards. Although the new standards will undoubtedly improve the ability of hospitals to remain functional in future earthquakes, the question of hospital location with respect to areas of potential ground failure remains important.

The County's Olive View Hospital complex and the Veterans Administration Hospital were both located close to the San Fernando fault in an area that experienced special shaking conditions. Whether or not these hospitals were to be reconstructed in the same location or relocated was a subject of debate after the earthquake.

The San Fernando Juvenile Hall is an example of a high occupancy facility which was destroyed in the earthquake. The site is within the fault zone in an area subject to ground failure and special shaking conditions. As with the hospitals, the question of relocation was debated after the earthquake.

Options. Land use options in these cases were essentially the same:

1. Require extensive site investigations to determine feasibility of constructing such facilities with reasonable safety, and reconstruct on original site with modifications in site, foundation and building design to reduce risk of damage in future earthquakes.
2. Relocate facilities on safer sites.

Action Taken. The V.A. Hospital was moved to Loma Linda on a site adjacent to the Seventh Day Adventist Medical School. The former site was acquired and de-

Figure 24. Olive View Hospital building under construction, Spring 1978

veloped by Los Angeles County as a park. Following extensive geologic and engineering analyses of both sites, decisions were made to reconstruct Olive View Hospital and Juvenile Hall at their existing sites. Juvenile Hall has been rebuilt and Olive View Hospital is currently under construction (Figure 24).

Reasons. The primary reason behind the decision to relocate the V.A. Hospital appears to be the opportunity to associate with a medical school. In the cases of Olive View Hospital and Juvenile Hall, structural engineering studies concluded that, with special design and construction features to withstand expected earthquake effects, safe buildings could be constructed on the sites. Site modifications and special design features were found to be less costly than finding and acquiring other sites. In the case of Juvenile Hall, discussion focused on whether such services should be decentralized. The decision to rebuild reflected a choice for centralization. Another important factor was federal interpretation of the Disaster Relief Act of 1970. Under this Act, the federal government ruled it would pay 100% of the cost to restore public facilities on existing sites, but would not cover the cost of purchasing new sites. As stated in the report of the County of Los Angeles submitted to the U.S. Senate Committee on Public Works:

> . . . we have been informed that should the County determine that it is inadvisable to rebuild at either Olive View or the current site of the San Fernando Valley Juvenile Hall, the County would not be reimbursed for the costs of the necessary land acquisition. (U.S. Senate Hearings, p. 447)

This lack of funding for site acquisition effectively precluded serious consideration of relocation in these two cases.

Issue: Land use below San Fernando Dam

The near failure of the San Fernando Dams and the evacuation of 80,000 people from the potential inundation area below the dams dramatized a potentially devastating earthquake effect. Land use modifications in the inundation area might be considered to reduce the risk of catastrophic loss of life and property damage from dam failure.

Options.

1. Reconstruct the dams using the best contemporary methods with no change in land use below the dams.
2. Reconstruct the dams and limit the density of future development and location of critical facilities in the inundation area below the dams and/or require flood-proofing or elevation of new structures in areas not subject to high velocity flow.
3. Do not reconstruct the dams and find alternative means of water storage.

Action Taken. Land use restrictions below the dam were not considered. Public discussion focused on whether to reconstruct the dams or seek alternate means of water storage. Many people who had been evacuated did not want a dam reconstructed in the same area. The City of Los Angeles Department of Water and Power, owner of the complex, argued that maintaining reservoir capacity at the site was essential because 80% of the city's water (that coming from the Los Angeles Aqueduct) flows through the complex. The reservoir is considered particularly effective for storing emergency water supply. Because of its elevation, it can supply most of the City of Los Angeles by gravity flow. Because no pumping is required, distribution is unaffected by power failures.

After extensive site investigations, the Department of Water and Power recommended building a new dam (the Los Angeles Dam) at a site about midway between the damaged Upper and Lower San Fernando Dams with a storage capacity of about half that of the two Van Norman Reservoirs. The dam design was subjected to dynamic analysis and every possible precaution was taken. It is one of the most extensively studied and carefully designed dams in the state. In convincing people below the dam to accept its construction, the Department assured them the risk of failure was virtually zero. The decision was made to construct the dam.

Reasons. Within the context of vocal public concern and repeated state and city government assurances about the safety of the dam, any action by the City of Los Angeles to restrict land use below the dam based on potential flood risk would have been contradictory. The decision to build the dam effectively precluded consideration of land use restrictions.

Issue: Land use in landslide-prone hillsides

Earthquakes often trigger landslides on unstable and potentially unstable slopes. In the 1971 earthquake, numerous landslides, rockfalls and shattered ridge tops occurred in the hillsides to the north of the Valley. These earthquake effects caused little damage because the affected areas were largely undeveloped at the time. It is important, however, that planning for the future development of these hillsides recognize the potential landslide hazard. With a few exceptions, most of the landslide-prone areas are within the Angeles National Forest or the jurisdiction of the County of Los Angeles.

Options.

1. No change in general plans and regulations.
2. Require geotechnical site investigations for subdivisions, building permits, and grading.
3. Lower permitted densities.
4. Lower permitted densities and prohibit development where provision of vital services cannot be guaranteed following an earthquake.
5. Acquire unstable areas to add to Angeles National Forest.

Action Taken. Almost all the unincorporated areas between the Angeles National Forest and the City of Los Angeles are designated in the proposed Los Angeles County general plan as rural residential (Figure 20). Proposed density standards vary depending on the natural characteristics of the site. Densities based on slope are:

Slope	Density
Under 15%	1 unit per 1-2 acres
15% to less than 30%	1 unit per 2 acres
30% to less than 50%	1 unit per 5 acres
50% and over	1 unit per 20 acres

The proposed plan also designates this entire area as a "hillside management area." Performance standards relating to grading, drainage, landscaping, street design, utilities, signs, open space, and hazards are recommended. Concerning geologic hazards, the standard is:

> Hazards such as landslides and liquefaction areas, identified in required soils and geologic reports, are to be avoided wherever possible.
>
> (Los Angeles County, 1978, p. 11-20)

Reasons. The attempt by the county to apply special standards to hillside development derives from a realization, in part borne out by the San Fernando earthquake, that hillside areas often have multiple natural hazards as well as natural and scenic values requiring sensitive treatment.

Conclusions

The possibility of reducing future seismic risk through land use change was not strongly considered after the San Fernando earthquake. Most decisions seemed to be based on the desire to return to normal quickly and were made possible by the availability of federal funds. Where the level of seismic risk was reduced, it was through improved design and construction of structures rather than through land use changes. An argument can be made for this response when one considers that changing land uses in a functioning urban area can be very difficult to achieve. The benefits may be long term and less certain than the immediate costs.

The local governmental decisions must be viewed from the perspective of local officials considering the information available to help them make rational judgments in the highly complex and volatile immediate post-earthquake situation. No explicit assessment of seismic risk was made in most decisions, but an evaluation of risk was implicit in actions taken. The local public official's perception of risk reflected his own experience and knowledge as well as that of his constituency. The perception of risk changed over time as a result of better information and changes in public attitudes.

Immediately after the earthquake, the sense of risk was at a peak. Certain areas appeared obviously more hazardous than others. Before geologists and engineers had completed their reports, areas of ground failure were readily discernible by physical effects such as buckled pavements, offset building foundations, and cracks in the ground. While the causes of ground breakage may not have been known, the public official had ample evidence that these areas were more hazardous than others. This led to a "go slow" attitude – avoiding decisions to permit reconstruction and repair in these areas.

Initially, the sense of high risk was reinforced by the reluctance of lending institutions to finance reconstruction in heavily damaged areas and the reluctance or refusal of insurance companies to write earthquake insurance. The occurrence of aftershocks heightened the sense of risk. During this period, decisions to reconstruct damaged critical facilities or high-occupancy structures were deferred. Repairs were limited to those necessary for immediate service and for public safety. Studies of the causes of failure and the feasibility of reconstruction were initiated. Concern for future safety for such facilities was high.

Reconstruction of private property began in areas where damage was scattered and relatively minor. Later, major repairs were undertaken as funds became available. The sense of risk began to decrease as repairs got underway and neighborhoods began to look normal. Restoration of public services and facilities further increased confidence in the safety of the community and its ability to achieve recovery. Possible land use or occupancy changes may have been considered on properties where buildings were demolished, but the result of public and private actions was to preserve the basic pre-earthquake land use pattern.

Information from geologic and engineering studies initiated immediately after the earthquake gradually became available. The general effect was to further allay fears. Most building failures were attributed to poor design or construction. Assurances were given that the unusually strong ground shaking experienced in some areas could be compensated for in building design and construction. Aside from some lingering concern about locating high occupancy or critical facilities in the now fairly precisely defined area of fault rupture, there was little in these studies that indicated the need for land use changes.

Reconstruction in the most heavily damaged areas occurred more slowly because of the time required to restore public services, resolve property line problems, and obtain financing. The geologic and engineering studies, public investments and willingness of the SBA to loan for reconstruction eased the fears of the private lending institutions and insurance companies. Although public officials had time to consider land use changes in these areas, the sense of urgency and risk had abated and the usual arguments against land use regulations became overriding.

The low sense of risk which emerged soon after the earthquake may have been reasonable. The frequency of damaging earthquakes in the area seems to be quite low. Although precise recurrence intervals cannot be determined, the experts seem to agree that a repetition of the 1971 event on the San Fernando fault might be expected once every 200 years or so. From the point of view of the person with a home in the fault zone who expects to live in the home for 20 years, this represents a chance of 1 in 10 that another earthquake, potentially affecting the home, will occur. In 1971, about one-third of the houses between 7th and 8th Streets in the fault zone were posted as unsafe (see page A-26). Assuming equivalent damage from a future earthquake on this fault, the risk in this area of an individual home suffering extensive damage is 1/3 x 1/10 or 1 in 30 during the 20 year period and 1 in 600 during any one year. The typical earthquake insurance rate for a single-family house, regardless of location, is $2.00 per $1,000 of insured value implying an annual risk of 1 in 500. The annual risk would be even lower if costs such as overhead and profit are deducted. This is remarkably close to the estimated risk of 1 in 600 for a house in the fault area described. However, the implied insurance risk does not take into account the 5% deductible typical in earthquake insurance policies and the fact that risk varies with location. The annual risk of 1 in 600 applies to a very hazardous area, and actually would be lower in most locations. Thus, insurance rates appear to overstate the risk.

Thus, considering risk alone, the decision of an individual to rebuild a house in the fault zone does not appear irrational. Although it is highly unlikely that the individual property owner attempts to calculate his exact risk, he is aware that earthquakes are infrequent and that most houses in the area of fault rupture survived with moderate damage or less. Adding to his sense of low risk is the commonly expressed notion that we've had our earthquake and the next one is a long way off, and the fact that, throughout the area impacted by the earthquake, only 4 lives were lost in single-family homes.

Even more important than risk as a factor in the individual's decision to rebuild is the usual lack of other viable options. The person whose home is partially destroyed typically has equity in the house and land which cannot be fully recovered after the earthquake. Unless government assumes the cost of relocation, the sensible economic choice for the individual usually is to rebuild. Rules for administering government disaster relief (SBA loans to home owners, in particular) encourage this response.

Local elected officials and staff members are influenced by this rather low individual assessment of risk and desire to rebuild. They face the difficult task of deciding whether the overall risk to the community is high enough to warrant land use changes or restrictions. The cost to society to rebuild once every 200 years or so may be less than the costs of relocating people, abandoning infrastructure, and acquiring land, or requiring less than optimum economic use of land. The benefits of relocation tend to pertain to the long-term and be less certain than the immediate costs. Many benefits and costs are intangible and difficult to analyze.

Costs vary between new development and rebuilding. In some cases, investment in existing infrastructure may be so great that no alternative location can offer equal or lesser infrastructure costs. Rebuilding with every reasonable design precaution often involves less public cost than relocation. This is usually the case where no other suitable location is available or for a facility, such as a reservoir, with very special locational requirements. The added public cost that might be required to relocate major facilities or even neighborhoods, over and above that required to rebuild at the original site, must be balanced against uncertain future savings in loss of life, injury and disaster assistance, and the problematic economic benefits from an improved urban pattern.

To discourage rebuilding in hazardous areas such as astride a fault could result in a peculiar urban pattern with scattered vacant lots – virtually unusable for either public or private uses. Costs of rebuilding and maintaining infrastructure to serve nearby undamaged properties may then be shared by fewer properties. There is a strong incentive, therefore, for local government and property owners to preserve the existing land use pattern. Perhaps, discouraging reconstruction makes most sense in those cases where large areas are rather uniformly damaged or where multiple factors favor an open space or lower intensity use. Often an established land use pattern is not optimum and an earthquake may provide an opportunity to improve the existing situation.

In addition to considering public attitudes, risk, cost and inherent difficulties in achieving land use changes, local officials are faced with the fact that actions taken during post-earthquake reconstruction tend to have a cumulative effect. It is politically necessary, as well as logical, for officials to justify each decision to reconstruct by judgments of low risk and uncertainty. This provides the rationale for subsequent actions and ultimately limits the options to respond on the basis of risk. A particularly vivid example is the decision to build the Los Angeles Dam. This decision, supported by strong assurances of extremely low probability of dam failure, made it virtually impossible to restrict land use below the dam to reduce flood risk.

Thus, neither the individual nor the public official is strongly motivated during post-earthquake reconstruction to act to reduce future risk or to favor land use changes as a means of reducing risk. The potential for achieving land use changes declines rapidly with time as individual and public decisions to reconstruct fix the land use pattern. In the absence of strong incentives to make changes, land use after an earthquake is likely to be the same as before.

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Alaska Case Study

appendix b

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Tony Burns, Senior Planner, working on the Coastal Zone Management Program, Department of Planning, Anchorage, Alaska, interview, August 2, 1978.

Dorothy Clifton, long-time resident and unofficial historian, Valdez, Alaska, interview, August 7, 1978.

Edwin Crittenden, Architect, CCC-HOK, Architects-Planners, prepared redevelopment plan for downtown Anchorage after the earthquake, interview, July 31, 1978.

Jackie Deck, librarian, Seward, Alaska, conversation, August 3, 1978.

Oscar Ferrians, Alaska Branch U.S. Geological Survey, telephone conversation, August 4, 1978.

Victor Fischer, Institute of Social and Economic Research, Anchorage, Alaska, formerly member of Alaska Field Committee of the Federal Reconstruction Commission from the Federal Housing and Home Finance Agency, interview, August 8, 1978.

Ronald H. Jarrell, Attorney, Hughes, Thorsness, Gantz, Powell & Brundin, Anchorage, Alaska, City Attorneys for Valdez, conversation, August 7, 1978.

C.E. "Johnny" Johnson, City Manager, Seward, Alaska, interview, August 3, 1978.

John Kelsey, former Mayor and Chairman of the Planning and Zoning Commission, Valdez, Alaska, telephone conversation, August 8, 1978.

Mark Lewis, Acting City Manager, Valdez, Alaska, interview, August 7, 1978.

Erwin Long, civil engineer, member of the Anchorage Geotechnical Advisory Committee and in 1964 with the U.S. Army Corps of Engineers, telephone conversation, August 1, 1978.

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Don Phillips, Regional Office, Seattle, Washington, U.S. Department of Housing and Urban Development, telephone conversation, October 17, 1978.

W.W. Rigby, Chief of Mortgage Credit, Regional Office, Anchorage, Alaska, U.S. Department of Housing and Urban Development, conversation, August 2, 1978.

Henry Schmoll, Engineering Geology Branch, U.S. Geological Survey, Denver, Colorado, telephone conversation, August 23, 1978.

Jack Schoop, Chief Planner, California Coastal Commission; Planning Director of Anchorage at time of earthquake, interview, July 28, 1978.

Lidia Selkregg, geologist and planner, professor at University of Alaska, member of the Anchorage Municipal Assembly, and in 1964 geologist with the Alaska State Housing Authority and organizer of the Engineering Geology Evaluation Group, interview, August 1, 1978.

George Sullivan, Mayor, Municipality of Anchorage, interview, August 2, 1978.

Wherever possible we tried to verify information obtained in conversations by reference to other sources; however, this was not possible in all cases. The authors assume full responsibility for any misstatement or misinterpretation of fact.

Introduction

The objective of the Alaska case study was to determine the main factors influencing reconstruction decisions following the 1964 Alaska earthquake. The study was carried out by an interdisciplinary team of planners, engineers and geologists. The team reviewed published reports of the geologic effects, structural damage and reconstruction effort in Alaska and, based on these reports, decided to concentrate on decisions concerning reconstruction in the communities of Valdez and Seward and in the areas of three major landslides in Anchorage. Field inspection and interviews with public officials in the three cities were conducted in August 1978.

Previous studies have documented the initial reconstruction effort and land use decisions in the three cities (Selkregg and others, 1970). This study provides a somewhat different perspective — a view of decisions made and the actual reconstruction that has occurred in the fourteen years since the earthquake. The focus is on identifying reasons for the sequences of actions, taken since 1964, regarding land use in hazardous areas in the three cities.

The Alaska Earthquake of 1964

The 1964 Alaska earthquake was one of the greatest of this century. Its occurrence, late in the afternoon of March 27, 1964, is described by Hansen and others (1966):

> Beneath a leaden sky, the chill of evening was just settling over the Alaskan countryside. Light snow was falling on some communities. It was Good Friday, schools were closed, and the business day was ending. Suddenly without warning half of Alaska was rocked and jarred by the most violent earthquake to occur in North America this century. . .
>
> This earthquake has become renowned for its savage destructiveness, for its long duration, and for the great breadth of its damage zone. Its magnitude has been computed by the U.S. Coast and Geodetic Survey as 8.3-8.4 on the Richter scale . . . Few earthquakes in history have been as large. In minutes, thousands of people were made homeless, 114 lives were lost, and the economy of an entire State was disrupted. Seismic sea waves swept the Pacific Ocean from the Gulf of Alaska to Antarctica.
>
> (Hansen and others, 1966, p. 1)

The Alaska earthquake, known also as the Good Friday earthquake, or the Prince William Sound earthquake caused over $300 million in damage (1964 dollars) in Alaska. Numerous attempts have been made to draw lessons from it both as a physical event and a cultural experience. The following summary of Alaska's geologic and seismic setting, and the earthquake effects has been compiled from available literature and through contact with knowledgeable persons. A forecast of future earthquake potential is also presented to identify possible hazards which may be mitigated or minimized through land use planning.

GEOLOGIC AND SEISMIC SETTING

Southern Alaska and the adjoining Aleutian Island chain together constitute one of the world's most active seismic zones. According to Gutenberg and Richter (1949), about seven percent of the seismic energy released each year originates in the Alaskan seismic zone. From 1899 through 1964, eight Alaskan earthquakes have equaled or exceeded magnitude 8, 56 have had magnitudes between 7 and 8, and 234 have had magnitudes between 6 and 7 (Wood, 1966, p. 23). The epicenters are shown on Figure 1.

Most of the earthquakes originate at shallow to intermediate depths — typically less than 30 miles (50 km) — between the Aleutian Trench and the Aleutian Volcanic Arc. It is noteworthy that four recent earthquakes (1912, 1928, and two in 1934) with magnitudes greater than 7 occurred near the epicenter of the 1964 earthquake (Wood, 1966). Hence, there was little reason to consider the 1964 event as an unusual occurrence.

In terms of geologic history, the Alaskan earthquake of 1964 was just the most recent pulse in an episode of deformation which is believed to have begun some two to three million years ago and which has continued intermittently to the present. The net effect of these movements has been gradual uplift along the Gulf of Alaska coast and some subsidence of the area landward. The fault along which this and other past earthquakes occurred is not well exposed at the surface on land. However, it is considered by some investigators to be a complex thrust fault which dips at a gentle angle beneath the continental margin (Wood, 1966).

GEOLOGIC EFFECTS

In 1964, Alaska experienced nearly all the effects that a major earthquake is capable of inflicting. Tectonic subsidence and uplift altered many shorelines and rendered many harbors useless. The resulting tsunami, seiches, and slide-induced waves caused great damage and loss of life in coastal communities. Landslides and soil failures of various kinds altered shorelines and caused severe damage. Ground shaking was felt over 700,000 square miles with damage occurring over an area of 80,000 square miles. The area of crustal deformation was more than 100,000 square miles. Surface fault rupture

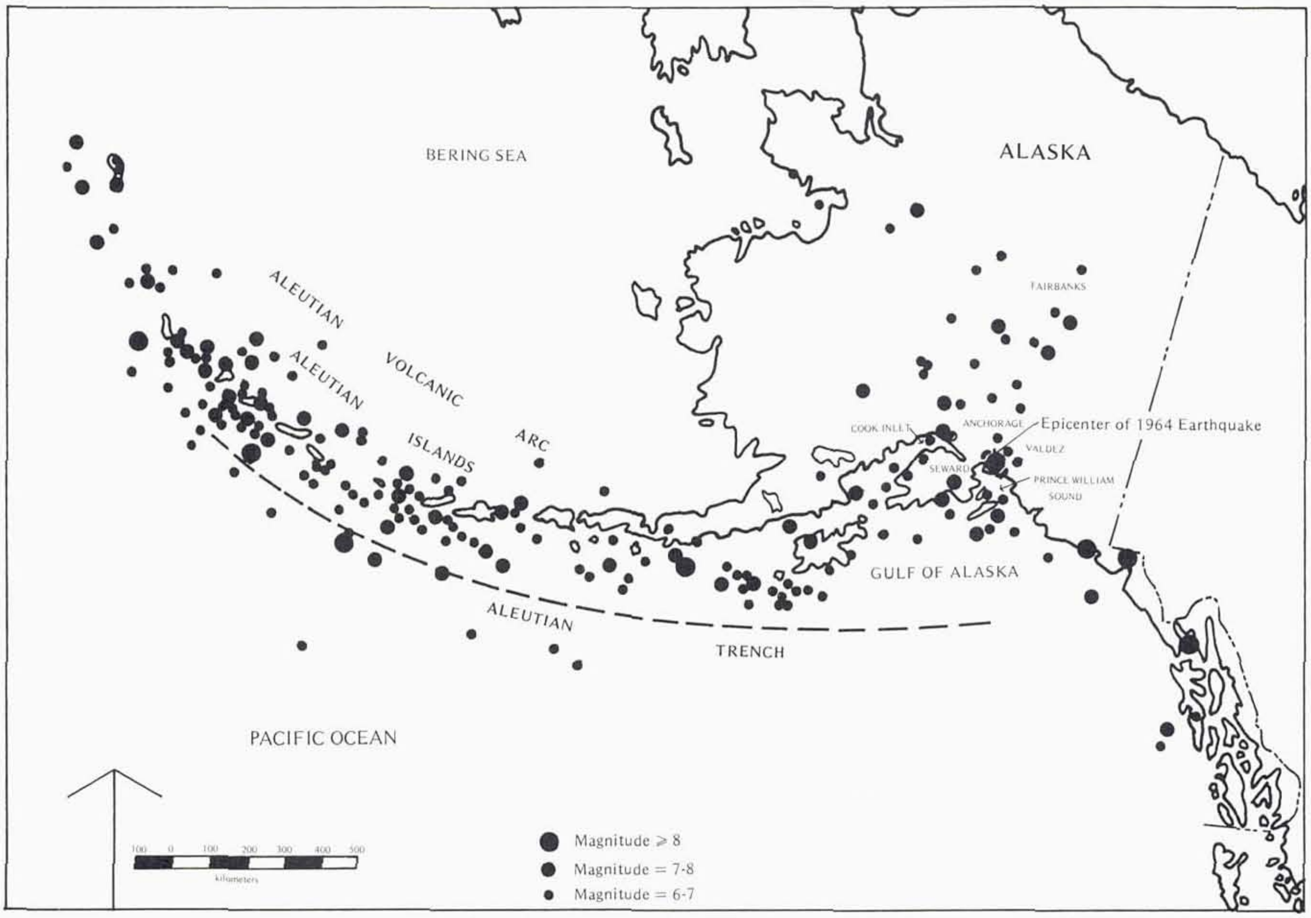


Figure 1. Earthquakes with magnitude ≥ 6.0 from 1899-1964, Alaska (Source: Wood, 1966, p. 22, modified by William Spangle and Associates, Inc.)

was evident on land only on one uninhabited island, and, therefore, was not a cause of damage.

The effects of the earthquake were intensified by the long duration of strong ground shaking – approximately three to four minutes. Structural damage was caused primarily by 1) direct shaking of structures; 2) landslides, consolidation of loose sediments, liquefaction and related soil failures; and 3) tsunamis. Damage to larger and taller buildings in Anchorage is attributed by structural engineers to the swaying of buildings caused by long period, large amplitude motions that typically occur at some distance from the epicenter of greater earthquakes.

An area approximately 600 miles long and as much as 250 miles wide was measurably displaced by the earthquake. Displacements occurred in two arcuate zones parallel to the continental margin. A "hinge" line, shown in Figure 2, separated the uplifted and subsided areas. The area to the northwest of the line subsided an average of 2.5 feet with a maximum of 7.5 feet. The area southeast of the line rose an average of 6 feet with a measured maximum of 38 feet. Geologic evidence in the tectonically uplifted region suggests regional warping of this type occurs about once every 1,000 years (Plafker, 1971).

Surface fault rupture was found in two places on Montague Island, an uninhabited island in Prince William Sound. Vertical displacements up to 23 feet were recorded along one of these faults. Comparable movement may have occurred unobserved on the sea floor. No movement is known to have occurred along any other faults on the mainland, although faulting at depth is suspected in some areas of unconsolidated surficial deposits characterized by linear zones of cracks and landslides (Plafker, 1971).

Numerous ground fissures, many of them marked by copious emissions of muddy or sandy water were concentrated within a 100 mile radius of the epicenter, but some were noted as far away as 450 miles. Flood plains, the tops and fronts of deltas, low terraces with steep fronts, and lake margins were among the geomorphic features most affected. Fissures in the ground varied greatly in length and width and some were reported to open and close during the period of ground shaking. Local subsidence caused by the ejection of water and mud from fissures was also observed.

Mass ground movements resulting from the earthquake caused the greatest amount of property damage in Alaska. These movements included rockslides, ava-

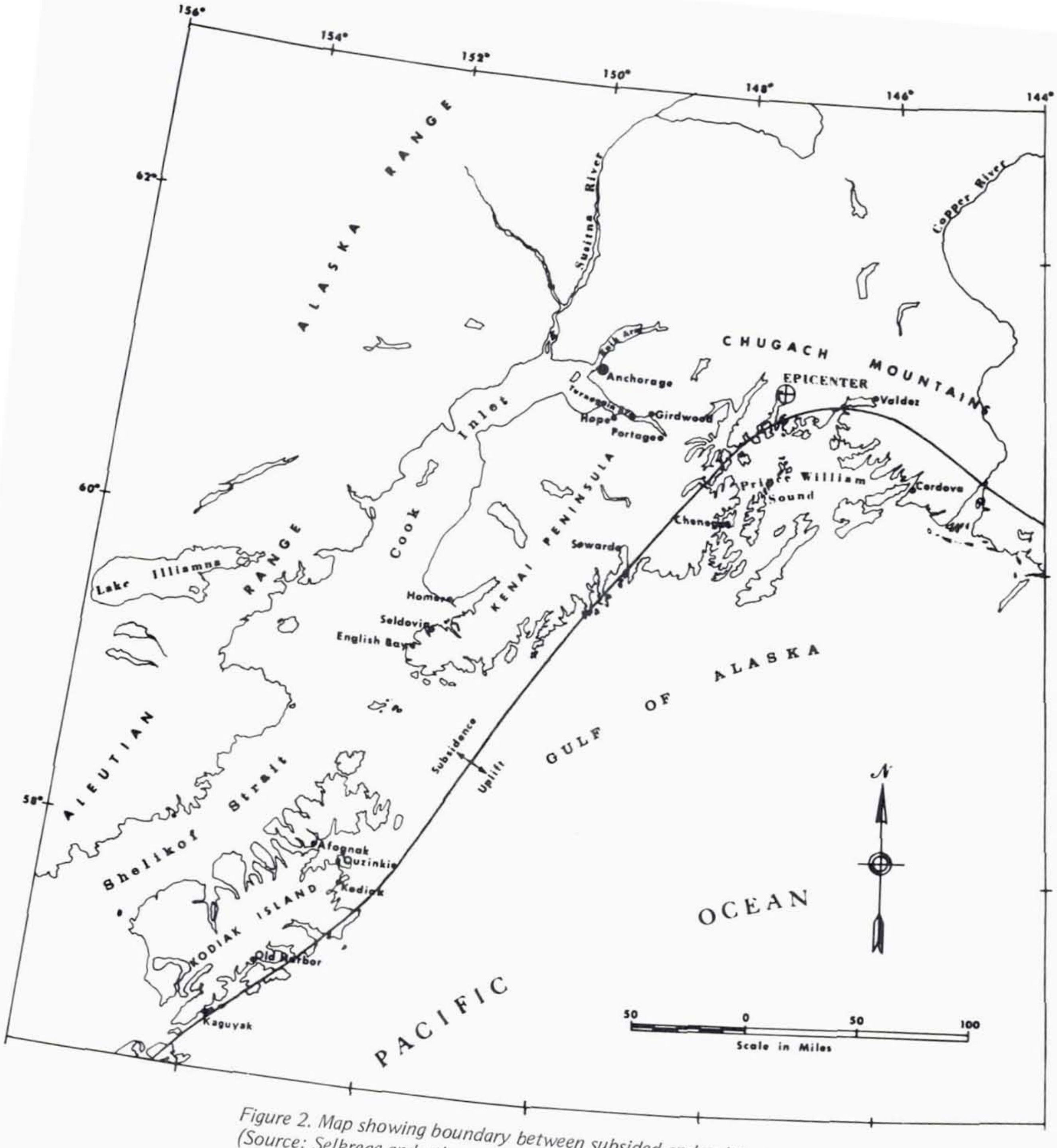


Figure 2. Map showing boundary between subsided and uplifted areas (Source: Selkregg and others, 1970, p. 187)

lanches, and landslides. Secondary effects resulting from some of these slides included highly destructive water waves generated by the sudden displacement of water by the slides. Seismic sea waves (tsunamis) and landslide-induced waves were responsible for most of the deaths. The tsunamis generated by the 1964 earthquake affected the entire North American coast and were recorded as far away as Antarctica. Damage was experienced in Alaska, British Columbia, Washington, Oregon and California. Heavy out-of-state damage occurred in Alberni, B.C., Hot Springs Cove, B.C., and Crescent City, California, where waves up to 20 feet high were recorded.

POTENTIAL FOR FUTURE EARTHQUAKES

The 1964 Alaska earthquake provided an opportunity to obtain reliable scientific and technical data concerning the cause and effect of seismic disturbances in Alaska. Through evaluating these data a better understanding of the geologic and geomorphic factors effecting earthquake damage has been reached.

Although it is clear that more earthquakes will occur in Alaska, prediction of when the next "Good Friday Earthquake" will strike the state is not yet possible. Interpretation of the existing seismic records suggests that approximately one earthquake magnitude 8 or larger occurs along the Aleutian Trench on an average of once every 10 years and that a magnitude 7 earthquake occurs approximately every year. Five earthquakes of magnitude 7 or larger, including the 1964 event, have occurred near Prince William Sound since 1912 indicating that large magnitude earthquakes frequent this area on the average of once every 13 years.

The idea that the 1964 earthquake "relieved the pressure" and accordingly reduced future risk of earthquakes has been suggested by some people, but the current views of seismologists do not appear to support this view. Rather, it appears that there are several kinds of potentially damaging earthquakes, with focal depths ranging from shallow to deep, which occur in the region, and that the probability of future occurrences is not necessarily diminished by the 1964 earthquake. While the statistics bearing on future damaging earthquakes are controversial, an annual probability of a damaging earthquake (either a Magnitude 8 within the general region or a Magnitude 7 located closer to any given site) on the order of one in fifty (i.e. 2 percent) seems reasonable. On this basis, the odds are even that another strong quake will affect any particular place in southern Alaska some time in the next 35 years.

STRUCTURAL DAMAGE

In many respects, the nature of damage caused by the 1964 Alaska earthquake was not typical of recent North American earthquakes. The major structural damage occurred in Anchorage about 80 miles from the epicenter. Many phenomena ordinarily associated with an earthquake of this magnitude and duration were not observed. In many areas, small objects did not overturn, chimneys did not fall, glass windows in houses did not break, bottled goods, groceries and books did not fall off shelves. Yet all the buildings five stories or over suffered damage with some total collapses. Major landslides occurred with consequent damage. Bridges and roadbeds for highways and the railroad were extensively damaged. Poorly tied together structures, even though designed to meet the earthquake requirements of the then current Uniform Building Code, suffered major damage and collapse. And a major tsunami was created that wiped out villages and caused death and destruction as far away as Crescent City, California.

The stricken areas contained almost half of the state's population and the heart of its economy. Considering the magnitude and duration of the earthquake, it is remarkable that loss of life, injury and structural damage were not worse. Few lives were lost as a direct result of the earthquake; most of the 114 deaths were caused by the tsunami and slide-induced sea waves. Injuries were very few; no more than 50 people were hospitalized. Medical personnel organized for a flood of casualties that never materialized. Structural damage was extensive in areas of ground failure and wave runup, but damage from ground shaking was more limited than one might expect in an earthquake of such great magnitude and long duration.

Table 1 lists the estimated cost of damages to public and private property in Alaska. Table 2 shows the distribution of damage to private property. More important than the dollar amount of damage was the nature of damage in the port communities hit by waves. In Valdez, Seward, Kodiak and other small towns, the local economies, dependent on fishing, shipping and related port activities, were virtually destroyed. Recovery in these towns required the rapid reconstruction of docks, harbors and ancillary facilities.

Damage to the railroad and highway system, coupled with loss of port facilities, severely affected the movement of goods. The Alaska Railroad and Anchorage-Seward Highway between Anchorage and Seward were nearly destroyed. Because of subsidence along Turnagain Arm, both roadbeds ended up below the high tide level and had to be elevated before reconstruction could occur. Seward was left cut off from the rest of Alaska except by air and suffered an economic blow from which the city still has not recovered.

Table 1
Summary of Damages – August 12, 1964
(1964 Dollars)

Public Property:		
Federal:		
Military	$ 35,610,000[1]	
Nonmilitary	35,641,000[1]	
Non-Federal:		
State and Local	107,373,000[2]	
Highways	55,568,000[3]	
		$234,192,000
Private Property:		
Real	$ 77,000,000[4]	
Personal	(no data)	
		$ 77,000,000[5]
Total Damage		**$311,192,000[5]**

1 U.S. Office of Emergency Preparedness Report, May 11, 1964.
2 U.S. Office of Emergency Preparedness Report, July 24, 1964.
3 Estimate provided by Bureau of Public Roads (BPR) and includes all highways on the Federal-aid system, BPR letter of May 15, 1964. The $55,568,000 figure is the amount required to restore to pre-earthquake condition. (The BPR estimate for construction to present design standards: $65,088,000).
4 Private-real property survey, Federal Housing and Home Finance Agency's telegram of May 7, 1964. Rounded to nearest million.
5 Does not include personal property or loss of income.

Source: Federal Reconstruction and Development Planning Commission for Alaska, 1964, p. 11

ORGANIZATION FOR RECONSTRUCTION

The organization for emergency response, recovery and reconstruction following the Alaskan earthquake has been well documented (Federal Reconstruction and Development Planning Commission for Alaska, 1964; Hansen and others, 1966; Krauskopf, 1970). The reconstruction organization and process was unusual in this case for several reasons:

1. Alaska had become a state only five years before the earthquake and was still in a period of transition from territorial status to assuming full responsibilities as a state.
2. The Alaskan economy was very dependent on federal activities; over half of the state's jobs were provided by the military or other federal agencies.
3. Military facilities in Alaska were considered crucial to the nation's defense.
4. Because of climatic conditions, the construction season was short, necessitating rapid reconstruction.
5. It was the largest and most spectacular earthquake to strike the United States since the 1906 San Francisco earthquake.

Table 2
Private Real Property Damage
(1964 Dollars)

Locality	Number of properties with damage over $1,000	Dollar Damage (in thousands)
Greater Anchorage Borough:		
Downtown area of Anchorage City	242	$11,716
Turnagain area of Anchorage City	670	12,905
Rest of city	320	9,678
City, total	1,232	34,299
School district, outside city	146	1,103
Portage	20	262
Girdwood	7	122
Eagle River-Chugiak	13	555
Basher	3	35
Private utilities	3	3,656
Subtotal	192	5,233
Total	1,424	39,532
Kodiak Island Borough:		
City, downtown	110	2,286
City, remainder and vicinity	13	2,286
Rest of borough	132	5,686
Private utilities	1	482
Total	256	8,670
Kenai Peninsula Borough:		
City of Seward	110	4,543
Homer	52	1,113
Hope	23	233
Kenai	7	62
Seldovia	93	1,040
Soldotna	5	18
Other	10	385
Total	300	7,394
Prince William Sound area:		
City of Valdez	237	2,911
Cordova and vicinity	85	683
Whittier	4	2,398
Canneries (all of sound area)	17	1,019
Total	343	7,009
Glenn and Richardson Highway areas	8	86
Matanuska-Susitna Borough	27	117
Grand Total	2,358	62,808[1]

Source: Property damage survey, Alaska State Housing Authority, April 1964 as reprinted in U.S. Senate, 1964, p. 33

[1] Total is lower than shown in Table 1. Most likely this is because of the different date and source of the estimate.

The Federal Reconstruction and Development Planning Commission

In 1963, the Bureau of the Budget drafted an executive order to establish a joint federal-state development commission to plan for Alaska's economic and social development but, because of the assassination of President Kennedy, the order was not signed. Immediately after the earthquake, it was resurrected and slightly reworked to provide a mechanism for coordinating relief and reconstruction activities of the various federal agencies in Alaska. Thus, the Federal Reconstruction and Development Planning Commission for Alaska (called more simply the Federal Reconstruction Commission) was established by Executive Order 11150 on April 2, 1964, less than a week after the earthquake. The late Senator Clinton P. Anderson from New Mexico was named chairman of the Commission and was instrumental in obtaining Congressional support for relief measures. Members of the Commission were the Secretary of Defense; Secretary of the Interior; Secretary of Agriculture; Secretary of Commerce; Secretary of Labor; Secretary of Health, Education, and Welfare; Director, Office of Emergency Planning; Administrator, Federal Aviation Agency; Chairman, Federal Power Commission; Administrator, Housing and Home Finance Agency, and Administrator, Small Business Administration. Because the Commission was composed of agency heads with the authority to act within broad areas of responsibility, recommendations could be quickly implemented.

Dwight A. Ink of the Atomic Energy Commission served full-time as executive director during the Commission's six month term. The staff was composed of personnel on loan from the various federal agencies involved. Much of the work of the Federal Reconstruction Commission was done by nine task forces: Community Facilities, Economic Stabilization, Financial Institutions, Housing, Industrial Development, Natural Resources Development, Ports and Fishing, Transportation, and Scientific and Engineering.

The Commission and staff operated in Washington, D.C., far from the disaster area. To coordinate activities on the scene and to bring state and local governments into the reconstruction planning process, a field committee composed of representatives of federal agencies with offices in Alaska was established. Formal state participation was provided through the Alaska Reconstruction and Development Planning Commission established by Alaskan Governor Egan to work with the Federal Commission. The coordinator of the state commission participated in meetings of the federal field committee. Further federal/state coordination was achieved through the Governor's appointment of the state Attorney General to serve as liaison with the Federal Reconstruction Commission in Washington, D.C. Members of the field committee met with local officials and councils to inform them of available assistance and procedures for obtaining it.

The Federal Reconstruction Commission coordinated the assessment of damages, recommended special legislation to achieve reconstruction, assisted in drawing up reconstruction plans and schedules, and backed the reconstruction of some public facilities with better design or greater capacity than before the earthquake. Special legislation arising from the Commission's efforts included:

1. Transitional funds of $23.5 million through June 30, 1966 (in addition to the original transitional grant of $28.5 million authorized by Congress when Alaska became a state in order to help it

assume public services previously provided by the federal government). The original grant was to expire in June 1964 – three months after the earthquake.

2. Amendments to the Alaska Omnibus Act of 1959 authorizing additional federal disaster assistance. Major provisions were:

   1. The Federal share of Federal-aid highway costs was increased from 50 percent to 94.9 percent.
   2. The Corps of Engineers was authorized to modify civil works projects, such as expansion of small-boat harbors, to meet prospective future requirements.
   3. Certain lending agencies were authorized to adjust the indebtedness of borrowers.
   4. The Housing and Home Finance Administration was authorized to contract for as much as $25 million for urban renewal projects; the Federal share of the participation was increased from 75 percent to 90 percent.
   5. The Federal Government was authorized to purchase as much as $25 million of State of Alaska bonds.
   6. The President was authorized to grant a total of $5.5 million to the State, on a 50-50 matching basis, to adjust or retire mortgage obligations on family dwellings.

   (Hansen and others, 1966, p. 49)

From the viewpoint of land use planning in a post-disaster situation, the authorization of $25 million for urban renewal projects with federal assumption of 90% of the total project costs was the most important provision. The Alaska State Housing Authority served as redevelopment agency for the local communities which approved renewal projects. It was through urban renewal projects that most reconstruction, particularly of private commercial and residential properties, was achieved. The use of this mechanism provided the opportunity to replan substantial areas in several communities including Anchorage and Seward for safer and more functional uses. The relocation of the entire Town of Valdez was accomplished through urban renewal powers.

On October 5, 1964, six months after the earthquake, the Commission was formally dissolved by Executive Order 11182. By this time reconstruction was well underway in Alaska and plans for long-term recovery through urban renewal projects were being prepared. Federal aid to Alaska, exceeding the estimated $311,000,000 in damages, had been authorized for purposes indicated in Table 3.

The Federal Reconstruction Commission was a remarkably effective organization for coordinating the federal disaster relief effort in Alaska principally because of its ability to implement decisions quickly. Projects were approved in days or weeks that ordinarily would have taken months or even years to process. However, by disbanding so soon after the earthquake, the Commission lost the opportunity to see some of its longer-term recommendations regarding economic development and scientific studies put into effect. The pre-earthquake concept of a permanent commission to plan for the state's economic and social future was never fully realized.

Table 3
Estimated Federal Assistance to Alaska
(1964 Dollars)

	Millions of Dollars
Federal aid to State and local governments:	
Disaster relief	60.0 - 70.0
Transitional grants	17.0 - 23.5
Highways	43.0 - 63.0
Urban renewal grants	25.0 - 40.0
Purchase of Alaska bonds	10.0 - 25.0
Planning advances	0.3 - 0.5
	155.3 - 222.0
Federal aid to private individuals and groups:	
Loans by Small Business Administration, Depts. of Interior, Agriculture	60.0 - 70.0
Forgiveness and other adjustments on outstanding loans	7.0 - 10.0
Tax refunds and offsets	20.0 - 30.0
	87.0 - 110.0
Restoration of Federal facilities and direct Federal operations:	
Defense facilities	35.6
The Alaska Railroad	27.0
All other Federal agencies	19.6
	82.2
Total (rounded)	**325.0 - 414.0**

Source: Federal Reconstruction and Development Planning Commission for Alaska, 1964, p. 20-21

Scientific and Engineering Task Force

The Scientific and Engineering Task Force was composed of structural engineers, engineering geologists and seismologists from the U.S. Army Corps of Engineers, U.S. Coast and Geodetic Survey and U.S. Geological Survey. Referred to as Task Force 9, this group was particularly influential in reconstruction planning. Its mission was to "advise the Commission immediately as to the physical parameters in Alaska which should be considered in connection with reconstruction" and to "participate in the conduct of a scientific study" (Federal Reconstruction and Development Planning Commission for Alaska, 1964, p. 50).

Task Force 9 concentrated on problems of reconstruction in areas of instability. It did not consider future risk of damage due to tectonic changes in ground level or seismic sea waves and left problems of what to do about individual buildings or facilities to the structural engineers. Geologic work needed for planning reconstruction of airports, the railroad and highways was done separately by the Federal Aviation Administration, the Department of Interior and the Bureau of Public Roads with little involvement of Task Force 9.

A Task Force 9 field team was organized to "develop plans for field studies pertinent to reconstruction" and to "recommend areas suitable for reconstruction and to establish interim zoning and design criteria to guide construction in this earthquake-prone region" (Federal Reconstruction and Development Commission for Alaska, 1964, p. 50). This charge to the field team led to unprecedented federal participation in decisions usually left to local government. Working in cooperation with Task Force 9, the Alaska District of the Corps of Engineers was assigned responsibility for soils investigations in several of the damaged communities. Most of the investigations were done by Shannon & Wilson, Inc. under a contract with the Corps of Engineers funded by the Office of Emergency Planning. These investigations plus work by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey provided the basis for Task Force 9 mapping of high-risk, nominal-risk, and provisional nominal-risk areas in Anchorage, Seward, and Homer. In high-risk areas, no federal aid was to be made available for reconstruction; in nominal-risk areas, use of federal funds was permitted for reconstruction meeting the engineering provisions of the 1964 Uniform Building Code for Seismic Zone 3. Provisional nominal-risk areas were to be treated as high-risk unless stabilization measures were taken, at which time, they would be reclassified nominal-risk.

Some of the original designations were subsequently modified as additional studies and interpretation were completed. In all cases, the Task Force 9 recommendations were approved by the Commission. Essentially, the Task Force recommendations determined where federal funds would be spent for ground stabilization, repair, reconstruction and relocation (Hansen and others, 1966). The Task Force 9 role and recommendations are discussed in more detail in the sections on the individual communities.

