WHEN THE GROUND FAILS

Planning and Engineering Response to Debris Flows

Martha L. Blair
et al.

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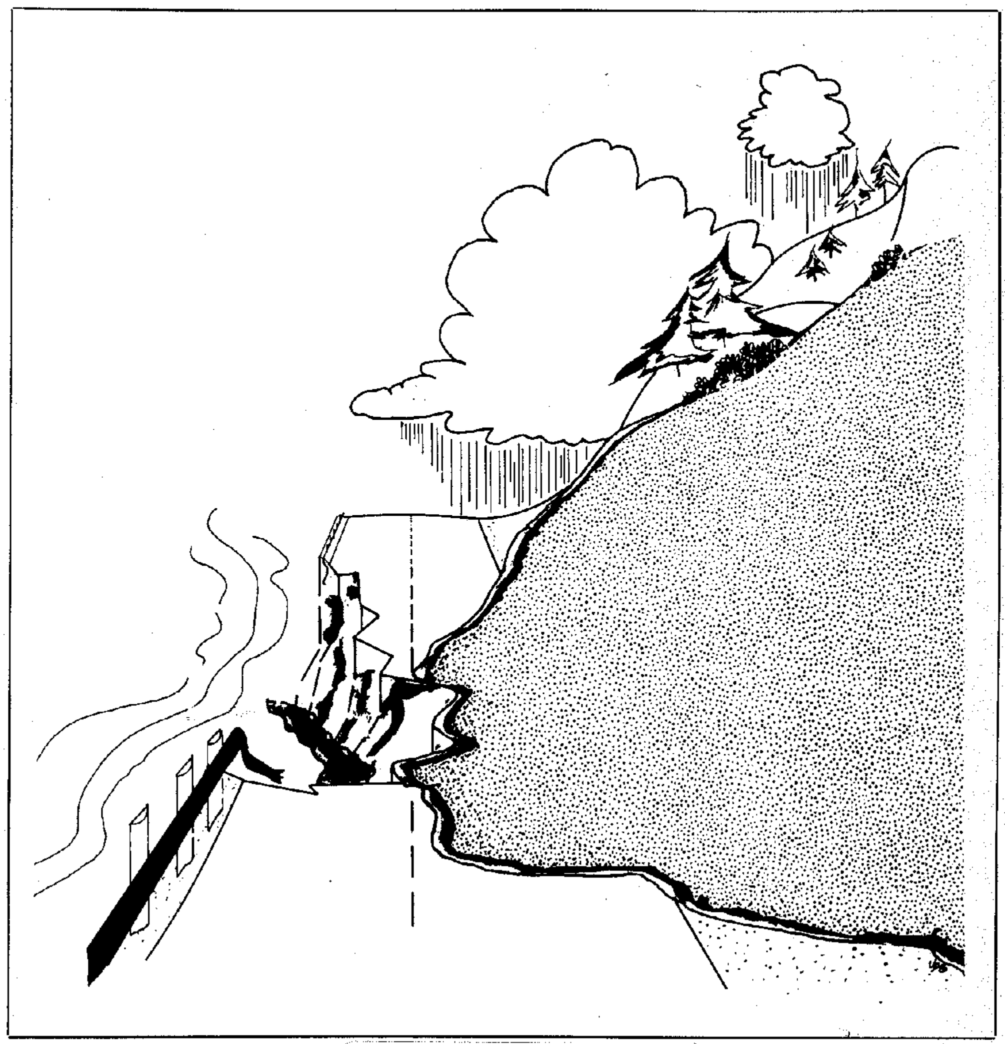

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The Committee on Natural Disasters of the National Research Council and the U.S. Geological Survey co-sponsored a conference on the flood and debris flow disaster. The conference, held at Stanford University in August, 1982, brought together people from many disciplines to exchange experience, ideas and recommendations for averting future disasters. Discussions during the conference provided ideas and stimulation which have been important to this effort.

Support throughout the project has been offered by William E. Spangle, President, and George G. Mader, Vice President of William Spangle and Associates, Inc. Their comments and suggestions have contributed to the clarity of this report. We are indebted to Karen Johnson of William Cotton and Associates, Inc., who drafted the illustrations used in the report.

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PREFACE

This report consists primarily of two case studies of response by public agencies to damaging debris flows. General background is provided as context for the case studies, and conclusions and recommendations are drawn from them. We believe that the development of accurate and detailed descriptions of recovery from natural disasters is essential to further our understanding of recovery and the influences on it. Slowly, case by case, we think the factual basis is being built for a workable model to guide recovery actions by public agencies at all levels.

Because we are urban planners, our focus is on changes in land use in the course of reconstruction. We look for influences on the decision to rebuild or not in hazardous locations, and for the effects a hazard