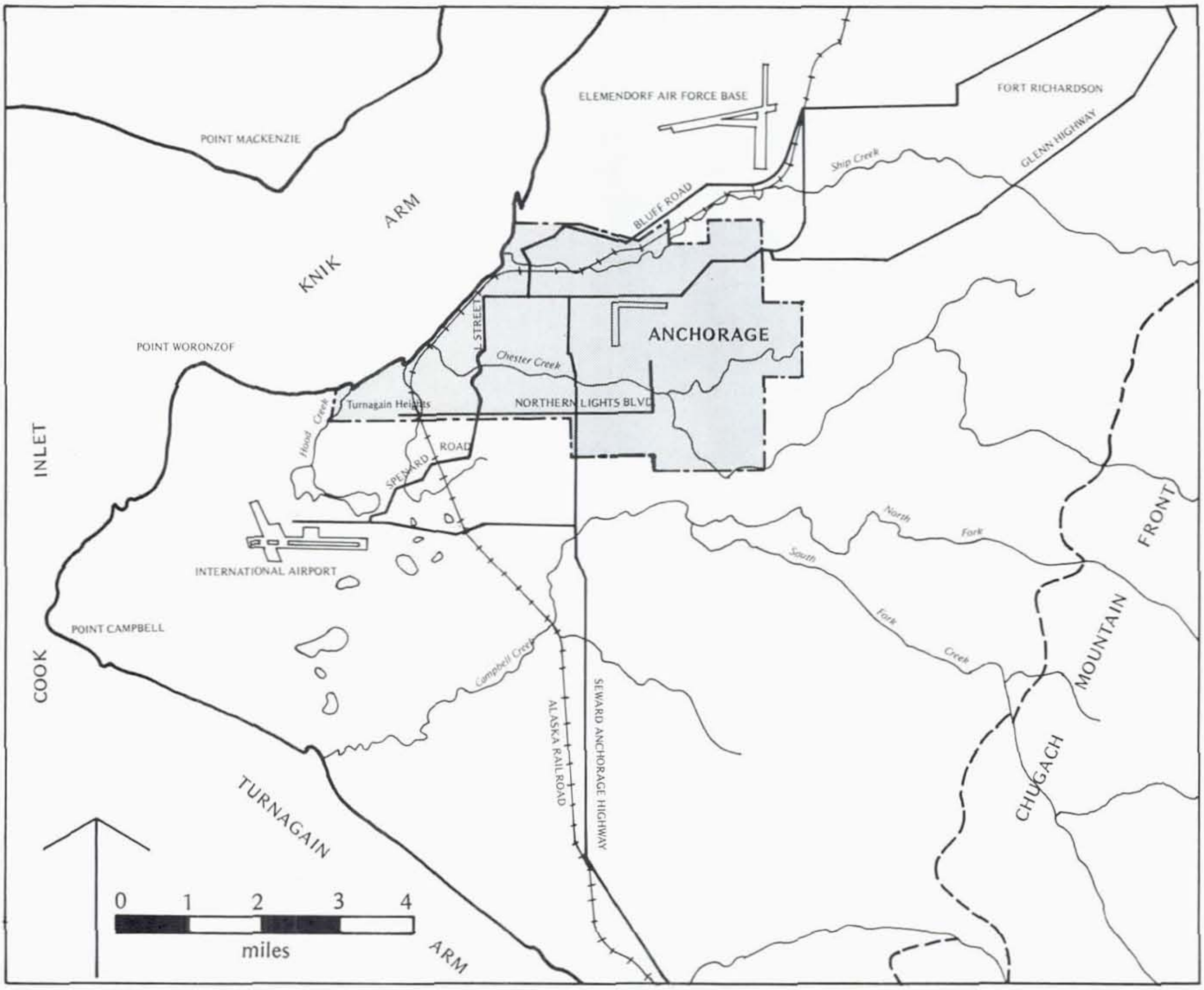


Figure 3. Map of Anchorage area
(Source: from Norton and Haas, 1970, p. 240)

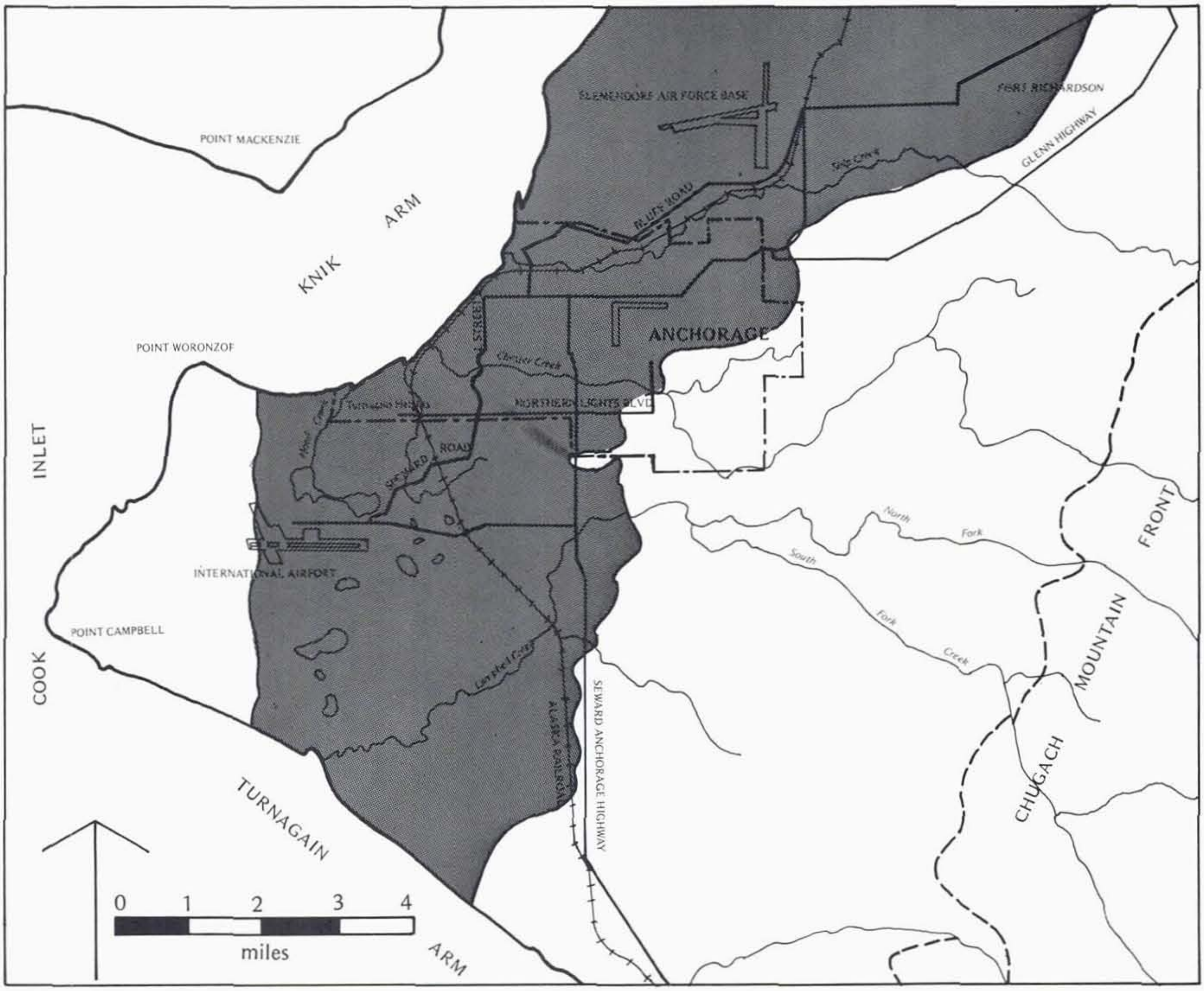


Figure 4. Distribution of Bootlegger Cove Clay in Anchorage and vicinity (Source: Modified from Dobrovolny, 1971, p. 740)

Earthquake Effects and Response

Anchorage, Alaska

Anchorage is located on Knik Arm of Cook Inlet on a plain west of the Chugach Mountains (Figure 3). At the time of the earthquake, the population of Anchorage was nearly 50,000; it was and still is, at a population of over 177,000, the largest city in Alaska. It was the center of retail and wholesale trade, transportation, communications and services for south central Alaska. Elmendorf Air Force Base and the Army's Fort Richardson and other federal facilities and activities constituted a large part of the local economy. Although other areas experienced more severe geologic effects, Anchorage, because of its size and degree of development, sustained greater losses than all the rest of Alaska combined. Earthquake-triggered landslides destroyed some of the most intensively developed parts of the city.

GEOLOGIC SETTING AND EFFECTS

Anchorage is located on a relatively flat plain of glacial deposits consisting of till, sand and gravel underlain by clay, locally referred to as the Bootlegger Cove Clay (Figure 4). This clay is an estuarine-marine deposit which is 50 to 200 feet thick and is interbedded with thin lenses of sand. Most of the Anchorage shoreline is marked by bluffs 60 to over 300 feet high. Many of these bluffs

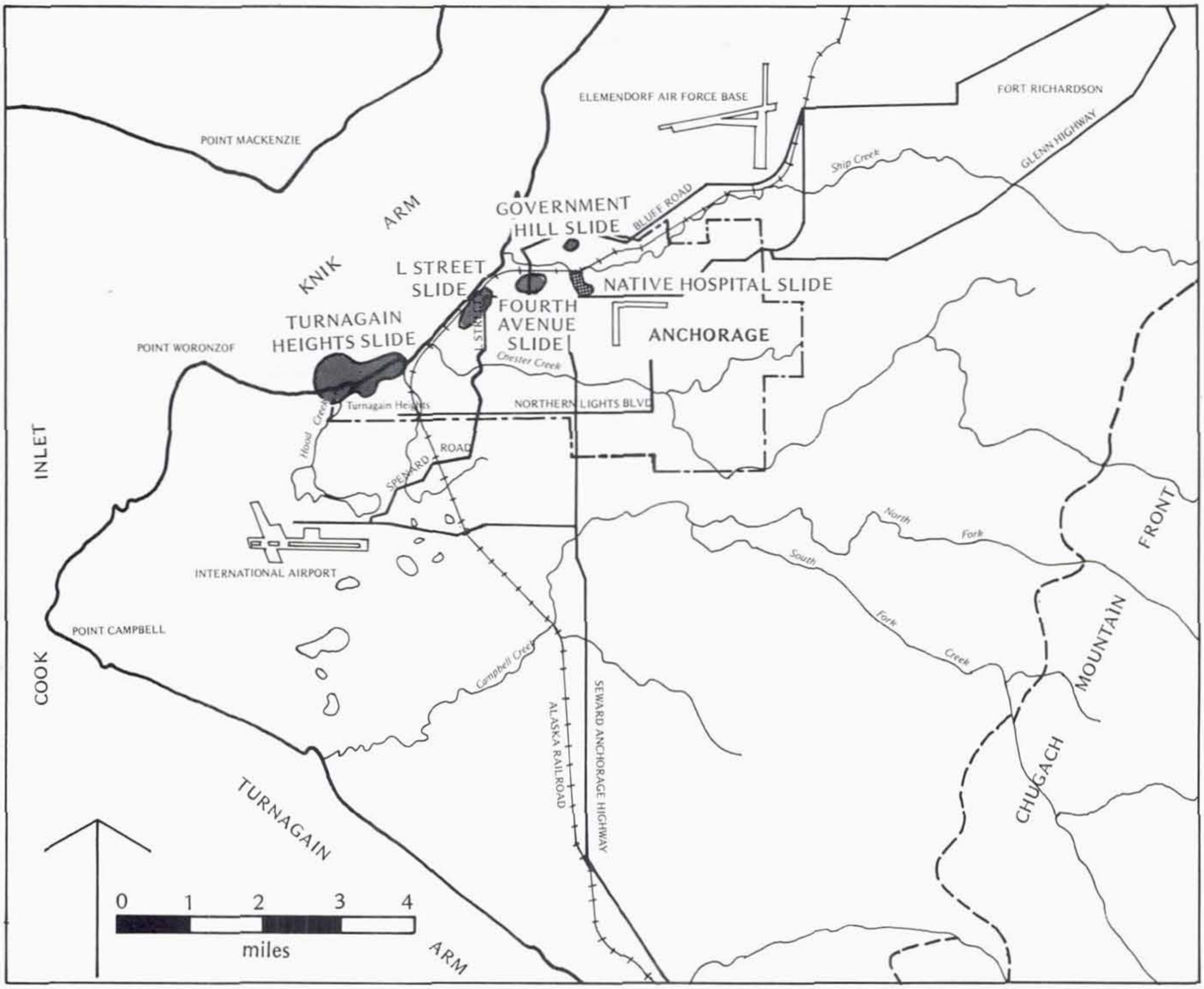


Figure 5. Earthquake effects at Anchorage
(Source: Modified from Hansen, 1965, p. A3, based on data provided by the Engineering Geology Evaluation Group, Anchorage, 1964)

have been or are being actively eroded by tidal currents, storm waves, and stream action. Since 1909, the Point Woronzof Bluff has retreated an average of 2.6 feet per year (Alaska Geological Society, 1973). Landsliding is commonly the agent of cliff retreat. This continuing process was recognized and documented as far back as 1959 when Miller and Dobrovolny described "areas covered by landslides, slumps or flows" where "shocks such as those associated with earthquakes will start moving material that under most conditions is stable."

In Anchorage the earthquake caused five major landslides, localized ground subsidence, widespread ground cracking, and large amplitude, long period ground shaking (Figure 5). The city was not affected by seismic sea waves. The five landslides – Fourth Avenue, L Street, Turnagain, Native Hospital and Government Hill – are shown in Figure 5 and the first three are described in the section, Reconstruction Planning. Most of the destructive landslides in Anchorage involved principally horizontal movement of ground toward seacliffs caused by failure of dynamically sensitive, saturated sand, silt and silty clay of the Bootlegger Cove Clay formation (Hansen, 1965, p. 12). Figure 6 is a block diagram showing characteristics of this type of landslide.

In most of the slides, damage was greatest around the edges of the slide. Some buildings on the slide block in the L Street area were little damaged despite movements of several feet. The large Turnagain slide, however, was characterized by a complete disintegration and drastic lowering of the pre-earthquake land surface. Geologic evidence indicates that landslides similar to those triggered by the March 27 earthquake have occurred in the Ancho-

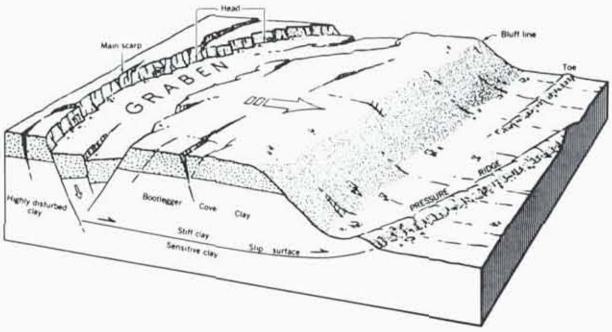


Figure 6. Block diagram of typical slide (Source: Hansen, 1965, p. A40)

rage area at various times in the past (Hansen, 1965).

Ground cracking and fissuring were most pronounced adjacent to landslides and were commonly a consequence of ground tension directly related to sliding. Other pre-existing zones of weakness in the ground such as back-filled utility trenches and peat or muskeg areas were highly susceptible to cracking under the stresses of prolonged vibrations and compaction. Several large sand boils were also evident indicating that portions of some deposits liquefied during the earthquake (Hansen, 1965).

Following the earthquake, Shannon and Wilson, Inc. conducted detailed studies of each of the major landslides to determine failure mechanisms and stability characteristics, and to recommend remedial measures. Procedures for analyzing the stability of slopes subjected to earthquake loading are rather approximate, and it is not surprising that there were, and still are, differences in viewpoint between various engineers and geologists regarding the exact causes of the slides and the susceptibility of other areas to future sliding.

STRUCTURAL DAMAGE

Landslides

The Anchorage landslides resulted in extensive damage. Several commercial buildings were destroyed along the graben of the Fourth Avenue slide and warehouses and other buildings were damaged by the pressure ridges. Several small office buildings and homes were destroyed along the graben of the L Street slide and the Turnagain slide resulted in the loss of 75 homes. A school, two residences and an Alaska Railroad building were destroyed by the Government Hill slide.

Ground Shaking

This earthquake illustrated the selective effect of ground shaking on structures. It is estimated that the maximum acceleration in Anchorage was about 15%g with a dominant period in the one-half to one second range. Estimates or measurements of the duration of felt ground motion ranged from three to seven minutes. From a tape recording of the earthquake, it is estimated that ground shaking lasted four minutes with 30 seconds of motion at 14%g and 20 seconds at 9%g.

This shaking did not damage well-built, low, stiff structures such as one story homes; nor did it overturn small objects or empty shelves. However, the taller structures fared badly. The three 14-story structures in the city were badly damaged and the Airport Control Tower and the six-story Four Season's apartment building collapsed. The five-story J.C. Penney store was so badly damaged that it had to be demolished. One major column of the six-story Cordova Building failed. The eight-story Hill Building was badly damaged. The latter four buildings had been designed to meet Zone 3 Uniform Building Code requirements. All of these buildings had natural periods of vibration in the one-half to one second range — the same as the dominant period of the ground shaking. Damage tends to be intensified when the period of ground shaking is close to the natural period of a structure.

Many lower buildings either collapsed or were badly damaged, but their difficulties could generally be traced to problems in design or construction. Some buildings were virtually unbraced; poor workmanship was observed in several cases; and in some instances, precast concrete units were welded together with brittle connections. As a result of these observations, many changes were made in the 1967 and 1970 editions of the Uniform Building Code.

Utilities

Water supplies in Anchorage came from seven wells and an impoundment on Ship Creek. The Ship Creek water, about half the total supply, passed through a treatment facility. The distribution system consisted of about 140 miles of pipe from 2 inches to 20 inches in diameter, buried a minimum of 10 feet to prevent freezing. About half the pipeline was of cast iron and half of asbestos cement. With the failure of the electrical power supply, pumps stopped and no water was available. After about an hour and a quarter the damaged treatment plant was judged to be usable, and the standby generator was started. Damaged pipes and pipes serving the landslide area were valved off, and water was supplied to the remaining parts of the city. Four of the seven wells were placed in operation when electrical power became available. Three of the wells were located in slide areas and were inoperable. The military supplied potable water in trucks for as long as two weeks in some areas. Surface pipelines were laid starting five days after the earthquake to service some areas.

Sewers were extremely vulnerable. Several of the nine outfalls and collector mains crossed slide areas and consequently were destroyed. When the electrical power failed, the lift pumps stopped operating, and with the water cut off, there was little sewage flowing. There were numerous leaks. These leaks and breaks, coupled with the broken water distribution system, meant that water was contaminated and users were cautioned to boil water. Because tectonic changes in elevation changed grades, sewage did not flow properly and the sewers plugged up.

The electrical generators switched off at the time of

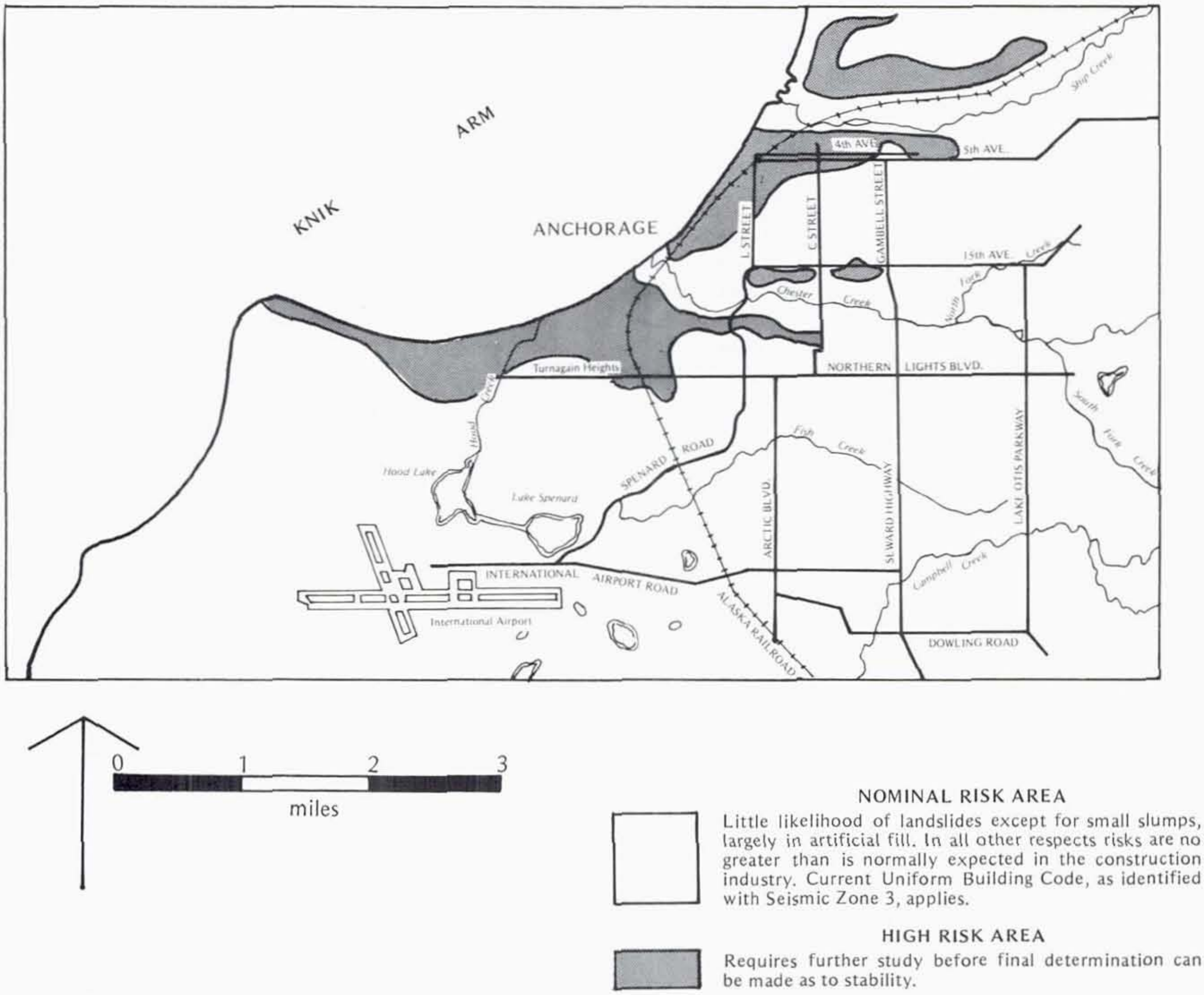


Figure 7. Map showing risk areas in Anchorage and vicinity, May 19, 1964
(Source: from Scientific and Engineering Task Force, 1964, reprinted in Hansen and others, 1966, p. 56)

the earthquake. One could not be used because the control panel tore loose from the floor and fell over. The natural gas fuel supply was cut off. Another generator was started on fuel oil but went off again about 2-1/2 hours after the earthquake because the fuel oil storage tank had been damaged by a slide. Most of the electrical distribution system was on poles above ground. While the poles broke, bent, or were displaced by shifting ground, the conductors generally held and the overhead system was 75% operational. Many underground ducts used for the downtown area were destroyed.

All of the telephone exchanges lost electrical power and switched to emergency batteries. The relay racks overturned at one exchange. Nearly all of the overhead cables throughout the area remained undamaged except in the slide areas. Underground cables were destroyed in the Fourth Avenue and L Street slides. Some areas and exchanges remained operational.

RECONSTRUCTION PLANNING

Recovery and reconstruction efforts in Anchorage centered on those areas extensively damaged by landsliding. The need for information on the extent and mechanism of failure and the likelihood of future failure was paramount. Under the leadership of Dr. Lidia Selkregg, a geologist with the Alaska State Housing Authority (ASHA), a volunteer group of local engineers and geologists called the Engineering Geology Evaluation Group, was formed immediately after the earthquake to conduct field investigations of the major slides in Anchorage. The work of this group was important in defining the major problem areas and providing focus to subsequent, more detailed investigations. As stated by U.S. Geological Survey geologist, Wallace Hansen:

> The work of the Engineering Geology Evaluation Group deserves high praise. Its preliminary findings and recommendations were completed on April 12,

1964, 2 weeks after the earthquake, and a final report was completed on May 8, 1964. The findings and conclusions of the group provided the basis for many subsequent investigations by other agencies.

(Hansen, 1965, p. A11)

The field team of the Scientific and Engineering Task Force (Task Force 9), established by the Federal Reconstruction Commission, drew upon the work of the Engineering Geology Evaluation Group in its initial mapping of high-risk areas in Anchorage. The Federal Reconstruction Commission, accepting the recommendations of the Scientific and Engineering Task Force, designated high-risk areas in Anchorage on May 19, 1964 (Figure 7). An immediate effect of the release of this map was to encourage repair and reconstruction in the major part of Anchorage designated "nominal risk." Federal aid was available for rebuilding in this area, but the Federal Reconstruction Commission withheld federal funds for rebuilding in the high-risk areas pending further study. The boundaries of the high-risk areas were drawn conservatively to prevent reconstruction until additional studies could be completed and possible stabilization measures and building design criteria developed.

On July 27, a revised map was released showing significantly smaller high-risk areas (Figure 8). An additional risk category called "provisional nominal-risk area" was used to designate areas which could be reclassified as "nominal risk" upon completion of stabilization projects. If stabilization was not carried out, these areas were to be considered "high risk" and, thus, ineligible for federal reconstruction assistance. Parts of the Fourth Avenue, L Street and Turnagain slide areas were reclassified from high risk to nominal risk.

On September 8, 1964, the final risk map was released (Figure 9). The risk classifications were based on comprehensive studies conducted by the U.S. Army Corps of Engineers, the U.S. Geological Survey, and Shannon and Wilson Inc., and guided federal funding for reconstruction. A press release issued with the final map presented the final recommendations of Task Force 9. For areas that actually slid, the Task Force stated that:

> . . . certain stabilization measures are considered necessary to assure the future safety of these and adjacent areas. It is believed that even though these areas are reasonably safe under normal static conditions, dynamic stresses from future similar earthquakes would cause renewed disastrous movements either in the disturbed areas or in adjacent land. In general, stabilization will probably take the form of regrading of the surface, drainage, some form of buttressing, or some combination of these.
>
> (Scientific and Engineering Task Force, Press Release of September 8, 1964, as reprinted in Hansen and others, 1966, p. 59)

Special engineering consideration was recommended for construction on any steep slope and, in all areas, the Task Force recommended that design and construction be in accord with Uniform Building Code provisions for Seismic Zone 3.

The functioning of Task Force 9 and the response to its recommendations is interesting. The progressive refining of information and, consequently, the reduction in the size of the high-risk areas is an interesting example of a process particularly suited to post-disaster planning situations in which the need to reach decisions rapidly is so important. Also, the members of the field team seemed to have been remarkably adept at establishing and maintaining good working relationships with the Corps of Engineers, Shannon and Wilson, the Federal and State Reconstruction Commissions, the Federal Office of Emergency Planning and local officials. Particularly important was the complete and generally favorable press coverage given to the Task Force efforts. Undoubtedly, the Task Force faced political pressures. A great deal was at stake for property owners in areas designated high risk and, at the least, the whole process delayed reconstruction decisions in suspected high-risk areas. However, it appears the Task Force remained objective and based its recommendations on the best information available.

The work of the Task Force provided the key information needed for reconstruction planning in a remarkably short period of time. Planning centered on what to do in the slide areas. Especially interesting are decisions relating to the three largest landslide areas: Fourth Avenue, L Street and Turnagain Heights. The following sections describe what was done in these three areas.

Fourth Avenue Slide

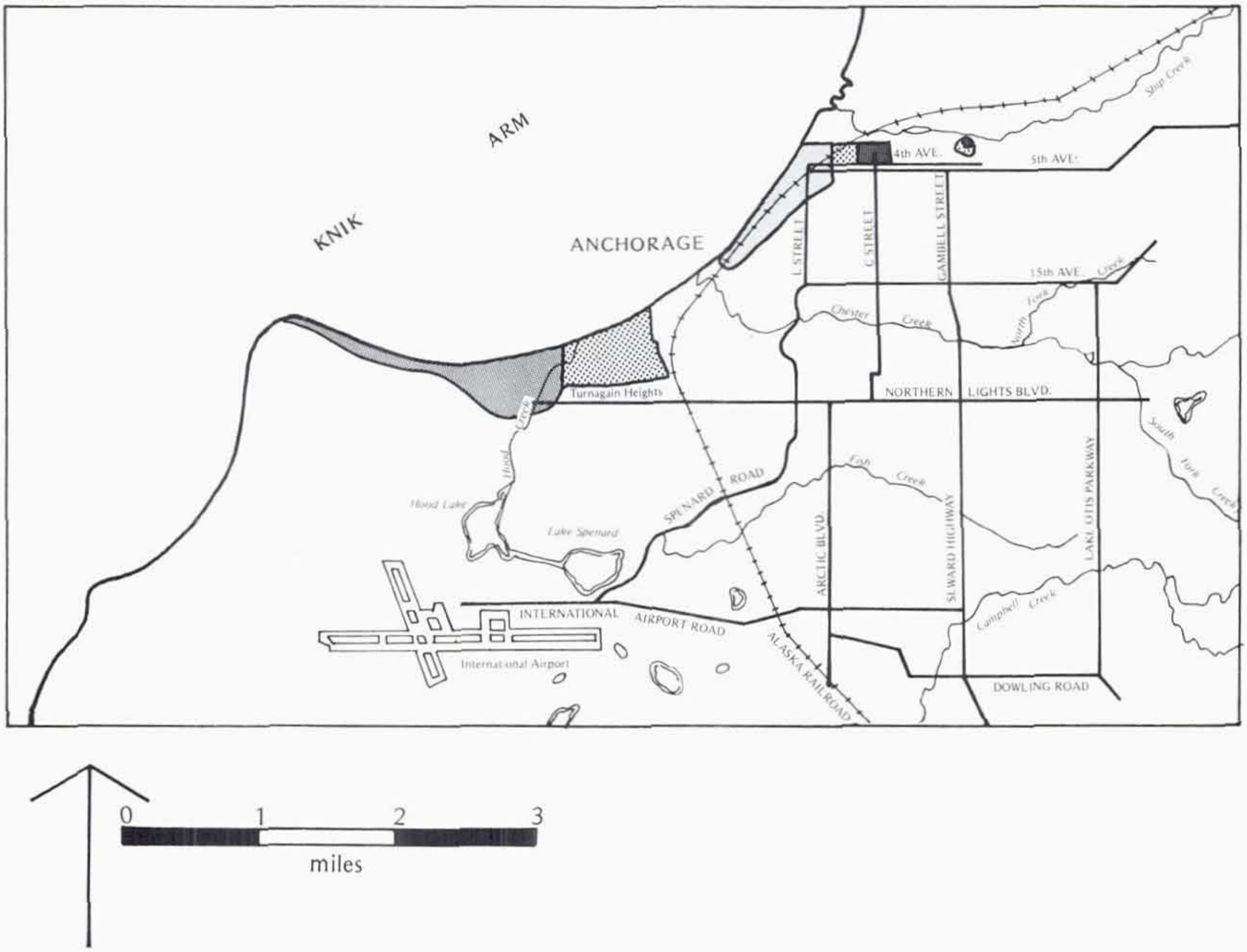
The Fourth Avenue slide is described by Stanley Wilson (1967) as a single 36 acre block which moved horizontally about 17 feet (Figure 10). A graben or trench-like depression approximately 11 feet deep, 100 feet wide and 1800 feet long developed along the southern edge of the slide causing the collapse of numerous buildings on the north side of Fourth Avenue (Figure 11). Pressure ridges at the toe of the slide pushed over buildings and warehouses between First and Second Avenues (Figure 10).

According to Wilson (1967), failure was apparently caused by loss of strength in one or more cohesionless zones within the Bootlegger Cove Clay and subsequent failures are to be expected. Wilson indicated the most effective remedial action would be to construct a buttress over a shallow trench near the toe of the slide near First Avenue and to regrade the entire slide area.

Task Force 9 Recommendations

Task Force 9 accepted the idea of constructing a buttress to stabilize the Fourth Avenue area and recommended that once stabilization had been achieved, the area be reclassified from high risk to nominal risk with the following conditions:

> 1. Construction below Fourth Avenue between Barrow and E Streets should be limited to parks, parking areas, and light structures not over two stories in height.
> 2. Even for such structures the depths of excavations and fills and weights of buildings should be restricted to prevent impairment of the buttress' effectiveness.
> 3. Particular attention should be given to the design of structures and their foundations in the entire slide area to prevent damage from anticipated localized vertical and horizontal movements caused by normal soil consolidation.
>
> (Scientific and Engineering Task Force, Press Release of September 8, 1964, as reprinted in Hansen and others, 1966, p. 59)



NOMINAL RISK AREA

Little likelihood of landslides except for small slumps, largely in artificial fill. In all other respects risks are no greater than is normally expected in the construction industry. Current Uniform Building Code for Seismic Zone 3 applies both to new buildings and to plans for rehabilitation of earthquake-damaged structures. Special engineering consideration should be given to construction near the top, at the base and on the steep slopes wherever the Bootlegger Cove Clay is present. No filling, cutting or construction should be permitted that will steepen or increase the load on or above these slopes.

Properties at bases of bluffs, such as Point Campbell and Rabbit Creek areas, may be subject to damage by future slump landslides even though outside of high risk zone.

PROVISIONAL NOMINAL RISK AREA

Reclassification to "Nominal Risk" in this area is contingent upon construction of property designed stabilization. Even with stabilization, certain restrictions on land utilization must be applied. If stabilization is not effected, land will be High Risk Final Classification.

Special consideration should be given to design in this area. This is because differential horizontal and vertical ground displacements can be expected.

Area subject to regrading. Should be used only for light structures of limited dimensions, parks and vehicle parking. Lower limit can be defined only after final design of stabilization measures.

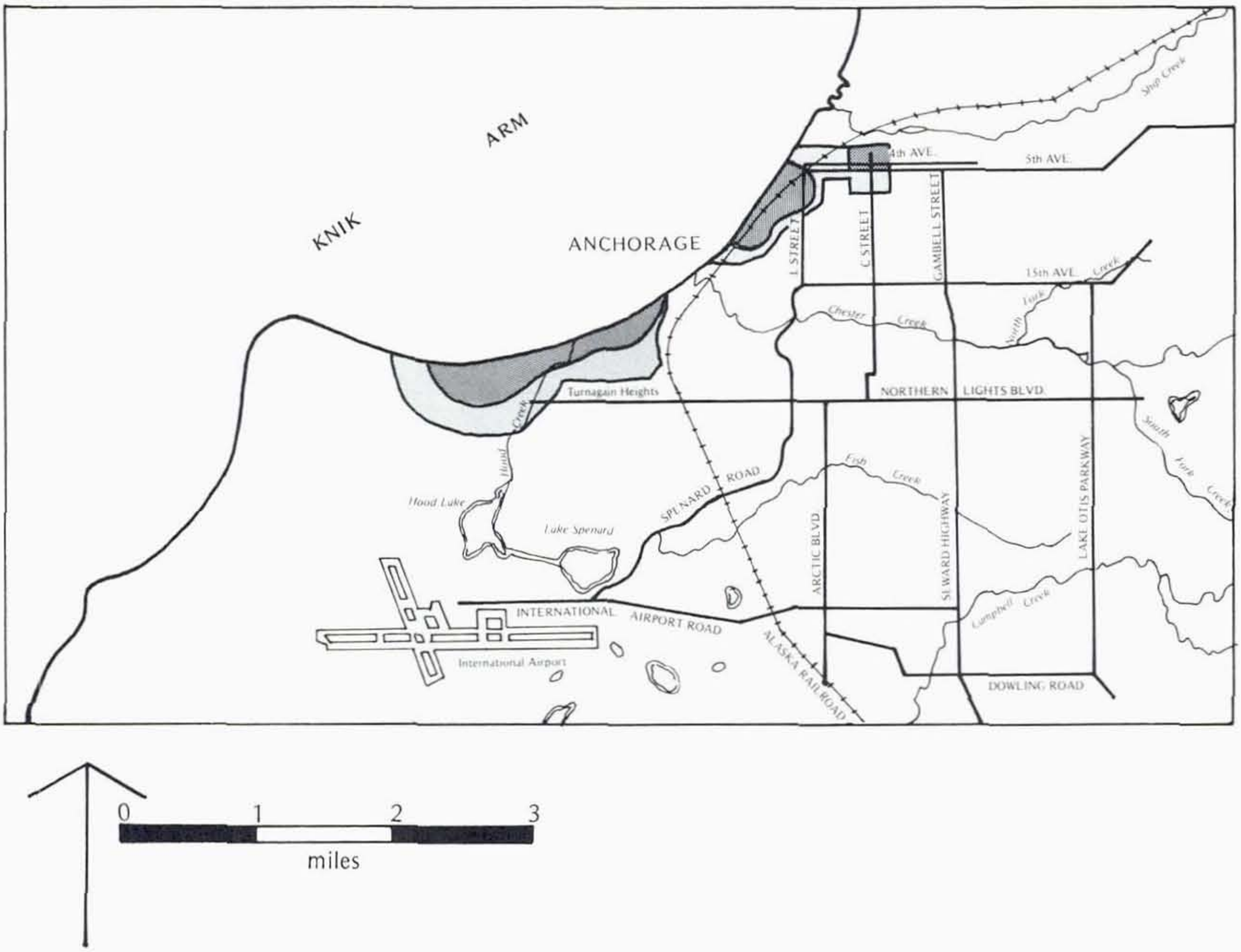
HIGH RISK FINAL CLASSIFICATION

Land considered unstable, particularly in event of future earthquakes; no economical means of stabilization known. No repair, rehabilitation or new construction involving use of Federal funds is recommended. The exact position of the line between High Risk and Provisional Nominal Risk in the Turnagain Heights area is dependent on the outcome of engineering studies of the proposed stabilization measures.

HIGH RISK PENDING FINAL CLASSIFICATION

Requires further study before final determinations can be made as to stability.

Figure 8. Map showing risk areas in Anchorage and vicinity, July 27, 1964 (Source: from Federal Reconstruction Commission, 1964, p. 61)



NOMINAL RISK AREA

Little likelihood of landslides except for small slumps, largely in artificial fill. In all other respects risks are no greater than is normally expected in the construction industry where structures are built on a thick sequence of unconsolidated sediments. Current Uniform Building Code for Seismic Zone 3 applies both to new buildings and to plans for rehabilitation of earthquake-damaged structures. Special engineering consideration should be given to construction near the top, at the base, and on steep slopes, especially wherever the Bootlegger Cove Clay is present. No filling, cutting, or construction should be permitted that will steepen or increase the load on or above these slopes.

PROVISIONAL NOMINAL RISK AREA

Reclassification to "nominal-risk" in these areas is contingent on stabilization of adjacent slide areas or stabilization within the areas themselves. If stabilization is not effected, land will be "high-risk" classification.

UNSTABLE AREA

Land considered unstable in the event of future earthquakes unless stabilization is attained. No new construction and only limited rehabilitation is recommended unless stabilization is attained. It is recommended that after stabilization new buildings on Fourth Avenue, L-K Streets, and Government Hill slides be limited to light structures not over two stories high. No buildings are recommended on the Turnagain Heights slide between the bluff and tidewater, nor on the First Avenue slides, even after stabilization. If stabilization is not effected, land will be "high-risk" classification.

Figure 9. Final map showing risk areas in Anchorage and vicinity, September 8, 1964
(Source: from Scientific and Engineering Task Force, 1964, reprinted in Hansen and others, 1966, p. 58)

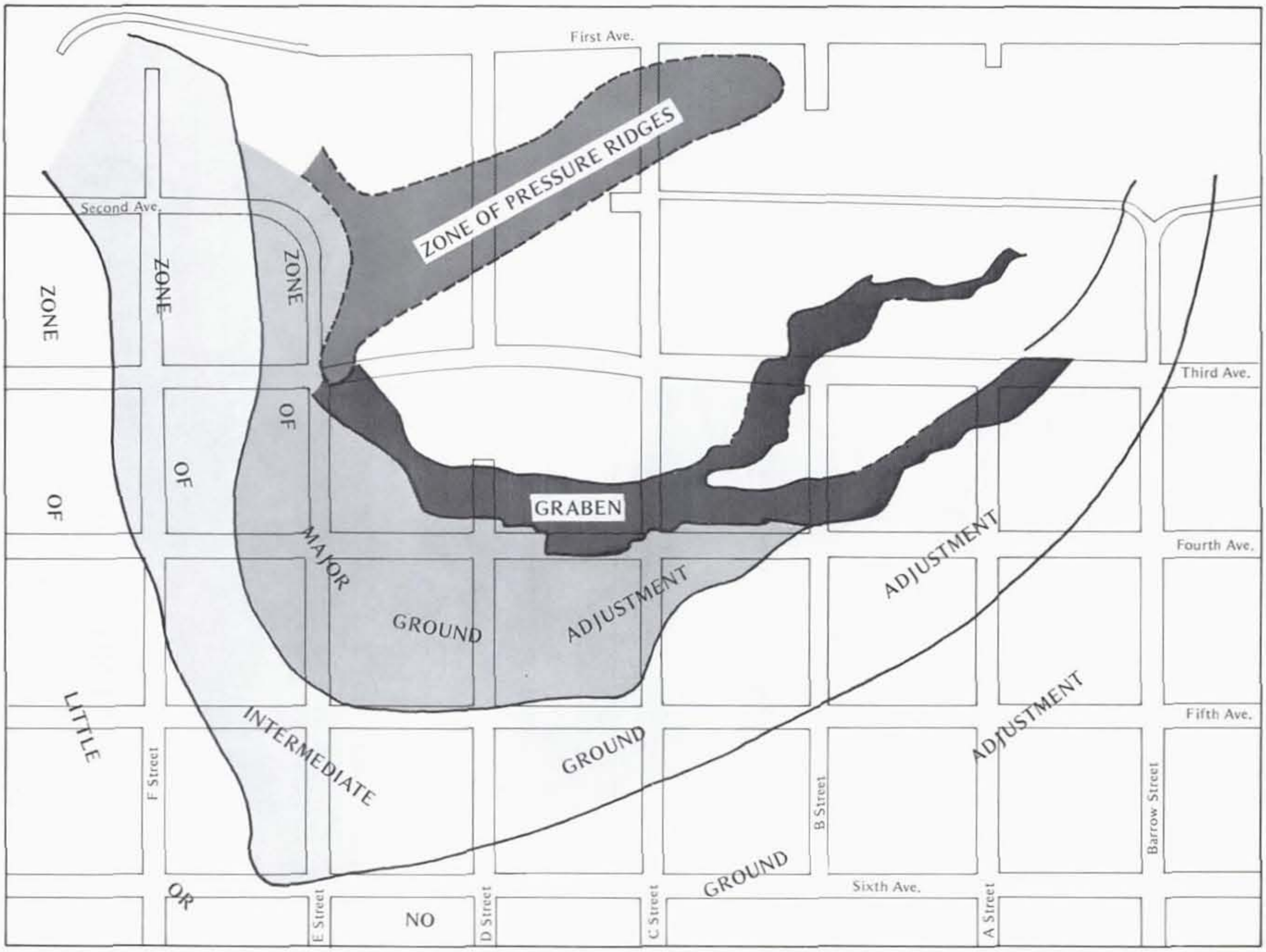


Figure 10. Fourth Avenue landslide area, Anchorage, Alaska (Source: Modified from Shannon and Wilson, 1964, p. 45)

Reconstruction Decisions

A significant portion of Anchorage's central business district was destroyed in the Fourth Avenue slide. At the time of the earthquake, a redevelopment plan for the downtown area was almost completed (Crittenden, 1964). The plan, however, did not deal with potential instability and was useful after the earthquake primarily as evidence of an on-going planning program in Anchorage and as support for the concept of using the reconstruction process as an opportunity to achieve broader revitalization objectives.

In the immediate post-earthquake period, the staff of the city planning department recognized the need and potential for achieving a major redevelopment of the downtown area (Saroff and Schoop, 1964, p. 321). Planning proceeded quickly, even before geologic information defining hazard areas was available. To deal with this lack of critical information, the planning staff generated four plans based on different assumptions about the degree of geologic instability. Each used floor space projections, parking demand and traffic information prepared for the pre-earthquake redevelopment plan. Each plan was based on one of the following assumptions:

1. the downtown should remain essentially as it had been except for the slide areas;
2. even sound structures within 500 feet of the slide areas should be eliminated;
3. the downtown should be shifted a few blocks to the south;
4. the downtown should be completely relocated to a site on the edge of the city.

The possibility of relocation of the downtown apparently drew the most attention from the planners; it was considered an intriguing idea (Saroff and Schoop, 1964, and Haas and others, 1977).

The geologic report of the Engineering Geology Evaluation Group, issued in April 1964, indicated that most of

Figure 11. Building damage along Fourth Avenue caused by the slide. The 14-story Anchorage-Westward Hotel, still under construction, is a few feet from the slide area in the right background.
(Source: Norton and Haas, 1970, p. 258) Photo Credit: U.S. Army

the downtown area was stable, thus forestalling further consideration of relocation of all or part of the central business district. The report prompted immediate action, in line with the second planning alternative, to plan for land reuse in the L Street and Fourth Avenue slide areas coupled with complete redevelopment of the downtown. Candeub, Fleissig, and Associates was retained, at the suggestion of the Federal Housing and Home Finance Agency (HHFA), to prepare a redevelopment plan for the downtown area including both the Fourth Avenue and L Street slides (Selkregg and others, 1970, p. 193). The plan, completed in April 1964, proposed open space in both slide areas with the core of the business district moved one block south to Fifth Avenue (Figure 12).

Architects Robert A. Alexander and Edwin B. Crittenden detailed the basic ideas of the April plan in a plan and model completed by June 1964 (Figure 13). The slide areas were to be publicly-acquired for use for off-street parking, parks, and landscaped areas with some light one-story pavilions and tourist attractions. No real effort was made to generate public support for this plan and with so much earthquake-caused destruction, people objected to the demolition of any sound buildings. Attention shifted to construction of a buttress to stabilize the Fourth Avenue slide and renewal of downtown at its pre-earthquake location. Financing the stabilization through a federally-funded urban renewal project appeared to be the most feasible approach.

When the Task Force 9 final map of risk areas and press release were issued on September 8 showing a reduced risk area around the Fourth Avenue slide and recommending stabilization, pressure mounted to reduce the

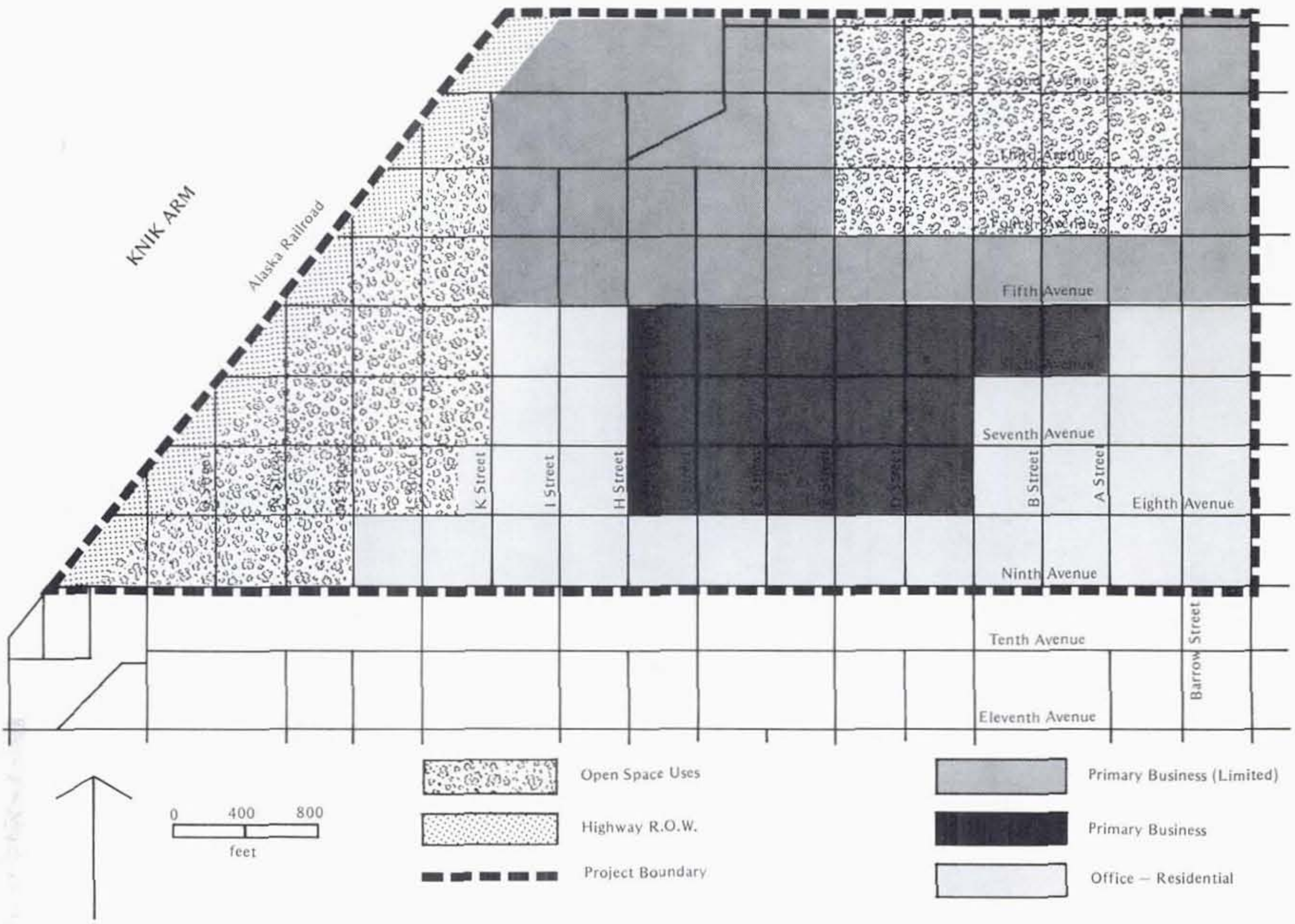


Figure 12. Candeub, Fleissig, and Associates redevelopment plan (Source: Selkregg and others, 1970, p. 195)

Figure 13. Model of CBD redevelopment proposed by Alexander and Crittenden (Source: Selkregg and others, 1970, p. 196)

size of the proposed urban renewal project area. A land reuse plan was prepared by the city planning staff and the Alaska State Housing Authority (ASHA) covering only the area north of Fourth Avenue which was needed for the construction of the buttress recommended by Shannon and Wilson (1964). This plan, approved by HHFA as Urban Renewal Project R-20, provided the basis for acquiring land for construction of the buttress and redeveloping the buttress area. Figure 14 shows debris clearance underway in part of the project area with the Anchorage Westward Hotel in the background. The properties were acquired by ASHA with owners compensated on the basis of the square footage stated in pre-earthquake deeds. Replatting was achieved through urban renewal (Selkregg and others, 1970, p. 234).

Changes in the project plan were made later to incorporate the Corps of Engineers' recommendations for construction on the buttress and provide for the A & C Streets traffic loop. The final plan, shown in Figure 15, was limited in scope, but expected to spur the private revitalization of the rest of the downtown. The buttress was completed in fall 1967 (Figure 16) and the urban renewal project was closed in August 1978 at a federal

Figure 14. Debris clearance from the Fourth Avenue slide area. Fourth Avenue is on the left; the slide moved toward the right. The high-rise building in the background is the Anchorage-Westward Hotel.
(Source: Eckel and Schaem, 1970, p. 173) Photo Credit: U.S. Army Corps of Engineers

cost of almost $9 million (Don Phillips, 1978, telephone conversation). Few privately-owned parcels were in the buttress area, as most of the land was owned by the Alaska Railroad, and very few repairable buildings had to be cleared to make way for the buttress construction or redevelopment. Privately-owned land was acquired and cleared along the north side of Fourth Avenue and in other scattered locations. The south side of Fourth Avenue was repaired and rebuilt with essentially the same uses existing before the earthquake. There is a marked difference in appearance between the two sides of the street.

Construction requirements, recommended by the Corps of Engineers and included in the urban renewal plan, limit the height and weight of structures and the depth of excavation and fill in the project area. Seismic design calculations, drawings and specifications must be done by registered professional structural and foundation engineers and furnished to the Alaska State Housing Authority.

So far, the recommendations of the Corps of Engineers governing construction on the buttress have been followed, and there appears to be great confidence in the safety of the buttressed area. Some concern has been expressed that large scale development in the areas adjacent to the buttress may affect stability through overloading. One approach has been to excavate soil equivalent in weight to the weight of the building prior to construction, however, the need for such measures is determined on case by case basis. Also, questions have been raised by geologists about the present stability of the area, but a recent consultant's report requested by the Corps of Engineers concludes that ripples observed in the parking lot pavement at the Alaska Railroad depot (at the base of the buttress) are the result of frost action and do not indicate

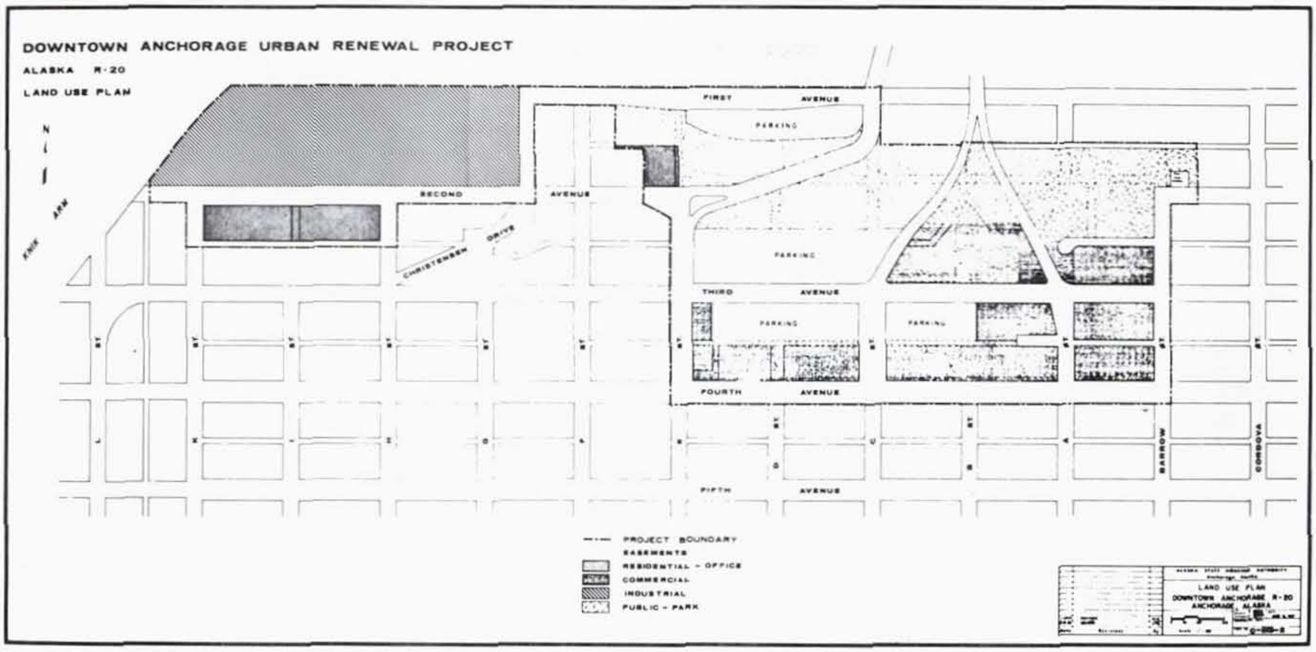


Figure 15. R-20 Redevelopment Project Plan — Fourth Avenue slide area (Source: Alaska State Housing Authority, Book 200, p. 339)

Figure 16. Fourth Avenue buttress looking toward Anchorage-Westward Hotel, Summer 1978

Figure 17. Shopping malls on north side of Fourth Avenue at top of buttress. Anchorage-Westward Hotel in background, Summer 1978.

any instability within the buttress (Schmoll, Ferrians, Long, 1978 telephone conversations). Instruments were installed to monitor the behavior of the buttress but there is some concern that there may be inadequate monitoring of stability conditions in the area.

Existing development in the redevelopment area closely parallels the adopted plan. A long, low Holiday Inn and parking lot cover most of the area between A and C Streets and Third and Fourth Avenues. Two malls — more open in design than the Holiday Inn — with space between the structures and associated parking cover the area between C and E Streets (Figure 17). All buildings have two levels facing Fourth Avenue and three levels facing Third.

Reasons

The Fourth Avenue area was the only slide area in Anchorage which was deliberately stabilized and the only area for which an urban renewal plan was accepted and carried out. As the extent of the high-risk area was decreased, so were the boundaries of the urban renewal project. As a redevelopment project, R-20 appears to be a mixed success. It apparently achieved its major objective of stabilization of the slide and, thus, reducing the risk of land failure in future earthquakes. However, other objectives, such as revitalizing and beautifying the downtown area were only partially met because of the limited scope of the finally adopted project.

Why was stabilization undertaken at all in the Fourth Avenue slide when nothing was done to stabilize the other slides?

1. A major reason is probably the relatively high value of the property to be stabilized. Amendments to the Alaska Omnibus Act authorized $25 million for urban renewal projects for all damaged communities in Alaska. Funds from this source were insufficient to stabilize all the slide areas in Anchorage and correct problems in other communities. It appears a choice was made to stabilize the highest value areas.
2. Another factor was undoubtedly that much of the land needed to achieve stabilization of the Fourth Avenue slide belonged to the federally-owned and operated Alaska Railroad. Compared with the L Street area, few private properties were needed and few repairable buildings had to be demolished. This limited interference with private property rights was important in gaining political acceptability of the project.
3. An additional reason was the desire to maintain the pre-earthquake location of the Central Business District. Commitments made almost immediately after the earthquake by Penney's and the Alaska National Bank to rebuild on their previous sites in the downtown area encouraged other businesses to seek to remain and effectively undercut any support for a major relocation of the business district. Stabilization was a pre-condition for business owners to obtain SBA loans for repair and reconstruction in the slide area.

Why was the redevelopment project limited to the area needed for stabilization?

1. Under the redevelopment proposals, property owners in the project area were to be paid the post-earthquake value for their properties. This was much lower than the value immediately before the earthquake and was considered inadequate compensation by those affected.
2. In this post-disaster situation the desire to return quickly to normal appears to have exceeded any desire to take advantage of the opportunity to achieve objectives not directly related to reconstruction. Strong and imaginative leadership would have been necessary to gain implementation of the early, bolder plans.
3. With so many buildings destroyed in the downtown area, there was little support for tearing down more in the name of urban renewal. The earthquake achieved only partial clearance; many structures, particularly along the south side of Fourth Avenue, remained in sound condition.
4. Under the leadership of Senator Anderson, the Federal Reconstruction Commission was reluctant to recommend funding of urban renewal projects extending beyond areas of destruction or achieving objectives other than recovery.

L Street Slide

The L Street slide was a block slide caused by failure in saturated sands, silts, and clays of the Bootlegger Cove Clay formation. Figure 18 is a map of the slide and Figure 19 shows three cross sections. Figure 20 is an aerial photograph showing the L Street slide and the collapsed Four Seasons apartment building. A graben approximately 250 feet wide and 7 to 10 feet deep opened up at the head of the slide. The 72 acre slide block moved up to 14 feet, but structures on the block were relatively undamaged; most of the damage occurred in the area of the graben (Figure 21). Stabilization of the

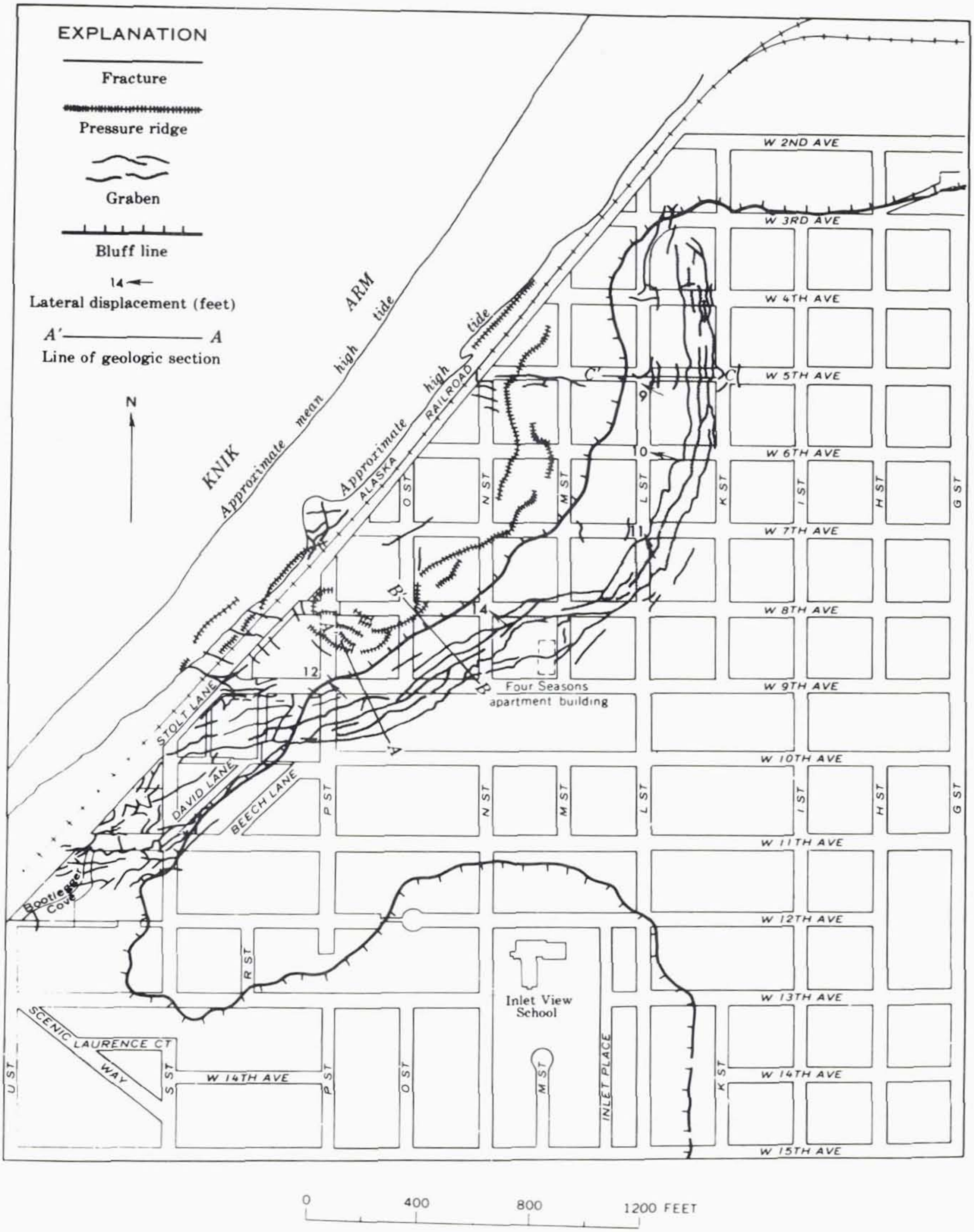


Figure 18. Map of L Street slide. Geologic sections shown in Figure 19. (Source: Hansen, 1965, p. A45)

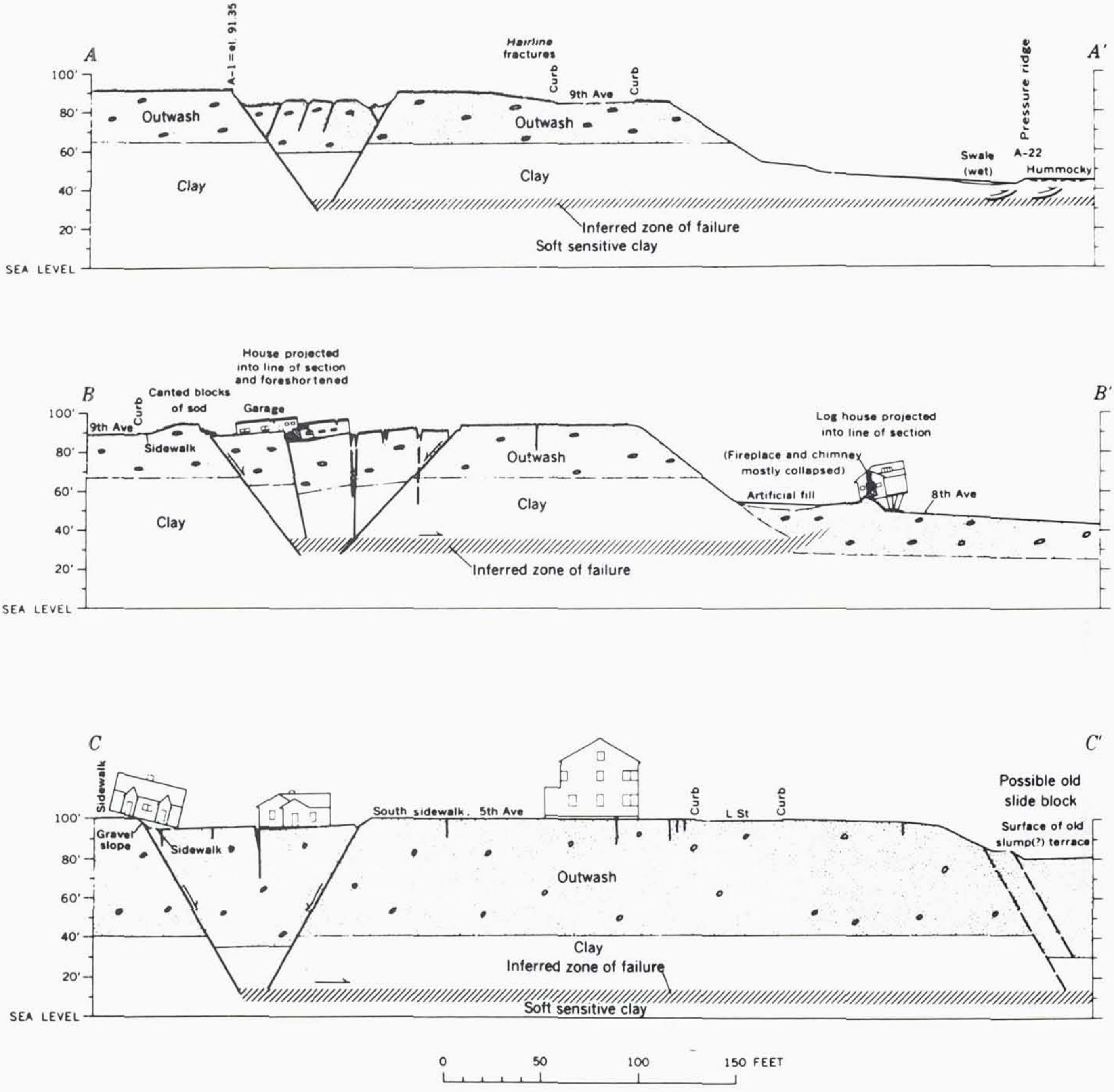


Figure 19. Geologic sections through the L Street slide (Source: Hansen, 1965, p. A48)

slide by a combination of filling and grading was considered technically feasible, but economically questionable (Wilson, 1967). Geologists and engineers who have studied the L Street slide admit that the exact cause and future behavior of the slide are uncertain. However, some recent studies suggest that the slide is "incomplete" and subject to further large-scale movements in future earthquakes.

Task Force 9 Recommendations

The initial Scientific and Engineering Task Force map showed the slide itself and considerable adjacent land in the high-risk category. The area was substantially reduced in the final map of September 8, but a significant area was still considered high risk unless stabilization was

Figure 20. Aerial view of L Street slide. Center right shows collapsed Four Seasons apartment building.
Photo Credit: U.S. Geological Survey

achieved. The Scientific and Engineering Task Force recommendations were:

> Additional studies in the L-K Slide Area have resulted in the conclusion that a significant portion of the area may be returned to Nominal Risk classification if certain stabilization action is taken. These measures may be a combination of slope flattening, drainage, and buttressing. Stabilization would permit the area landward of the graben to be returned to Nominal Risk. In the remaining area toward Knik Arm (seaward), it is anticipated that stabilization, if undertaken, may require removal of some existing buildings. The extent of such removal cannot be forecast until detailed designs for stabilization are completed.
>
> The same design precautions should be applied in the area above the graben line as are outlined for the Fourth Avenue Slide area. In the area below the graben line and toward Knik Arm construction should be limited to light occupancy structures not over two stories in height.
>
> (Scientific and Engineering Task Force, Press Release of September 8, 1964, as reprinted in Hansen and others, 1966, p. 59)

Figure 21. Relatively undamaged house at edge of graben, L Street slide
Photo Credit: Stewart's Photo Shop, Anchorage

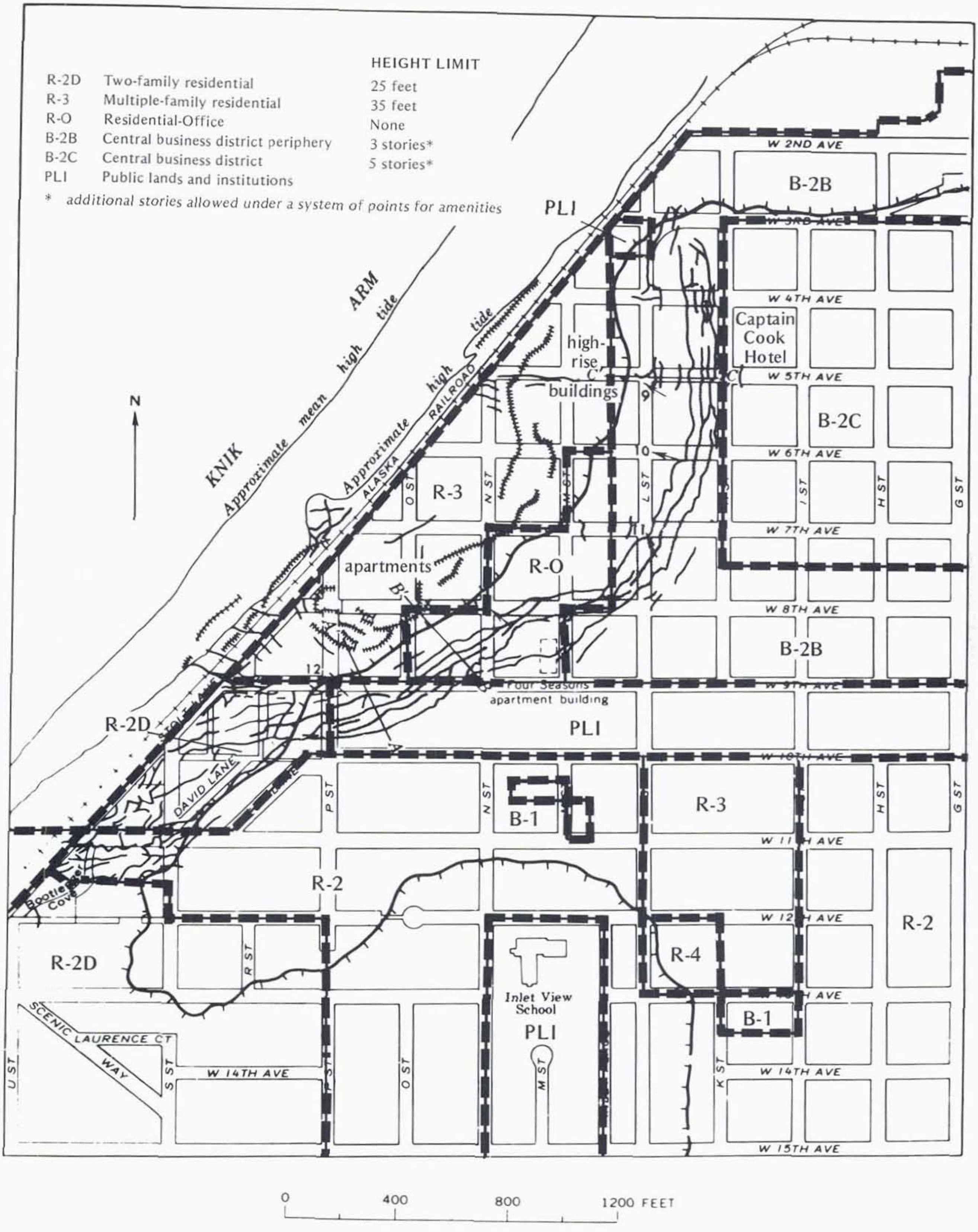


Figure 22. Zoning in L Street slide area (Zones added by William Spangle and Associates, Inc. from Zoning Map of the Greater Anchorage Area Borough, Alaska, updated to May 1978, Sheet 7)

Figure 23. Two new high-rise buildings on L Street slide. See Figure 22 for location, Summer 1978

Reconstruction Decisions

The recommendations of the Task Force were not followed in the L Street area. No engineering or economic study of stabilization was undertaken, no stabilization measures employed, and no special restrictions imposed on reconstruction or new building. Plans proposed by the city staff, Candeub, Fleissig and Associates, and Alexander and Crittenden for the reuse of the L Street slide area as well as the Fourth Avenue slide area were not adopted by the City Council. The area retains its high-risk classification and the Department of Housing and Urban Development (HUD) will not insure loans on property in the area (Rigby, 1978, conversation).

The L Street slide posed a difficult problem for the city. Many structures on the slide block were relatively undamaged although they moved laterally up to 14 feet toward Knik Arm. The high-risk designation precluded federal assistance to property owners for repair or reconstruction, but federal disaster relief funds were used to repair and restore utilities, roads and other public services. Without this, sound structures on the slide would have been rendered useless.

A major problem in the L Street area was reestablishing property lines after the earthquake. This was accomplished by the complete replatting of the area under special legislation enacted by the Alaska State Legislature (Alaska Statute 09.45.860). The basic premise of the replatting was to accept the new location of the land and to rearrange the boundaries as equitably as possible. Public rights-of-way were vacated and added to contiguous lots where needed to create full-size lots.

Since 1964, extensive new construction, including five new high-rise buildings, has occurred on or adjacent to the slide. About a year after the earthquake, the Anchorage City Council voted to rezone the area to permit higher residential densities (Makinson, 1977). In addition, previously designated multiple-family residential areas were rezoned to allow offices uses and, hence, high-rise construction. The Anchorage Comprehensive Development Plan permits residential development at densities ranging from 1 to 40 units per acre. The present (1978) zoning at the L Street slide area is shown in Figure 22. There is no height limitation in the R-O district which spans part of the graben of the slide, and several buildings have been constructed there (Figure 23). New

Figure 24. New apartments below bluff line at the end of 8th Avenue, L Street slide, Summer 1978. See Figure 22 for location

apartments are being built below the bluff in the R-3 zone (Figure 24). No restrictions on development have been imposed in the area to reduce seismic risk and the zoning changes have certainly increased the potential for casualties and property damage in future earthquakes.

Reasons

Property owners in the L Street area did not wish to abandon structures that were undamaged or easily repaired. Compensation at post-disaster values was not sufficient inducement to relocate. Owners began repairs with private funds almost immediately after the earthquake. The city apparently felt it could afford neither stabilization of the slide nor purchase of the properties on the slide. Funds were not even allocated to undertake an economic study of stabilization. The relatively low value uses in the area at the time of the earthquake led to the feeling that stabilization could not be economically justified. Apparently, no one anticipated the high intensity development that characterizes the area today.

Political influences undoubtedly played a part in the decisions concerning L Street. Soon after the earthquake, Walter Hickel, at that time a prominent Anchorage businessman, received a permit to construct a high-rise luxury hotel (The Captain Cook) on the edge of the slide (Figure 25). Other construction permits in and adjacent to the slide area soon followed, and major structures began rising in the L Street area.

Figure 25. Captain Cook Hotel in center background on right side of K Street, Summer 1978. See Figure 22 for location

Figure 26. Aerial view of Turnagain Heights slide (Source: Krauskopf, 1970, p. 252)

Subsequent building in the high-risk area may have been acceptable to developers and investors because they could obtain earthquake insurance. They apparently assumed that any future losses would be covered by insurance or federal disaster assistance. This rationale was further reinforced by the willingness of local financial institutions to fund construction in the area in spite of federal refusal to insure loans.

Risk from future earthquakes is largely discounted, in part, because of the feeling that, having had a major earthquake, another one is a long way off. As stated by a zoning officer in the Anchorage planning department:

> We look at earthquakes here more as a historical incident than as a recurring danger.
>
> (Makinson, 1977)

This view is in sharp contrast to the view held by seismologists, who have researched the historical record and causes of earthquakes in the region, that recurrence of earthquakes is a virtual certainty.

Differences in emphasis between geologists and engineers also play a part in decisions to permit construction in high-risk areas. Some engineers tend to view geologists as ultra-conservative and prone to looking at risk in terms of a geologic time scale. One structural engineer who participated in the design of a large building on the L Street slide bluff claimed:

> The geologist comes as close as anyone I can think of to creating wild rumors. They look at things entirely differently. They're a breed to themselves.

This view was seconded by another engineer:

> There's geologists, and then there's soils mechanics. The geologists, they're looking 10,000 feet down and 10 million years back. The soils mechanic is looking at the structure immediately under his feet; the first few hundred feet down. There's a world of difference in the way they look at things.
>
> (Makinson, 1977)

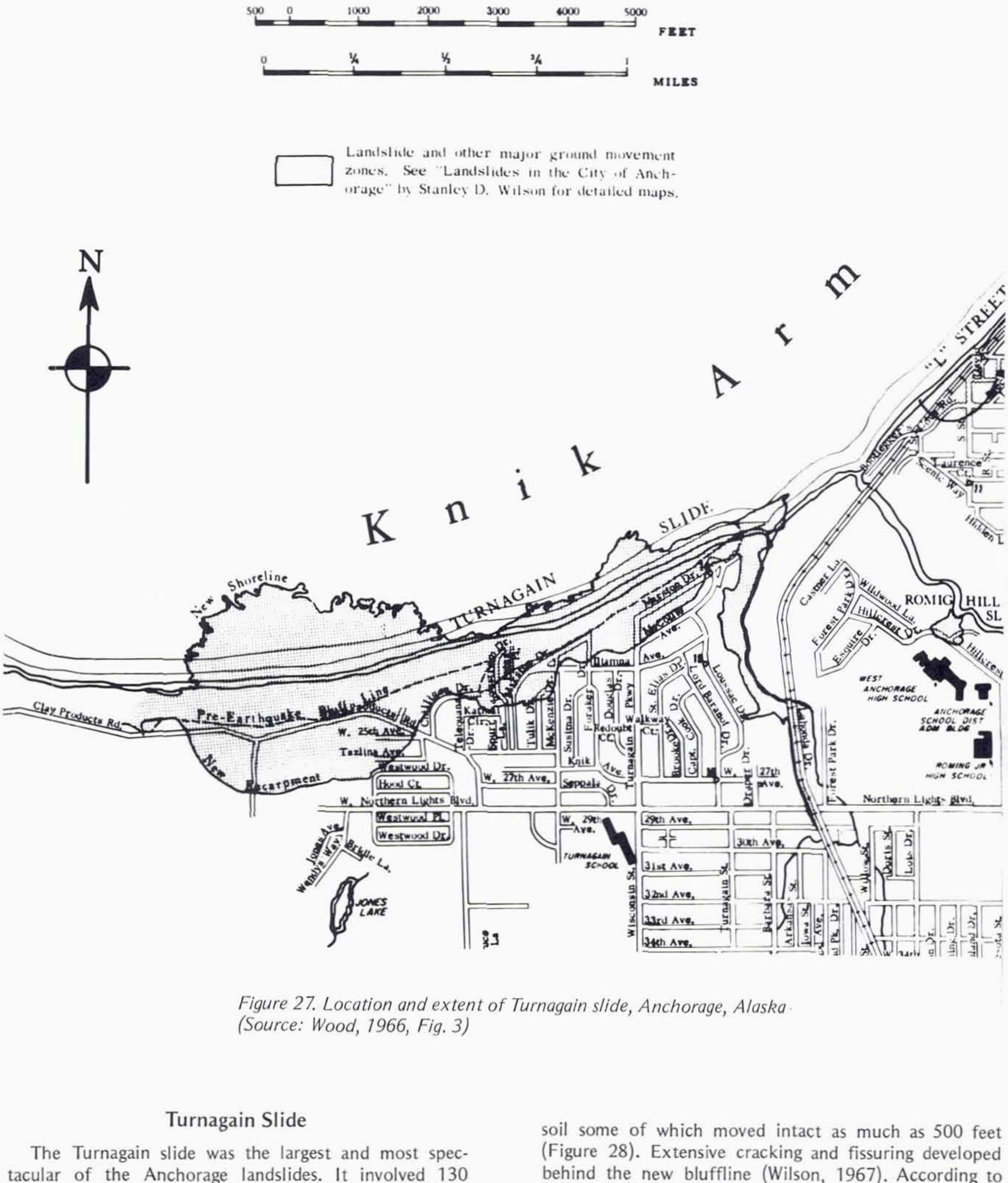


Figure 27. Location and extent of Turnagain slide, Anchorage, Alaska (Source: Wood, 1966, Fig. 3)

Turnagain Slide

The Turnagain slide was the largest and most spectacular of the Anchorage landslides. It involved 130 acres and destroyed 75 homes (Figure 26). The slide extended 8,000 feet alone the coastline and extended inland approximately 600 feet at the east end and about 1,200 feet at the west end (Figure 27). Failure occurred within a weakened zone within the Bootlegger Cove Clay and resulted in a progressive "peeling off" of blocks of soil some of which moved intact as much as 500 feet (Figure 28). Extensive cracking and fissuring developed behind the new bluffline (Wilson, 1967). According to Wilson (1967), "stabilization of the slide and adjacent area to prevent further sliding during a future earthquake must necessarily involve either a substantial general improvement in strength characteristics of the soils in the area, or the provision of a buttress to support the soil mass in the potential failure zone."

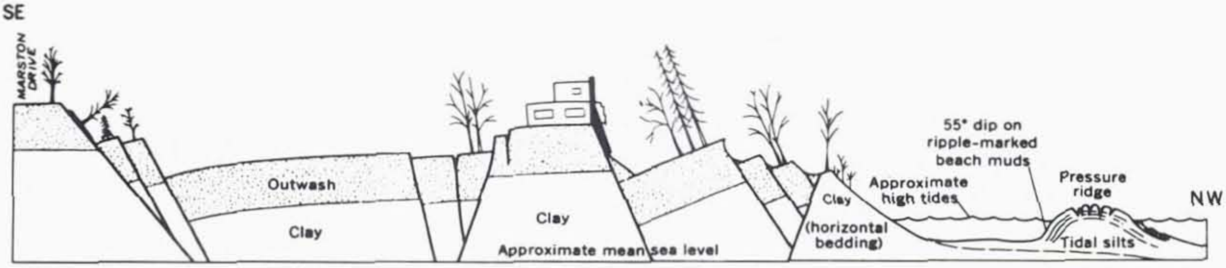


Figure 28. Sketch section through eastern part of Turnagain slide (Source: Hansen, 1965, p. A65)

Task Force 9 Recommendations

The Scientific and Engineering Task Force classified the Turnagain area as "provisional nominal risk" and deemed the area above the new bluffline as suitable for residential construction "after its stability is assured by strengthening of the slide." (Scientific and Engineering Task Force, Press Release of September 8, 1964 as reprinted in Hansen and others, 1966, p. 59). No construction other than drives or walks should be permitted on the slide area itself. Testing to determine the best means of stabilizing the slide was recommended.

Reconstruction Decisions

The Urban Renewal Administration authorized $633,872 for stabilization studies of the Turnagain slide as part of a feasibility survey for a proposed urban renewal project for the area. Several methods of stabilization were tested by the Corps of Engineers and its consultant, Shannon and Wilson, Inc., but all proved unsuccessful (Selkregg and others, 1970). In April 1966, the Corps released a statement that said, in part:

> On the basis of the field and laboratory work that has been done, we have reached the following conclusions. In the interval since the Good Friday quake, the strength of the zone of failure in the Turnagain area has been increasing and has reached or in the fairly near future will reach its original value. The natural slope of slide material that now exists forms a natural buttress that will withstand a quake of similar intensity and duration to the one of Good Friday. The buttress area will remain in a stable condition and the zone behind the escarpment can be removed from the high-risk area provided the buttress is protected against beach erosion. The buttress itself, however, will be subject to substantial differential movements for some time to come, and may experience locally large distortions in future earthquakes. Therefore, construction upon it should not be permitted . . . The natural buttress formed by the earthquake slide must, however, be preserved at its present width between the slide scarp and the existing beach line.
>
> (as reprinted in Selkregg and others, 1970, p. 201)

Based on the Corps recommendations, the Alaska State Housing Authority prepared a redevelopment plan for the area seaward of the new bluffline (new escarpment on Figure 27) calling for park and recreation uses, erosion control measures and a road along the waterfront (Figure 29). The Anchorage Council voted against the plan in June 1967 and moved to consider applications for building permits in the slide area (Selkregg and others 1970). The Federal Housing Administration agreed to insure loans for purchase of property landward of the escarpment with the stipulation that buyers be informed that FHA would not cover losses from another earthquake (Selkregg and others, 1970).

At this time (1978) houses are being constructed on the edge of the new bluffline and at least one duplex is under construction on the slide itself. No erosion control measures have been taken and it appears unlikely that they will be. Shoreline erosion before the earthquake averaged ten feet per year; fifteen to twenty-five feet can erode in a single storm occurring when the beaches are not frozen. There have been no such storms since 1965, but they are likely to occur. In addition, annual erosion of about six inches occurs from "anchor ice" – by a process called "rafting" or "ice plucking" (Irwin Long, 1978, telephone conversation). Much of the toe of the slide, in some places as much as 400 to 500 feet, has already washed away (Irwin Long quoted in Makinson, 1977). Because the slide mass formed a natural buttress to the area landward of the present bluffline, erosion of the slide seriously jeopardizes the stability of not only the slide mass, but also of the development area extending landward almost to Northern Lights Boulevard (see Figure 27). Rubble from destroyed houses, covered over by grading of the slide after the earthquake, is now exposed in several places along the beach – a vivid, but ignored, reminder of the devastation wrought by the 1964 earthquake in the Turnagain area (Figure 30).

Controversy over the issue of rebuilding on the slide in Turnagain led to the formation in 1977 of the Anchorage Geotechnical Advisory Commission. This commission, appointed by the Mayor, advises the municipal adminis-

Figure 29. Aerial photo of Turnagain taken in May 1964 after grading of part of the slide. Proposed urban renewal boundary added.
Photo Credit: Air Photo Tech, Inc., Anchorage

tration and Anchorage Assembly on development in geologically hazardous areas. The commission has consistently advised the Assembly not to permit development of the Turnagain slide area unless its long-term stability can be assured. All presently available information indicates that stability cannot be assured unless erosion of the toe is controlled.

After the earthquake, state land in eastern Anchorage was subdivided and lots made available at a nominal cost to families whose homes had been destroyed at Turnagain. This was accomplished under provisions of previously adopted State Law 116 which permits the relocation of uses from hazardous land to state-owned land. However, acquisition of the hazardous land is optional, and, in the Turnagain case, the state did not take title to the land. Many Turnagain residents received lots in the subdivided state land called Zodiak Manor, but few built homes there. Although land in the Turnagain area was massively disturbed, no replatting has occurred and the pre-earthquake subdivision pattern still pertains.

After the earthquake, the publicly-owned and undeveloped land comprising the western portion of the slide was designated Earthquake Park and was left in its post-earthquake condition as a reminder of the 1964 disaster (Figure 31). The rest of the Turnagain area is shown on the land use plan as residential with a permitted density of 1-10 units per acre. Most of the area is zoned R-1A with a minimum lot size of 8,400 sq. ft. An area bounded by Iliamna Avenue, Clay Products Drive, McKenzie Drive and Marston Drive is zoned for duplexes (R-2A). Figure 27 shows street locations. The Municipality of Anchorage has no zoning district for open space or conservation uses on privately-owned land; the PLI district, which applies to Earthquake Park, is used only for public and quasi-public lands and institutions.

Control of development on the slide area presently depends on the municipality's actions with respect to utility extensions. Suggestions have been made to create a special service district or road improvement district (RID) to finance construction of water, sewer and other

Figure 30. Rubble from houses destroyed in the 1964 Turnagain landslide exposed at low tide, Summer 1978

Figure 31. Earthquake Park — western portion of Turnagain landside left in its post-earthquake condition

Figure 32. Duplex under construction at end of McKenzie Drive on the Turnagain landslide, Summer 1978. See Figure 27 for location.

utility lines and roads in the slide area. Assessments could be as much as $28,000 per lot under such a scheme. Because of this high cost, there appears to be pressure to permit higher density residential construction than presently allowed, greatly increasing the potential exposure to seismic hazards. Otherwise, housing built on the slide would be prohibitively expensive for most families. The first structure built on the slide itself is a duplex under construction in August 1978 (Figure 32).

An ordinance adopted by the Anchorage Assembly in 1978 prohibits development on the Turnagain slide except when the Director of Public Works certifies in writing that the following improvements have been provided: paved streets, including curbs and gutters, constructed in accordance with the standards and specifications of the municipality applicable to subdivisions; a water supply system; a sanitary sewer system; public utilities, street name signs and street lighting; monumentation and lot corner markers installed in accordance with an accurate survey by a surveyor registered in the State of Alaska (Municipality of Anchorage, 1978, Section 2).

Development on the Turnagain slide area presently depends on the willingness of the lot owners to pay for extending roads, water and sewers to the area. Risk is only one of the issues involved in public discussion of development in the Turnagain area. Other issues include protection of views, density of development and preservation of a high-income residential neighborhood. Many property owners in the Turnagain area are influential community and business leaders with more than the usual political sophistication. This fact may well be determining in the ultimate decisions regarding Turnagain.

Following the earthquake, property owners in Turnagain received the following kinds of assistance:

1. SBA loans for repair or rebuilding at 3% interest for 30 years.
2. Reduced taxes on lots – as low as $12-15 (Mayor Sullivan, 1978, interview) a year for lots on the slide now considered to be worth $60,000 to $80,000 (Anchorage Municipal Assembly, 1977, statement of Bill Sherwood).
3. Mortgage relief in cases where damage exceeded 50%.
4. Lots in Zodiak Manor – 88 families acquired 2 lots apiece for a total of 176 lots. Fifty lots are in original ownership and another 48 are vacant (KAKM, Channel 7, 1978).
5. Federal tax rebates on losses.

It has been said that the well-to-do received the lion's share of federal funds allocated for assistance to private property owners (Vic Fischer, 1978, interview, and KAKM, Channel 7, 1978). Certainly, the Turnagain residents fared well economically in the years after the earthquake. Many sold their lots in Zodiak Manor or held them as investments while purchasing homes elsewhere. At the same time, they still own their original properties in Turnagain which appear to be increasing in value as the city moves gradually toward permitting development on the slide.

Reasons

One critical decision in the Turnagain situation was the failure of the State Division of Lands to acquire title to Turnagain properties in exchange for lots in Zodiak Manor. Another critical decision was not to pursue the urban renewal project. As time has passed since the earthquake, public acquisition of the slide area has become increasingly less feasible because of rising costs and decreasing concern over earthquake risk. Purchase of the slide area at current values could cost as much as $5 million (74 lots at $60,000 to $80,000 each = $4,440,000 - $5,920,000) (Anchorage Municipal Assembly, 1977, statement by Bill Sherwood).

The failure to seek public ownership of the slide area immediately after the earthquake probably was simple oversight coupled with the supposition, as described by Mayor Sullivan, that nobody would ever again be foolish enough to build in such a hazardous location. The passage of time after a major disaster, however, has a way of eroding concern for safety. Most people now living in Anchorage were not there during the earthquake and even the reminder of debris from shattered houses still on the beach fails to deter those who would build there.

Apparently some of those seeking to build have no intention of living there themselves. For example, in testimony before the Anchorage Municipal Assembly (formerly the City Council):

> Bill Sherwood stated that he lived in the area at the time of the earthquake. It has been almost 14 years now that property owners have been waiting for some action on the property to take place. He never plans to live there again and so he would like to get as much for his property as he can.
>
> (Anchorage Municipal Assembly, 1977, p. 5)

One of the major attractions of the Turnagain area is its view across Knik Arm and back to downtown Anchorage. Bluff-edge lots sell at a premium because of this view. The earthquake created a whole new group of bluff-edge property owners. Many of these owners are now concerned about pressures to permit building on the slide because they don't want to lose the views they so fortuitously gained. They also express concern that construction on the slide will reduce the bluff's stability.

A feeling underlying much of the debate concerning building on the Turnagain slide is that the property owners should not be denied the use of their land unless the city is willing to purchase it. The use of restrictive land use regulations in the area appears to be unpopular with many members of the Anchorage Municipal Assembly. As one Assembly person states, government shouldn't be "big brother"; let people assume the risk if they want to (KAKM, Channel 7, 1978).

It also appears that no one wants to take responsibility for restricting development in the area. The Assembly has generally put off decisions as long as possible; the Geotechnical Advisory Committee has been asked by the Assembly to recommend building restrictions and design criteria to be applied to construction when and if it occurs on the slide and has responded by recommending a new study of the area's stability and erosion problems; the building department feels it's up to the Anchorage

Assembly if it wants special rules applied to the area; geologic and soils engineers disagree as to the extent and nature of the problem and prefer to stay out of the policy question. The city also finds itself in a bind when Turnagain owners point out that no restrictions were placed on development in the equally hazardous L Street slide area.

GENERAL PLANNING

At the time of the earthquake, Anchorage was one of the few Alaskan cities with an adopted general plan and zoning and subdivision regulations. However, this plan did not recognize potential ground failure and was, therefore, of little help in guiding reconstruction decisions in hazardous areas.

In 1976, the Municipality of Anchorage (the City of Anchorage and Greater Anchorage Area Borough consolidated as the Municipality of Anchorage in 1975) adopted a Comprehensive Development Plan (Municipality of Anchorage, 1976). The word "earthquake" does not appear in the adopted plan although the preliminary draft addressed the subject. The changes are described in a newspaper article by Larry Makinson:

> The preliminary draft of the Municipality's Comprehensive Development Plan echoed both the warnings of the consultants and of Task Force Nine. Among its recommendations for policies to be followed by the local government:
>
> "The portions of the CBD which have been identified as being susceptible to earthquake-induced landslides and given a high risk classification by Task Force Nine must be respected. Any development in these areas should conform with the specifications governing the development of such areas."
>
> That recommendation was deleted in its entirety from the final Comprehensive Plan, adopted last July.
>
> Also included as a suggested policy for the government, under the section on Natural and Man-Made Hazards:
>
> "The preservation of bluffs overlooking Cook Inlet, particularly those subject to earthquake-triggered landslides, shall be encouraged and pursued through curtailment of development and through public ownership."
>
> That too was deleted in its entirety from the final Comprehensive Plan.
>
> Also deleted from the plan was any mention at all of the word "earthquake."
>
> Privately, the planners say little has been done with the recommendations of the federal task force, the consultants and the planning department, because of simple political pressure.
>
> But politicians, after all, often reflect the attitudes of their constituents. And people in Anchorage seem to have largely forgotten the Great Alaska Earthquake of 1964 except as history.
>
> (Makinson, 1977)

Some references to potentially hazardous lands are included in the final plan. Hazardous lands are:

> Those areas where the unique geologic features or geographical conditions create hazards to life and property and should not be developed. Conditions such as geologic fault lines, unstable subsoils, sluffing (erosion or collapse of bluff areas), avalanche, or high velocity winds could typically be encountered.
>
> (p. 16)

Objectives pertaining to natural and man-made hazards are:

> a. To protect the public from natural and man-made hazards and nuisances by:
>
> Regulating development of those lands which, if improperly developed, would be hazardous to the health, safety or property of individuals in the community.
>
> Minimizing potential hazards from development on unstable soils.
>
> b. To minimize the possibility of structural damage or failure and excessive public installation and maintenance costs resulting from building on unstable soils, the Municipality shall insure that development will avoid such areas unless adequately designed and engineered.
>
> c. Developers shall be encouraged to utilize marginal lands by incorporating them in their development plans as open space and less intensively used areas.
>
> (p. 7)

A related recreational objective is:

> To promote use of geological hazard areas and marginal lands for parks, recreation and open space.
>
> (p. 12)

One part of a proposed work program is:

> Conduct a study that would precisely identify hazardous lands and methods of dealing with them.
>
> (p. 10)

The U.S. Geological Survey is presently conducting two studies relevant to this item:

1. A study by the Engineering Geology Branch in Denver of the characteristics and behavior of Bootlegger Cove Clay to be completed in one to one and a half years. Remarkably, little has been done since the initial studies after the earthquake to describe the behavior of this clay which is believed responsible for most of the land failures. Disagreement still exists among experts on the mechanism of failure and, consequently, on the appropriate engineering and design criteria for construction on land underlain by the clay (Schmoll, 1978, telephone conversation).
2. Hazard mapping of the Anchorage area. The results of this effort are expected to be used by the Municipality in preparing its Coastal Zone Management Plan. Work on this plan is now underway. (Tony Burns, 1978, interview).

General planning in Anchorage both before and after the earthquake has largely ignored geologic hazards. In part, this may be due to the relatively transient and growing population in Anchorage. A majority of present residents were not living in Anchorage at the time of the earthquake. It also probably reflects the state of economic development in the city. The economy of Anchorage is still largely resource-based and dependent (although to a decreasing extent) on the federal government. The city is seeking diversified economic growth and appears reluctant to impose development controls. In such an atmosphere, hazard mitigation measures can be expected to fare poorly.

Also to be reckoned with is the nature of people that are attracted to Alaska. The notion that Alaska is the "last frontier" is a persistent political theme. In Alaska, as opposed to the "lower forty-eight," a man can still make a fortune and live his life relatively unfettered by bureaucratic restrictions – at least so the myth goes. Whatever the reality, the belief is not conducive to restrictive government actions.

The harshness of the Alaskan environment is also a factor limiting concern for geologic hazards. As stated succinctly by a local seismologist:

> *If you've lived in Alaska long enough, you're a survivor of something. Everyone's got a story – almost killed in an earthquake, almost eaten by a bear. Mine's a near-drowning in a boat. You come to think you can survive anything.*
>
> (Gillette, 1978 – quoting George Carte, seismologist, Commerce Dept., Tsunami Warning Center in Palmer)

Geologic hazard mitigation may play a more important role in the Coastal Zone Management program than in previous planning efforts. Pursuant to the Federal Coastal Zone Management Act of 1972, Alaska created a state council to establish guidelines for the development of district programs, review and approve district programs, and establish and oversee a state interagency program of comprehensive coastal resource planning for each of nine geographic regions (Alaska Coastal Management Act of 1977). Anchorage Municipality is one of the nine coastal resource districts and is in the process of preparing its management plan. Geologic hazard areas are being designated and criteria proposed for land use and development in such areas. Since areas most prone to landsliding in the next earthquake are in the coastal zone, this plan could have a significant impact on the future safety of the area; it is presently (1978) too early to tell.

Earthquake Effects and Response
Seward, Alaska

Seward is located on an alluvial fan delta near the head of Resurrection Bay on the southeast coast of the Kenai Peninsula (Figure 2). A town of 2,300 people at the time of the earthquake, Seward is an ice-free port and the southern terminus of the Anchorage-Seward Highway and the Alaska Railroad. It presently has about 1,700 people and an economy based on government services, shipping, fishing and some tourism. Figure 33 shows downtown Seward looking toward Resurrection Bay.

Figure 33. Downtown Seward, looking toward Resurrection Bay, Summer 1978

GEOLOGIC EFFECTS

Parts of Seward subsided about 3 1/2 feet during the earthquake rendering over 50 acres of waterfront land unusable. Strong ground motion lasted three to four minutes triggering rockfalls and avalanches in the canyons and valleys around Seward. The most damaging effects of the earthquake were along the waterfront. Thirty to forty-five seconds after violent shaking began the edge of the Seward alluvial fan began sliding seaward as a result of large-scale offshore landsliding. Slice after slice of land, in an area extending from the Standard Oil Company dock to beyond the San Juan dock, slid into the bay. A 40 acre area 50-500 feet wide disappeared under water. Large fractures, some at least 20 feet deep, broke the ground surface behind the slide area. Some fractures near the Texaco tanks reportedly opened and closed repeatedly during the shaking alternately filling with water and spewing forth muddy water. Figures 34 and 35 are aerial photos of Seward taken before and after the earthquake. When shaking ended, the shoreline had receded to the position shown in Figure 35 (Lemke, 1967, p. E4).

Tanks at the Standard Oil Company dock overturned and slid into the bay. Spilled fuel exploded and burst into flame. Water displaced by landsliding receded rapidly carrying burning fuel on its surface. The receding water formed a large mound several hundred yards out in the bay from which waves radiated in all directions, causing much damage along the Seward waterfront and at the head of the bay. These waves, caused by continued submarine sliding or by seiche action, were followed by tsunamis. The first tsunami hit about 25 minutes after shaking stopped. It was 30-40 feet high and carried burning oil into the town. A series of waves followed at approximately 1/2 hour intervals with the third generally acknowledged to be the highest. The white line on Figure 35 shows the maximum height reached by any wave (Lemke, 1967, p. E4).

DAMAGES

Thirteen people were killed and five injured – almost all by wave action. Most harbor facilities between the

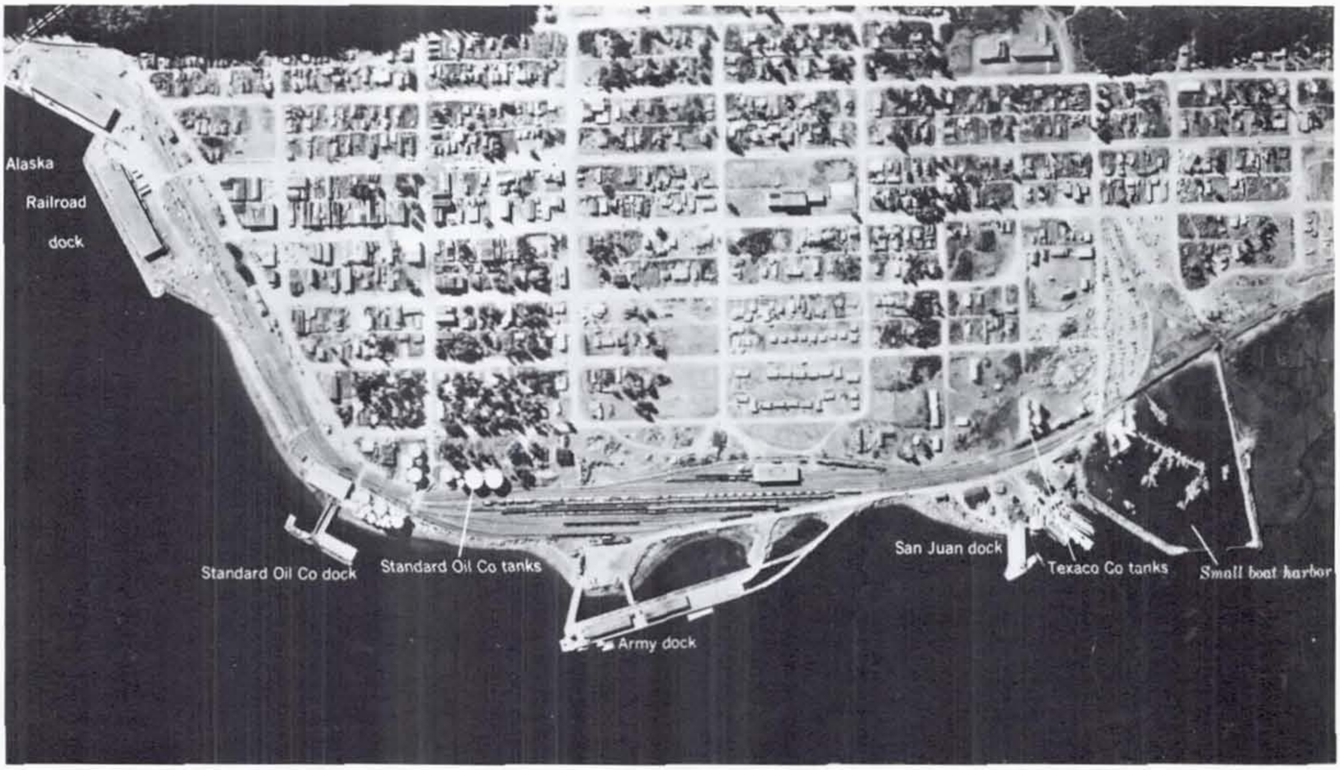
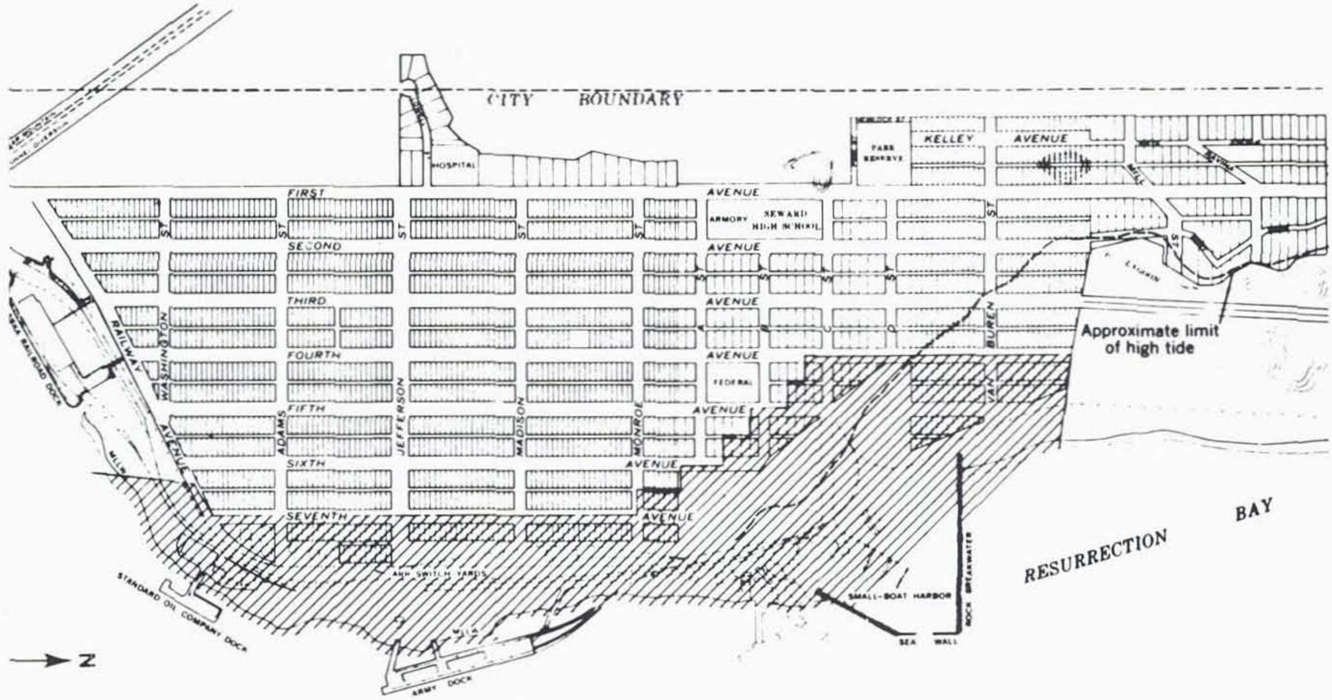


Figure 34. Aerial photo of Seward, Alaska taken before the earthquake (Source: Lemke, 1967, p. E6, E7)

Figure 35. Aerial photo of Seward, Alaska taken after the earthquake. White line shows maximum wave runup. (Source: Lemke, 1967, p E6, E7)



EXPLANATION

NOMINAL RISK AREA

Little likelihood of landslides except for small slumps, largely in artificial fill. In all other respects risks are no greater than is normally expected in the construction industry. Current Uniform Building Code for Seismic Zone 3 applies both to new buildings and to plans for rehabilitation of earthquake-damaged structures.

HIGH RISK AREA

Land considered unstable, particularly in event of future earthquakes; no economically feasible means of stabilization known. No repair, rehabilitation or new construction involving use of Federal funds is recommended, except for grading and light fill.

MLLW — Mean lower low water line

0 400 800 1200 1600 FEET

Figure 36. High-risk classification, Seward, Alaska, July 25, 1964
(Source: Scientific and Engineering Task Force, 1964, as reprinted in Hansen and others, 1966, p. 64)

Standard Oil and Texaco tanks were destroyed. The Standard Oil dock, 13 oil tanks, Army dock, San Juan dock and cannery disappeared into the bay (Lemke, 1967). Several Texaco tanks burned. The Alaska Railroad dock and marshalling yards were almost destroyed as were a warehouse, a halibut cannery, the small boat harbor and a fleet of more than 30 fishing boats and 40 pleasure craft valued at nearly $2 million (Norton and Haas, 1970, p. 322). Two gantry cranes at the Alaska Railroad dock bounced off their tracks, chimneys fell, windows shattered and city hall, in poor condition before the earthquake, was damaged beyond repair (Lemke, 1967).

> Fires had leveled three residences; quake or waves had demolished or made unfit for salvage 83 others; in all, 261 homes, 15 percent of Seward's residences, had some damage. A number of public buildings had been damaged to varying degrees; the old Federal Building, housing city and state offices, was beyond repair. Central water and sewer systems were damaged and unusable, and several wells had been destroyed. Quake and waves had knocked out the lines which brought power from Chugach Electric's Cooper Lake plant 50 mi. to the north, and fire had destroyed the city's emergency generating plant.
>
> (Norton and Haas, 1970, p. 322)

Damage to public and private facilities in Seward and vicinity was estimated at $22,636,349 in 1964 dollars (Alaskan Construction Consultant Comm., 1964, p. 44; cited in Lemke, 1967, p. E14).

RECONSTRUCTION PLANNING

A major concern of the town after the disaster was to ensure reconstruction of the Alaska Railroad dock and yards without which the economy of the town was crippled. Reconstruction was recommended by the Interior Department which operates the railroad and by the Federal Reconstruction Commission task force on transportation.

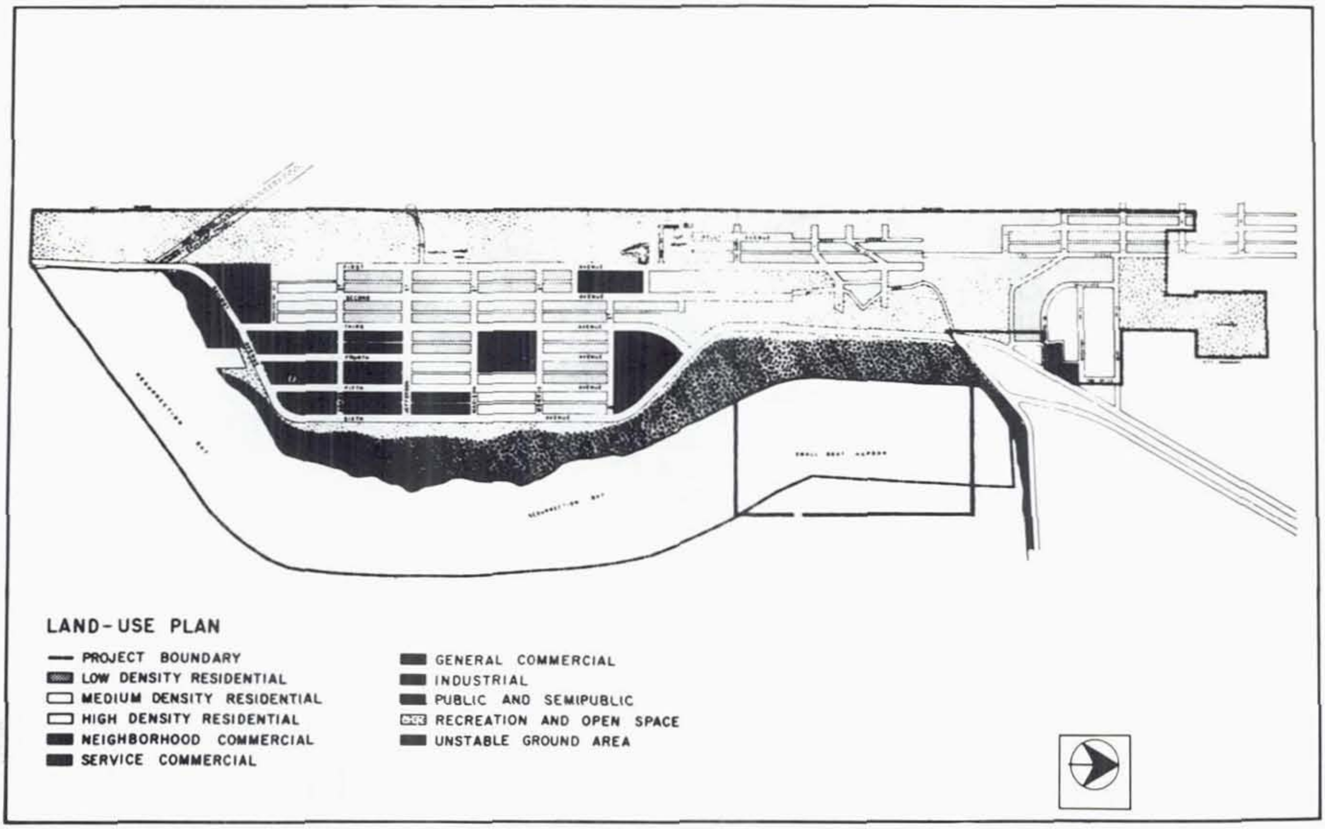


Figure 37. City Planning Associates Urban Renewal Plan for Seward (Source: Selkregg and others, 1970, p. 226)

Military officials stressed the importance of Seward as an ice-free port linked to Anchorage and Fairbanks by the Alaska Railroad. On April 28, President Johnson committed the federal government to rebuilding the railroad and terminal. The announcement was made by Commission Chairman, Senator Anderson, while on tour in Anchorage. As he described it:

> At noon on Tuesday, my last day in Alaska, I was to address a group of businessmen at Fort Richardson. It was 6 o'clock in Washington, past the end of the official day for federal offices. The auditorium was jammed as I started talking about the work of the Commission. I was interrupted by a phone call from President Johnson, who told me that the tracks and docks at Seward would be reconstructed. I passed the good news to the audience whose enthusiastic reaction was instantaneous. The Seward decision convinced skeptical Alaskans that the federal government meant to honor its commitments.
>
> (Anderson, 1970, p. 159-160)

Geologic studies were begun in Seward almost immediately after the earthquake by the USGS and a staff geologist with ASHA. In July, the Scientific and Engineering Task Force issued its risk map for the city (Figure 36) showing a large portion of the waterfront as high risk because of the possibility of sliding in future earthquakes and the lack of economically feasible means of stabilization.

At the time of the earthquake, Seward had a planning and zoning commission and a general plan prepared by the Alaska State Housing Authority in 1959. Seward's economy had been in decline and the plan envisioned little growth or change. Planning for the city is presently (1978) done by the Kenai Peninsula Borough and the city has no planners on its staff.

By April 4, eight days after the earthquake, a feasibility survey for a disaster urban renewal project had been completed by the Urban Renewal Regional Office. Completion of the survey, which normally takes months, in only eight days is an example of how rapidly the federal bureaucracy was able to move under the pressure of the disaster situation. The consulting firm, City Planning Associates, was retained to prepare an urban renewal plan for the revitalization of the entire community. This plan, shown in Figure 37, featured park and recreation use along the unstable waterfront area, relocation of the city dock to a small alluvial fan across the bay, and a central commercial core. The plan became a focal point of controversy over whether urban renewal projects arising from the disaster should be used to achieve objectives other than reconstruction of destroyed areas. The issue came to a head in the debate on the amendments to the Alaska Omnibus bill over the question of whether the local contribution to renewal projects should be reduced from 25% to

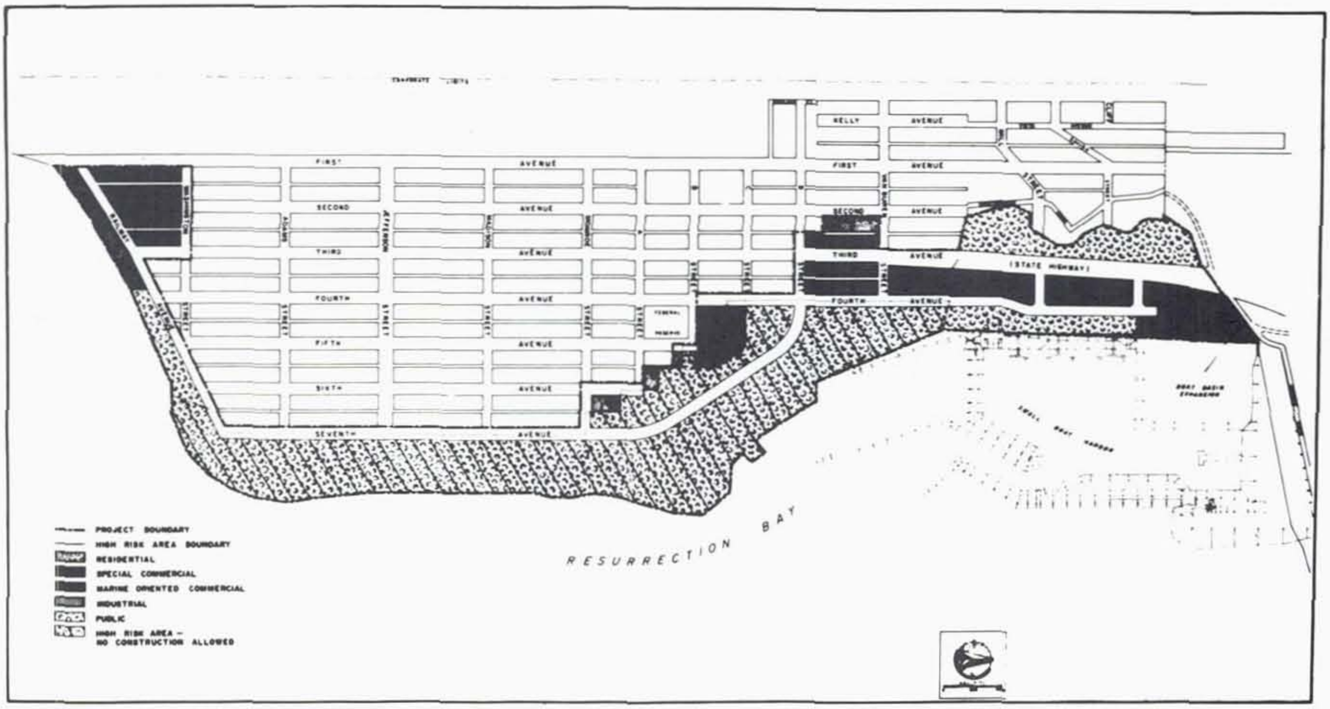


Figure 38. Final Urban Renewal Project Plan, Seward (Source: Selkregg and others, 1970, p. 229)

10% of the project cost. Senator Anderson's position is clearly stated in telegrams sent to the mayors of several Alaskan cities. To Seward's mayor he wrote:

> U.S. Senate, June 2, 1964
>
> Hon. Perry R. Stockton,
> Mayor of Seward, Seward, Alaska
>
> Dear Mayor Stockton: I have your telegram reading: "City of Seward urgently requests change in Federal participation in urban renewal project for Seward work caused by disaster from 75 to 90 percent. City absolutely financially unable to raise 25 percent due to complete loss of industry. Greatly appreciate your fine efforts in our behalf."
>
> I am not sure how a telegram like this should be answered. You doubtless are familiar with the fact that the urban renewal program prepared for Alaska grew to some fantastic figures – a total of $69,508,673. From that were to be deducted proceeds from the sale of project land and things of that nature. But the total Federal grant on a 90 percent basis was $53,145,305 and on a 75 percent basis was still $44,262,652.
>
> I think almost anyone would have concluded that those figures were too high and that people could not justify the spending of any such sums on urban renewal.
>
> To show how large these figures run, the urban renewal for your community of Seward is $6,566,183 and to put this on a 90 percent basis a total Federal capital grant would be $5,832,513. There were reports that fire broke out in Seward, and, therefore, some of your losses might have been covered by fire insurance policies, but even so, the urban renewal proposal lists $1,543,514 for real estate purchases and $2,897,104 for project or site improvements. When you compare these figures to the population of Seward, you recognize that they are very high and possibly the only way of bringing them into reasonable proportions would be to insist that Seward bear a part of the expense. We have proposed the rebuilding of the railroad to Seward and the construction of a terminal and dock at a Federal cost of $7,800,000. A great many other expenses will be made at Seward and then to add $6 1/2 million for urban renewal seems like quite a burden.
>
> I hope you will discuss this with your people because I have grave doubts that the Congress will want to go on a program of urban renewal as elaborate as is now planned unless there is a large participation by the State of Alaska or the city of Seward.
>
> Sincerely yours,
>
> Clinton P. Anderson, Chairman.
>
> (U.S. Senate, 1964, p. 24-25)

Congress finally accepted the 90/10 split in federal/local funding but limited the total federal contribution to all urban renewal projects in Alaska to $25,000,000 resulting in less ambitious renewal projects. By August 1964, when the city submitted the second part of its

Figure 39. View of portion of cleared waterfront, Resurrection Bay and, in background, the new city dock and small boat harbor at end of Bay, Summer 1978

application for urban renewal, the project boundaries had been changed to exclude all but the damaged waterfront area (Figure 38). This plan called for relocation of the city dock, railroad terminus and small boat harbor to an area near the head of the bay with better stability than the pre-earthquake locations, but subject to flooding. Park and recreation use was planned for the high-risk waterfront area. The renewal project cost, excluding the construction of federal facilities, was pared down from over $6,500,000 to $1,591,828 (1964 dollars).

The new location of the docks and harbor provides space, lacking at the former location, for associated industrial expansion. However, the location may be subject to flooding from the glacial-fed Resurrection River and future tsunamis (Selkregg and others, 1970). The Alaska Railroad facilities were reconstructed, and a new city dock and small boat harbor were built by the Corps of Engineers (Figure 39). The harbor berths 500 boats and is too small for the present demand for about 1,300 spaces. No disaster relief funds were made available to Seward to improve harbor facilities over their pre-earthquake condition. The high-risk area remains free of new construction. Most of the area was publicly-owned so that land acquisition posed little problem. The Standard Oil and Texaco facilities were on land leased from the federal government. The approved urban renewal project R-21 contains the following statement concerning use of the high-risk area:

> No permanent structures of any type except for toilet facilities or pavilions shall be constructed within the Urban Renewal Project Area in any area designated on the Land Use Plan as "high risk" area. The boundaries of the area designated as "high risk" are those boundaries that had been established by the Scientific and Engineering Task Force of the Federal Reconstruction Commission for Alaska, and are shown on the *LAND USE PLAN*, Map C-213-3.
>
> (Alaska State Housing Authority, 1964, revised 1971)

The city is now (1978) expecting to receive Coastal Energy Impact funds to develop camping, recreation areas and parks along the waterfront. Seward is the only Alaska community which has not officially challenged the high-risk classification.

REASONS

Are residents in Seward more concerned about safety than those in other Alaskan communities? Probably not. Although the community has followed the Task Force 9 recommendations, the reasons apparently have much less to do with earthquake hazards than with the city's economic stagnation.

Seward did not make an economic recovery from the earthquake. Many people left Seward after the earthquake and never returned. Seasonal unemployment runs about 30%. Population figures are revealing:

March 1964	2,300
1965	2,213
1966	1,800
1967	1,417
1970	1,500
1978	1,756

In 1965 with an influx of workers to assist in reconstruction, Seward still had fewer people than before the earthquake. A low was reached in 1967 with some recovery occurring from 1967 to 1978 as a result of general growth in Alaska spurred, in part, by construction of the pipeline.

The main reason for the decline was the growth in year-around shipping in Anchorage. As the only South Central

Alaskan port not destroyed in the earthquake, Anchorage quickly captured and retained a large share of the shipping business. In addition, Texaco and Standard Oil did not rebuild their facilities in Seward and the canneries did not return. In this situation there was no motivation to seek to build in the waterfront area.

If significant new industry were attracted to Seward, pressure to develop in the high-risk area to accommodate new population might arise because of topographic limits to expansion of the existing town. At present, the major opposition to building there appears to be a desire to keep the area open to views and a concern that apartments might be built in the area thus disrupting the basically single-family community. Safety is not a major consideration as expressed well by a secretary in the City Manager's office in response to the interviewer questions:

> You were here when the earthquake hit, weren't you?
>
> Right.
>
> If someone wanted to build housing down next to the bay, what would the people here in Seward think?
>
> I don't think they would mind. I know I wouldn't mind. And my folks used to have a house right down on Second, the very first block right down where the tidal wave came in. I happened to be there that evening – I went down to get my boy – and by the time we got my mother, who had polio and was paralyzed from the waist down, to the car, the water was lapping at the back of our car and we were all turning around and looking and watching it while I was driving away. It was quite an experience; I wouldn't want to go through it again.
>
> But would you move back down there?
>
> I would move back, yes.
>
> Why would you do that, why wouldn't you object to housing down there?
>
> Well, the idea of another tidal wave doesn't bother me.
>
> Why, because you think it won't happen again?
>
> Oh, it will probably happen again.
>
> You think it could happen again?
>
> Oh yes, if we got hit with another earthquake, sure, it is more than likely we would have another tsunami, but you're going to run fast enough.
>
> Then you must be presuming that the warning system would be such that you could get out?
>
> Yes, I would be able to get out. The first little shake now, I'm already dressed!
>
> As I understand it, you think that a tsunami could come again but people could be evacuated?
>
> Yes, they could get out fast enough. People might lose their houses, but that's a risk anywhere; maybe more of a risk there.
>
> You would be willing to take that risk?
>
> Yes, lots of people who lost their homes wanted to build in the same location.

Earthquake Effects and Response Valdez, Alaska

Valdez is a town of over 5,000 people located on a glacial outwash delta at the head of Port Valdez (Figure 2). At the time of the earthquake, its population was about 1,000. The town is important as Alaska's northernmost ice-free port and as the southern terminus of the Alaska pipeline and the Richardson Highway – a direct route to Fairbanks and Alaska's vast interior. The economy in 1964 was based on shipping and commercial and sport fishing.

GEOLOGIC EFFECTS

The most devastating effect of the earthquake at Valdez was a seismically-triggered massive submarine slide, involving almost 100 million cubic yards of material, that completely destroyed the harbor facilities and nearshore installations (Coulter and Migliaccio, 1966). Waves generated by the slide and subsequent strong seiches did additional damage to the downtown area. Stresses generated by the seismic shocks and the slide developed an extensive system of fissures throughout the unconsolidated deposits at the head of the fiord (Figure 40). Portions of the shore area subsided below high tide level and the entire area was severely shaken.

There is evidence to indicate that slides similar to this one may have occurred in as many as five previous earthquakes (Coulter and Migliaccio, 1966). Post-earthquake investigations of ground conditions at Valdez led to the conclusion that the town site was unsuitable for habitation or a port facility because of numerous adverse geologic conditions, including exposure to ground failure, slide- or seismically-induced sea waves, poor foundation conditions, and serious floods. In contrast to the unfavorable geologic conditions at that area, the conditions at a nearby site called Mineral Creek were determined to be favorable from a geotechnical standpoint (Figure 41). This site is situated on an alluvial fan which has excellent foundation conditions, and is not subject to sliding even under seismic conditions. In addition, it is at a higher elevation which protects it from flooding and seismically-induced sea waves.

DAMAGES

Damage in the areas battered by waves or subject to sliding was nearly total, dwarfing in importance the usual structural damage caused by ground shaking. The extent of the destroyed area can be seen in Figures 42 and 43, aerial photographs taken before and after the earthquake.

Ground breakage also caused extensive damage. About 40% of the homes and most of the commercial buildings were damaged, especially at their foundations. Buildings on heavily-reinforced concrete-pad foundations suffered less damage from ground fissures than other types of construction. The water and sewer systems were heavily

Figure 40. Earthquake effects at Valdez (Source: Coulter and Migliaccio, 1966)

damaged. Damage to harbor and port facilities alone was estimated at $3,585,000 in 1964 dollars (Hansen and others, 1966, p. 31).

RECONSTRUCTION PLANNING

Almost immediately after the earthquake, it became apparent to geologists on the scene, that Valdez occupied a particularly hazardous site – one subject to future sliding, ground cracking and flooding. It is not clear exactly when the decision was made to move Valdez to the Mineral Creek site, four miles northwest of the old site, but it is clear that the decision was made and carried out by the federal government. From the federal point-of-view the choice appeared to be to abandon Valdez altogether or to relocate it.

The Federal Reconstruction Commission, particularly Senator Anderson, apparently felt it was irrational and foolhardy to spend federal money to reconstruct Valdez. The initial thought, supported by Anderson, was apparently to relocate the residents in other communities and abandon the town (Victor Fischer, 1978, interview). However, it was recognized that this would be very unpopular with Alaskans and politically difficult to achieve especially in view of the fact that Valdez was the home town of Alaska's Governor William Egan. In addition,

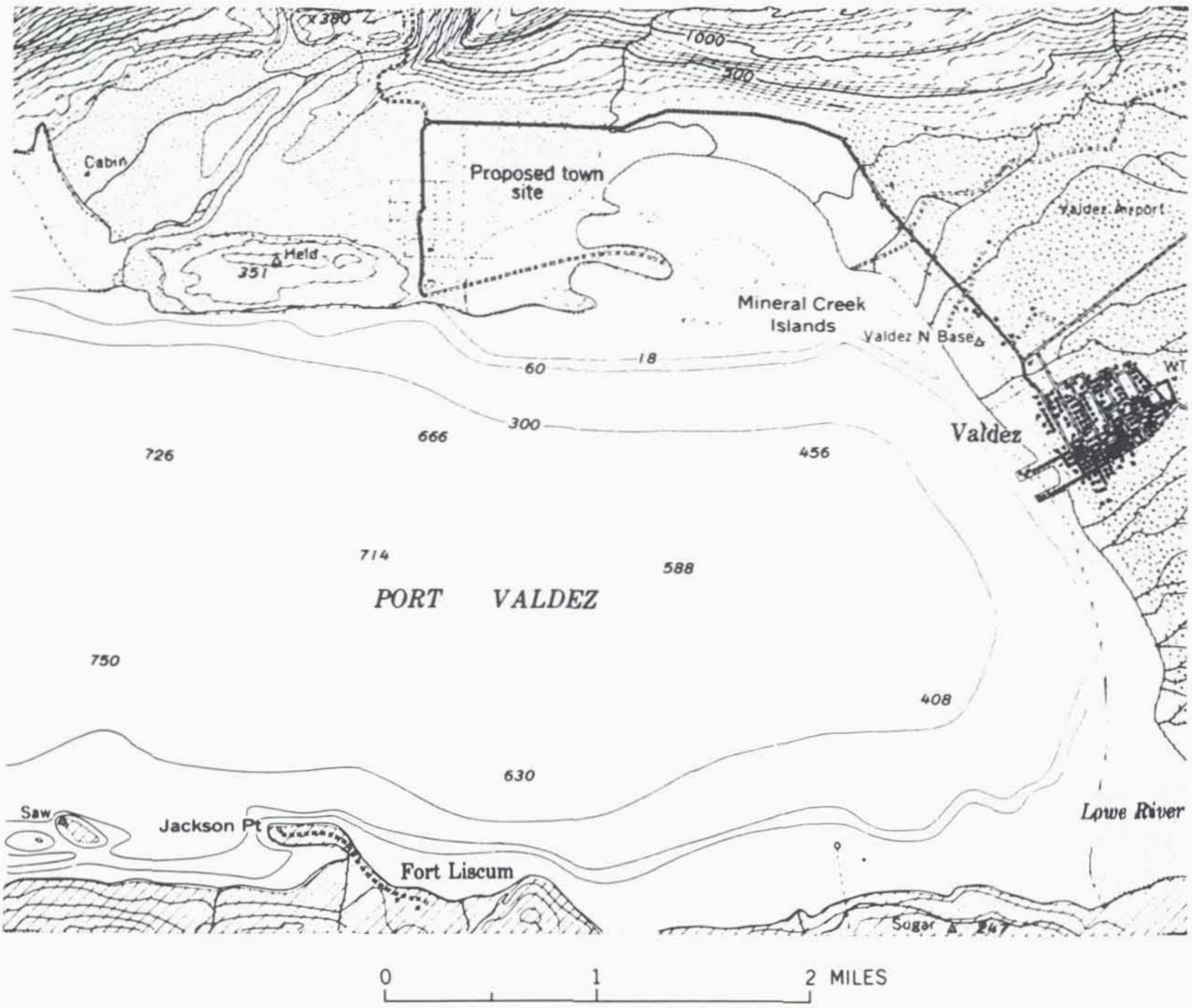


Figure 41. Location of old and new town sites, Valdez (Source: Coulter and Migliaccio, 1966, p. C4)

Valdez was strategically located at the southern terminus of the Richardson Highway providing access to the resource-rich interior and was Alaska's northernmost ice-free port. Thus, Senator Anderson became convinced that the best course of action was to rebuild Valdez at a safer site.

From the point of view of the residents of Valdez, however, the choice was whether to stay put and possibly be cut off from federal assistance or to accept relocation. Accounts of how the local decision to move came about vary. The whole process is enveloped in controversy and a bitterness that remains to this day. What is clear is that the determining decision was made by the federal government. In effect, the local residents were left with a Hobson's choice – relocate or try to rebuild at the old location on their own.

Given the decision to relocate, urban renewal was chosen as the mechanism to accomplish it. Two projects were initiated – R-22 to acquire land at the old town site and R-25 to develop the Mineral Creek site. City Planning Associates was retained to prepare a plan for the new town and emergency repairs were made at the old site to tide residents over until relocation could be completed.

Planning for the Old Site

The R-22 renewal plan called for public open space, park and recreation use of the project area which included all areas within the corporate limits of Valdez as of April 28, 1964. No permanent structures were to be permitted within this area. Buildings still in sound condition could be relocated to the new town site.

The plan called for ASHA to acquire all improved property within the project area and any vacant property needed to carry out the objectives of the plan. Land was to be disposed of by ASHA for purposes consistent with

Figure 42. Aerial photo of Valdez dock area, September 23, 1963
(Source: Coulter and Migliaccio, 1966, p. C12)

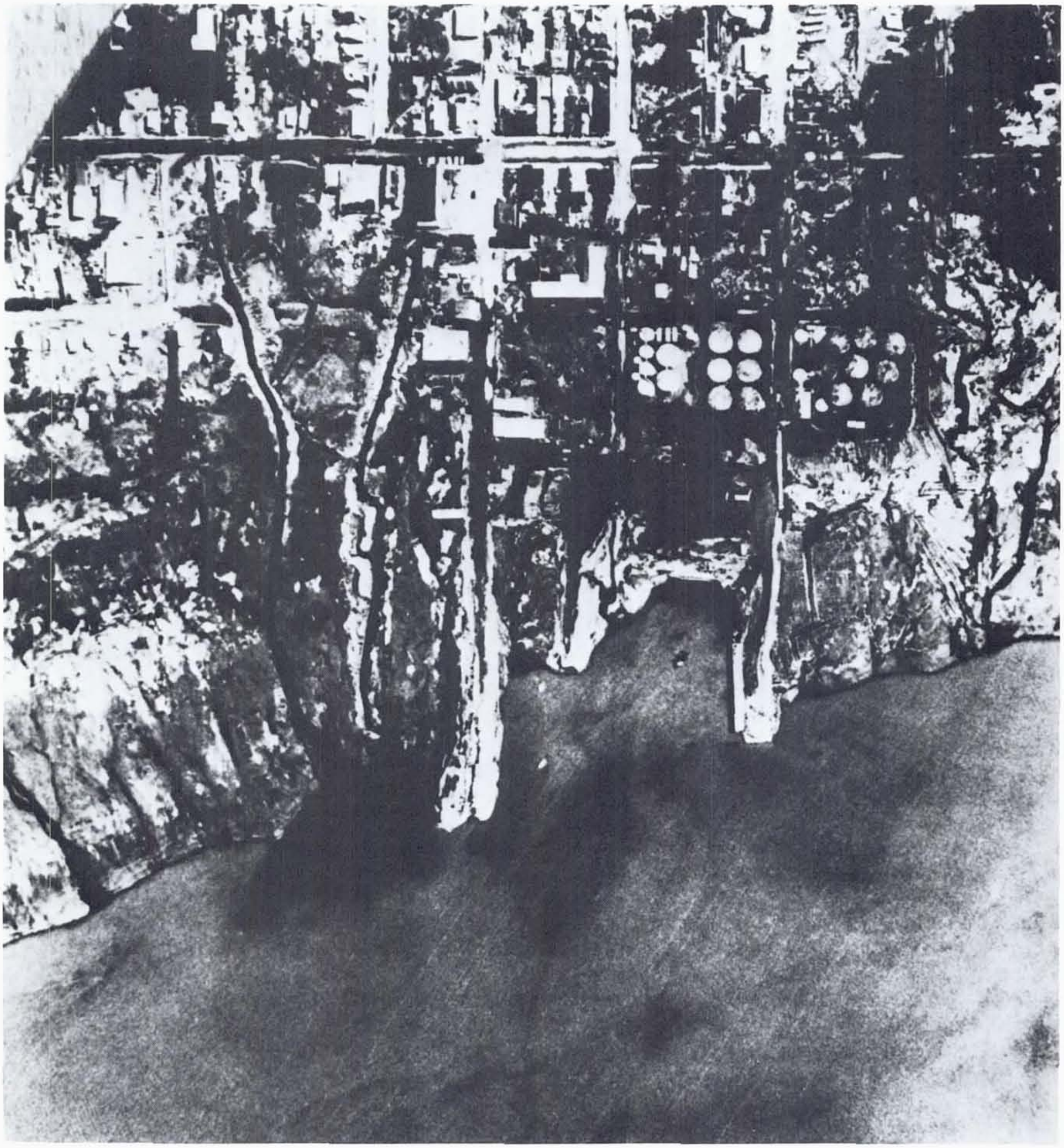


Figure 43. Aerial photo of Valdez dock area, June 13, 1964, showing earthquake damage (Source: Coulter and Migliaccio, 1966, p. C12)

Figure 44. Project team member standing at former corner of Alaska Avenue and McKinley Street, center of the old town of Valdez, Summer 1978. See location on Figure 40. In background, oil storage tanks at end of Alaska pipeline can be seen.

the permitted land uses. Acquisition took several years to complete with some property owners holding out for higher prices and ultimately settling for less than originally offered (Dorothy Clifton, interview).

The renewal project was completed at a cost of about $2,885,000 (Phillips, 1978, telephone conversation). At present, little evidence remains of the former town (Figure 44). Some remnants of pavement remain and, at low tide, pilings from the destroyed city dock are visible; otherwise it is hard to believe that a town of up to 2,000 people once occupied the site. However, the site has not been developed for open space, park and recreation uses as called for in the plan. Part has been leased to Alyeska for use as a staging area for truck and barge transport; part contains the city's sewage treatment facility; and most of the rest is cleared, vacant land.

Valdez is in the process of planning a major expansion of its port facilities. A study done by Dames & Moore states that the portion of the old town site north of the previous location of Hobart Street (Figure 40) could be used, from a geotechnical standpoint, for long-term storage, warehousing, and light industrial buildings. The report recommends that any permanent structure in this area be built of flexible materials on heavily reinforced mat foundations and limited to two stories in height (Dames and Moore, 1978). This type of use of the old town site appears more likely to be approved by the city than the park uses envisioned in the urban renewal plan.

The reasons for this include the interest of the city in economic development and the fact that Valdez is the terminal for the Alaska pipeline. During construction of the pipeline, Valdez experienced a tremendous economic boom. Prices for everything from housing to food soared. Since completion of construction, the private sector of the economy has suffered a serious decline, but the city's fiscal position is unbelievably favorable with the pipeline terminal facilities on its tax rolls. With a present population of between 5,500 and 7,000, Valdez' 1978-1979 budget is $12,998,104 financed by a tax base of $1.5-$1.6 billion. Nearly $5,000,000 in capital improvements projects, including a new city hall, are to be paid for in cash (Ronald H. Jarrell, City Attorney, conversation).

In this situation, it can be anticipated that the city will go ahead with the port expansion and seek industrial development to bolster the private sector of the economy. Although it could afford to develop the old town site as a park, there is no indication of interest in doing so on the part of city officials.

Planning for the New Town

Development of the new town at the Mineral Creek site was accomplished through an "Open-Land Project" especially authorized by Congress to deal with the unusual circumstance of using urban renewal funding for developing vacant land. All but one parcel of land in the new location was donated to the City of Valdez by Owen Meals and after considerable negotiation made available for the renewal project. The plan, prepared by City Planning Associates, was submitted to the Federal Urban Renewal office in September 1964 (Figures 45 and 46). The plan was intended to achieve the following goals:

- Development of a community for an initial population of 1,500
- Community facilities designed to cope with massive snowfall
- Walking distance for children from home to school
- Shopping and other community facilities close to housing areas
- Development of adequate deep-water dock facility and warehousing
- Small-boat harbor to serve the expanding fishing fleet
- Enhancement of the area as a tourist attraction and development of commercial recreation facilities

(Selkregg and others, 1970, p. 207)

Construction of public facilities including a new city dock, small boat harbor, schools, civic buildings, a state mental hospital and the Alaska Department of Highways complex was completed in the fall of 1966. Complete relocation to the new site was accomplished a year later following a decision by the city administration to shut down all utility service to the old site by October 1967 (Selkregg and others, 1970). Figure 47 is an aerial view of the new town taken in summer 1978.

Sound structures from the old site were relocated in the new town, 14 units of low-rent housing were built and residential, public and commercial buildings constructed. The architectural style of the residential areas ranging from log cabin to mobile home, while not distinguished, lacks the uniformity often found in new towns or large

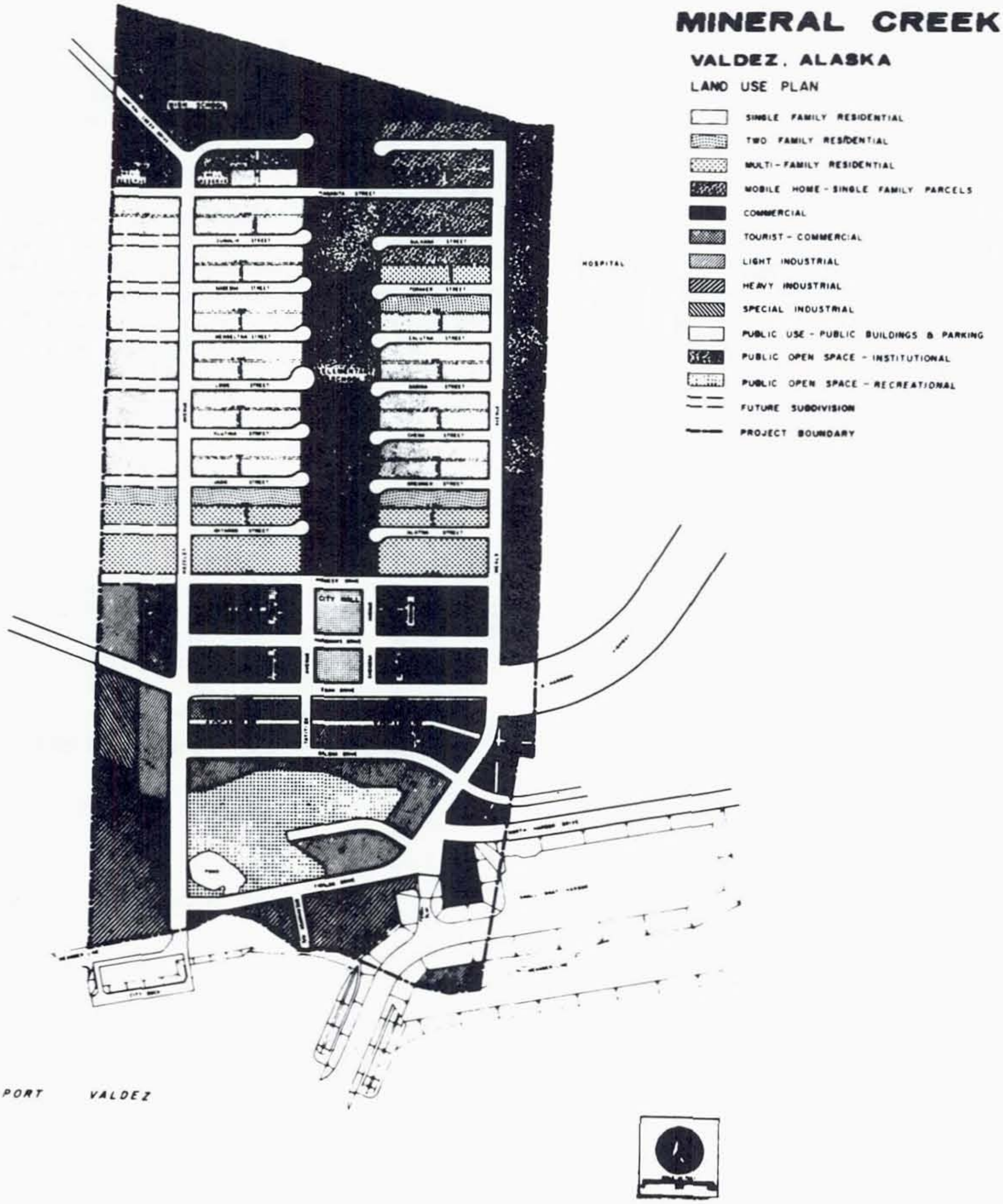


Figure 45. Valdez: Land use plan for Mineral Creek (Source: Selkregg and others, 1970, p. 206)

subdivisions. Some people still complain about being forced to leave their old homes, but relatively few present residents of Valdez ever lived in the old town and those that were relocated generally ended up with nicer homes (Dorothy Clifton, interview). In spite of local hearings and public review, the fact that the plan was done by outsiders caused some problems. Some aspects of the design posed problems in the special environmental conditions of Valdez. For example, the residential cul-de-sacs surrounding the central park make snow removal difficult and the laying of utility pipes in the street exposes them to freezing which would not occur if they were placed at the rear property lines where they would be insulated by the snow cover (John Kelsey, 1978, telephone conversation). For the most part, however, the new town appears functional and reasonably well laid out.

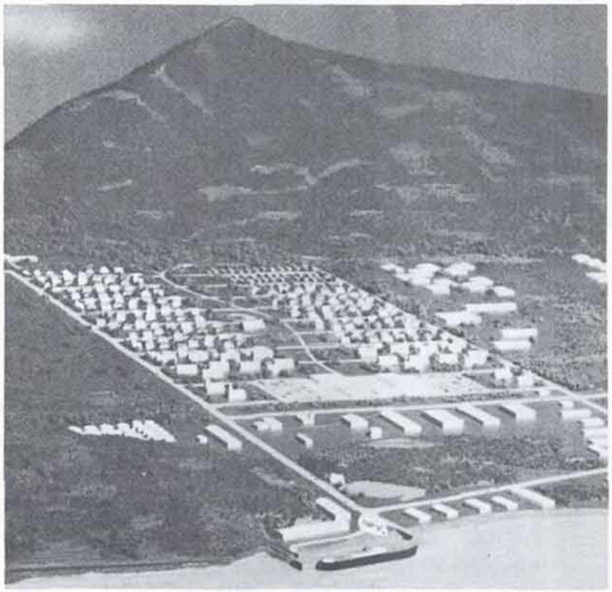


Figure 46. Model of plan for Mineral Creek town site (Source: Selkregg and others, 1970, p. 207)

REASONS

The relocation of Valdez is one of the most dramatic examples of post-earthquake land use change based almost solely on reducing risk from future earthquakes. It occurred, over local opposition, because the federal government essentially left the town with no other choice.

One could be left with the impression that the residents, in opposing the move, had very little concern for safety. It should be remembered, however, that many people left Valdez after the earthquake, never to return. Those who stayed probably had stronger economic and sentimental ties to the town than those who left.

In addition, much of the resistance to relocation was based, not on the concept, but on the way in which it was carried out through urban renewal. Questions concerning what was fair compensation for property in the old town site dominated much of the discussion. Also important was concern over who would get which parcels in the new town. This was resolved through use of a lottery system.

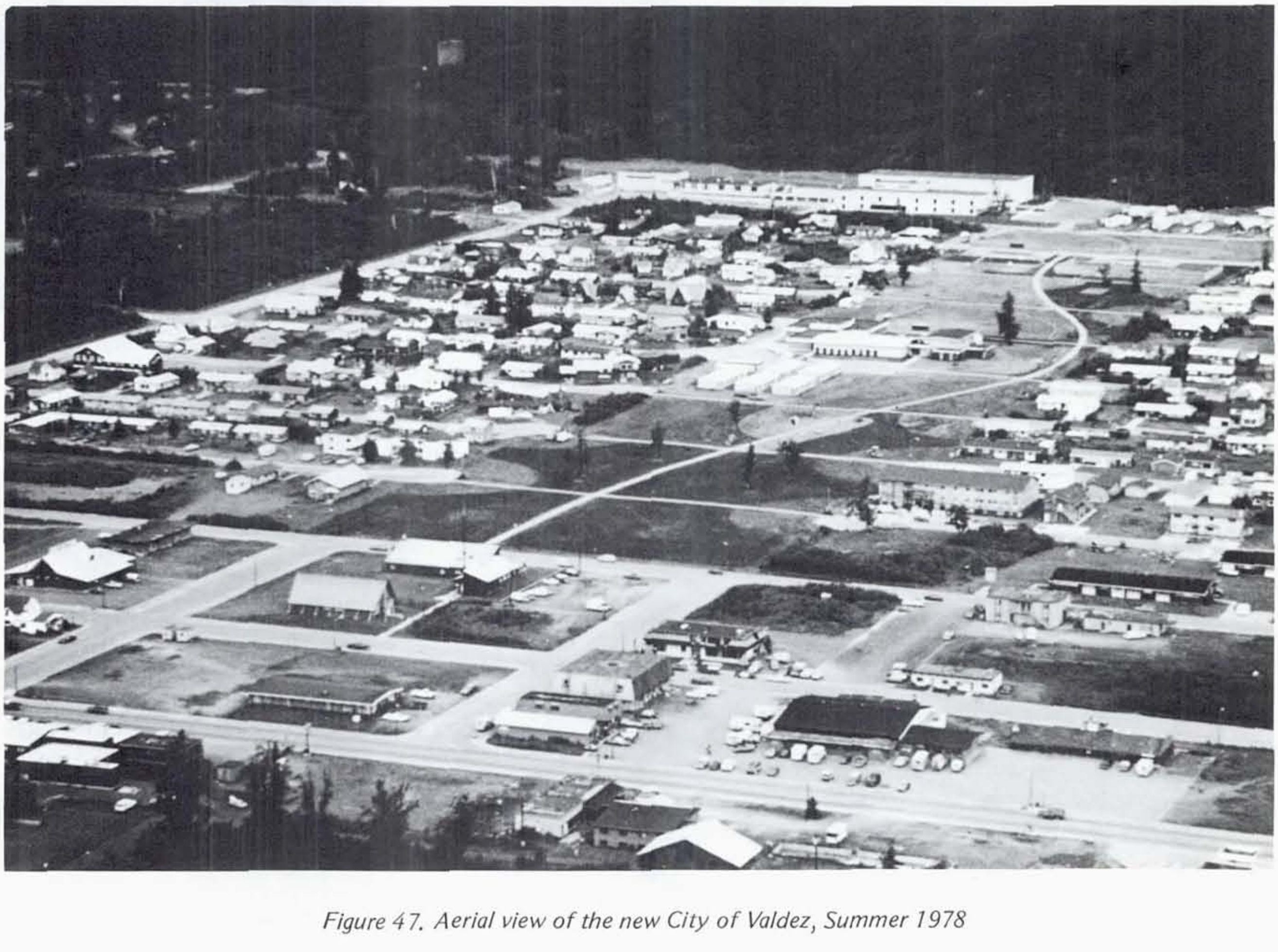


Figure 47. Aerial view of the new City of Valdez, Summer 1978

Conclusions

It is difficult to draw a line between pre- and post-earthquake planning. In Alaska, decisions concerning rebuilding in areas devastated 14 years ago are still being made. Should this be considered planning, or failing to plan, for the next earthquake or responding to the past one? Elements of both are present in the consideration by public agencies. The Alaskan experience points up the necessity for and difficulty of achieving continuous concern for seismic risk in land use planning and development decisions. To the degree that post-earthquake planning is aimed at reducing risk from future earthquakes, it can be considered a kind of pre-earthquake planning conducted under extraordinary conditions. Those extraordinary conditions do not last long, however, and a job initially done well may be undone when the planning function returns to normal. The Alaska experience points to the following conclusions:

1. The Federal Reconstruction Commission, field committees and task forces provided an effective mechanism for coordination and quick decision-making in reconstruction planning in Alaska. However, many recommendations were not followed by local jurisdictions. A sound organizational structure for immediate post-disaster reconstruction does not guarantee good long-term results.
2. The dismantling of the federal organizational structure for reconstruction planning six months after the earthquake appears to have been premature. No effective mechanism was provided for long-term monitoring of actions affecting the high-risk areas or for modifying the high-risk area designations based on further investigations.
3. The federal government's need to protect its investment in reconstruction is often in conflict with traditional feelings about local control. Yet, without sufficient federal follow-through, recommendations to mitigate hazards were often ignored locally — by government, lending institutions and private developers and investors. Moreover, it took a strong federal hand, stronger than ordinarily accepted, to achieve the relocation of Valdez.
4. Owners of and investors in profitable commercial or industrial property in hazardous areas had little incentive to relocate or avoid building in these areas because they could get earthquake insurance, private financing, publicly provided services and facilities, and possibly federal disaster assistance, if needed for a future disaster. (L Street)
5. Reconstruction decisions which effectively reduce future risk tend to be made when the local public and private costs of such decisions are low. (Seward, Earthquake Park, Fourth Avenue slide stabilization)
6. Some people who have survived terrifying experiences in an earthquake would willingly move back to a high-risk area rather than relocate, in part because of a strong attachment to "home."
7. Outside expertise is often needed to help with reconstruction planning after earthquakes. However, such planning should involve local representatives familiar with local conditions to avoid needless mistakes such as the design problems of the new town of Valdez.
8. Few local government officials or private property owners believed the federal government would ever deny future disaster relief to people who chose to rebuild in hazardous areas. (e.g. City Manager, Seward; Mayor, Anchorage)
9. Engineers and geologists tend to approach hazard evaluation and mitigation from fundamentally different points of view. Also, there are differences of opinion within the professions. Even when there is agreement on the technical matters, opinions on the appropriate public response may differ. Thus, planners and public officials often receive conflicting recommendations from technical experts and as a result may favor the recommendation that supports an action they wish to take for other reasons.
10. Attempting to use reconstruction after a disaster to achieve land use changes not directly related to recovery may be counterproductive. Unless such changes have been well thought out, have the support of the community, and, if federal funding is to be used, meet normal program funding criteria, the attempt may become controversial and slow down reconstruction planning. At a time when a community is already disrupted additional change is not likely to be welcomed. (Downtown Anchorage, Seward)
11. Seismic safety objectives are more likely to be achieved in reconstruction if they coincide with other community objectives. (Turnagain and Seward)
12. General delineation of high-risk areas can be done quickly after an earthquake to guide initial reconstruction decisions. It is important that the boundaries be drawn conservatively so that subsequent refinements result in smaller high-risk areas. It is noteworthy that the ultimate high-risk designations in Alaska have not been challenged on technical grounds.

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Santa Rosa Case Study

appendix c

Contents

Figures

C 1-a

Acknowledgments

Although the geologic effects and structural damage of the Santa Rosa earthquakes have been documented, very little has been written or published about reconstruction following the earthquakes. Thus, the material in this report concerning the actions taken by the City of Santa Rosa has been derived largely from public records and documents and from interviews with people who played, or are still playing, major roles in the reconstruction effort. Interviews were conducted by telephone, and in person, by Martha Blair on November 8, 1978, and George Mader and Martha Blair on December 5, 1978. Without exception, the people interviewed were helpful and cooperative and we gladly acknowledge their contributions to this study:

- Kenneth R. Blackman, City Manager, City of Santa Rosa
- William E. Myers, Director, Building & Code Compliance, Department of Community Development, City of Santa Rosa
- Mickey Karagan, Executive Assistant, Department of Community Development, City of Santa Rosa
- Gordon Husby, Executive Vice President, Exchange Bank, Santa Rosa
- Marvin Hyman, first property owner to undertake rehabilitation of commercial buildings on 4th Street, Santa Rosa
- Larry Simons, architect, designer of several rehabilitation projects and buildings in redevelopment area

Efforts were made to verify information obtained in the interviews by reference to other sources, but this was not possible in all cases. The authors assume full responsibility for the content of this report.

Introduction

In October 1969, the Santa Rosa Valley in Sonoma County was struck by two moderate earthquakes within a period of two hours. Although the earthquakes were felt throughout the San Francisco Bay Area, almost all damage was concentrated in the City of Santa Rosa, located about fifty miles north of San Francisco. At the time of the earthquakes, Santa Rosa, with a population of 50,000, was the largest city in Sonoma County and the center of the county's commercial, governmental, educational and medical services. The city had been severely damaged in the 1906 earthquake and many of the buildings in the older parts of town were constructed soon after 1906.

No deaths and few injuries resulted from the 1969 earthquakes, but damage to buildings, especially old unreinforced masonry buildings in the downtown area was heavy. In all, the earthquakes caused more than $6 million in damage to public and private facilities in the city.

The objective of the Santa Rosa case study is to determine the main factors influencing reconstruction decisions following the 1969 Santa Rosa earthquakes. The study was carried out by an interdisciplinary team of planners, engineers and geologists. The team reviewed published reports of the geologic effects, structural damage and reconstruction effort in Santa Rosa and, based on these reports, decided to concentrate on decisions concerning reconstruction in the downtown area. Field inspection and interviews with public officials and individuals involved with reconstruction were conducted in November and December 1978.

Geology and Seismology

The two earthquakes of Richter magnitude 5.6 and 5.7 which struck the City of Santa Rosa on October 1, 1969 are vividly described by M.E. Huffman of the California Division of Mines and Geology (Cloud and others, 1970):

> First came the state of dumfounded bewilderment . . . the clatter of falling books, dishes, lamps and even television sets meant an earthquake was occurring . . . Parents groped and staggered their way into darkened bedrooms to rescue their now awakened children. Persons stumbled to get outside onto their lawns and as they did so, saw the skyline flashing eerily as, in neighborhood after neighborhood, the lights flashed rapidly on and off before finally going out. Drivers were jerked about by automobiles suddenly bucking unmanageably, some even swerving into adjacent lanes.

GEOLOGIC AND SEISMIC SETTING

Santa Rosa is located on the eastern side of Santa Rosa Valley, a northwest-trending, intermountain valley of the California Coastal Ranges. The valley is bounded on the west by the Mendocino Range and on the east by the Sonoma and Mayacmas Mountains. The relatively flat valley floor is underlain by loosely consolidated sand, clay, and gravel. Well logs indicate that the depth of these sediments may be greater than 1000 feet in the vicinity of Santa Rosa.

The regional geologic structure of the area is typical of the Coast Ranges and features several northwest-trending faults. Some of the major faults are known to be active. The most prominent is the San Andreas fault, located about 20 miles west of Santa Rosa (Figure 1). Other active, or potentially active faults of the region

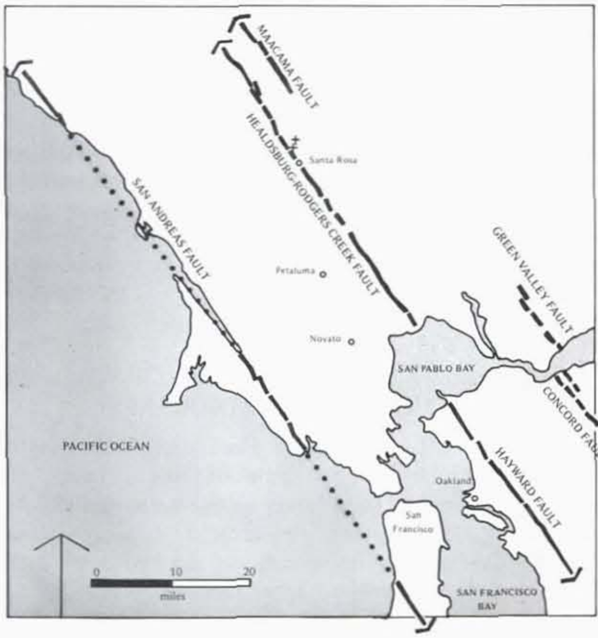


Figure 1. Regional fault map, Santa Rosa area (Source: Envicom Corporation, 1976, p. 101, modified by William Spangle and Associates, Inc.)

include the Hayward, Healdsburg-Rodgers Creek, Maacama, Concord, and Green Valley faults.

The earthquakes of October 1, 1969 were centered just north of the City of Santa Rosa along the Healdsburg fault. Southeast of the city is the Rodgers Creek fault; because of its proximity and general alignment with the Healdsburg fault, some geologists think the two are related and refer to the pair as the Healdsburg-Rodgers Creek fault. The precise manner in which the faults may be connected and the fault pattern through the Santa Rosa city area are not clearly understood. Near the Community Hospital of Sonoma County in Santa Rosa, trenching has revealed a zone of recent (within the last 10,000 years) faulting at least 980 wide.

The Healdsburg-Rodgers Creek fault system has apparently not caused rupture of the ground in historic times, but considerable earthquake activity has been attributed to it, with some 194 detectable seismic events occurring between 1855 and 1974. Nineteen of these events had magnitudes or apparent magnitudes of 4.0 or greater. According to seismologist T.V. McEvilly (Cloud and others, 1970):

> The October 1969 Santa Rosa earthquakes were not anomalous. Rather they reflect the historical record of repeated moderately strong earthquakes and earthquake sequences in the region. The zone of activity just north of town seems to be a region of concentrated moderately deep shocks . . .

EARTHQUAKE SENSITIVITY OF SANTA ROSA

The Santa Rosa Valley and, in particular, the site of the City of Santa Rosa, seem to be especially sensitive to earthquakes, whether the earthquakes originate on the San Andreas fault or on other faults nearer the city. It appears the local geologic conditions, such as the presence of deposits of rather elastic alluvial soils, tend to amplify the normal ground shaking that accompanies earthquakes, with the result that shaking in Santa Rosa is unusually damaging. For example, in the 1906 earthquake, Santa Rosa suffered more damage in proportion to its size than any other city in the state. The damage was proportionately worse in Santa Rosa, 20 miles from the causative San Andreas fault, than it was in San Francisco, which lies much nearer the fault. Local amplification of earthquake vibrations has been observed in other areas throughout the world.

SEISMIC AND GEOLOGIC EFFECTS – 1969 SANTA ROSA EARTHQUAKES

The October 1, 1969 Santa Rosa earthquakes, with magnitudes of 5.6 and 5.7, were felt over an area of 10,000 square miles, as far away as Sacramento and San Jose (Figure 2). However, the ground shaking caused either no damage or relatively minor damage outside of the immediate Santa Rosa area. Damage within Santa Rosa was more severe than would have been expected for these moderate earthquakes, further evidence of Santa Rosa's unusual earthquake sensitivity. Based on a review of the effects of the earthquake in the city, an intensity of VII to VIII has been assigned to the Santa Rosa area for the 1969 earthquakes. Secondary seismic effects, such as liquefaction or earthquake-triggered landsliding, did not occur during the 1969 earthquakes. There was no surface fault rupture. Hence, all the damage in Santa Rosa was caused by ground shaking.

FORECAST OF EFFECT OF FUTURE EARTHQUAKES

Several recent geological and seismological studies have attempted to predict effects of future earthquakes in the Santa Rosa area (e.g. Cooper-Clark and Associates, 1978; Dames and Moore, 1974; Envicom, 1976). An interpretive summary of these studies and other seismological data follows:

1. Small, local earthquakes will continue to occur in the area every few years.
2. Moderately strong earthquakes, similar to the 1969 earthquakes, can be expected every few decades.
3. The Healdsburg-Rodgers Creek fault, which appears to pass through Santa Rosa, could generate a maximum credible earthquake of magnitude 6.5 to 7.0. Such an earthquake probably happens every 100-300 years or so. Shaking in Santa Rosa in such an event would be very severe. Surface fault rupture on the order of two feet could accompany such an earthquake. Areas of the city underlain by saturated sand may be subject to settlement and liquefaction, which could damage buildings not supported on deep foundations.

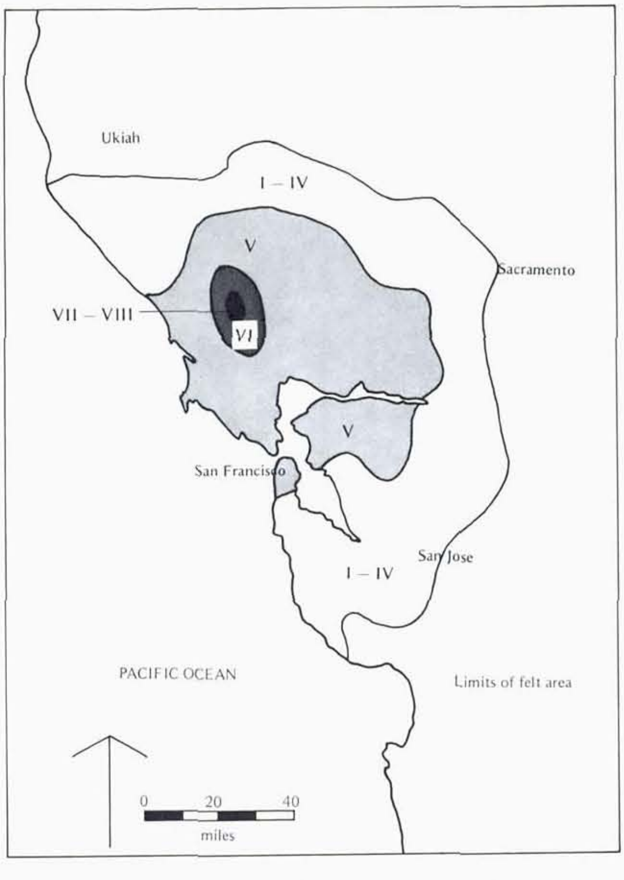


Figure 2. Distribution of Modified Mercalli intensities for the Santa Rosa earthquakes of October 1, 1969 (Source: from Steinbrugge and others, 1970, p. 95)

Figure 3. Distribution of buildings in central Santa Rosa severely damaged by the 1969 earthquakes (Source: from Cloud and others, 1970, p. 53)

4. An earthquake on the San Andreas fault with a magnitude of 8 or more (similar to the 1906 earthquake) is likely to occur every 100-300 years. Hence, the probability that Santa Rosa will experience severe ground shaking, and consequent heavy building damage, from a major earthquake on either the San Andreas or the Healdsburg-Rodgers Creek fault during the next fifty years or so is high.

Structural Damage

The Santa Rosa earthquakes were not strong enough to cause building collapse, and did not lead to the intensive structural investigations that usually follow major earthquakes. However, the earthquakes are worth studying for several reasons. First, the distribution of the damage was related to soft ground conditions and not necessarily to the proximity of the fault. Second, although most damage was to the old unreinforced masonry buildings in the central business district, some very new buildings were damaged in a way that suggested that the 1967 Uniform Building Code (latest edition available in 1969) should be revised. Probably of greatest significance to the study of post-earthquake land use planning, however, were the public decisions and actions regarding the older damaged buildings.

Although no deaths occurred and buildings did not collapse in the earthquakes, brick walls were cracked (one partially fell), hundreds of brick chimneys fell and a number of older wood frame houses fell off their foundations or were otherwise damaged. Of the commercial buildings in the central business district, it was reported that (Mayor Jack Ryerson in Steinbrugge and others, 1970):

1. Twenty-one buildings were damaged beyond repair and must be demolished;
2. Thirty-five were damaged but are capable of being repaired to meet vertical load requirements, but not lateral load requirements; and
3. Eighteen were damaged but can be repaired to meet vertical and lateral load requirements.

Figure 3 shows the distribution of damaged buildings in central Santa Rosa. Most were old unreinforced masonry buildings built after the 1906 San Francisco earthquake (Figure 4). From the structural engineering point of view, there was little to learn from these failures, because the probability and nature of damage to such structures were already well documented.

The earthquake also damaged three very recently built buildings — the Sonoma County Social Services building, the grandstand at the Sonoma County Fairgrounds, and the Crocker-Citizens Bank building. All three structures suffered extensive damage, although they had been conservatively and carefully designed in accordance with the Uniform Building Code and were constructed with more than ordinary care and inspection.

The Social Services building was designed with flexible columns and beams to resist earthquake forces. The columns and beams were constructed in accordance with the latest Uniform Building Code requirements with the concrete dimensions and the amount and arrangement of the reinforcing steel carefully calculated. Yet, the building proved so flexible that ceilings fell and partitions were dislodged. Concrete columns cracked in a manner that might have led to building collapse in a stronger earthquake. Similar problems were observed in the other two recently constructed buildings. The Northern California engineers, who examined the damage in Santa Rosa, were concerned enough about this poor performance to seek and attain changes in the San Francisco Building Code in 1969. However, it was not until similar problems were observed after the 1971 San Fernando earthquake that changes were made in the Uniform Building Code in 1973.

Figure 4. Unreinforced brick masonry failure, Third Street at Mendocino Avenue.
(Source: Steinbrugge and others, 1970, p. 5)
Photo credit: San Francisco Examiner

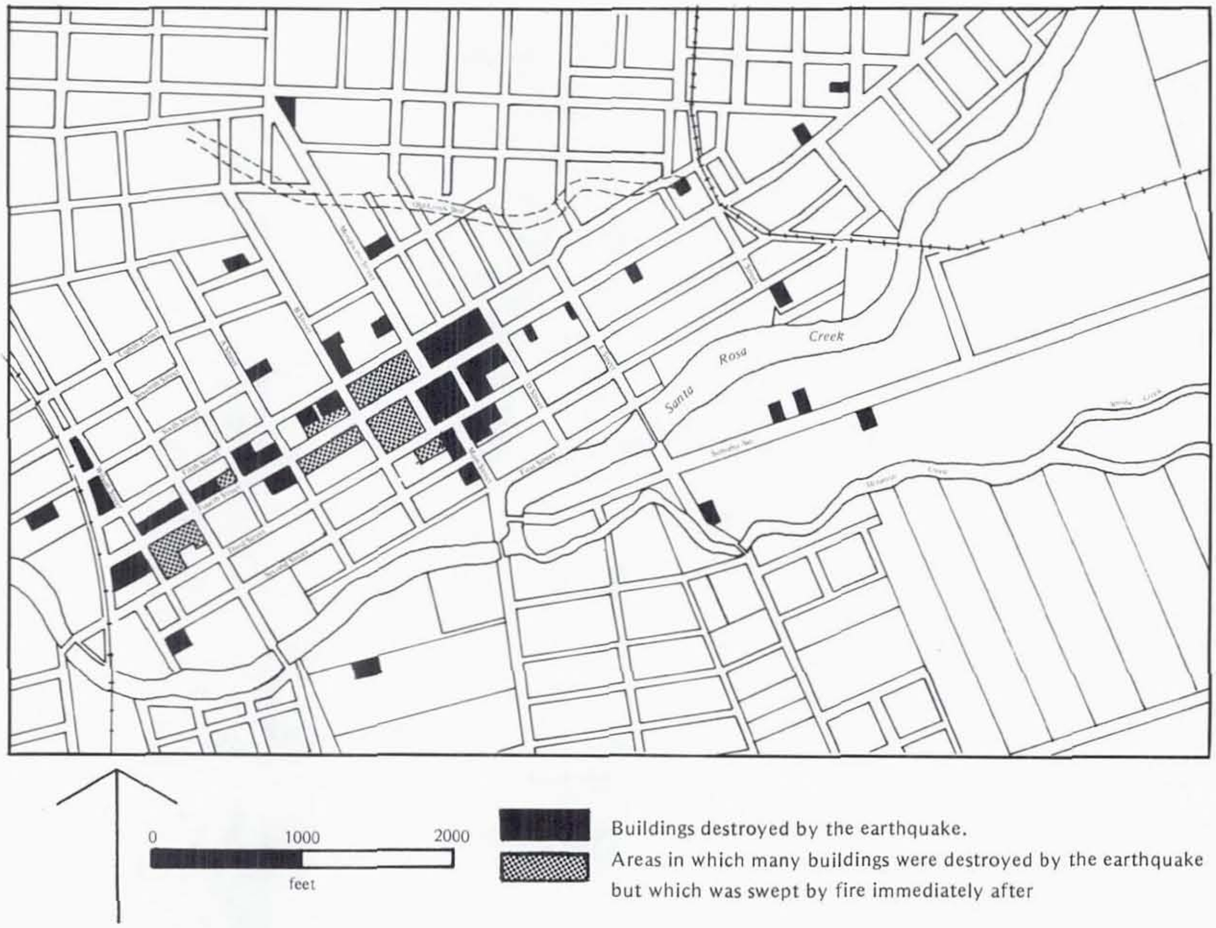
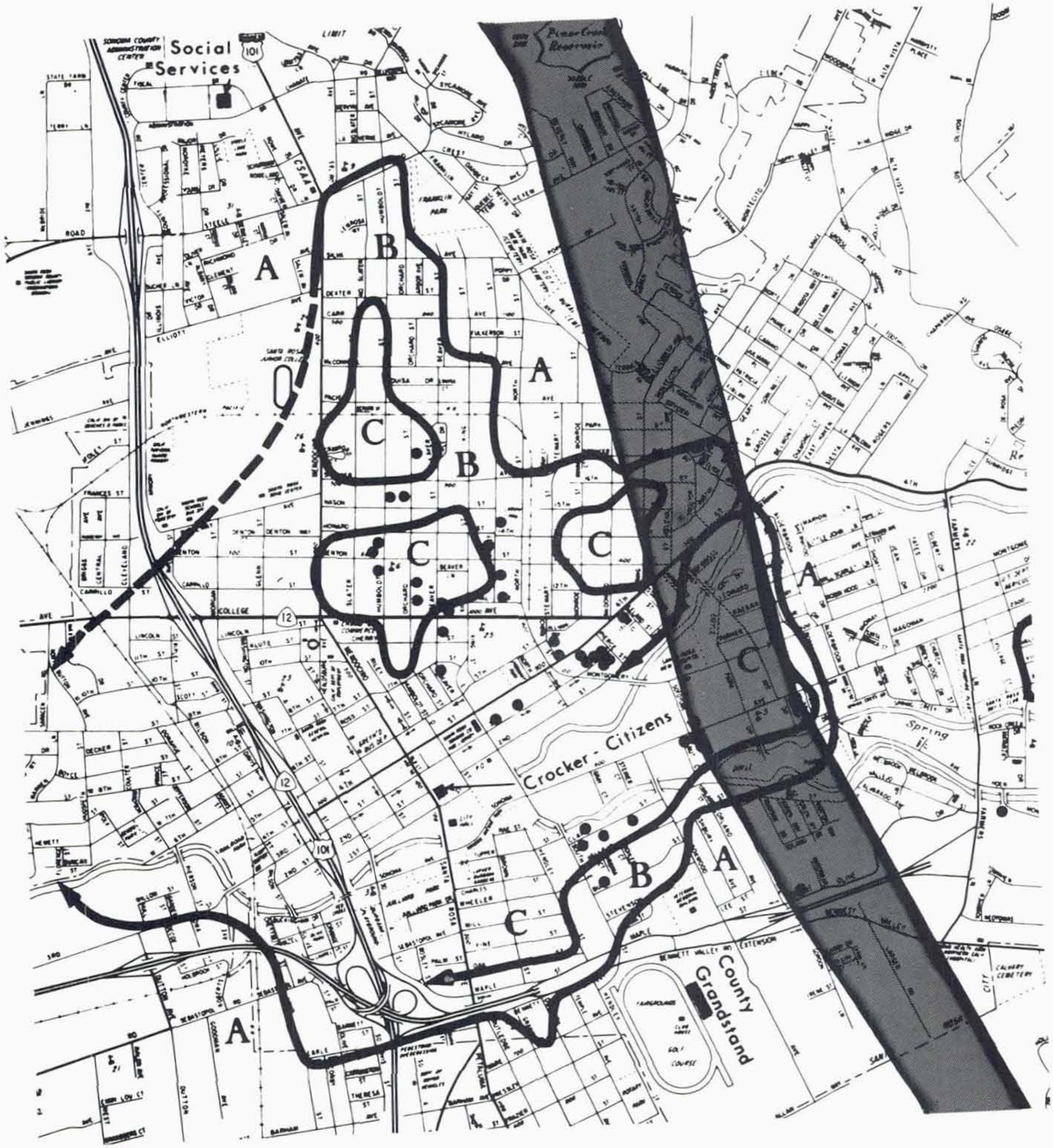


Figure 5. Map of portion of Santa Rosa showing areas destroyed by the 1906 earthquake and fire (Source: Steinbrugge and others, 1970, p. 17, as adopted from Lawson et al, 1908)

As shown in Figure 5, Santa Rosa also suffered severe damage in the 1906 earthquake which occurred on the San Andreas fault over 20 miles away. That experience coupled with the unusually heavy damage inflicted by the relatively small 1969 earthquakes seems to indicate that the city is more vulnerable to damage from ground shaking than the typical California city. To compensate for this increased vulnerability, the city adopted the 1973 Uniform Building Code with the additional requirement that the design earthquake forces be 50% greater than specified in the Code. Further, critical facilities housing fire, police, utility and administrative services are required to have design earthquake forces twice those of the 1973 Code. Other special requirements were adopted pertaining to foundations, elevators and equipment. Requirements similar to those adopted by Santa Rosa in 1973 are now incorporated in the 1976 Uniform Building Code which relates design requirements to the proximity of active faults and imposes special requirements for places of public assembly and for essential facilities – those which must remain safe and usable for emergency purposes following an earthquake.

The distribution of damage from ground shaking depends on the structural integrity of buildings as well as on differences in ground conditions. In the case of Santa Rosa, more damage would be expected, and occurred, in the central business district with its old unreinforced masonry structures than in areas, for example, with one-story, wood-frame houses. It is more difficult to assess the effect of ground conditions on the distribution of damage. One method is to map failure of some construction detail that is prevalent throughout the area. In the case of Santa Rosa, brick chimneys on single-story, wood-frame houses were a common element which could serve as a rough indicator of relative ground shaking. Figure 6 shows the distribution of damage to brick chimneys based on a survey by Steinbrugge (1970). There were two other surveys of residential damage and another plot of other damage such as water main breaks and damaged sidewalks. While there are differences, these indicators show reasonably consistent results. Clearly, some areas experienced intense damage (areas "C" on Figure 6) that cannot be explained by construction types alone. These are areas in which ground conditions apparently intensify earthquake effects.



A — Areas of generally minimal brick chimney damage.

B — Areas of generally moderate brick chimney damage.

C — Areas of generally heaviest brick chimney damage.

Boundary line between degrees of brick chimney damage. Good confidence limits.

Boundary line between degrees of brick chimney damage. Poor confidence limits.

Alquist-Priolo special studies zone.

Figure 6. Distribution of damage to brick chimneys, Santa Rosa earthquakes, 1969 (Source: Steinbrugge and others, 1970, figure 8, modified by William Spangle & Associates, Inc., 1979)

Of greater interest to this report, however, were the actions of the City Council with respect to the continued use of the older buildings that were damaged by the earthquakes. Before the earthquakes, the central business district was in competition with modern suburban shopping centers and steadily losing ground. However, it still employed many residents and provided a substantial portion of the city's tax base. Because of the deteriorating conditions, a redevelopment project had been started to the east of the commercial core and, at the time of the earthquakes, the city staff had just moved into a new, modern city hall in the redevelopment area.

The earthquakes seriously damaged 74 buildings in the central business district, 21 of which were damaged beyond repair. The question immediately arose as to the degree of repair that would be required. The amount of damage caused by these relatively small earthquakes indicated a need for significantly strengthening the structures to withstand comparable or larger earthquakes in the future. However, it was impractical and uneconomical to reinforce many of the buildings to the level required by the then current building code (1967). Demolition would cost many people their jobs and significantly reduce the city's tax base. Faced with these problems, the Santa Rosa City Council sought a compromise between requiring the demolition or repair to current code requirements of all hazardous buildings and ignoring the hazard. As stated by the Mayor (Steinbrugge and others, 1970):

> An immediate conflict developed on the extent to which building codes should be applied in the post-earthquake period. When a building becomes condemned or its status is marginal, there are economic consequences that cannot be dismissed. Businesses must be moved and employees and their families become affected.

Acting on the recommendations of an informal committee of local structural engineers and several San Francisco structural engineers, the City Council adopted a resolution providing that all buildings open to the public must meet the vertical load requirements of the 1967 Uniform Building Code. In addition, some lateral bracing was required for all commercial buildings damaged by the earthquake with the amount of bracing and timing of placement subject to further review by the structural engineers and the City Council (Resolution 9165, November 4, 1969 as cited in Steinbrugge and others, 1970, p. 3 and 4). On December 16, 1969, the City Council reaffirmed its adoption of the Uniform Building Code's Volume IV, Dangerous Buildings, 1967 edition. This code required buildings to be brought up to some proportion of the strength of a new building, but not the full strength.

Santa Rosa's building department was overburdened in the aftermath of the earthquakes. As stated by the Mayor (Steinbrugge and others, 1970):

> The problem of giving even a cursory visual inspection to the many buildings involved was almost beyond the Building Department's manpower capacity. Obviously dangerous buildings were immediately closed and barricaded. This problem was further compounded by the fact that as later aftershocks struck, it was necessary to reinspect buildings previously inspected.

Inspectors from the public works department and private engineers were enlisted to help out the Building Department with the inspections.

Some store owners were looking beyond the emergency repairs and considering the possibility of permanent reinforcement of their structures. Engineers and architects retained by some of the building owners to investigate means and cost of reinforcing their buildings raised questions concerning the provisions of the Dangerous Buildings Code. It became evident that the code was not very suitable for old structures with materials, practices and systems no longer recognized in current codes or used in modern buildings. After about a year of trying to work with the Dangerous Buildings Code, the city retained a consulting engineer in March 1971 to develop: 1) procedures for examining all older buildings – not just those damaged in the 1969 earthquakes, and 2) criteria for evaluation and reinforcement.

The consulting engineer worked with an advisory group of local structural engineers, the City Manager and the City Attorney, and a final report was jointly submitted to the City Council on June 16, 1971. The report included the text for a proposed ordinance which was adopted by the City Council as Resolution 9820 on October 12, 1971. A major reason for the acceptance of the ordinance was the direct involvement in its preparation of the local engineers who would have to use it. Each provision was discussed until there was essentially unanimous agreement or, at least, acceptance. Drafts were sent to the local engineering and architectural societies for discussion. Representatives of the realtors and building owners were brought in to discuss the various provisions and the reasons they were considered to be necessary. With the backing of the professional groups and the absence of objections by the property owners, the City Council adopted the provisions by resolution (described in the following section). In the seven years since adoption, it has had only minor revisions and seems to be working well.

Reconstruction Planning

At the time of the earthquakes, Santa Rosa was a community of about 50,000 people. Since then it has grown about 5% per year to about 75,000 people in the city and 100,000 in the Greater Santa Rosa area. It is the commercial, educational, medical and governmental center of Sonoma County, serving a market area population of 250,000 – 300,000 people.

In the 1969 earthquakes, many buildings in the already deteriorating downtown were damaged or substantially weakened by ground shaking. Although the geological and seismological evidence, previously discussed, shows that the downtown area is clearly subject to strong ground

Figure 7. Santa Rosa Urban Renewal Project Area
(Source: Santa Rosa Redevelopment, Annual Report, undated, modified by William Spangle & Associates, Inc., 1979)

shaking, options for land use changes to reduce occupancy of this area were limited because of the substantial prior public and private investment and the fact that no structures collapsed and most could be repaired. In addition, it was known that damage from future ground shaking can usually be reduced through proper design and construction of buildings. Thus, in Santa Rosa, the main effort after the earthquake was directed at abating structural hazards at a reasonable public and private cost. The city approached this through a combination of redevelopment, designed to increase seismic safety as well as revitalize the downtown area, and a systematic program to abate individual structural hazards throughout the city.

DOWNTOWN REDEVELOPMENT

Santa Rosa is an older California city with a downtown area built mostly in the early 1900's. Many of the buildings are brick or stone, two-story structures typical of that period. In 1961, the city began a redevelopment project under the federal urban renewal program covering the eastern portion of the downtown area (Phase I, Figure 7). At the time of the earthquakes, the City Hall, Crocker-

Citizens Bank and Bank of America buildings had just been completed and land had been cleared for the other buildings.

In 1968, a year before the earthquakes, Santa Rosa adopted a Central Business District plan envisioning significant upgrading of the commercial area to the west of the urban renewal area, but rejecting further urban renewal as a technique. Many buildings in this part of downtown were damaged in the earthquakes. Because of the extent of the damage and limited availability of local private and public funds for repair, outside financial assistance was obviously needed. Redevelopment appeared to the city to be the only viable option. Using the 1968 plan as a basis, the Urban Renewal Agency prepared an application for federal urban renewal funds for the damaged commercial area. At that time, the federal government was no longer funding commercial redevelopment and the regional office turned down the city's application for this new project. The City Manager and Mayor went to Washington, D.C. to plead with the Department of Housing and Urban Development (HUD) for approval of the project, as Phase II of the 1961 project rather than as a separate project. Approval was received in 1970, about one year after the earthquakes – an amazingly short period of time especially considering the initial disapproval of the project by the regional office.

The city originally had hoped to redevelop the entire area between 5th Street and Sonoma Avenue and between Santa Rosa Avenue and Route 101. However, HUD placed a limit of $5,000,000 on federal assistance for the project, and the city reduced the project area to a size it considered manageable with the federal contribution of $5,000,000 and a local share of one-fourth or $1,250,000. In the area finally selected (Phase II, Figure 7), seventy structures out of a total of eighty-five were sufficiently deteriorated or damaged to warrant clearance (City of Santa Rosa, application to HUD for Phase II Redevelopment). A major objective of Phase II redevelopment was "to remove certain buildings which have sustained earthquake damage and which otherwise do not meet requirements for safe occupancy" (Santa Rosa Urban Renewal Agency, 1970, p. 3). In 1974, additional land to the north of the Phase II area was added as Phase III of the original 1961 project to provide sufficient area for a large-scale regional shopping center (Phase III, Figure 7).

The Phase II redevelopment plan called for total clearance of the project area and development of a regional shopping center as an integral part of downtown Santa Rosa. This unusual opportunity to develop a major shopping center as a part of, rather than in competition with, downtown is possible largely because of the excellent freeway access to the site. The Downtown Development Association joined with the city in retaining a consultant to prepare a design plan to insure the integration of the existing downtown area with the regional shopping center (EDAW Inc., 1977).

Status Today

Phase I of the project is almost complete. Only one parcel, reserved for a state office building, remains undeveloped. A well-designed civic and financial center has been built along with scattered office and commercial buildings and a major open space area called Courthouse Square (Figure 8).

Figure 9 shows the basic layout of the proposed shopping center, featuring three department stores, a shopping mall, two-level parking and pedestrian access to the existing downtown and Railroad Square. Clearance in this Phase II area is almost completed; three buildings remain, but will soon be demolished. Buildings occupied by Wells Fargo Bank, Northern California Savings & Loan, Pacific Telephone, and Traverso's Market have been constructed or rehabilitated (Figure 10). Construction is just beginning on the foundation for the Sears store – one of the department stores serving as cornerstones for the regional shopping center (Figure 11).

Figure 8. Phase I redevelopment area looking east across part of Courthouse Square to Eureka Federal Savings building, Fall 1978

Reasons for Actions

1. The Phase II redevelopment area was in need of renewal before the earthquakes; the damage caused by the earthquakes provided the needed impetus.
2. The existence of an up-to-date plan for the downtown area and a functioning redevelopment agency made the choice easier to implement than it otherwise would have been.
3. Federal funding was sought to redevelop part of the damaged downtown area because other possible sources of funding appeared inadequate. The willingness of the federal government to permit annexation of the damaged area to the existing commercial redevelopment project was essential to the use of redevelopment as a means of reducing future seismic risk.
4. The fact that Santa Rosa was, and is, experiencing steady population and economic growth also made redevelopment a logical choice. The city could support an expanded commercial area and generate sufficient tax revenue to pay for the local share of redevelopment project costs and other public improvements.

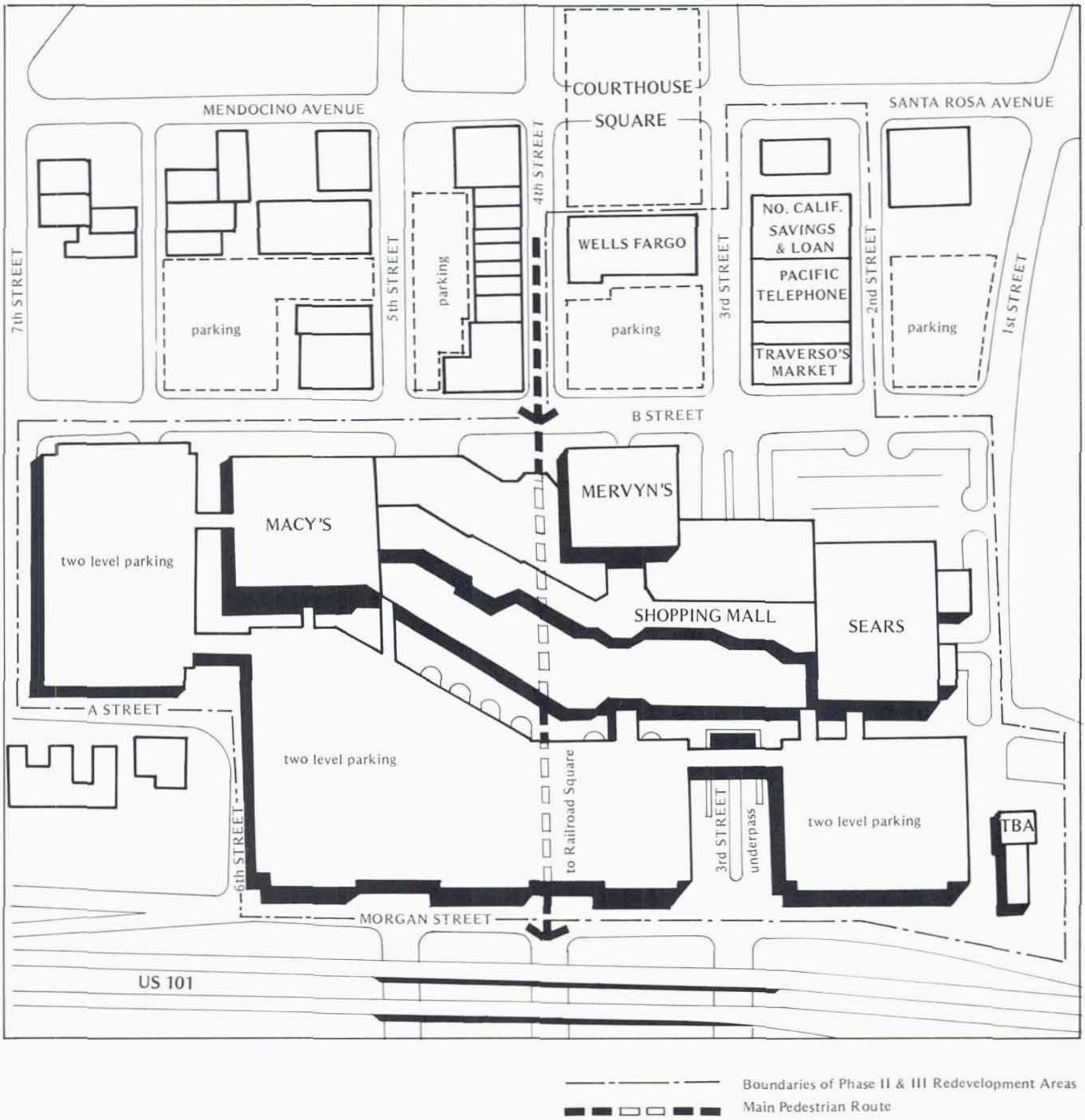


Figure 9. Design plan for regional shopping center, Santa Rosa (Source: City of Santa Rosa, modified by William Spangle and Associates, Inc.)

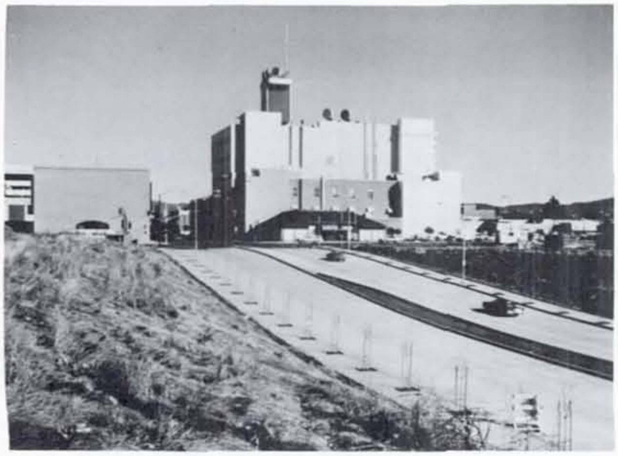


Figure 10. Looking east along 3rd Street, part of Phase II redevelopment area cleared for the shopping center. To the left of 3rd Street is the new Wells Fargo Bank building; to the right, Traverso's Market and the Pacific Telephone building (see Figure 9).

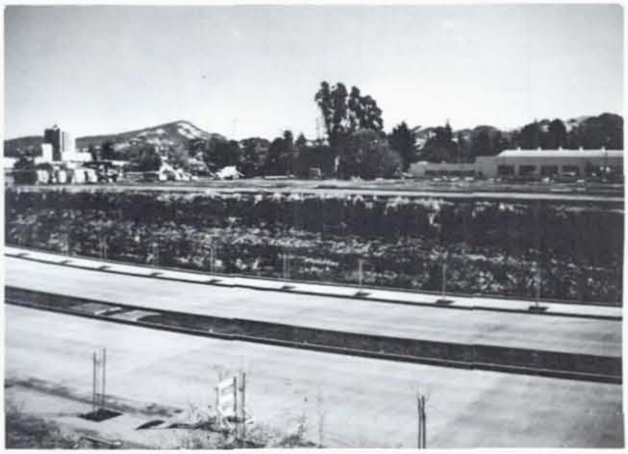


Figure 11. Cleared Phase II redevelopment area. To the right, construction underway for Sears store, Fall 1978.

5. Changes in ownership in the downtown area since the earthquakes have resulted in a vital and progressive business community committed to the redevelopment of downtown Santa Rosa.
6. The city staff enjoys strong local support, is deemed competent, and works well with the property owners and businesses involved in the project in pursuing the shared objective of revitalizing the downtown area.
7. The success of Phase I redevelopment has led to confidence that Phase II can be successfully completed and has kept alive support for the project.

ABATEMENT OF STRUCTURAL HAZARDS

Many older buildings outside the redevelopment area were also damaged in the earthquakes. Soon after the earthquakes, a committee was formed by the city to recommend procedures for evaluating building safety and abating structural hazards in areas not being cleared for redevelopment. After meeting for about four months, it became apparent that the committee would need more technical expertise to come to grips with the problems and develop realistic and workable procedures for the city. A structural engineer was engaged to draft recommended procedures.

Following almost two years of discussions, drafts and revisions, summarized in the section Structural Damage, Resolution 9820, establishing criteria for the inspection of buildings, was adopted by the City Council on October 12, 1971. Essentially, the resolution ordered a preliminary structural review of 1) buildings constructed before 1958 except public schools and one- and two-family dwellings, 2) buildings with unreinforced masonry walls, and 3) wood buildings located in Fire Zone I. Priority for review was as follows (City of Santa Rosa, 1971, Resolution 9820, p. 2):

1. Theaters, hotels, places of public assemblage of 100 persons or more, hospitals, clinics and governmental public buildings.
2. Buildings adjacent to sidewalks with large volumes of pedestrian traffic.
3. Buildings open to the general public such as stores, markets, shops, clubs, restaurants, office buildings and public assemblages of less than 100 persons.
4. Apartments of more than 10 units.
5. Apartments of 10 units or less.
6. Shops, garages, warehouses and other buildings not generally open to the public which have low occupancy loads.
7. Any other buildings.

This review was undertaken by the city at no expense to the property owner and was intended to determine whether or not the building complied with provisions of the 1955 Uniform Building Code. New construction in the city must comply with the current Uniform Building Code. Use of the 1955 Code, rather than later codes, for abating structural hazards was a compromise to encourage rehabilitation rather than demolition and to ease the financial burden on the property owner forced to comply while at the same time providing a reasonable level of safety.

If the preliminary review found that the building failed to meet 1955 Code requirements, the property owner had to engage a structural engineer to review the structure. The resolution established different structural criteria for different terms of occupancy: long term, up to five years, one year, and ninety days. Under these criteria, in theory at least, buildings could gradually be brought up to code standards for long term occupancy. In fact, it became apparent that, in most cases, the work required to meet the standards for even one year occupancy was so extensive and expensive that it was uneconomical to bring buildings up to code incrementally.

The resolution, reaffirmed by the Council several times, provided the basis for abating structural hazards throughout the city. In August 1978, the major provisions of the resolution were added to the City Code as part of Ordinance 1944, Building Regulations. However, the provisions are still referred to as Resolution 9820. Several changes were made in the original resolution when it was adopted as an ordinance:

1. Motels were added to the list of first priority buildings for preliminary review.
2. Further investigations required of the property owner may be done by a civil engineer; a structural engineer is no longer required.
3. A property owner has one year to voluntarily abate identified hazards, after which the city can force compliance under procedures set forth in the Uniform Code for the Abatement of Dangerous Buildings.
4. A moderately reduced safety factor is permitted for certain structural elements.

Since the original resolution was adopted in 1971, some 200 to 250 buildings have been reviewed and many have been rehabilitated. Approximately 500 buildings remain to be reviewed. Most priority 1 buildings have been reviewed and a start has been made on priority 2 buildings – those in the Montgomery Village and Coddington shopping centers and in downtown Santa Rosa (outside of the redevelopment area).

In 1972, demolition was completed for a city parking lot between B Street and Mendocino Avenue on 5th Street. The backs of the buildings fronting on the 500 block of 4th Street were so unsightly that the City Council requested staff to inspect the buildings out of priority for compliance with 9820. All were found to require extensive work to meet the minimum standards for occupancy and the owners protested to the Council. A four-year moratorium was finally granted to property owners. During this time, they could occupy the buildings, change tenants, make repairs and, in general, conduct business as usual without meeting building code standards. By the end of the moratorium in October 1977, the buildings had to be rehabilitated to meet code standards or removed. One owner chose to demolish his buildings; the others sold their buildings, most of which have now been rehabilitated by the new owners.

Rehabilitation of the 500 block of 4th Street began with the purchase of three adjacent buildings by the owner of a pawnshop whose store had been razed to make way for Phase II of the redevelopment project. Originally denied a conditional use permit by the Planning Commission, which was opposed to a pawnshop in what was planned to become a "high-class" retail area, the owner hired an architect to design the rehabilitation of the three buildings for a variety of uses including a "high-class" pawnshop. The commission approved the design and granted the use permit. With the assistance of his Congressman, the owner was able to obtain a Small Business Administration disaster assistance loan to cover some of the cost of rehabilitation (one of the fewer than 6 SBA loans granted in Santa Rosa after the earthquakes). Work started in 1974 and today is complete except for the second floor of one building. The success of this project has been instrumental in encouraging other owners on the block to undertake rehabilitation of their buildings (Figure 12).

Figure 12. Part of the 500 block of 4th Street showing, in the background, the first successful commercial rehabilitation project involving three old buildings and, in the foreground, rehabilitation underway of three more buildings, Fall 1978

Rehabilitation is a risky and expensive undertaking. Costs are almost impossible to estimate in advance and innumerable unforeseen problems can be expected to arise as reconstruction proceeds. Although rehabilitation appears to be less expensive than tearing down an old building and constructing a new one, it is often difficult or impossible to design the kind of space needed for a particular use.

The costs of rehabilitation are significant. For the typical, early 1900's two-story, masonry, commercial building on a 40' x 90' lot, structural work can cost over $100,000 ($14 per sq. ft.). Architectural and functional remodeling ordinarily adds another $100,000 to the total cost. It is not unusual for rehabilitation costs for such a building to exceed a quarter million dollars ($35 per sq. ft.). This translates into relatively high rents for space in rehabilitated buildings. The shopping center is expected to attract sufficient numbers of people to the downtown area to interest prime tenants who can afford to pay the high rents for retail and office space in rehabilitated buildings. Thus, the private rehabilitation of buildings outside the redevelopment areas in downtown Santa Rosa is economically predicated on the completion of Phase II of the redevelopment project.

Similar rehabilitation is beginning to occur in an area called Railroad Square, west of the freeway, and in other areas in and near downtown Santa Rosa (Figure 13). In all cases, the structural safety of the buildings is being significantly improved. Although the process is slow, Santa

Figure 13. Restaurant in part of rehabilitated warehouse, Railroad Square, Fall 1978

Rosa is making substantial progress in abating the structural hazards inherent in old, unreinforced masonry buildings.

Several tactics have been used to win public support for the program and convince property owners that the city is committed to enforcing the provisions of 9820. The first formal review was of church buildings. Most were designed by architects and engineers and, of the many churches in the city, only four required any significant amount of work to meet the 1955 code. This encouraged property owners of other first priority buildings to accept the preliminary review more readily and even, in some cases, to request it.

The staff of Building and Code Compliance in the Department of Community Development has devoted considerable time and effort convincing realtors that they are obligated under State law to inform prospective buyers and renters of potential structural hazards. Most people now purchasing pre-1958 buildings (other than one- or two-family houses) are informed of the possible hazard and of the provisions of 9820 that pertain to the structures.

Once commercial space in an unrehabilitated older building is vacated, the city takes whatever administrative action it can to keep it vacant until it is brought up to code. The staff may try to convince potential tenants that a building is unsafe and that they should either look elsewhere for space or persuade the owner to make the necessary improvements. Sometimes business licenses or use permits for operation in unsafe buildings are denied until the building is strengthened.

In general, the city has found it easier to achieve rehabilitation when a property changes ownership. Many of the owners at the time of the earthquakes were unwilling or financially unable to rehabilitate their buildings. Only two buildings have been rehabilitated under the original ownership. Newer owners in the city have moved more readily, and often voluntarily, into rehabilitation. The engineer responsible for code compliance has found it unnecessary to go out of the office to make an unrequested review of a building in over two years. Owners are coming to him and the process is being handled by negotiation. He agrees to walk through buildings unofficially and give the owner his opinion of the building's condition. He stresses that formal review is only about a year away on his "schedule" and that the owner might just as well bring the building up to code now since he'll be forced to later, probably at greater cost. The argument is often convincing.

The effect of the recent rapid escalation of real estate values in Santa Rosa (as in the whole Bay Area) is mixed. On the one hand, the value of the property has increased to the point that rehabilitation makes economic sense from the owner's point of view. On the other hand, the cost of rehabilitation has risen sharply. On balance, it appears that rising values have encouraged rehabilitation of older buildings by assuring owners that the amount spent will be recoverable in the future.

Reasons for Actions

Why has the abatement of structural hazards in older buildings in Santa Rosa been more successful than in many other earthquake-prone communities?

1. The city staff is committed to the program and competent to carry it out. The City Manager has supported the hiring of and work of the engineers carrying out the program.
2. The staff has been able to retain City Council members' support for the program, in part through convincing them of its importance, and in part by employing enough flexibility in administrating the program to avoid the kinds of controversy that reach the attention of Council members.
3. Full use has been made of administrative powers and discretion in carrying out the program, thus avoiding, to the extent possible, the more politically volatile legislative arena.
4. The steady growth of the community coupled with rising property values has provided incentives for property owners to comply.
5. Efforts to bring the real estate community into the process have been important in lending credibility to the program.
6. The city has been generally helpful and equitable in dealing with owners and has allowed time for ownership changes to occur. They have found that new owners are then much more interested in rehabilitating the structures than the prior owners.
7. The business community is committed to maintaining a vital downtown area and has been willing to work for and help finance improvements which have made rehabilitation an attractive option for the property owner.

SEISMIC SAFETY ELEMENT

The seismic safety element of the city General Plan, adopted in March 1978, reaffirms the commitment to abate structural hazards. Policy 1 is "continue to provide for the identification and evaluation of existing structural hazards (Resolution 9820), and abate those hazards to acceptable levels of risk" (City of Santa Rosa, 1978, p. 97). Recommended priorities for inspection and abatement of hazards emphasize facilities critical for emergency response. First priority facilities are (City of Santa Rosa, 1978, p. 95):

> Hospitals, fire stations, police stations, civil defense headquarters, gas, electric, water "lifelines", ambulance services, emergency broadcast services, power plants, sewage treatment plants, certain bridges.

Suggested approaches to abate structural hazards include structural rehabilitation, occupancy reduction and demolition and reconstruction.

Another policy is to regulate land use in the areas of significant natural hazard. Such areas include the Healdsburg-Rodgers Creek fault zone, areas with landslide or liquefaction potential, the 100-year flood plain, areas of potential inundation from dam failure, and fire hazard areas. The element calls for geologic or other appropriate investigations prior to permitting development, especially of critical facilities, in such areas.

The Healdsburg-Rodgers Creek fault zone which passes through Santa Rosa to the east of the downtown area (see Figure 6) has been designated by the state as a special studies zone under the Alquist-Priolo Special Studies Zones Act of 1972 (amended in 1974 and 1975). Within this zone, Santa Rosa must require geologic investigations before approving projects involving structures for human occupancy other than one- or two-story, single-family, wood-frame houses on single lots and single-family, wood-frame houses in subdivisions of fewer than four lots. Such investigations are often inconclusive in areas of deep alluvium as found in the fault zone within Santa Rosa. With the exception of investigations of the Sonoma County Hospital site, most geologic investigations, including trenching, have failed to reveal evidence of faulting, and the possible hazard of surface fault rupture often cannot be verified or quantified with present investigative techniques. No surface fault rupture occurred in the 1969 earthquakes and damage within the fault zone was relatively minor. Given the difficulty of verifying fault location in the alluvium, uncertainties concerning the likelihood and amount of potential surface fault rupture and the lack of historical evidence that the hazard is severe, the city has not regulated or restricted land use in the fault zone to reduce risk from surface fault rupture.

Conclusions

Immediately after an earthquake, a community understandably exhibits a high degree of concern over questions of seismic hazards. This concern fades quite rapidly with time, and whatever programs and policies to reduce risk were initiated or proposed right after the earthquake are often shelved or given very low priority. Santa Rosa is unusual in maintaining an active program to reduce structural hazards for so many years after the 1969 earthquakes. Tentative conclusions drawn from Santa Rosa's experience include:

1. A competent staff committed to developing and carrying out a reasonable hazard reduction program is a critical factor in the program's success.
2. Flexibility and equity in administering a program to abate structural hazards are very important. Public officials need to recognize the very real economic impact a program may have on individual property owners and be willing to work with owners to achieve reasonable safety with the least adverse financial impact.
3. Economic growth and rising property values can stimulate rehabilitation of hazardous structures.
4. The support and cooperation of the business community in abating hazards in commercial structures are important to the success of a program.
5. Public investment in redevelopment and public facilities can be critical in spurring private rehabilitation and redevelopment.
6. Public redevelopment projects are a logical approach for abating structural hazards in older areas of a community which have sustained significant damage and are in need of revitalization anyway.
7. Federal funding regulations and criteria need to be flexible enough to permit the use of redevelopment in reconstructing earthquake-damaged areas.
8. The existence before an earthquake of an adopted, up-to-date plan for potential redevelopment areas can significantly reduce the time and effort needed to get a redevelopment project underway after an earthquake.
9. When damage from an earthquake is relatively limited with little outright building collapse, the local jurisdiction has time to develop a comprehensive approach to abating structural hazards. Time is available to gain public support and ease the economic burden on property owners.

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Laguna Beach Case Study

appendix d

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Figures

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Solomon, Fred, Former City Manager, City of Laguna Beach

Temple, Terry, Sergeant, City of Laguna Beach Police Department

Interviews in Laguna Beach were conducted on October 5, 1978 by Thomas Vlasic and Martha Blair; on November 30 and December 1, 1978 by Thomas Vlasic, and on July 2, 1979 by Thomas Vlasic and Gerald Hobrecht. Thomas Vlasic, Martha Blair and Gerald Hobrecht had responsibility for writing the report. General overview was provided by George Mader and William Spangle. Graphics were prepared by Stephanie Stubbs-Hogan and photographs taken by Thomas Vlasic.

Every effort has been made to verify facts contained in the report. But, because of the evolving nature of the landslide and response, this proved difficult. The authors readily acknowledge the contribution of the people contacted but assume responsibility for any errors of fact or interpretation.

Introduction

Shortly before 6 a.m. on October 2, 1978, a massive landslide began moving in the Bluebird Canyon area of Laguna Beach, California. Residents of the area were sent running from their homes in predawn darkness as the landslide carried homes and automobiles down the hillside, uprooted trees and telephone poles, severed water, sewer and gas lines, and destroyed several hundred yards of roadway. The disaster scene is vividly described in the following eyewitness account of a local police officer:

> We saw one house tilt four feet and we ran like hell. You could see wires snapping and sparking, but there was no fire. I could hear houses crashing, water running, gas hissing . . . and my heart beating very fast.
>
> (Palo Alto Times, October 2, 1978)

The Bluebird Canyon landslide occurred during the course of the study of post-earthquake land use planning and, because of some similarities in problems of reconstruction after landslides and earthquakes, the original study was expanded to allow the study team to follow the response to the Bluebird Canyon landslide. The Laguna Beach study is valuable because it is the only case study that gave the team a firsthand view of the actions and decisions in the period immediately following the disaster.

The study was conducted by establishing and maintaining contact with key people, particularly at the local level, involved with the response. Newspaper accounts, and minutes of City Council and Planning Commission meetings were followed throughout the study. Valuable information was obtained from site visits and interviews on three occasions between October 1978 and July 1979.

The weeks and months following the landslide were marked by disagreement between federal and local officials over who would pay for emergency stabilization of the slide, permanent reconstruction of public improvements, and rebuilding of homes on the slide area. As of July 2, 1979 most issues had been resolved, the landslide was essentially stabilized and rough grading for reconstruction of public roads was completed. City officials estimated that utility installation and road reconstruction would be completed by October 1979 and were accepting applications for building permits for reconstruction of houses on the slide. This report describes the landslide and the actions taken by various government agencies up to July 1979 in response to the landslide. The emphasis is on tracing the decisions concerning the post-disaster land use of the slide area.

The Bluebird Canyon Landslide and Response

The Bluebird Canyon landslide set in motion a complex series of actions by federal, state and local agencies to lessen the impact of the disaster on the city and the landslide victims. This section describes the landslide, the geotechnical investigations, emergency response and proposals for stabilization. The purpose is to establish the context in which federal, state and local decisions were made which determined the future use of the slide area.

SETTING

The Bluebird Canyon landslide area is entirely within the City of Laguna Beach, a city of approximately 16,500 people located in Orange County, California, fifty miles south of Los Angeles (Figure 1). Laguna Beach is a coastal community with a thriving tourist industry based on its seaside location and "art colony" reputation. Its steep hillsides are among the more desirable suburban areas on the Southern California coast and many residents are willing to commute to jobs elsewhere in Orange County where employment opportunities are more diverse.

Laguna Beach is bounded on the west by the Pacific Ocean and, on its other sides, by undeveloped, unincorporated, hilly land (Figure 2). The older part of the city is on the flat coastal plain that extends inland for about a half mile.

Figure 1. Map of a portion of Southern California showing location of Laguna Beach

Figure 2. Photo showing coastal plain and hills of Laguna Beach, Summer 1979

Newer residential development constructed since World War II extends into several hillside canyons, including Laguna, Rim Rock and Bluebird canyons, which run perpendicular to the coastline (Figure 3). Much of the residential development in these canyons and similar canyons in Southern California occurred during the rapid growth period following World War II, usually without benefit of the soils and geologic investigations that are standard in many communities today. As a result, geologic problems like those in Bluebird Canyon were often unrecognized and few, if any, controls were placed on hillside development to regulate grading, control erosion or provide adequate drainage. The result has been dramatic cases of landsliding, destroying homes and public improvements, in many Southern California hillside subdivisions approved during the 1940's and early 1950's.

The Bluebird Canyon landslide took place in a thirty-year old, residential subdivision along the ridgeline between Bluebird and Rim Rock canyons. The landslide occurred within Tract 1252, an 11.6 acre, 53 lot single-family home subdivision. Although lots vary in size and shape, the average lot within the tract is approximately 6,000 square feet. The subdivision map for Tract 1252 was filed in 1947 and the grading of roads and lots began shortly thereafter. Thirty houses and the tract's three roads (Oriole Drive, Meadowlark Lane, and Meadowlark Drive) were constructed by 1957. Nineteen houses were built between March 1957 and September 1967 and one was built sometime after September 1967. By 1978, only three lots remained undeveloped.

THE LANDSLIDE AND DAMAGE

The initial landsliding on October 2 involved 3.5 acres and over 250 thousand cubic yards of earth. The slide mass, a largely intact block approximately 440 feet long, 410 feet wide and 70 to 80 feet deep, moved downslope toward the bottom of Bluebird Canyon leaving a headscarp of up to 35 feet high (Figures 4 and 5). During the first 40 minutes, the slide moved about 30 feet. After the initial fairly rapid movement, sliding continued at a rate of inches per day for several days. Horizontal displacement reached 50 to 60 feet and vertical displacement 20 to 25 feet. There was little or no rotational movement of the slide mass during descent.

Total property damage has been estimated at $15 million (City of Laguna Beach). Twenty-two houses were destroyed or sufficiently damaged by the initial slide to require demolition and two more were razed following a headscarp failure in April 1979. Within the area of the active landslide all utilities, including water, sewer, gas and electrical lines, were destroyed. Portions of Meadowlark Drive, Meadowlark Lane and Oriole Drive – some 775 feet of pavement – were destroyed. Figures 6-12 are photos of the slide area taken on October 5, 1978 – three days after the initial movement. In addition to the 22 houses destroyed by the landslide on October 2, 25 houses were initially vacated because of the threat of renewed earth movement, nonexistent or unsafe access, or disrupted utilities and services. Some 200 residents were evacuated from their homes on the day of the slide.

Despite extensive damage within the slide-ravaged area, no deaths occurred and only a handful of minor injuries were reported. This is probably because the initial movement occurred over a period of about 40 minutes giving residents time to escape. Moreover, residents were warned of impending danger by the noise that accompanied the landslide as it began to move. Many residents were awakened by the sounds of splintering walls, falling roofs, snapping power lines, breaking glass, and escaping gas. One resident reported: "It sounded like all hell was breaking loose. It sounded like sledge hammers pounding and there was a ripping sound like pulling nails out of wood" (Palo Alto Times, October 3, 1978).

The landslide is a reactivated portion of a larger prehistoric slide, approximately five acres in size, which underlies much of Tract 1252. The location and a cross section of the prehistoric landslide and the portion that moved on October 2, 1978 are shown in Figures 4 and 5. Houses within the five-acre area which were not damaged

Figure 3. Photo showing residential development in Rim Rock Canyon, Laguna Beach, Winter 1979

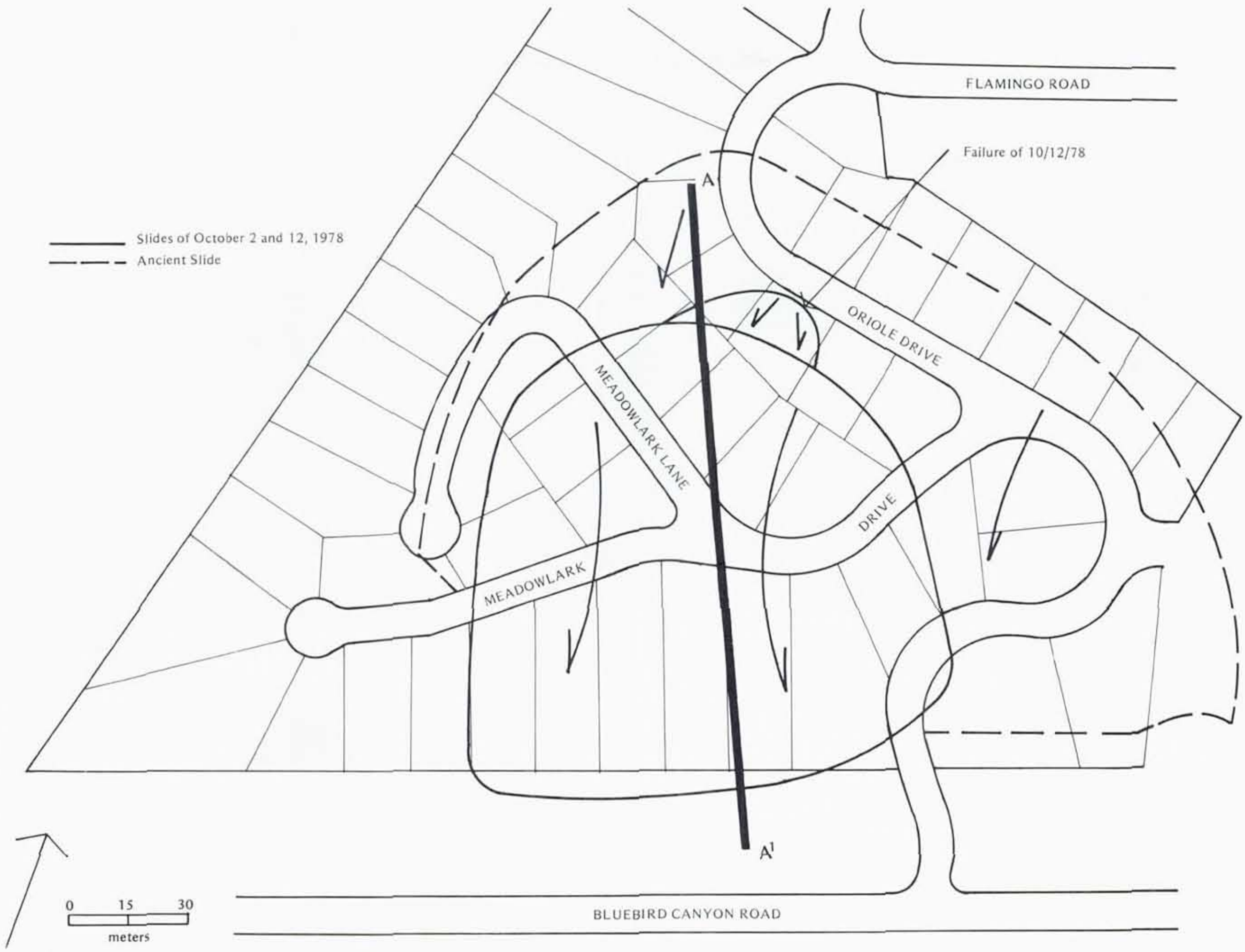

Figure 4. Map showing Bluebird Canyon landslides of October 2 and October 12, 1978. Cross section A-A[1] is shown in Figure 5.
(Source: Leighton and Associates, December 1978)

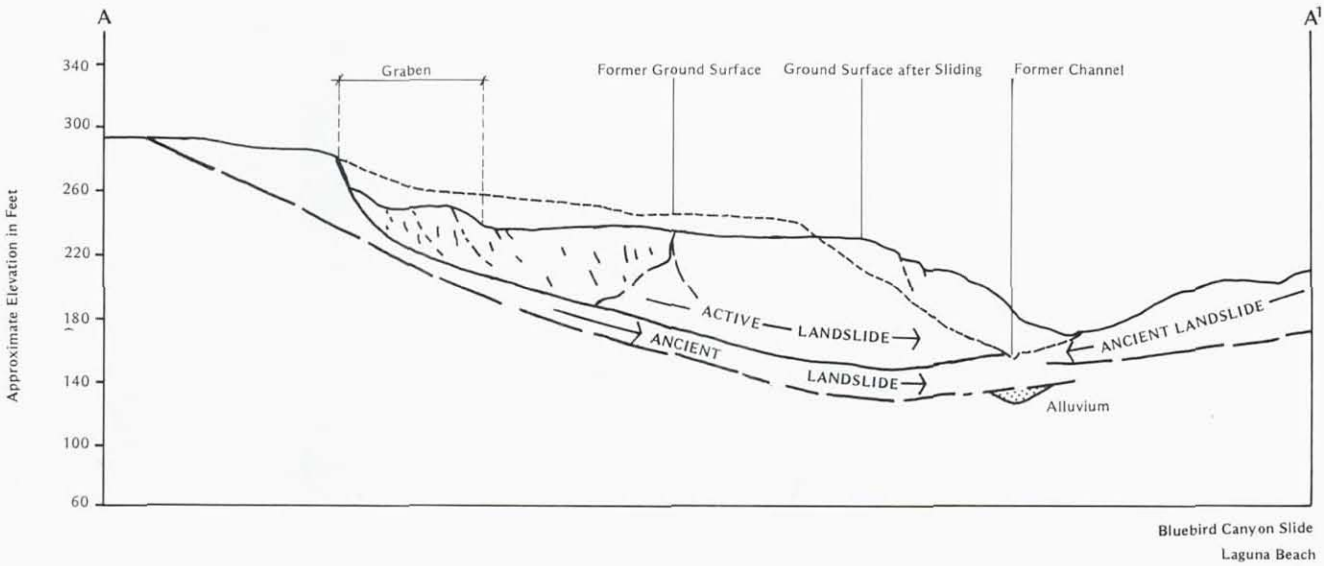

Figure 5. Schematic cross section of A-A[1] shown in Figure 4
(Source: Leighton and Associates, December 1978)

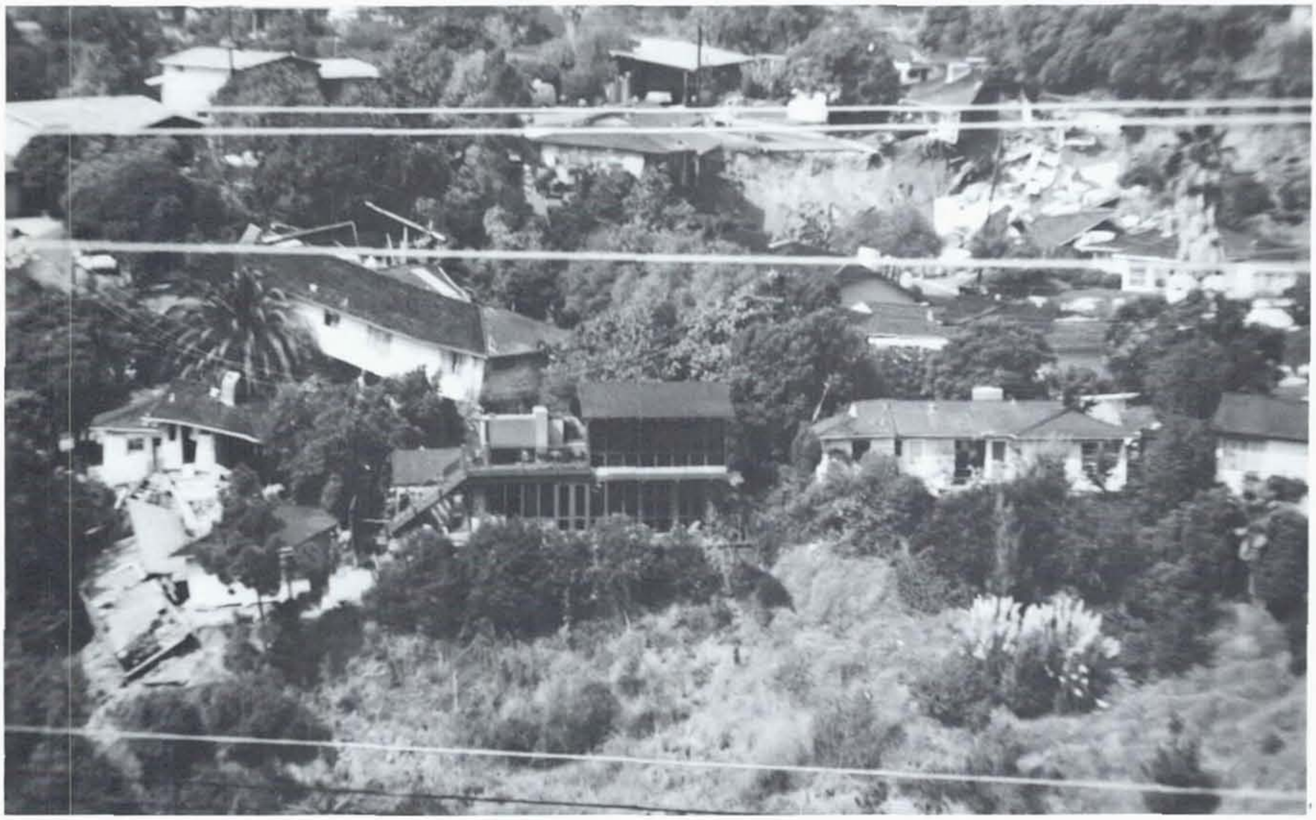

Figure 6. Overview of Bluebird Canyon landside and damaged houses, October 5, 1978

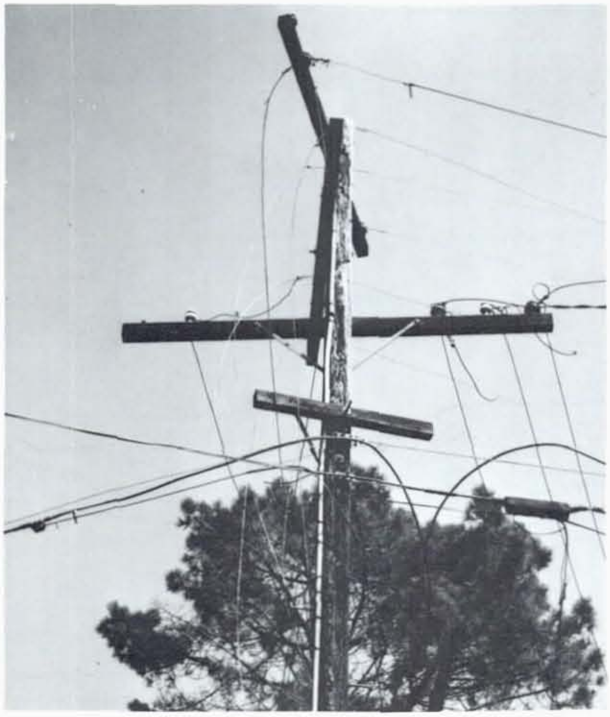

Figure 7. Broken utility lines, October 5, 1978

Figure 8. Graben at Meadowlark Drive. Pavement dropped 20-25 feet, October 5, 1978.

Figure 9. House fallen onto Meadowlark Drive, October 5, 1978

Figure 10. Interior of house shown in Figure 9, October 5, 1978

Figure 11. Headscarp below Oriole Drive viewed from the break in Meadowlark Drive, October 5, 1978

Figure 12. Toe of the landslide at Oriole Drive, October 5, 1978

or destroyed in the October 2 slide were endangered by possible reactivation of the ancient landslide and by failure of the headscarp in the months following October 2, 1978. Further land movement and headscarp failure occurred on several occasions following the landslide causing additional structural damage in some cases. Between October 2 and October 4, 1978, the slide mass moved another four feet and on October 12, 1978, a section of the headscarp failed, carrying with it the remains of one house already destroyed. On December 29, 1978, a 90-foot long fissure developed on the west embankment of Oriole Drive and on January 6, 1979, a 60-foot section of upper Oriole Drive collapsed. Another fissure opened up on February 9, 1979. These renewed movements caused no additional structural damage. However, on April 23, 1979, two homes were destroyed when another section of the headscarp failed as a result of excavation work being done to stabilize the headscarp. Two other homes were threatened as a result of another headscarp failure on May 12, 1979. The repeated movements in the months following the October 2 landslide underscored the precarious stability of the five-acre ancient landslide.

GEOTECHNICAL INVESTIGATIONS

On the day of the landslide, Leighton and Associates was contacted by the city and immediately prepared a draft proposal to conduct a preliminary geotechnical investigation of the landslide. The draft proposal was approved and funds for the study appropriated by the City Council on October 3. The investigation was to assess if, and under what conditions, it was safe to allow residents into the area to retrieve personal possessions, the geotechnical conditions which contributed to the landslide, the potential for further movement and possible stabilization measures (City Council Minutes, October 3, 1978). On October 5 and October 10, 1978, tiltmeters were installed by Leighton and Associates' geologists to monitor ongoing ground movements in the area.

In a preliminary report dated November 6, 1978, Leighton and Associates concluded that the heavy rainfall in February 1978 was primarily responsible for triggering the landslide:

> The heavy rains of 1978 provided the significant triggering or initiating factors that decreased stability in the subject slide area and caused higher shear stress and renewed movement of a portion of the previously existing Bluebird Canyon Landslide. This occurred in two ways: (1) by rainwater percolating into the slide mass and contributing as a driving force and destroying bonds between mineral and rock grains, (2) by providing large discharges that eroded quantities of debris from the toe of the slide area, thus undercutting and oversteepening the slide mass.
>
> (Leighton and Associates, November 6, 1978, p. 3)

This conclusion is supported by chemical analysis showing that the water within the slide mass was rainwater, thus ruling out overwatering or water system leakage as major causal factors. Also, a comparison of 1964 and 1978 topographic maps reveals significant erosion of the toe of the ancient landslide. This erosion, accelerated by heavy runoff during the February rains, removed essential support of the slide mass. These factors interacted with the adverse geologic conditions of the area to produce the October 2 landslide (Leighton and Associates, 1978).

In a report released on December 16, 1978, Leighton and Associates made a final determination on the cause of the landslide and recommended emergency stabilization measures for the area. The geology firm reaffirmed its preliminary conclusion that several major factors interacted to produce the landslide of October 2, 1978:

> In our professional opinion, the Bluebird Canyon landslide was triggered by a combination of the heavy infiltrating rains of 1978 and the removal of earth material at its toe by erosion and piecemeal sloughing. These triggering devices were the final supplement to the more basic causes that had brought the landslide to the breaking point and determined the timing of the slide. However, the natural environmental conditions, namely, the relationship of rock type (clayey siltstone) and geologic structure (dip-slope) to the slope height and slope angle provided the fundamental geological and geometrical basis for failure.
>
> (Leighton and Associates, December 16, 1978, p. 14)

It is interesting to note that a 1969 study by Leighton and Associates, *Final Geologic Study on the General Plan Study for the City of Laguna Beach,* conducted more than 20 years after the subdivision map was filed, determined the area to be prone to sliding. This study indicated that Tract 1252 is within an area described as "major bedrock area subject to potential instability" due to the "presence of slide prone formations, adverse geologic structure and indications of possible previous instability" (Leighton and Associates, 1969).

A Preliminary Geologic Stability Map prepared by Leighton and Associates in 1975 as part of a background report for the Seismic Safety Element of the Laguna Beach General Plan reaffirmed the potential instability of the south facing slopes of the city's canyons including Bluebird Canyon (Leighton and Associates, 1975). Figure 13 shows the 1975 map. The boundaries of the October 1978 landslide and the ancient landslide have been added to the Leighton map. The information in the 1969 and 1975 reports by Leighton and Associates was not incorporated into city land use policy until six months after the slide, when the city adopted the Laguna Beach Seismic and Public Safety Element.

EMERGENCY RESPONSE

A city-wide disaster was declared by Laguna Beach Mayor, Jack McDowell, on the day of the landslide, thereby enabling county agencies to aid the city. On October 5, Governor Brown proclaimed a state of emergency in the city and on October 9, President Carter declared the city a major disaster area. As a result of the Governor's proclamation, staff members of the State Office of Emegency Services were assigned to assist local officials in disaster relief operations and to coordinate communications between local and federal officials. As a federally-declared major disaster area, the city was eligible for federal funding of emergency work on the slide and victims were eligible for housing assistance and SBA

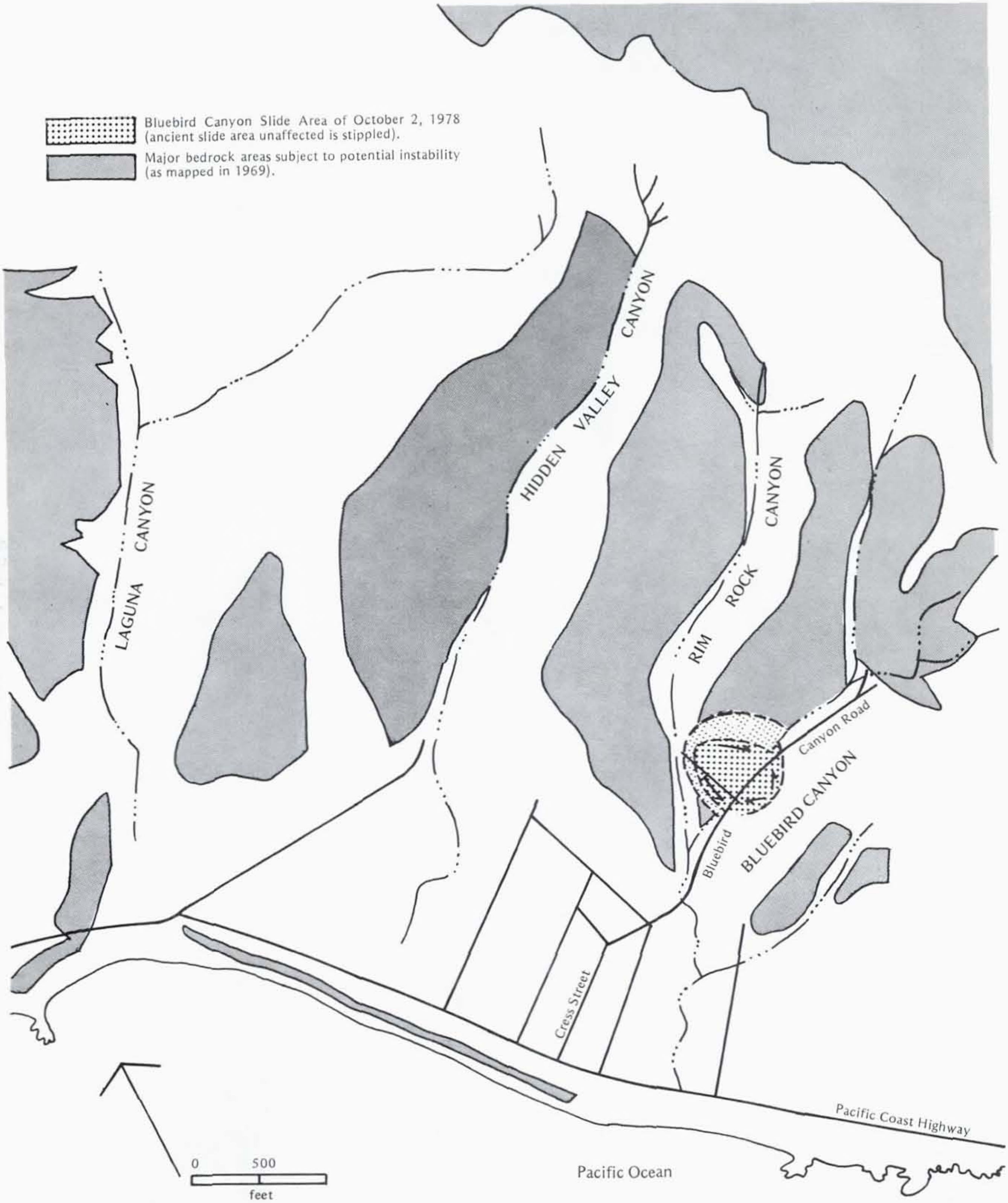

Figure 13. Preliminary Geologic Stability Map of the City of Laguna Beach (Source: Leighton, 1969, modified by William Spangle and Associates, Inc.)

Figure 14. Command post on Bluebird Canyon Road, October 5, 1978

low-interest loans (Federal and state assistance is discussed in later sections).

To avoid further injury and to prevent looting of the evacuated houses, the landslide area was sealed off and patrolled by Laguna Beach policemen and Orange County Sheriff's deputies. The police department established a disaster command post on Bluebird Canyon Road to control access to the slide area (Figure 14). A few days after the slide, limited access was permitted to residents and volunteers to salvage personal belongings.

Emergency services, including food, clothing, medical assistance and temporary housing, were provided by a number of service agencies, including the American Red Cross, the Salvation Army and Mennonite Church. The Red Cross was notified of the disaster within 20 minutes after the slide started and was on the scene 45 minutes later (7:15 a.m.). The Salvation Army provided food to landslide victims. Laguna Beach firemen, with several hundred volunteers from all over Southern California, assisted residents in removing belongings from the damaged and destroyed houses.

STABILIZATION

Repeated movement of the slide in the days following the initial slide made it clear to the geologists and city officials that some kind of immediate stabilization effort was essential to prevent further sliding and damage to public and private property. Leighton and Associates conducted geotechnical investigations to determine what measures were necessary to prevent further losses.

Recommendations for Emergency Stabilization

First priority was to provide drainage and erosion control before the winter rains which normally start sometime in November. The toe of the landslide had, in effect, created a dam in the existing drainage channel at the bottom of Bluebird Canyon. Runoff impounded behind this dam could back up and flood upstream properties and, if the dam were to break, flooding would occur downstream, potentially washing away part of Bluebird Canyon Road, the only means of access to hundreds of homes in the canyon. To solve this problem, Leighton and Associates proposed construction of a drainage pipe through the dam. On November 6, to clear the way for construction work on private property, the City Manager declared that the obstruction of the natural drainage channel constituted a public nuisance. Installation of the storm drain was completed several weeks later (Figure 15).

To control runoff and erosion on the slide and prevent further sliding, emergency grading was recommended which required the demolition and removal of 22 damaged homes. The owners of the houses designated for removal were asked to sign agreements allowing the houses to be demolished. They refused, indicating that they wanted to confer with their attorneys before authorizing the demolitions. On November 7, 1978, the City Council adopted an ordinance suspending Municipal Code provisions which allow persons aggrieved by any administrative decision in a matter of abatement to appeal to the City Council. This action was taken because the Council felt that appeals by slide victims could prolong actions needed to protect habitable properties surrounding the slide area from the effects of approaching winter rains. With the possibility of time-consuming appeals removed, on November 8, 1978, the City Manager, with confirmation from the City Council, declared a nuisance to exist in Bluebird Canyon and ordered the demolition of the 22 houses. Demolition began two weeks later and was completed by December 12, 1978 (Figure 16).

In order to prevent further land movement, Leighton and Associates recommended on December 16 the construction of two earth buttresses: one, an earth shear-key buttress, below Oriole Drive to stabilize the head-

Figure 15. Storm drain installed in channel at the bottom of Bluebird Canyon, December 1978

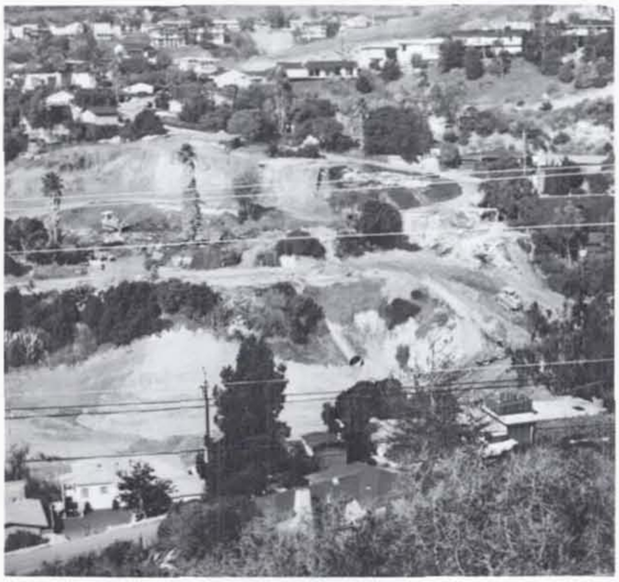

Figure 16. Bluebird Canyon landslide after demolition and removal of houses, December 1978

scarp of the landslide, and the other, an earth gravity buttress, at the toe of the slide to improve the overall stability of the active slide mass and to protect the drainage work (Figure 17). Although alternative stabilization measures were considered, Leighton and Associates determined the buttressing project to be the most economical way to provide a reasonable level of safety against future earth failure. Total construction cost was estimated in December 1978 to be about $650,000 (Leighton and Associates, December 1978).

The upper buttress, just below Oriole Drive, was designed as a 70-80 foot wide, all-earth, shear-key buttress located 40-70 feet below and roughly parallel to the headscarp of the landslide (Figure 18). During the excavation phase of the buttress construction, a steep backcut with a high potential for failure would be exposed endangering construction workers. To reduce this risk, Leighton and Associates recommended carrying out the backcut excavation in relatively small sections and installing a row of 48 reinforced-concrete shoring "soldier" piles 10-50 feet above and parallel to the headscarp of the landslide.

Funding for Stabilization

Although President Carter declared Laguna Beach a major disaster area on October 9, 1978, the Federal-State Agreement, which is part of any such declaration, limited the use of federal funds to emergency work necessary to protect public and private property from further sliding and damage. Under the agreement, federal funding for "permanent" reconstruction of the site was not provided. As a result of the limited scope of the federal commitment, considerable controversy arose over the distinction between the "emergency" and "permanent" nature of the stabilization work recommended by Leighton and Associates.

After many meetings with federal officials studying the recommendations of Leighton and Associates, City Manager, Fred Solomon, finally announced on January 2, 1979 that the federal government had approved funding of the shear-key buttress to stabilize the headscarp of the slide. However, the federal representatives had not yet reached a decision on the lower gravity buttress.

On February 12, 1979, still waiting for a final decision on funding from the Federal Disaster Assistance Administration (FDAA), the city began work on the emergency buttressing project. On the following day, FDAA representatives from Washington, D.C. visited Laguna Beach and toured the landslide area. Their visit was prompted by the disagreement between FDAA regional representatives and city and county officials over the amount of federal aid to be provided for the buttressing project. Regional FDAA officials contended that some of the work was reconstructive in nature and did not qualify under the agency's emergency funding criteria.

Reaching agreement on the question of funding the buttress was, according to city officials, complicated because FDAA had not assigned an official to be in Laguna Beach during the stabilization period. This resulted in inadequate communication between the city and FDAA and may have caused unnecessary delays in the stabilization work. In addition, FDAA spent considerable time evaluting in detail the geologic work done for the city by Leighton and Associates which, according to city officials, further delayed stabilization.

On February 20, 1979, the FDAA announced that federal funds for the full cost of the two emergency buttresses would be provided. Although FDAA officials agreed that the buttressing projects were appropriate under the "emergency" definition, they continued to

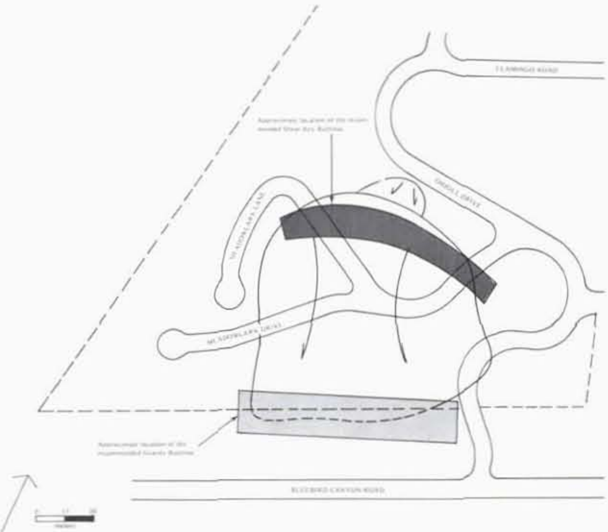

Figure 17. Map showing approximate location of buttresses recommended by Leighton and Associates (Source: Leighton and Associates, December 1978)

question design details, such as the angle of finished slopes and number of soldier piles, to insure that work would be limited to that necessary to protect properties adjacent to the slide area from damage from further sliding. As of May 1979, approximately $885,000 in federal funds had been committed to the emergency stabilization effort.

As of July 2, 1979 the stabilization work and rough grading for road reconstruction were essentially completed (Figures 19-21). The city was accepting building permit applications for construction of houses on the individual lots and lot owners were exploring ways of financing construction of new homes.

Figure 18. Rough grading of headscarp just prior to work on the shear-key buttress, December 1978

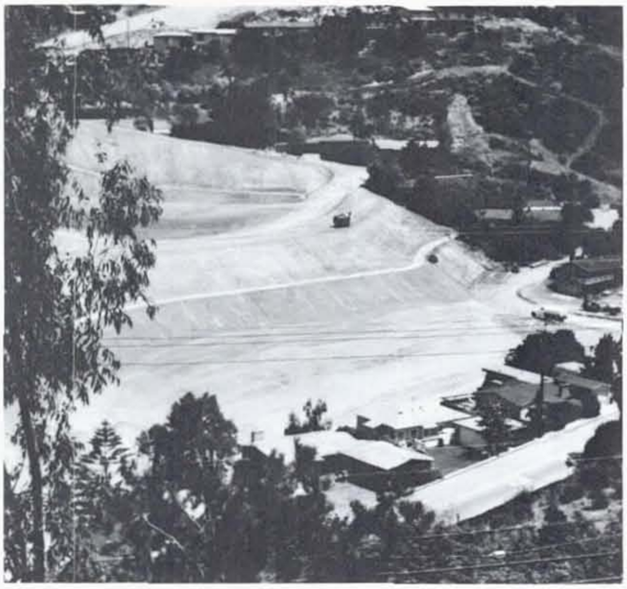

Figure 19. Landslide area with buttressing essentially complete and rough grading for roads and utilities underway, July 1979

Figure 20. Compaction of lower gravity buttress, July 1979

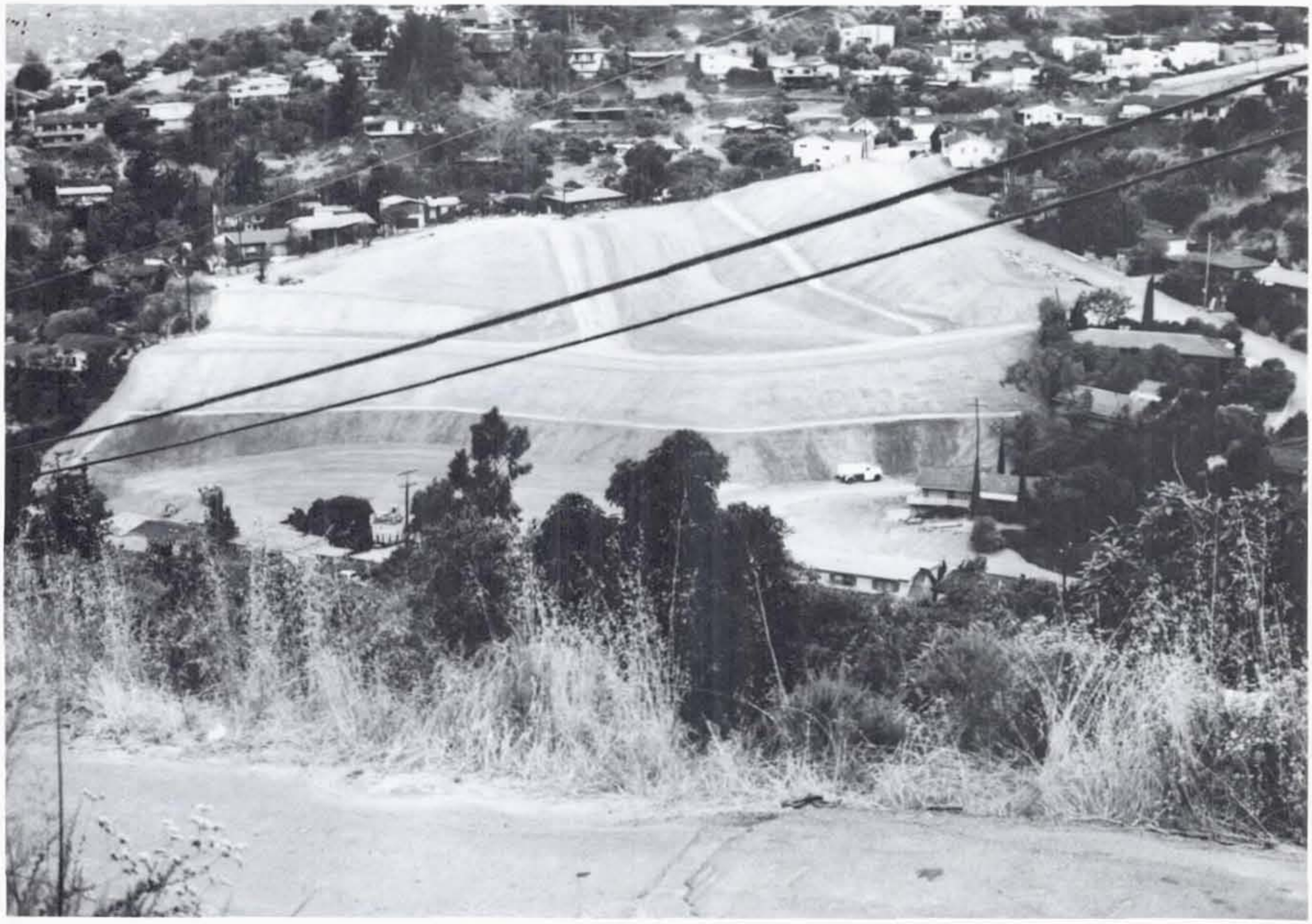

Figure 21. Completed landslide stabilization. Shear-key buttress and surface drain to the right; gravity buttress across center of picture, July 1979.

Planning for Reconstruction

No formal planning effort was undertaken to explore options for the future use of the area destroyed by the slide. Decisions affecting the future use of the slide area were being made from the outset of the recovery effort by many individuals and agencies in a decidedly uncoordinated way and without the benefit of agreement as to what should eventually become of the real estate in question. The actions and decisions of the various groups involved in determining the future of the slide area are described in the following sections.

FEDERAL ROLE

The Federal Disaster Assistance Administration (FDAA) had primary responsibility for the federal response to the landslide. Although FDAA was deactivated in July 1979 and its functions transferred to the new Federal Emergency Management Agency (FEMA), the key decisions involving the Bluebird Canyon landslide were made by FDAA. FDAA operated from the outset from the position that federal funds should be used only for emergency work necessary to avert further property losses, and, consequently, not for permanent stabilization that would permit rebuilding of homes on the slide area. This position stemmed, in part, from the disaster declaration which authorized federal funding for emergency work only and, in part, from increasing emphasis on hazard mitigation within FDAA.

The federal position concerning reconstruction was apparently not stated in writing until July 1979, and, at least from the point of view of the landslide victims, the federal position came as a shock. The position is succinctly stated in a letter from Robert Stevens, FDAA Regional Director in San Francisco to Alex Cunningham, Director of the California Office of Emergency Services. The text is quoted in its entirety below:

> We understand that the City plans to allow the residents affected by the October 1978 landslide in Bluebird Canyon to rebuild on the newly completed emergency buttress fill, that was approved and funded by FDAA as an emergency measure to prevent additional loss of public and private property.

> We are quite concerned by this decision, because there is an implied FDAA concurrence with the City's action and an inferred Federal liability should there be a subsequent failure in the buttress fill.
>
> In order to avoid potential future misunderstandings, you are requested to advise the applicant that:
>
> 1. The FDAA approval was based on providing an emergency buttress fill to reduce the immediate threats to public health and safety and to public and private property.
> 2. The approval of the buttress design was made on the basis of providing a static factor of safety of 1.2 to 1.3, which is less than that required by Orange County grading ordinances for construction purposes.
>
>   The approval was not made for the purpose of *repairing/reconstructing private residential* lots.
> 3. The Federal government is not liable for any future losses that may result in the City's decision to allow the residents to rebuild on the buttress fill.
> 4. As a hazard mitigation measure, it is FDAA's recommendation that no permanent structures be constructed on the emergency buttress fill.
>
> I would appreciate information on changes that were made during buttress construction which now allow reconstruction in conformance with applicable grading ordinances.

At the time the letter was written, the buttressing work had been completed and rough grading for the reconstruction of roads in the slide area was underway. The city had announced that it would accept applications for building permits to rebuild houses on the slide. Property owners responded to the letter by seeking assurances from the city and the engineering geology firm that the buttressed slide was indeed safe enough for rebuilding.

The FDAA position appears to differ from that of the Small Business Administration (SBA). SBA is making low-interest loans to landslide victims up to $55,000 to rebuild their homes. The loans are available regardless of where the recipients choose to build, including the slide area. Thus, state and local agencies and the victims are faced with two federal positions with FDAA stating opposition to rebuilding on the slide and SBA loaning money to permit rebuilding on the slide. More important, neither agency seems to have based its position on a specific evaluation of risk or consideration of options for use of the slide area or of realistic options for the slide victims to relocate.

STATE ROLE

The State Office of Emergency Services (OES) coordinated the state response to the Bluebird Canyon landslide. The role consisted primarily of helping Laguna Beach deal with the requirements of the federal agencies for disaster assistance. The state did not consider planning for future use of the slide area as a part of its function. The OES position with regard to the Stevens letter is that, as long as the geologists state that rebuilding can be permitted with reasonable safety, the matter is up to local government to decide (Cliff Brooks, OES, telephone conversation, October 10, 1979).

As authorized under a disaster declaration by the Governor, OES has agreed to provide funds for the permanent restoration of roads and utilities in the slide area. The estimated cost is $300,000 and, in accord with provisions of the State Natural Disaster Assistance Act, the state will cover 60% of the cost with the other 40% to be covered by the City of Laguna Beach. However, according to local officials, factors taken into account in the formula (e.g. state gas tax allocations to local governments) mean that the split is more nearly 50-50.

CITY OF LAGUNA BEACH

The primary responsibility for planning for the uses of the slide area rested with Laguna Beach. In the period immediately after the landslide, little consideration was given to the question of long-term use of the site. The city concentrated on providing and seeking emergency assistance for the victims and arranging for the geologic studies and emergency work needed to prevent additional failures.

Before release of the geologic report recommending the buttressing project, the city did make efforts to provide a site or sites to relocate the slide victims. The city applied to Orange County for Housing and Community Development Block Grant funds to purchase land for new building sites and to provide low-interest loans to lower-income victims. The idea was that existing houses slated for demolition to make way for street widening, redevelopment or other public projects could be acquired and moved to the site. Some mention was made, in this connection, of turning the slide area into park or open space use, but there is no evidence the idea was ever developed or seriously considered. The whole concept of relocation ran into problems, because every time a site was mentioned, opposition from neighboring residents quickly emerged.

According to city officials, once they had received and reviewed the buttressing recommendations for slide stabilization, there was no question that homes should be reconstructed on the slide area. The city became a strong advocate for the victims in seeking funding to restore the slide area to buildable condition.

The city plans to allocate approximately $75,000 of its fifth year Housing and Community Development Block Grant funds to pay for part of the local share of the cost of rebuilding public roads and utility lines on the site. City officials hope that the remainder can be covered by future HCD funds the city is presently applying for. However, until such other funds are actually in hand, other city resources (either reserve funds or funds diverted from other budget items) will have to be used to cover the local share of the cost.

LEIGHTON AND ASSOCIATES

The work of the engineering geology firm, Leighton and Associates, was critical to any planning for future use of the slide. Hired by the city, funded by FDAA, and working within the emergency guidelines set by FDAA, the firm was in a most pivotal and sensitive position from the beginning. The future of the slide area depended on the firm's recommendations.

One of the most difficult parts of the firm's effort was to work within the FDAA requirement that work be emergency, not permanent, in nature. In fact, the geologists found that in order to stabilize the headscarp to prevent further sliding and property damage, the slide itself would have to be stabilized. FDAA was initially willing to pay for the former but not the latter and much discussion ensued over project details to fit it within the category of emergency work. The eventual federal approval of the two-buttress project was based on FDAA's judgment that the project would not permit stabilization to the point that the slide area itself would be safe enough for rebuilding.

The question of safety is important. The buttresses were designed to achieve a safety factor of 1.2. This means that the slide mass would be restrained by a force 20% stronger than the force of gravity pulling the slide downslope. The normal safety factor for such stabilization work is 1.5. However, the geologists calculated the 1.2 safety factor very conservatively and state that it is essentially equivalent to a 1.5. In this regard, it is important to recognize that determining safety factors is an inexact science and that considerable professional judgment is involved in selecting the method of calculation and interpreting the results. More important in terms of decisions regarding the use of the slide area, was the confusion that arose, particularly among the landslide victims, as to the significance of the safety factors. This confusion and lingering doubts about the safety of the slide were essentially removed by a letter from Leighton and Associates dated August 29, 1979 to the Laguna Beach City Council:

> The final geotechnical report of August 24, 1979 by Leighton and Associates makes it clear that it is now safe to rebuild the 24 homes destroyed during the landslides of Bluebird Canyon. This follows 9 months of construction of major drainage networks, as well as excavation and recompaction of most of the upslope slide materials. As indicated in our report, it is our professional opinion that the reconstructed area will provide a stable residential building area, subject to follow-on geotechnical review of additional construction in the zone.
>
> As you know, planning and design for new streets, utilities and lots is now underway. Twenty-two families still vacated from homes left intact but threatened by extension of the slide during remedial grading can move back once streets are reinstated and utilities are completed this winter. The twenty-four families whose lots were lost now have rebuildable lots. Thus residents of the forty-eight homes destroyed or endangered can look forward to the same relative degree of safety as other stable hillside areas in Southern California.
>
> Leighton and Associates is proud to have served the City of Laguna Beach as geotechnical consultants on the emergency stabilization of the Bluebird Canyon Landslide. From a personal viewpoint, please bear in mind the overall geotechnical setting of Laguna Beach as treated in earlier planning and geotechnical documents. More optimistically, I personally would now have no hesitancy about building and living on the site of the Bluebird Canyon Landslide of October 2, 1978.

LANDSLIDE VICTIMS

Certainly the most long term and far reaching impacts of the disaster are those shared by the individuals and families who lost their homes. The landslide displaced 47 families, including 114 people, from their homes. Of the people displaced, 23 are over age 62; 15 are single women over age 50; and 25 are under age 18. Most of the families had resided in their homes for over 15 years and many were the original owners. This long residency helps explain why the economic profile of the residents does not show the affluence that was attributed to the area in the early news articles about the disaster. Information provided by the Bluebird Knolls Community Association, the organization of landslide victims, shows nineteen families having annual incomes of under $10,000; nine of which earn less than $6,500. The majority of the families report annual incomes of between $15,000 and $25,000.

From the beginning, most of the landslide victims favored rebuilding on the landslide site. On December 5, 1978, before the release of the Leighton and Associates report on stabilization measures, a representative of victims informed the City Council that a majority of the victims wanted to rebuild and requested city assistance. After release of the December Leighton report, the resolve of the victims to rebuild hardened. The Bluebird Knolls Community Association became a cohesive and very effective organization pressuring the federal, state and local agencies and obtaining aid from private organizations to achieve the goal of rebuilding.

For most of the victims, there has never been any economically realistic alternative to rebuilding on the slide. The losses are not covered by homeowners insurance. In addition, the victims remain liable to lending institutions for mortgage payments on their destroyed homes. Although some lending institutions have declared temporary moratoriums on payments, more than half of the affected homeowners have had to continue making monthly payments ranging from $100 to $600. Even in cases in which loan payments have been suspended, interest is accrued. As a result, when monthly payments resume, they will be higher than prior to the disaster.

Under these circumstances, the purchase of a new home is economically out of the question for most of the victims and they have pinned their hopes on eventually being able to rebuild on their reconstructed lots.

Even assuming the victims will be able to rebuild on their lots, their short-term economic situation is difficult. The displaced families have had to absorb some, if not all, of the costs of temporary housing. Although 35 families received HUD rental assistance, the subsidy in most cases is inadequate to cover the high rents typical of Laguna Beach. In addition, the subsidy is for one year and reconstruction of houses on the landslide will probably take from one to two years after installation of roads and utilities projected for completion in October 1979. This means that those people intending to reconstruct will face one to two years of rent payments in addition to payments for loans on destroyed houses and new monthly payments for the SBA loans.

Residents are eligible for up to $55,000 in low-interest SBA loans to assist with rebuilding. However, $55,000 is not adequate for rebuilding houses equivalent to those destroyed. Local building costs have been estimated at $60.00 - $80.00 a square foot (Summer 1979). For a 1,500 sq. ft. home this would mean $90,000 - $120,000 not including surveying, grading, utility connection, architectural, or permit costs. As a result, those intending to rebuild must find additional financing.

The problems described above often include frustrating complications. For example, on October 1, 1978 – one day before the landslide – the law setting the interest rate on SBA loans at 3% expired and the rate automatically became 7.35%. A Congressional bill to reestablish the 3% rate was vetoed by President Carter on October 25. Laguna Beach officials contended that the cause of the landslide was heavy rainfall in February 1978 which had resulted in federal declaration of a major disaster at that time. If the slide could be considered a continuation of the previously declared disaster, slide victims would be eligible for SBA loans at the 3% interest rate in effect before October 1, 1978. Federal Disaster Assistance Administration (FDAA) officials initially denied the city's request to link the slide to the February disaster declaration to make victims eligible for the 3% loans in spite of the geological report concluding that the February 1978 rains had triggered the failure. However, following a plea by a landslide victim made in person to FDAA officials in Washington, D.C., the agency reversed its decision and announced on January 22, 1979 that slide victims were eligible for 3% loans. As of January 15, 1979, thirty-one SBA disaster loans totaling $785,000 had been approved for Laguna Beach landslide victims (Daily Pilot, January 16, 1979).

City officials, in an effort to provide additional financial assistance to low income victims, have applied for HCD funds to be used for housing reconstruction. However, the City Manager stated that because of the competition for limited dollars, the city does not consider prospects for such funding to be very good.

Conclusions

The central objective of this study has been to identify the factors influencing land use planning for the landslide site. The key finding is that, for all practical purposes, land use alternatives were never really considered. This stems from the following findings:

1. The buttressing project was found by the geologists to be the most effective and economical way to provide a reasonable level of safety against future earth failure. This alternative has resulted in effectively stabilizing the slide so that according to the engineering geologists, the area is "safe" for reconstruction of houses.
2. Disagreement between FDAA and the city over whether the proposed buttressing project was emergency or permanent work appears to have been the major issue in the aftermath of the slide. Federal funds were eventually authorized for the project. The federal concern was limited to protecting property next to the slide from damage from additional sliding. To the extent that federal officials addressed the concerns of future land use on the slide itself and possible risk of rebuilding on the slide, these concerns were apparently not clearly communicated to local officials and, particularly, not to slide victims until well after decisions had been made to permit rebuilding of homes on the slide.
3. Geologists quickly determined the cause of the slide, evaluated the potential for additional land failure and recommended measures to prevent further failures.
4. Those who lost their homes in the slide became a cohesive, and politically effective, group supporting federal, state and local actions that would permit rebuilding of homes on the site. The group's determination to rebuild on the slide, stemmed, at least in part, from the lack of economically feasible alternatives. The desire of the victims to rebuild and community sympathy for their plight appear to be factors in limiting consideration by local government of land use changes or restrictions on rebuilding.
5. The timing of both emergency and reconstructive actions depended on federal decisions. Delays occurred because of local/federal disagreement over the level of federal funding and the line between emergency and permanent work. During the debate over stabilization, no federal representative was assigned to the local area and local officials had difficulty reaching federal officials with the authority to make decisions.
6. The experience in Laguna Beach points up the need for a mechanism allowing the federal and state agencies funding recovery operations and the local agencies and disaster victims to reach agreement, soon after the disaster, on a plan for long-term reconstruction. In situations like Laguna Beach, the plan should be based on evaluation of the technical feasibility of stabilization and the cost of stabilization relative to relocation. Any stabilization project should be designed to provide an acceptable level of safety for the planned use or uses of the stabilized area and funding decisions should be based on the plan.

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Other Disasters

appendix e

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Acknowledgments

In this study of the planning and reconstruction efforts following six natural disasters, we were dependent primarily upon published materials. In some instances, we were extremely fortunate to be able to supplement the published records through personal contacts with individuals who had special knowledge of the post-disaster recovery efforts or through access to unpublished materials. We particularly appreciate the cooperation of the following people:

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Blythe J. Kubovec, City Planner, Omaha, Nebraska

David L. Lyon, City Planner, Xenia, Ohio

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The author is also appreciative of the perspective on post-disaster recovery gained by a visit to Skopje, Yugoslavia in 1974, participation in the panel discussion, *Natural Disasters: Rebuilding and Sound Planning,* at the 1978 National Planning Conference of the American Society of Planning Officials, and attendance at the 1978 and 1979 Natural Hazards Reserach Applications workshops of the University of Colorado.

This report was prepared by William Spangle with assistance from Gerald Hobrecht who brought together source materials and contributed initial drafts of several sections. In draft form, portions of the report benefited from review by other members of the project team. The author, however, assumes full responsibility for the final content.

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Introduction

Published accounts and readily accessible records of rebuilding after other selected disasters were reviewed to identify possible similarities between reconstruction after earthquakes and other kinds of disasters and the contrasts between reconstruction after large, foreign earthquakes and that following the less damaging U.S. earthquakes. In some cases, review of literature and records was supplemented by personal contacts with individuals who had key roles in the post-disaster planning. Disasters studied included the Omaha, Nebraska and Xenia, Ohio tornadoes, the Rapid City, South Dakota flood, the Hilo, Hawaii tsunami, and the Managua, Nicaragua and Skopje, Yugoslavia earthquakes.

Rapid City Flood of 1972

On the evening of June 9 and the morning of June 10, 1972, torrential rains in western South Dakota resulted in a flash flood causing extensive damage in Rapid City, South Dakota. A second flood occurred one week later. The number of dead and missing totaled 238, and 1,600 buildings were severely damaged or destroyed, including the homes of some 3,000 families. Estimated property damage amounted to about $80 million 1972 dollars (Haas and others, 1977).

Rapid City is located along Rapid Creek in southwestern South Dakota in an area west of the Black Hills. Following World War II, the city experienced very rapid growth with population increasing from about 10,000 in 1945 to approximately 45,000 at the time of the 1972 flood. Growth pressure led to urban development in the city's flood plain which previously had been largely unoccupied (Barnett, 1976).

The devastating 1972 floods were the most damaging of a series of floods occurring over several decades. The long history of flooding was paralleled by a history of flood protection investigations by the Army Corps of Engineers and the U.S. Bureau of Reclamation dating from the 1930's. These investigations focused primarily on structural solutions and resulted in two dams being built, one in 1956 on Rapid Creek at Pactola 16 miles upstream from the city, and the other, a small dam on a tributary stream, in 1959. Although these dams were designed to provide only partial protection, they tended to encourage continued development of lands in the flood plain at Rapid City. Consideration of nonstructural solutions to the flood problem began in the early 1960's when proposals were made to restrict further urban development in the flood plain. The effort failed because of local opposition and lack of specific state authorization for flood plain zoning. Local interests favored structural solutions (dams or levees) which would allow further development of the flood plain (Erickson, 1975).

In 1968 the city began a thirty-year open space program to increase recreational uses and decrease uses with high flood damage potential along Rapid Creek. Other flood hazard related actions followed, apparently looking towards possible nonstructural solutions. These included:

December 1970: Corps of Engineers asked to prepare a Flood Plain Information Report to help identify high risk areas. Work on the report was not started until January 1972 – six months prior to the 1972 flash flood disaster.

March 1971: Application submitted to enter the National Flood Insurance Administration Program. Based on a pledge to adopt flood plain regulations, the city was accepted into the NFIA emergency program in April 1971.

May 1971: The Soil Conservation Service was asked to aid the city in a survey to help define actuarial rates on flood losses. A preliminary report was submitted to NFIA in February 1972.

June 1971: Application submitted for federal assistance for urban renewal under the Neighborhood Development Program.

April 1972: Enactment of flood plain zoning postponed because of lack of data and insufficient time for preparation (Erickson, 1975).

Thus on the eve of the disastrous 1972 flood several actions were pending looking towards long term measures for flood hazard reduction through changes in land uses in the flood plain. Structural flood protection measures proved to be completely inadequate to cope with the 1972 flood which exceeded the 100-year level. This inadequacy was demonstrated again when a second flood occurred one week later in the same area of Rapid City killing two people. Emergency response activities ended after about three weeks with the completion of debris removal and the final accounting for dead and missing persons. Most displaced families were relocated from emergency to temporary housing after about twelve weeks – mainly in trailers provided by the Department of Housing and Urban Development (Haas and others, 1977). New development within the flooded area was temporarily prohibited and owners of damaged buildings were advised that any repairs would be undertaken at the owner's risk (Erickson, 1975).

Following the flood, the city decided that the safety of future generations required major land use changes in the flood plain. Within two weeks of the disaster the city received a $300,000 planning grant to prepare a renewal plan for the disaster area. The plan was completed in 60 days and an application for urban renewal funds submitted to the Department of Housing and Urban Development. Forty days later the application received federal approval and action began on property acquisition and relocation of site occupants. The plan called for purchase of the entire floodway and relocation of 1,100 households and 157 businesses in order to reduce flood risk and redevelop the land for outdoor recreation uses. By October 1976, 95% of the area had been cleared of buildings, 50% of it developed for recreational use, and the final phase of redevelopment was in process (Barnett, 1976).

Community attitudes and outside assistance were the critical factors affecting post-disaster planning and decisions. A post-flood sample survey revealed, for instance, that seventy percent of the families from the flooded area did not wish to return to the area even if permitted to do so. Funds for reconstruction were primarily from federal sources totalling over $150 million in loans and grants. The U.S. Department of Housing and Urban Development contributed funds for the floodway acquisition, provided housing grants, and supplied rent-free mobile homes to flood victims (Haas and others, 1977). The Small Business Administration provided low-interest loans to flood victims and the U.S. Bureau of Outdoor Recreation assisted in the development of the multi-million dollar recreational facilities within the flood plain. Only twenty-seven houses and two businesses were insured against flooding by the Federal Insurance Administration; only half of these sustained damage significant enough to warrant a claim (Barnett, 1976).

FINDINGS

1. With inadequate upstream protection works, the failure of the city to enact flood plain regulations permitted flood risk to rise in Rapid City during the post-war period as development increased within the city's flood plain.
2. Following the flood of 1972, a number of factors influenced the city's decision to change land use policies for the flood plain. The availability of substantial financial assistance from the federal government was of paramount importance. Without such assistance, it is unlikely that acquisition of the floodway and its conversion to recreational uses would have taken place because of the very high costs involved. Other factors likely influencing the city's decision to alter land use patterns within the floodway included:
   a. The requirements of the National Flood Insurance Program for participating jurisdictions to enact regulations controlling development in areas subject to the 100-year flood and the work in process by the city to meet this requirement at the time of the 1972 floods.
   b. The findings from several federal studies that costs for providing adequate flood protection by structural measures exceeded probable benefits.
   c. The history of frequent flooding.
   d. The attitude of flood victims who did not wish to reoccupy the flood plain.
   e. The relatively small amount of commercial and industrial property damaged. Relocation of a large number of commercial-industrial establishments would have been difficult because of high costs and possible negative effects on the local economy.

Xenia Tornado of 1974

On April 3, 1974, a devastating tornado struck the city of Xenia, Ohio. One-third of the city was either destroyed or damaged by the tornado which cut a swath of destruction three-quarters of a mile wide and four miles long through the city. Thirty-four people were killed, 500 were injured, 1,300 buildings were destroyed and several thousand more damaged. Estimated property damage was $100 million in 1974 dollars (Francaviglia, 1978). Approximately twenty-five percent of the city's housing units and a quarter of its central business district were destroyed (Lyon, 1978).

Xenia, with a population of 27,500 at the time of the tornado, was a growing suburbanizing sub-center of the Dayton metropolitan area with a substantial but deteriorating core of residential and commercial structures, many dating from the period 1880-1910. The intersection of three U.S. highways marked the center of the city. Its central business district (CBD) was suffering from competition of commercial strip development, growth of nearby shopping centers, and the impact of through traffic. West of the CBD the flood plain along Shawnee Creek was heavily built up despite a long record of frequently recurring flooding (Francaviglia, 1978).

The area devastated by the tornado included a heavily built up portion of the Shawnee Creek flood plain, a portion of the CBD, an area of low-income deteriorated housing west of the CBD, a portion of an older attractive neighborhood to the north, and relatively high-income housing in new subdivisions to the northeast. Nearly a thousand damaged buildings were removed by the Army Corps of Engineers within two months of the disaster. Because of the high vacancy rate in the Dayton area at the time, the Federal Disaster Assistance Administration quickly found temporary housing for tornado victims during the emergency period (Francaviglia, 1978).

The Xenia City Commission recognized that the disaster gave them an opportunity to rectify existing zoning and land use incompatibilities and avoid duplicating past mistakes in development. A partial moratorium on rebuilding was being prepared by the Miami Valley Regional Planning Commission (MVRPC) of which Xenia was a member (Francaviglia, 1978). Pending completion of the plan, building permits were to be issued only as exceptions where no change from the former use was involved and the use would not be in conflict with future plans (Lyon, 1978).

The MVRPC plan was completed within sixty days presenting three alternative land use proposals, one of which was strongly recommended by MVRPC and adopted by the City Commission in late June 1974. This plan called for the development of a downtown shopping mall integrated with the remaining structures in the CBD; the construction of a variety of housing types in the devastated area adjacent to the CBD; and the development of a green belt along Shawnee Creek which would buffer the CBD from the highway-oriented commercial strip development on West Main Street and prevent rebuilding in the once built-up flood plain (Lyon, 1978).

Soon after adoption of the MVRPC plan, disagreement arose over the design of the downtown shopping mall and after debate the City Commission selected an outside firm to prepare a redevelopment project for the heavily damaged section of the CBD. This developer's plan provoked more debate and was rejected in June 1976. Six months later a new developer and a new plan were approved by the City Commission. The developer stated that speed was of the essence in completing the shopping mall in order to halt further spread of strip development on the city's two main arteries. However, decisions on tenants and construction details delayed construction for many months (Francaviglia, 1978).

At the time of adopting the MVRPC Plan, the City Commission also approved "overlay zoning" which permitted exceptions to the plan through an appeal process. Dozens of appeals were approved in the months following the plan's adoption so that the plan became altered and pre-tornado land use patterns were permitted to reassert themselves in critical areas contrary to the adopted plan. Rebuilding was permitted in the Shawnee Creek flood plain. A number of automobile-oriented (rather than pedestrian-oriented) commercial uses were reestabilished in the CBD. The planned construction of housing in the devastated residential area west of the CBD did not take place; instead, the result was scattered commercial development surrounded by large empty spaces. Following the tornado, there was very little new housing built in the low-income area, whereas in other more affluent residential neighborhoods, where owners were adequately insured, reconstruction was rapid (Francaviglia, 1978). As of June 1978, construction of the downtown shopping mall redevelopment project had not yet begun but was scheduled for late in the summer (Lyon, 1978).

Federal agencies providing financial assistance to Xenia included the Economic Development Administration (EDA) and the Department of Housing and Urban Development (HUD). EDA provided a capital grant of $800,000 for development of an industrial park as a means of replacing industry destroyed by the tornado. HUD allocated $3.5 million for the $6.5 million downtown shopping mall urban renewal project (Lyon, 1978).

FINDINGS

1. In the absence of flood plain zoning and funding for land acquisition in the Shawnee Creek flood plain, rebuilding by private owners was inevitable. (In the sources reviewed, there was no indication of any effort to include this flood-prone area in a federal redevelopment project or to require restrictions on rebuilding in the flood plain as a condition of securing federal aid for use in other areas.)
2. The overlay zoning was an ineffective tool for protecting the adopted plan either because of inadequate criteria for administration or inadequate administration.
3. There appears to have been a need for some staging of development with high priority for relocation of businesses displaced by the plan and lower priority for new businesses.
4. Positive programs were needed, but not forthcoming, to rehouse low-moderate income families displaced from rental housing by the disaster.
5. Homeowners in Xenia with tornado insurance were able to rebuild quickly.
6. Xenians saw the opportunity to rectify land use problems in their city and the need to plan for changes beyond the damaged area but were unsuccessful in implementing the reconstruction plan because of disagreements and delays which allowed the pre-tornado land use pattern to emerge. Thus, in spite of substantial federal aid for the CBD redevelopment project and for other purposes, plan implementation was largely unsuccessful.

Omaha Tornado of 1975

On May 6, 1975 the City of Omaha, Nebraska, a community of about 350,000 residents, experienced a devastating tornado. It laid waste a section of the city nine miles long and a quarter mile wide. Three people were killed, 150 were injured, 2,650 structures were damaged and, of these, 627 were destroyed or heavily damaged. Estimated total property damage was $120 million in 1975 dollars (Omaha City Planning Department, 1977).

City officials recognized the disaster presented opportunities to correct existing land use incompatibilities in the devastated section and to improve traffic circulation. One area zoned for industrial uses was recommended to be re-zoned for commercial uses. The Mayor and the City Council opposed this change, insisting that land owners in the area had experienced enough problems already and the industrial zoning was not changed (Kubovic, 1978).

In another area, local officials saw an opportunity to purchase severely damaged residential property fronting on a major arterial, where widening had been proposed before the tornado. It was also suggested that additional damaged houses along the arterial be acquired to increase the size of an existing park to benefit the community at large and serve as a buffer between commercial and residential areas. Most owner occupants affected by the proposals were initially willing to consider selling their land for street widening or park expansion (Omaha City Planning Department, 1977). However, delays were encountered because of state and federal procedures including the need for project plans, public hearings and appraisals before discussing purchase prices with owners. Consequently, the majority of owners lost interest in selling their properties and, because of their immediate needs for housing, decided they could not afford to wait. They began rebuilding, and the street widening and park expansion projects were not accomplished (Kubovec,1978).

FINDINGS

1. Omaha did not experience any major reconstruction problems because damage was largely confined to economically and socially stable areas of suburban commercial property and middle and upper-middle income residences, most of which were adequately insured against wind damage. Pre-disaster land uses in these areas quickly re-established themselves as the inclination to rebuild and the funds needed were present.
2. Outside assistance from regional, state, and national sources expedited cleanup operations and reconstruction activities during the post-disaster period. Omaha was declared a federal disaster area thus making it eligible to receive federal financial assistance. Four million dollars was allocated from the President's disaster fund, 254 home loans and 34 business loans were granted by the Small Business Administration, 82 families received grants under the federal "408" program (designed for those who did not qualify for SBA loans).
3. Efforts to effect the street widening project were hindered by state and federal regulations and procedures which were not responsive to the disaster situation. The tornado victims were in need of immediate help and reassurance, and delays imposed by federal regulations and state procedures undermined their willingness to consider selling. The proposed street widening might have been implemented under different conditions such as the following:
   a. If a definite time frame for public decisions and actions had been established as quickly as possible, the property owners might have been reassured and more willing to sell.
   b. If clear guidelines for valuing properties to be acquired had been established prior to the disaster, the uncertainties created by the state's reluctance to discuss property price estimates might have been reduced.
   c. If the state had been willing or able to use "quick taking" procedures under eminent domain leaving only value questions to be settled through negotiations or court action (this may not be possible in Nebraska), the street widening probably could have been accomplished.
   d. If suitable long-term temporary housing had been provided through governmental action, the owners of property affected might have been willing to defer rebuilding pending the fixing of offering prices for their lots.

Hilo Tsunami of 1960

On May 23, 1960, a tsunami struck Hilo, on the western shore of the island of Hawaii, wiping out structures in a 350 acre area including the town's downtown area. Sixty-one people were killed, 288 structures demolished, and communication and transportation systems severed. Property damage was estimated to have been about $22 million in 1960 dollars. Hilo's geographical setting makes it unusually prone to tsunami damage, and the probability of future large tsunamis impacting the Hilo waterfront is extremely high. The business and residential area demolished in 1960 was only 15 years old, having been rebuilt after the 1946 tsunami which claimed 96 lives. Changes in land use and relocation of site occupants were discussed at that time, but not done. Instead a small buffer zone was established and a rock revetment placed near the shore. The revetment proved counterproductive. It was washed out in the 1960 tsunami contributing debris to the destructive waves (Marx, 1977).

Hilo was declared a federal disaster area paving the way for obtaining federal disaster assistance and designation of most of the devastated area as a federal Disaster Renewal Project to be administered by the Housing and Home Finance Agency (HHFA). This designation made Hilo eligible for special funding and for expedited review and approval of redevelopment plans.

State and federal agencies indicated they were unwilling to provide financial assistance for restoring pre-disaster occupancies in the tsunami run-up area and Hawaii County decided to propose redevelopment for predominantly open space uses and seek federal funding. With people starting to return to the damaged area, Hawaii County restrained people from reoccupying structures which had sustained more than 60% damage. Rehabilitation and new construction were prohibited in the damaged area for seven months pending the preparation of a redevelopment plan.

Soon after the disaster Hawaii County established the Hawaii Redevelopment Agency and certified the damaged area as an area needing redevelopment in order to qualify for federal funds. To cover the local share of the renewal project the state authorized a $2.5 million bond issue and the federal government authorized a grant of $6.8 million.

A consultant, Belt, Collins and Associates, was preparing a city plan for Hilo at the time of the tsunami, and was commissioned to do a renewal plan for a federal Disaster Renewal Project which was designated as the Kaiko'o Project. A Draft Urban Renewal Plan was submitted to the HHFA regional office for "information" on December 13, 1960 and the urban renewal plan for the Kaiko'o Project was approved on February 27, 1961.

KEY PROVISIONS OF THE URBAN RENEWAL PLAN

The plan, as subsequently amended to June 25, 1965, included 349 acres within the project area. All real property in the project area was acquired for clearance and redevelopment except for: lands owned by the state or the county and designated for public use and properties to be redeveloped under owner-participation agreements. Lands in the project area were placed in two major categories: 1) Elevated and 2) Open. The purpose was to strike a balance between hazard avoidance and risk exposure with maximum protection being given to high occupancy uses by restricting them to the "Elevated Area" – presumably above the reach of most tsunamis. As required by the plan the Elevated Area was filled to a height above sea level "sufficient to afford a reasonable degree of protection from damage from a tsunami of the size and nature of the May 23, 1960 event" (Hawaii Redevelopment Agency, 1965). Fill materials were obtained from off-site state lands. Land uses in the Elevated Area are restricted to commercial uses, a civic center complex, bus terminals and public utility facilities.

The balance of the project area, designated as the "Open Area," includes lands which were inundated by the May 1960 tsunami and are identified in the plan as being subject to possible inundation and damage by future tsunamis. Land uses are restricted to open uses, temporary non-conforming uses, and certain limited industrial and commercial uses in specifically designated locations. Some lower intensity commercial uses such as service stations and drive-ins requiring minimum structural improvements are permitted at two intersections of major streets in order to meet service demands. Industrial uses requiring water access such as boat service and repair, commercial fishing facilities and related services and supplies are permitted within two small areas subject to conditions and requirements designed to reduce risk exposure. All structural uses in the Open Area are subject to special conditions to protect health and safety. Provisions are also included requiring phased discontinuance of non-conforming uses. Every document conveying rights and interests in property in the Open Area category is required to include indemnity and hold harmless clauses in favor of the Redevelopment Agency. The clauses are intended to reduce the liability of the Agency for selling or leasing lands that could be exposed to the effects of probable future tsunamis. Restrictions and requirements imposed on the land are binding on purchasers and lessees and their successors and assignees for a period of 35 years from the date the Agency disposed of the first parcel (Hawaii Redevelopment Agency, 1965).

FACTORS AFFECTING POST-DISASTER DECISIONS

Community attitudes were apparently mixed. At least some site occupants wanted to move back into the damaged area and some absentee land owners wished to lease land for rebuilding commercial structures in the run-up areas, but public agencies did not want to incur the risk of paying again for damages (Marx, 1977).

The feasibility of protecting the area by building a sea wall was studied by the U.S. Army Corps of Engineers and found to be too costly (Marx, 1977). The Corps wanted assurances from HHFA that the intensity of land use could be increased (i.e. changed from open space uses to commercial, hotel and other uses requiring structures) if the sea wall tsunami barrier project was approved. HHFA, however, held very firm on Urban Renewal Manual provisions relating to precautions to be taken in areas subject to recurring disasters and took the position that change in use to more intensive use could be approved only when an effective protective device was actually installed. The Corps was then unable to include benefits for prospective higher value, more intensive uses in its cost/benefit evaluation. HHFA also questioned whether the proposed uses in the renewal plan would be suitable if the barrier were constructed since a substantial wall would obstruct bay views (HHFA correspondence). The urban renewal plan (as amended to 1965) included a clause permitting the Hawaii Redevelopment Agency to redesignate permissible uses in open areas if and when adequate measures were taken for tsunami protection (Hawaii Redevelopment Agency, 1965).

Initially, the new downtown proposed in the redevelopment plan for the Elevated Area failed to attract private developers. However, public investment for a $1.7 million county headquarters and a $1.7 million state administrative complex provided needed life to the project. Small Business Administration lease payment guarantees to landlords helped local merchants compete with major chains for space in the renewal area. State-owned lands in other parts of Hilo were made available for relocation of former residents of the redevelopment area. At the time of "project closeout" in July 1972, redevelopment in accordance with the plan was nearing completion. Only 2% of the project site remained to be sold or leased and new construction was 77% complete.

FINDINGS

1. Without federal and state assistance, it is unlikely that Hawaii County could have replanned the devastated area or provided for relocation of residents and businesses.

2. Clear historic evidence of frequent tsunamis and the very recent prior event (1946) provided substantial impetus to decisions to relocate former uses out of the run-up area and to protect new uses.
3. Without the strong role of HHFA insisting on hazard mitigation measures as a prerequisite to federal funding for the renewal project, post-disaster planning probably would have failed to respond adequately to tsunami hazards.
4. The pattern of land ownership in Hilo appears to have had significant impact on both the nature of the renewal plan and the execution of the plan. State lands provided space for relocation and a borrow pit for fill material needed to raise the level of the Elevated Area. A number of established uses were recognized as non-conforming uses and permitted to continue even though this resulted in somewhat higher exposure to risk.

Skopje Earthquake of 1963

The rebuilding of Skopje provides a quite different view of post-disaster planning and reconstruction than that offered by study of reconstruction following any of the other disasters. This is due, in part, to the difference from all the others, except Managua, in the magnitude of destruction in a single city. It is also due to the differences in the economies, political systems, and the attitudes of the people affected and their national leaders. However, there are also many similarities. Although Yugoslavia is a socialist nation, there are many private enterprises and substantial private ownership of real estate. It has a federal system of government with the central government able to exert substantial influence on local actions, particularly through making grants and loans available.

THE EARTHQUAKE AND ITS EFFECTS

On July 26, 1963 Skopje, the capital city of Macedonia, Yugoslavia, was struck by an earthquake of magnitude 6.25 on the Richter Scale. Because of its shallow focus directly beneath the city and inadequate building construction, massive destruction resulted. The early estimate indicated 1,000 people were killed, 3,000 others injured, and 150,000 of the city's 200,000 residents were left homeless. A ten square kilometer (3.6 sq. mi.) area around the city center was almost completely destroyed and damage was extensive in the remainder of the city. Virtually all of the government buildings, schools, hospitals and other public service buildings were destroyed. However, because of uniform soil conditions, the water and sewer lines remained virtually intact. Most factory buildings survived without severe structural damage, but many of these were inoperative because of damage to machinery and contents. None of Skopje's buildings had been specifically designed to withstand earthquake forces but some reinforced concrete buildings which had been well designed to resist wind stresses survived the quake with little damage (UNDP 1970).

Another earthquake of slightly lower magnitude followed immediately after the initial shock, followed by 82 tremors of further decreasing magnitude. They were all a part of a series with the same focus — directly beneath Skopje's large central square. It was the second time in four centuries that Skopje had suffered a disastrous earthquake. Numerous other earthquakes had occurred in the Skopje region in historic times with the first known catastrophic occurrence in 518 AD destroying the metropolis of Skupi which was located on a site some 5 kilometers northwest of the present Skopje (Scekic, 1963).

Because of the magnitude of the rebuilding effort needed and considerations of public safety, Yugoslav Federal authorities questioned the appropriateness of rebuilding on the same seismically sensitive site. In October 1963, following a preliminary investigation, a British earthquake engineer reported that there was no technical reason not to build on the same site provided flooding problems were resolved, relatively small areas of high water table were avoided, and structures were designed to withstand lateral forces. Somewhat later a panel of experts confirmed this view finding that other sites in the region would be no safer because Macedonia is located in a tectonic zone extending from Morocco to Southeast Asia. The region experiences earthquakes of medium magnitude (generally less than 6.3) and shallow focus in scattered locations about once each 50 years. However, the people of Macedonia apparently never had any doubt that the city should be rebuilt on the historic site — better, bigger, more glorious, and earthquake proof (UNDP, 1970).

The enormity of the 1963 disaster drew worldwide attention and within 36 hours massive aid from around the world began to arrive in Skopje — food, clothing, supplies and technical assistance (UNDP, 1970). Yugoslavia's non-aligned status engendered competition between western and eastern block nations in providing assistance. This competition enhanced the flow of emergency aid but profoundly affected the post-earthquake planning and rebuilding effort (Nez, 1978).

Skopje, with its complex interrelated physical, political and technical problems, provided a made-to-order opportunity for the United Nations to demonstrate the benefits of concerted application of scientific and technical expertise in post-disaster rebuilding. Within three days of the disaster, UNESCO sent Ernest Weisman, the head of its Housing, Building and Planning Branch, to Skopje to identify the assistance needed. In a report, submitted three weeks later, he recommended, among other things, a joint engineering, seismological, and planning mission with one expert from each of these fields to work with and advise local planners.

At the time of the earthquake, physical and economic planning was a normal on-going function of local government in Yugoslavia. The process of planning and decision making reflected the country's organization as a federal republic with a highly decentralized system of administration. Subject to broad directives from the Federal Government and allocation of federal resources, each of the six constituent republics decided how to use available federal and local resources available to it and each local authority (town, village) determined policies and standards to be expressed in its local plan. Local physical planning was done by the town planning institutes, public consultant corporations of expert professionals, working under contract with local authorities. However, the initiative for making specific physical development proposals rested mainly with individual land-using public enterprises, including municipal departments. Responsibility for administration of approved plans – passing judment on proposed projects – was ordinarily lodged with the Town Planning Committee of the City Council.

This, then, was the general framework for planning and decision making at the time of the earthquake. Skopje had an approved Town Plan which had been prepared by the Skopje Institute for Town Planning and Architecture. This plan was administered by the Town Planning Committee of the City Council. However, the plan was geared to gradual change in the development patterns which had emerged over the centuries and new guidelines and new procedures were needed to direct the massive reconstruction effort (UNDP, 1970).

FEDERAL AND WORLDWIDE SUPPORT

President Tito, in Skopje the day following the earthquake, set the tone for the rebuilding effort with the promise ". . . to build, with world help, a more beautiful and joyful Skopje as a symbol of the fraternity and equality of the Yugoslav people . . ." Within a week of the earthquake the Executive Board of the Central Committee of Yugoslav Communists appealed to the entire nation to help get Skopje rebuilt within 5 years. The following week, the Yugoslav Federal Executive Council: set the end of the year as the target date for the completion of temporary housing for the city's 120,000 citizens; took responsibility for educating the 20,000 school-age children of Skopje in other parts of Yugoslavia; made provisions for building new factories; extended consumer credit to disaster victims and declared a moratorium on loan repayments. In addition, the Republic of Macedonia was relieved of its obligations to contribute to federal funds for social, cultural and educational activities during the emergency period.

Financing for Reconstruction

Five weeks later, the Yugoslav Federal Assembly authorized an advance in credit to the City of Skopje of 30 billion dinars ($40 million)* to be followed in 1964 by contributions of 64 billion dinars ($87 million). Later, a federal grant for first stage (1965-71) reconstruction was fixed at 400 billion dinars ($533 million). This was ten percent more than the amount of the official damage estimate (UNDP, 1970). The grant was financed by a bond issue levied on the northern republics (Nez, 1972). The Republic of Macedonia and City of Skopje provided an additional 130 billion dinars ($173 million). Loans for restoration of industry came from both eastern and western European nations and the United States (UNDP, 1970).

On September 23, 1963, thirty-five nations supported the Yugoslav government in asking the United Nations (UN) to put relief for Skopje on its agenda. In response to this request, the UN General Assembly, on October 14, 1963, unanimously resolved to provide aid for the city's long-term needs. This action led to UN support for substantial technical assistance for post-earthquake planning and for other major reconstruction efforts. UN assistance for planning was provided through two programs, the Technical Assistance Programme and the Urban Plan Project under the UN Special Fund Programme. The latter was one of four UN Special Fund projects in Skopje. Other international organizations and many nations also provided materials, and technical assistance and extended credits to aid in planning and reconstruction (UNDP, 1970). The United Nations provided the principal outside source of support for planning contributing $200,000 to support the Technical Assistance phase and $1,529,000 for the Urban Plan project. The total Yugoslav contribution to the UN planning projects was $176,000 in currency and $4,662,500 in kind through professional staff, local contracts, office space and other support (UNDP, 1970).

* Dollar values are calculated at 750 dinars to the US dollar; the Yugoslav currency fluctuated widely in 1963-64 and the value of New Dinar issued in 1965 was fixed at 1250 dinars to the US dollar. The figures used here are intended to convey the relative orders of magnitude of the assistance from various sources.

POST-EARTHQUAKE LAND USE PLANNING AND RECONSTRUCTION

The post-earthquake planning effort encompassed three major phases:

- The Initial Planning Effort – primarily with local resources (August 1963-March 1964).
- The UN Technical Assistance Programme (January-June, 1964).
- The UN Urban Plan Project – concurrent with other related UN Special Fund projects (May 1964-1966).

There was considerable overlap between phases which is reflected in the discussion. In all phases, reconstruction proceeded concurrently with planning and new methodologies and procedures for planning and project review evolved in response to this condition.

Initial Planning Effort

The immediate local priorities were to meet human needs, coordinate outside help, prevent additional damage from aftershocks, and resume industrial production. Within this context, the Skopje Institute for Town Planning and Architecture (ITPA) began to assess the planning and reconstruction problems facing the city and region. ITPA was aided in this effort by ideas contributed by a number of foreign planners appointed by the UN, most particularly Maurice Rotival (from France) and A. Rimsha (from

USSR), who visited Skopje during the first few months following the earthquake (UNDP, 1970).

In September 1963, the City Council set up the Consultative Committee for Reconstruction and Development of Skopje. This committee included representatives of federal and republican (Macedonian) agencies, the arts, sciences and civic organizations. Its function was to assist in resolving interjurisdictional problems and speed up communication among the agencies represented. By the end of October, the Skopje ITPA (working in tents) produced a first draft plan for reconstruction, based in part on alternative concepts of Rotival and Rimsha.

By this time, the local authorities had decided on a two stage reconstruction program – priority reconstruction during 1964 and reconstruction according to plan in the years 1965-1971.

In 1964, priority was to be given to meeting the most urgent physical, economic, and social needs – restore essential services; get factories back into production, provide the city's homeless with temporary housing and a means of existence. Physical investment necessary to do this was to be made whether or not the urban planners had made up their minds about land use for specific sites needed for temporary housing or employment (UNDP, 1970). However, even in the emergency period, it appears that major construction was channeled away from the City Center area, pending the formulation of a plan for rebuilding in this area.

During 1965-1971, physical development projects would be reconciled with requirements of the new plan for reconstruction (so far as these were known at any given time). While the plan was being prepared (during 1965) the reconciliation was to be a two way process of mutual adjustment; but once the plan was formally approved all new development would be required to conform with the plan.

In addition to defining the two stage reconstruction program, the local authorities decided that a long-term plan for the period 1971 through 1981 should be prepared concurrently with the reconstruction plan. (UNDP, 1970).

By October 1963, the program to re-activate industry was quite successful, with production already reported at 80% of the pre-earthquake level. But housing was still critically short and it was decided to repair every dwelling that could be made habitable even if not earthquake safe. This decision resulted from weighing the relative risks of another major disaster against the danger to regional economy and risk to public health of keeping willing workers idle in remote refugee camps. The local authorities recognized that much of the "patch, prop, and plaster" effort was in the long run, an uneconomic use of labor. However, the lack of knowledge and variable quality of construction materials in the old dwellings inhibited the use of measures to strengthen buildings while making emergency repairs.

Based on advice from foreign experts, programs were instituted for "in service" education of Yugoslav architects and engineers and specialists were brought in to report on the selection of structures for demolition and repair, cost effective use of materials and labor, and methods of repair recognizing the limited skills of the work force. The final assessment of damage to dwelling units showed that 42% required demolition, 36% were capable of repair and reconstruction, 19% were suitable for immediate rehabilitation and 3% were virtually undamaged and in uninterrupted use.

What was lacking at this time was evaluation of the impact of the emergency development on the planning for the city as a whole. Within a few months of the earthquake, prefabs rehousing 35% of the displaced population had been erected on sites selected primarily on the basis of comparative service costs and the spatial concept of the official pre-earthquake Town Plan was vitiated. A new plan was needed and it was evident that the City Council and the ITPA needed technical assistance because of the magnitude and complexity of the tasks to be accomplished (UNDP, 1970).

The action of the UN General Assembly in October 1963, authorizing aid to Skopje provided assurance of needed assistance. An "International Consultative Group" was established chaired by Ernest Weisman representing the United Nations with the other members (5 Yugoslavs and 5 foreigners) being experts in economics, urban planning, engineering, geology, seismology, and architecture. This body was reconstituted as the International Board of Consultants and its membership expanded to 21 at the start of the UN Special Fund Programmes. The basic assumptions were that Skopje would continue as the center of the Macedonia Republic, and that growth would be rapid. The first meeting resulted in these recommendations:

- Rebuild on present site and make additional investigations of underground conditions to aid in land use planning – microseismic and soil testing, field investigations of water levels and geologic conditions
- Prepare a map of "seismic and geotechtonic regionalization" for the whole of Yugoslavia
- Improve and standardize building materials
- Set up a building code for strengthening damaged buildings and requiring earthquake-resistant design for new buildings
- Set up, in Skopje, an institute for research and training of specialists in earthquake engineering and town planning in seismic regions
- Start work on the multipurpose Vardar River regulation project at once

The International Consultative Group also recommended:

- Preparation of a regional plan
- Cost analysis of alternative development patterns
- International competition for the design of the City Center
- Evaluation of earthquake damage by areas
- Expansion of Skopje's construction and building materials industries

These recommendations were welcomed by the City

Council as guidelines for a concerted attack on identified long-range problems. In subsequent months action was taken in accordance with all of the recommendations (UNDP, 1970).

The UN Technical Assistance Programme

This program was the beginning of a massive, complex planning effort with participation from experts from several disciplines and many nations – an undertaking described by some as one long, intensive, international planning seminar. There were language and disciplinary barriers, ideological and cultural differences, and personal ego problems to overcome. The International Consultative Group was an important unifying element in the endeavor.

The UN Technical Assistance Programme provided technical help, paving the way for the UN Skopje Urban Plan Project which was highly interrelated with two other UN special fund projects for Skopje: the Vardar River Regulation Project and the Training Center for Building Construction Personnel. Before these special fund projects could become operational, basic data evaluation and interpretation were needed. To these ends the UN allotted $200,000 to the Skopje Technical Assistance Programme to do systematic surveys of demography, transport, infrastructure and condition of buildings, to provide specialized equipment for geological, seismological and planning studies, and to draft a program for the entire UN Urban Plan Project (UNDP, 1970).

The Technical Assistance Programme officially started about six months after the earthquake with George Nez, a planner from the United States, assigned to work with the locally appointed Director General of Reconstruction and Development. Doxiadis Associates from Athens was selected to work with an ITPA team on a new outline plan, a plan to guide reconstruction in the period 1965-1971 taking into account social targets set by local authorities and resources to be provided by the Federal Government of Yugoslavia. In addition, a long-term program looking 30 years ahead was to be prepared.

The new outline plan was prepared by the Doxiadis-ITPA team and submitted to the International Board of Consultants (formerly the International Consultative Group) for consideration at its second session in June 1964. The major recommendations were:

- Entire Skopje Valley should be subject to plan development control.
- Development in swampy area in eastern part of the valley should be prohibited, at least temporarily, to allow time for further investigation of seismic sensitivity of this area.
- Plan should provide for a future population of 800,000 to 900,000.
- Construction targets should be set at 2 1/2 times the rate previously achieved.
- Clear and move a major existing industrial area to another location.

The plan discussed and highlighted the difficulty in preparing definitive short-range plans before reaching soundly based conclusions on limitations to growth because of seismic hazards or fully assessing the actual extent of damage to existing buildings and cost and feasibility of repairs. The recommendation to move the industrial area was in conflict with actions taken to reactivate industrial production. It also posed problems in relation to pre-earthquake actions of the Federal Government which, in the six years prior to the earthquake, had invested heavily in industrial development in Macedonia with concentration in Skopje and had recruited key workers from other parts of the country. Local and Federal authorities had therefore concluded that task number one was to get industry going again – a task which had been substantially completed. The industrial area was not moved (UNDP, 1970).

In addition to the Doxiadis-ITPA plan, the City of Skopje, in June 1964, received a study of comprehensive development worked out, as a voluntary effort, in the Warsaw Council Town Planning Office by a special planning team as a contribution of the Government of Poland. In its work, the team drew on its experience in planning for the reconstruction of Warsaw following World War II. The document presented extensive analyses and alternative development proposals for consideration by the Skopje planners. While preparing the plan, the Warsaw Council's Skopje planning team had substantial contact with ITPA planners and Yugoslav earth scientists and all available information was provided to the Warsaw team. The study indicated that more information on seismic hazards and other natural restrictions would be needed for land use planning and included appropriate qualifications regarding the proposals made (Chief Architect of Warsaw, 1964).

Recognizing the need for a continuing staff planning function, the Skopje City Council established a Town Planning Department in May 1964. Initially, its powers were limited to review functions; it was not to prepare plans or initiate development proposals.

During the transition from the Technical Assistance phase to the Special Programme phase, work continued on an outline regional plan for the Skopje Valley under a team headed by Nez, and two Yugoslav planners Kolev, and Sokolov. Although economic and demographic studies had been done as a basis for the Republic of Macedonia's economic plans prior to the earthquake, no regional physical planning had been done. Thus, with the completion of the Outline Regional Plan in December 1964, an important new frame of reference was provided for the intensive town planning to be done through the UN Special Fund Urban Plan Project.

UN Urban Plan Project

In June 1964, the Governing Council of the United Nations Special Fund approved Yugoslavia's request for major assistance in the Skopje Urban Plan Project. This marked the beginning of transition from the UN phase of International Technical Assistance to the Special Fund Programme. The action almost coincided with the second session of the International Consultative Group now reconstituted as the International Board of Consultants. The Board received the work of the Doxiadis-ITPA team and the Warsaw team and found it "to be a satisfactory basis for future planning work" (UNDP, 1970).

Thus, the Special Fund phase of UN operations began while the priority stage of reconstruction had six months to run. The City was still in emergency status and was beginning to recognize the need to break with the traditional ways of life and adopt modern technology to quickly regain the same level of prosperity as existed before the earthquake. The accumulated capital of centuries had been wiped out by the earthquake and a "new plant" had to be put in place in a few years. Established procedures were not adequate to the situation so that a new decision making process had to be devised and many contractual obligations taken on trust. There was no time for the "traditional planning approach" with survey before plan and plan before implementation with decisions made hierarchically and review and sign off at each step in a bureaucratic process. In Skopje, implementation could not wait (UNDP, 1970).

In October 1964, the City Council approved the Outline Plan prepared in the Technical Assistance phase establishing a policy base for the more detailed planning to be done in the Urban Plan Project (UNDP, 1970).

Organization

The organization of the Urban Plan Project was devised to continue to be responsive to the urgency for both long-term policy and quick decisions on construction of critically needed facilities. Survey and analysis, general policy formulation, long-range physical planning, project planning, project review and design, and project construction were to proceed concurrently.

Adolph Ciborowski, Chief Architect of Warsaw, was appointed Project Manager for the Urban Plan Project and came to Skopje in August 1964. By the end of October, the UN had selected Polservice (the official Polish agency for land use and construction) and Doxiadis Associates from Athens as the principal contractors for urban planning to work in collaboration with the ITPA and other Yugoslav professionals. Polservice was to prepare the master plan, the social survey, and the regional plan. Doxiadis Associates was to do the built up area survey, a housing program, and infrastructure studies. The principal contractors started work in December 1964, with staff contingents from the ITPA assigned to work jointly with them. In addition to the principal contractors, there were task forces and special studies drawing on experts in geology, seismology, engineering and other fields.

Recognizing the need to coordinate the work of the several working groups and maintain the pace of reconstruction while definitive plans were being prepared, two special groups were established in November 1964 as part of the Urban Plan Project organization: the Professional Working Committee and the Day to Day Realization Team. This action formalized an arrangement started by UN Planning Coordinator George Nez during the Technical Assistance phase. It was formalized under the Special Fund Programme as a decision making and problem solving instrument and was a key to the success of the planning and rebuilding program.

The Professional Working Committee was chaired jointly by the Project Manager and the Director of the Skopje ITPA. Other members were the head of the Skopje Town Planning Department, and the chiefs of the Polservice and Doxiadis Associates Skopje team. The functions of the committee were to:

Review progress on survey and planning;

Resolve key organizational and technical problems as these arose with colleagues of diverse backgrounds and differing professional expertise; and

Confer on the nature of advice to give to operating agencies and policy bodies on the location of urgently needed developments.

The Day to Day Realization Team was established within the Master Plan Section of the Project with the setting up of the working sections of the Project in November 1964. Its function was to quickly review all physical development proposals for their planning implications and give prompt reports to the Project Manager as to locations most compatible with the evolving concepts of the Master Plan. The Project Manager was then responsible for evaluating the findings, reviewing them with the Professional Working Committee, if necessary, and advising the local authorities on project locations. The Project Manager then fed the formal decisions of local authorities to the Master Plan Section and other units of the project (UNDP, 1970).

The contributions to the project team from the Professional Working Committee and the Day to Day Realization Team came primarily through:

- Advice promptly given came to be accepted as authoritative by the City Council and could be fed immediately into planning and reconstruction operations.
- Frequent meetings kept the Project in touch with local authorities and brought about incessant confrontation of diverging views.
- Continuous dialogue with municipal and republican (Macedonian) bodies enabled them to grasp concepts of the Master Plan as it evolved. They understood the reasons for its provisions.

The Planning Process

As in the Technical Assistance stage, data collection and analysis, design study, economic analysis, formal expression in plan documents, and project review and construction proceeded concurrently. Likewise, regional, city and sub-area plans were in process simultaneously. The planning methodology is described as one of progressive clarification with each element of planning making a series of circuits through four segments of continuing activity: information, design study, economic analysis, and formal expression.

The first circuit brought forth the mutual confrontation of independently developed conceptions (alternatives)

The second circuit resulted in a coherent general synthesis (an outline plan)

The third circuit resulted in a definitive plan.

The interconnection of the circuits took place primarily in frequent meetings of the Professional Working Committee. For each element, the end result of each circuit was fed in to the beginning of the next circuit of all other elements.

The Professional Working Committee played a vital part in the process both in reviewing work in process at various stages of completion and in providing a formal communication center for the several sections of the project. The Project Manager and his Yugoslav counterpart, the Director of the Skopje ITPA, shared responsibility for coordination and for communication to local and federal officials and the diverse public and private agencies and enterprises involved in reconstruction (UNDP, 1970).

The Plans

The Urban Plan Project team produced a quite definitive citywide master plan with components geared to specific time frames:

- a short-term plan for the reconstruction period 1965-1970
- a medium-term plan targeted to 1981
- a longer-range plan for development to the end of the century

The master plan was adopted by the City Council on November 16, 1965.

Other plans developed by the Project included:

- A detailed City Center Plan formulated in a three step process, i.e. international competition February-July 1965, concept plan, adopted in March 1966, and detailed urban design plans completed in June 1966
- A detailed layout for the eastern industrial zone
- Engineering plans for the most urgent parts of the road system
- A detailed layout plan for the northern residential zone where slum clearance was needed

The work on regional planning started in the Technical Assistance Programme was picked up by the Regional Plan Section of the Urban Plan Project under the direction of Kolev. This section included eight staff members of ITPA and two Polservice consultants. Other local professional institutes and other experts also contributed to the effort. Interim findings on the Regional Plan were reported to the International Board of Consultants in March and July 1965. Relevant conclusions were included in the Final Report of Master Plan Section in September 1965. ITPA's official report of November 1965 provided more detailed forecasts of regional economic development. The plan although not yet completed at Project's end, did provide guidelines regarding necessary regional and subregional functions to be accommodated in Skopje (UNDP, 1970).

Implementation

Even prior to adoption of the Master Plan in November 1965, very substantial progress had been made in improving the planning-construction process and in actual reconstruction of the city. For example:

- The highly specialized work done by a number of individual foreign consultants (dealing with urban sanitation, social survey techniques, seismology, technology of building materials production, and development of the building industry) together with the experts working on a day to day basis with local professionals, provided continuing training and experience for both the locals and the foreign experts. It was a broadening experience for all concerned including policy makers at local, republic and federal levels.
- The Training Center for Building Construction Personnel became operational in 1965, and 1,500 trainees graduated in the two years following.
- Some 14,000 prefabricated dwellings had been erected providing the start of 18 "new settlements" and, although these settlements had not yet been fully developed into "neighborhoods", the process had started with programs for schools and other local facilities included in the Master Plan.
- Industrial production had largely been restored.
- Substantial progress had been made on the vast Vardar River Regulation Project and by September 1966 it was fully operational. In addition to flood control of the groundwater table, it provided for:
  a. Controlling flow of Vardar tributaries to capture their hydroelectric potential.
  b. Draining of swampland, to be made into agricultural land.
  c. Channeling of water from gullies.
  d. Works to deepen and widen the channel of the Vardar River, to reduce siltation problems.

Following City Council adoption of the Master Plan in November 1965 the focus shifted. A planning-development process was needed for the long term. The Director of Skopje's two-year old Town Planning Department recognized that the newly adopted Master Plan would work only if fully understood by those responsible for administering it. As Town Planning Director, he had responsibility for plan implementation but was only empowered to issue formal authorizations for specific development proposals when initiated by scores of independent private and public investment agencies and enterprises. He asked the International Board of Consultants to recommend that the UN Special Fund Urban Plan Project be extended to help the Town Planning Department through the initial phase of plan implementation. The UN agreed and assigned the leader of the Day to Day Realization Team to advise the Town Planning Department on interpretation of the Master Plan and the preparation of a set of Town planning by-laws. An initial report outlined major functions the Town Planning Department should discharge in addition to routine administrative duties:

- compile and annually revise Town planning by-laws indicating the scope, aims, methods and procedures of Town planning and providing instruction to developers on preparing detailed designs and presenting them for approval
- keep progress in Master Plan implementation under review and warn of needs to adjust the plan

- weld projects of individual agencies and enterprises into a program
- work out Town planning guidelines, policies and relevant information for the design offices preparing detailed plans.
- undertake minor design work

Between October 1965 and June 1966 the Town Planning Department worked out guidelines for nine major residential districts, the eastern industrial district, and the Skopje sector of the Adriatic Highway. The Department also issued 99 location decisions for specific projects. A special team was set up within the Department to continue to update the Master Plan and coordinate the investment program. By August 1966, major elements of the highway system were in the design stage, several segments were under construction, and one was complete. Work was started on new railway links, new public buildings and residential neighborhoods.

The Institute of Seismology, Earthquake Engineering and Town Planning (recommended by the International Consultative Group) was established in 1966 and has made great progress in seismic and engineering investigations with UN support. Following the 1963 earthquake, Yugoslav federal legislation has been adopted requiring geologic investigations and microzonation as a basis for urban planning. In addition, for all public use buildings and other major structures, a report is required from a qualified earth scientist prior to project approval by the local Town Planning Department (Stefanovic, 1979).

THE NEW SKOPJE

A very quick visit to Skopje in October 1974 revealed a functioning modern city. The rebuilding in the City Center was particularly impressive. Much had been accomplished and work was still in process on new construction and rehabilitation of older buildings. The three stage program for the City Center appeared to be moving on schedule. Most first stage (1966-71) elements appeared to be in place with work starting on second stage (1971-75) elements. Very substantial new construction was in evidence in the outlying areas. One negative impression from this very short visit was that the city seemed to be designed for over-dependence on the automobile and in many places lacked pedestrian scale. This may have been the result of efforts to deconcentrate population as a safety measure in the event of another earthquake.

In addition to expansion of its pre-earthquake role as the government, manufacturing and distribution center for Macedonia, Skopje has become the hub for a large tourist industry with a large expansion of hotels and other tourist accommodations (W. Spangle visit 1974).

FINDINGS

1. Assistance from the Federal Government, the United Nations, and other nations was critical to the success of planning and reconstruction in Skopje.
2. Policies of the Yugoslav Federal Government were achieved, in large measure, through loans and grants for rebuilding.
3. Support of the Central Committee of Yugoslav Communists for federal aid to Skopje no doubt had substantial influence on the availability of federal support.
4. The pre-earthquake history of federal investment in Macedonia with massive aid to industrial development in Skopje was another important factor in federal decisions providing post-earthquake aid to Skopje.
5. Although the three phase planning effort flowed rather logically from schematic planning to more definitive plans, the changes in personnel and project direction accompanying changes in sponsorship (i.e. Yugoslavia – UNESCO – UN Development Programme) did affect continuity.
6. Key factors of special importance to the success of planned post-disaster reconstruction, particularly where there has been massive destruction of an important regional city, are:
   a. Establishing attainable goals and a credible and acceptable general program for planning and reconstruction, a program meeting immediate human needs and providing for longer term reconstruction in accordance with an evolving plan.
   b. Anticipating and scheduling, at an early stage in planning, the lead time needed for each major step in planning, construction, and re-housing and re-employment of persons displaced by the disaster. In this process the normal city building process of decades is compressed to a decade or less.
   c. Establishing a central information and control process for reconstruction projects, a process bringing together the planners formulating the comprehensive reconstruction plan and the representatives of public and private agencies responsible for project planning and execution. The process needs to be one of mutual accommodation, particularly in the early stages of reconstruction.
   d. Planning should proceed from rough outline plans designed to guide early decisions of major significance, to definitive plans for adoption as official policy with binding effect on development projects.
   e. A regional perspective is essential to realistic post-earthquake planning.
   f. Where there are substantial areas of concentrated destruction and substantially different patterns of land use are needed for contemporary development, some method is needed for pooling small parcels formerly held in separate ownerships.

Managua Earthquake of 1972

THE SETTING AND THE DISASTER

Shortly after midnight on December 23, 1972, Managua, Nicaragua was struck by three moderate-sized earthquakes within less than an hour. The first and largest of the three, measuring 5.6 on the Richter Scale, struck at 12:30 a.m., local time. Aftershocks of Richter magnitude 5.0 and 5.2 were felt at 1:18 a.m. and 1:20 a.m. Although smaller than the first, the two aftershocks were large enough to cause substantial additional damage (Brown and others, 1973).

Managua is Nicaragua's largest city, where a quarter of the nation's two million people lived at the time of the disaster. It is also Nicaragua's political capital, and the country's business and industrial center.

Early estimates indicated more than 11,000 people killed and another 20,000 injured; seventy-five percent of the city's housing stock destroyed or made uninhabitable leaving between 200,000-250,000 of the city's near half million residents homeless; and property damage totaling more than $500 million (in 1973 dollars). Damage and the loss of life was high because: 1) the earthquakes were centered directly beneath the city; 2) most buildings were not constructed to resist strong seismic shaking; and 3) surface movement occurred on at least four faults extending through the Managua area causing displacement of buildings and breaks in utility lines. The very high death count was primarily due to the collapse of numerous buildings constructed of taquezal (wood frame and adobe) and masonry. Managua's entire central district was destroyed and damage was extensive throughout the city. Although aftershocks continued for several weeks after December 23, the three earthquakes on that day and the fires that followed thereafter were responsible for all of the significant damage (Brown and others, 1973).

Managua is situated in a highly seismic region and, in addition, nearby dormant volcanic centers pose a possible hazard that may be as great as earthquakes. The two most recent prior damaging earthquakes occurred in 1932 and 1968. The 1932 event was devastating. Registering a magnitude between 5.2 and 5.9, it caused ground fracturing along a fault in the western part of the city and violent shaking. It killed about 1,000 of the city's 40,000 inhabitants, destroyed most homes, and seriously damaged the utilities. The 1968 earthquake (magnitude 4.6) caused only local damage on the southeast outskirts of the city. The history of seismic activity and the presence of several known active faults below the city indicate that damaging earthquakes will occur again in the Managua area (Brown and others, 1973).

A view of disaster response capabilities is provided in the report "Human Impact of the Managua Earthquake Disaster":

> ". . . at the time of the 1972 earthquake, the nation was governed by a three man junta – an uneasy alliance of two major parties – with former president Anastasio Somosa at the helm of the National Guard."
>
> (Kates and others, 1973)

With this tenuous alliance heading the highly centralized government and a weak and undisciplined civil service force, the nation was left with a government incapable of quick action. This problem became acute when agency heads, because of the strong family ties, gave priority to measures to protect their own families. In the midst of the general confusion, subordinate officials were unwilling to act without new directives from top authorities. Organized assistance was spotty and unreliable for three to five days after the earthquake. The regular personnel of most of the emergency organizations frequently were not available for operations. Effectively, the government began operating only when the Somosa family took charge. The leader of the opposition resigned from the junta (Kates and others, 1973).

The formation of the emergency government is described in a paper presented in 1973 by the Minister of Public Works. In the first formal governmental response to the earthquake devastation, the Nicaraguan National Governing Board, meeting as a Council of Ministers at 5 a.m. on the morning of the earthquake, decreed a State of National Emergency, imposed martial law, and created the National Emergency Committee (NEC) responsible for coordinating all emergency measures to insure the life and property of citizens and proceed with national reconstruction. The committee, headed by General Somosa, was comprised of the ministers of the executive departments plus the Secretary of the National Governing Board (Nunez, 1973).

On December 24, the NEC ordered the mass evacuation of Managua and, using vehicles requisitioned from private companies, moved refugees to different points outside the Managua area. This effort supplemented what was already in process with homeless people fleeing the city to take refuge with families in other locations. It was estimated that some 350,000 of the city's 400,000 population left the city in the three days following the earthquake (Nunez, 1973).

To discharge its duties the NEC operated 24 hours a day and met in plenary session every night to coordinate activities and work out problems. The meetings were tape recorded and broadcast on the national radio network to inform emergency workers and the public of actions being taken (Nunez, 1973). After the immediate emergency period, which was devoted largely to restoring essential services and caring for disaster victims, the committee's efforts were extended to city planning resolutions, building safety, re-establishing economic activity, and decentralizing commercial and industrial activities in order to keep refugees in their places of shelter as long as possible.

PLANNING RESPONSE

Managua, twice destroyed by earthquake in four decades, faced the problem of rebuilding a safer city. Following the devastating 1931 earthquake, the city grew in a highly concentrated form which proved to be both inefficient and dangerous. Long-term considerations seldom affected land use decisions. At the time of the 1972 earthquake, Nicaragua had long been a classic private enterprise economy operating with minimum governmental regulations. This was particularly true in the field of land-use planning and regulation and real estate transactions (Hazen, 1975). However, some changes had begun, in part because of the 1968 earthquake. In July, 1972 the National Planning Office, Ministry of Public Works had contracted with DEPLAN of Mexico, a private firm, for a planning study of Managua but work had not been completed at the time of the earthquake (Nunez, 1973). A law requiring major structures to be seismic resistant had been passed shortly before the 1972 earthquake but had yet to be implemented (Kates and others, 1973).

To assist the Nicaraguan government, international aid began to flow from a number of sources. The United States Agency for International Development (AID) began providing substantial financial and technical aid including assignment of planners with disaster reconstruction experience to advise the Nicaraguan government. The World Bank also provided financial assistance and the Mexican government provided a planning team. The United States Geological Survey (USGS) made two investigations. One for the purpose of recording and interpreting preliminary geologic and seismological data, and evaluating these data as an aid to those who were making difficult decisions regarding rebuilding the city, and another to investigate the general area to see if there were any possible safer sites for the capital city.

Using advanced techniques, the field work for the first USGS investigation was started about a week after the earthquake and completed in less than a month (Brown and others, 1973). The report was completed and published very quickly and was released in late May 1973. However, some of the results were made available to decision makers much sooner — even before the field work was completed. Specific information related to a new U.S. Embassy site was provided to the U.S. Ambassador by memo of January 12, 1973 and influenced decisions regarding reconstruction of the Embassy. In part, the memo indicated that, taken together, seismicity and geology presented unusual hazards throughout the city area and that the cost of rebuilding a safe city on the present site could be substantially greater than on a safer site. While the report was still in manuscript, representatives of the World Bank met with USGS personnel and were briefed on the seismic and geologic hazards impacting the Managua site (Brown, 1979).

The second investigation by USGS was made in February 1973 at the request of AID for the purpose of determining whether any areas within 15 km of the present city were better suited than others for reconstruction taking into consideration volcanism, geologic materials, and seismicity. No site substantially better suited for the capital was found within the study area (Schmoll, 1975). Although the report stemming from this study was not published until December 1975, the results were recorded in an open file report and were available to planners and decision makers responsible for preparing and executing reconstruction plans very soon after completion of field work in February 1973 (Brown, 1979).

The two reports of the USGS identified seismic and geologic hazards to be considered in replanning the city and recommended intensive investigations to precisely locate faults and further define fault hazards and seismicity.

At a very early time a decision was apparently made to rebuild on the same site. Public arguments for so doing cited several factors including: the heavy investment in roadways, sewers, and waterlines which, aside from numerous breaks caused by surface fault rupture, remained largely intact, and the survival of ninety percent of the heavy industry and 20,000 housing sites on the existing site; the absence of a nearby, safer site on which to rebuild the city; and the potential for constructing seismic-resistant structures (Kates and others, 1973).

Although the need was recognized for a reconstruction plan and program to avoid past mistakes and meet World Bank and U.S. Agency for International Development (AID) requirements for reconstruction assistance, the political-economic climate was not favorable to a tightly structured, highly controlled planning-development process. In addition, the capability, within the government, for planning and programming was not adequate for the magnitude of the effort required.

In response to a request from the Government of Nicaragua, the Mexican government provided a planning team composed of technicians from the Mexican Ministry of Public Works and staff from DEPLAN. Using studies previously completed by DEPLAN and new information, this team quickly prepared alternate plans for the rebuilding of Managua (Nunez, 1973). The first of these, a plan for rebuilding Managua as the "high-rise capital of Latin America", was soon submitted. This proposal, however, was unacceptable to the people and was rejected. A second plan, submitted by the Mexican team by May 1973, was more in tune with recent trends. This plan called for the development of six satellite centers near the periphery of the city and away from the destroyed central business district, development of a neighborhood around each shopping center with housing for various income groups together with a community center for each neighborhood, and redevelopment of the central area with low-rise government buildings in an open setting. The intent of the plan was to decentralize and deconcentrate the city's population and commercial activities into numerous peripheral nuclei as a defense against future earthquakes. It was also intended to provide an improved environment and shorter trips to work. In addition, there was a vision of a city less segregated by economic class (McCahill, 1973).

The National Emergency Committee, immediately after the earthquake, ordered the drafting of an emergency code requiring earthquake resistant construction applying both to new buildings and to rehabilitation of repairable buildings. This code was ratified on January 15, 1973 and became effective immediately. The National City Planning Office was given the job enforcing the code and its budget was increased to provide needed staff and special expertise (Nunez, 1973).

Other emergency measures taken by the NEC which were expected to have substantial effect on planning and reconstruction were:

- Accepting the Mexican team's plan for deconcentration in the rebuilding of the city
- Creating a Technical Seismic Department (within the National City Planning Office) and a Seismological Institute to establish a network of seismographs throughout Pacific seaboard of Nicaragua to study seismic phenomena
- Creating a National Ministry of Reconstruction, a Vice Ministry of Urban Planning, and a special Implementation Division within the Ministry of Finance
- Ordering the fencing of the devastated central area and imposing a strict moratorium on construction in this area (Nunez, 1973).

Information was not available in the sources reviewed on the timing of these actions nor were some of the organizational relationships defined. It is evident from several sources that responsibilities earlier assigned to the National City Planning Office were later being discharged by the sections within the Vice Ministry of Urban Planning and it is assumed that this office became part of the Vice Ministry.

Within a few days of the earthquake, Managua's 400-square block central area was fenced off as a public safety measure and a moratorium was imposed to prevent rebuilding until a plan of development could be prepared for this area. Public officials, however, were slow in developing a detailed plan for the destroyed central city area. The problems were extremely complex. Without clearly defined goals for the area's future and with some 6,000 lots and as many as 2,000 separate owners, the task of preparing a suitable plan and executing a development program required approaches that were without precedent in Nicaragua. Officials were preoccupied with the more immediate concerns of providing and repairing housing, establishing and enforcing building codes, and developing the infrastructure for the new decentralized city. Three years after the earthquake, a redevelopment plan for the new city center was released. Although official plans called for completion of reconstruction within eight years of the earthquake, completion of the new city center is expected to take longer (Haas and others, 1977).

In a May 1974 report to AID and the Government of Nicaragua, Robert Hazen, a consultant to AID recommended a development process for reconstruction of Nicaragua, a process he characterized as necessarily complex and everchanging but comprised of four basic components:

1. Continuous planning for the progressive refinement of the Master Plan to a level of detail needed for specific investment and construction decisions.
2. Site planning for the sub-centers proposed in the Master Plan locating, for each sub-center, areas for housing, services, commerce and industry
3. Land development including careful negotiation with private developers to insure quick action and conformity with specific development plans
4. Land assembly and land valuation addressing two special concerns: first, the need for suitably sized and located development parcels for deconcentration of activities and execution of sub-center plans; second, the pressing need for equitable treatment of land owners and reinvestment opportunities for central area property owners

In his report, Hazen identified carefully timed public infrastructure improvements and control of the timing and sequence of private development as critical components of the rebuilding process. The vital role of private enterprise is recognized while recommending a stronger government role in guiding land development. The principal recommendation of the report is that the Government of Nicaragua establish a Managua Reconstruction Agency with responsibility for the development activities needed to carry out the Master Plan for reconstruction. These recommendations were a radical departure from the laissez-faire private enterprise economy traditional in Nicaragua (Hazen, 1974). In the review of literature describing post-earthquake development, no reference to specific actions by the Government of Nicaragua to implement Hazen's recommendations is found.

Detailed investigations by earth scientists and engineers confirmed preliminary findings and indicated that the major causes of damage from the 1972 earthquake stemmed from ground shaking and surface fault rupture. In response to recommendations from these experts, the Nicaraguan government took measures to respond to these two clearly identified hazards.

Improved Building Code

As indicated previously, an emergency code requiring earthquake resistant construction was enacted and became effective within three weeks of the earthquake. This code was strictly limited to structural design for seismic loading and even in this regard had substantial deficiencies. However, it marked a substantial step for improved safety (Wright and Lamana, 1975).

To aid the Government of Nicaragua in developing a new building code, a technical review of the problem was sponsored by the Organization of American States (OAS), AID and the U.S. National Bureau of Standards (NBS). The OAS/AID team's work started in July 1973 and its report was presented to representatives of the sponsoring agencies on August 21, 1973. In the interim, a draft code, prepared by a group in the University of Mexico under subcontract with DEPLAN (contractor to the Ministry of Public Works), was submitted to the Nicaraguan Seismic Review Committee in May 1973. This draft code is characterized by the OAS/AID team as "a promising forward step in structural design standards", and "a major resource for development of a Nicaraguan Code" (Wright and Lamana, 1975).

The conclusions and recommendations of the OAS/AID team covered all major aspects of building regulation and building construction. The portions of the recommendations most relevant to post-earthquake land use planning are summarized as follows:

1. Future earthquake damage can be reduced through land use planning and earthquake resistant design and construction practices.
2. Efforts to implement a building regulatory system have been generally effective, although administrative problems have arisen because of the large volume of repairs and construction, the inexperience of building designers in using the emergency code, the lack of an adequately trained staff to review and inspect proposed projects, and the need to make decisions quickly to avoid stagnation of the reconstruction effort.
3. The draft building code should not be adopted in its present form, but considered as a first step in a two or three year program to develop a new building code. Improvements needed include control over the quality of materials, standards for non-seismic structural loading, and performance standards for non-structural building elements.
4. A Nicaraguan Building Institute should be established to test building materials and to develop building codes and standards appropriate to Nicaraguan conditions.
5. Educational programs for architects, engineers and building inspectors should be organized.

(Wright and Lamana, 1975)

Zoning to Reduce Hazards of Surface Faulting

Based on a study undertaken by the USGS under the sponsorship of AID, a plan for zoning Managua to reduce hazards of surface faulting was formulated in 1973. Four categories of hazard exposure were defined and general guidelines and policies suggested for three groups of uses based on the relative importance or critical nature of the installation and the concentration of human occupants (Wallace, 1973). This concept is embodied in a scheme for zoning of areas exposed to surface faulting later developed by the Vice Ministry of Urban Planning in concert with architects, structural engineers, geologists and an independent Consulting and Review Board. Land uses were classified into six use groups by nature of occupancy and five hazard zones presenting a range of risk exposure were defined based on a preliminary map of surface faulting released for public use in 1975. The validity of the preliminary map was evaluated against findings from 16 km. of trenching done for 28 separate property developments within the mapped area and the map was found to be highly reliable (Cluff and others, 1977). The zoning scheme which evolved was identified as a "Seismic Risk Planning Matrix – a guide to minimize risks of surface faults" (Table 1).

Table 1. SEISMIC RISK PLANNING MATRIX
A guide to minimize risks of surface faults

	Known Active Faults		Probable Active Faults	Doubtful Areas*	No Evidence
Uses	Major Fault	Minor Fault	Major Trace	Minor Trace	
Hospitals, electric power stations, water plants and pumping stations, fire departments, medicine and drug centers, overpass roadways and buildings with more than eight stories which height is at least 1.5 times larger than minimum plan dimension.	Exclude	Exclude	Exclude	N	N
Underground public utilities, fire mains, main sewer lines, electric conduits.	Special Design	Special Design	Special Design	N	N
Schools, large hotels, churches, government centers, museums, theaters, auditoriums, ammunition storage.	Exclude	Exclude	N	N	N
Housing developments, multifamily apartment houses, small hotels, office buildings, commercial buildings (all structures in this category less than three stories high).	Exclude	Exclude	N	N or Standard A	N or Standard A
Open markets, one family homes, industrial buildings, parking buildings, repair shops, inhabited warehouses.	Exclude	Standard A	N	Standard B	Standard B
Uninhabited warehouses, animal shelters, car shelters, parking lots, wood frame houses, special construction with light roofs not for permanent habitation, light structures for bus terminals or pickup points.	Standard B	Standard B	Standard B	Standard B	Standard B

N: Local fault study needed. **Standard A**: Structures designed to resist the maximum surface fault displacement, tilting or warping. Foundations are designed as a single unit. **Standard B**: Comply with building code. ***Doubtful Areas**: Faults may be located somewhere within the indicated area.

Source: Hinojosa and Gelman, 1977, from Woodward and Clyde, Volume 1, Geologic Report on Investigation of Active Faulting in Managua and vicinity.

The Vice Ministry of Urban Planning was charged with responsibility for preparing the Immediate Reconstruction Action Program (PRAI) which, in concept, was to be the first stage of a long-term general plan for reconstruction. The PRAI was approved by President Somosa in May 1975, more than two years after the earthquake, as a guide to action in the period 1975-1978. The dominant strategy, as in the Mexican team's plan submitted in 1973, was deconcentration. Policies proposed by the PRAI included:

1. Reconstruction of Managua on the same site with strict seismic and zoning regulations.
2. Deconcentrated development on the basis of lower densities to increase the safety in case of new earthquakes.
3. Development of Managua in concentric rings from the destroyed area to the Pista de Circumvalacion with an emphasis on the east-west axis.
4. Development of Managua as a multi-center city.
5. Development will occur in the form of urban cells, with housing and services.
6. Special attention will be given to the needs of the low-income sector.
7. The urban center of Managua will be rebuilt as a non-residential area, with public buildings, parks and open spaces.
8. Participation of the private sector will be stimulated during the planning and implementation process.

(Kreimer, 1978)

These became the long-term strategies of the General Plan of Urban Development (PGDU). The PGDU is described as being "conceived as a process of continuous evolution which will define the orientation of the middle and long-term policies to be adopted" (Kreimer, 1978).

RECONSTRUCTION

Early decisions on locations for low and lower-middle income housing followed pre-earthquake trends and placed this housing on the outskirts of the city. The "Las Americas" projects, temporary housing built with AID funds, were under contract within two weeks of the earthquake on four sites in the eastern sector of the city – near the area of pre-earthquake expansion of industry. The total population increase in this sector was 60,000 with almost 90% of this in the Las Americas projects (Haas and others, 1977).

New upper and upper-middle income housing was built in an outlying area southeast of the city center and in some smaller clusters resulting in a highly segregated city (Haas and others, 1977).

Almost immediately after the earthquake, restrictions were placed on rebuilding. Rebuilding in the central area (as indicated previously) was prohibited by special edict; in the rest of the city repair or rebuilding required a special permit. In addition, no lending by the savings and loans associations was allowed until February, 1973 for construction or repairs in Managua. In general, middle and upper income families complied with these rules – where damage was great they waited for professional help. Inspection procedures and permit systems became operational by the time such help was available. Plans and specifications were prepared to respond to the new requirements for seismic resistance so that permits could be issued. However, many lower-middle and low income families proceeded with repairs themselves without permits or inspection. In addition, by June 1973 illegal new construction had become a serious problem. So the impact of the new building code on residential safety was mixed with a substantial portion of the lower income population returning to dwellings that would be unsafe in the next moderate-to-large earthquake (Haas and others, 1977). The lower income families housed in the Las Americas and other temporary dwellings were in quarters quite safe from earthquakes. Because the quality of construction and space standards in these "temporaries" were higher than usual for these income groups, the temporaries tended to become permanent (Kreimer, 1978).

In the absence of the needed strong government role in reconstruction, private developers took matters into their own hands by constructing unplanned, uncoordinated commercial centers away from the old city center to serve the upper income areas. Consequently, the pattern of commercial development was completely changed. The government did not prohibit this construction so long as it satisfied the limited building regulations and took place within the very broad policy frame of the new city plan. Competing developments by the business community and the construction industry soon led to an oversupply of commercial space in Managua. However, it would have been difficult for public officials to have placed a limit on the amount of commercial building because neither they nor the private sector had adequate data in 1973 on which to estimate the amount of commercial space needed (Haas and others, 1977).

Owners and developers of the larger commercial and industrial structures tended to follow the new building code requirements for seismic resistance. Where major buildings were involved, extensive geologic investigations were the rule and some investors, following the advice of their structural engineers, went beyond code requirements to provide a higher level of seismic safety.

The results of the Seismic Risk Planning Matrix were mixed. Many buildings were repaired or built before it was in use. In addition, the application of the matrix was haphazard until the end of 1975 when it was officially adopted to control most large developments. Small developments were officially excepted. In the case of large developments involving politically powerful individuals, professional staff decisions were frequently overruled by higher level officials (Utush, 1979).

The results of reconstruction are mixed. There have been some improvements in seismic safety through improved building standards, the application of the Seismic Risk Planning Matrix, and greater safety in the temporary housing which has tended to become permanent. Additional safety may have been provided through the deconcentration of population. But to some degree the safety provided by deconcentration may have been offset by building in areas with seismic hazards less well defined but possibly as great as those in more central locations.

Since safety is not the only concern in rebuilding a city, other factors require evaluation. Early decisions regarding the location of temporary housing for low and low-moderate income households helped set a pattern for decentralization and socio-economic segregation. This pattern was reinforced by building shopping centers at the periphery of the city to serve new upper income housing and new traffic arteries were built in a radial concentric pattern connecting the shopping centers with the new upper income residential areas (Kreimer, 1978). Meanwhile, the city center remained vacant and although other areas had been rebuilt or made habitable (sometimes only marginally so) there is a widespread feeling that reconstruction has not yet started. However, an over-extended and amorphous Managua composed of poorly related fragments of development exists. The chaotic dispersed pattern has worked great hardship on the poor and lower-middle income population because they have no effective transportation to allow them to get to jobs or shopping (Kreimer, 1978).

In short, the pattern that has emerged in Managua, partly by government policy but mostly through an aggregation of uncoordinated actions, poorly serves the largest segment of the population. In the long run, the dispersed pattern may provide freedom to make substantial adjustments in home-jobs-services relationships if the city continues to grow and infilling is done in accordance with a soundly conceived plan.

FINDINGS

1. Effective post-disaster land use planning is extremely difficult in a situation where planning and plan implementation have not been regular functions of government. In Managua this difficulty was compounded by the prevailing socio-political-economic conditions and the ways in which different segments of the population responded to the disaster situation. Although the results of the post-earthquake planning efforts, described in the sources reviewed, fall short of producing a safe, functional and humane environment, some improvements are noted in relation to the conditions existing prior to the earthquake:

   - The steps taken to improve seismic safety have had positive effects and, if identified weaknesses in the building code and administrative procedures are corrected, seismic safety would be greatly increased in future construction.

   - The planned deconcentration of land uses, although currently producing major adverse impacts on the low and moderate income population, could yield positive effects in the long term if regional growth continues and adequate attention is given to channeling new job centers and service functions into locations appropriately related to places of residence.

2. Requirements imposed or perceived as a condition of international aid provided impetus for post-earthquake land use planning and adoption of building regulations to increase seismic safety.

3. Effective use of outside technical and financial assistance requires good coordination and prompt action on recommendations from experts.

4. The process of plan formulation and project review was inadequate to cope with the magnitude and pace of reconstruction and resettlement. For example, the Immediate Reconstruction Action Program was not issued until May 1975, when major elements of the post-earthquake city were already in place.

5. The effectiveness of post-earthquake land use planning was substantially diminished by staff inexperience in plan implementation and building code administration together with a long standing practice of preferential treatment in enforcing regulations and providing services.

6. Experience in Managua demonstrates that seismic-geologic information can be developed quickly enough to provide a basis for reconstruction planning and decisions even in an area where pre-earthquake information was scant.

7. Although substantial progress was achieved in the field of building construction regulation, much remained to be done. The approaches used and recommended by the U.S. National Bureau of Standards team should have substantial application in other areas where there is a professional-technical cadre with little knowledge of or experience in building to withstand earthquake forces.

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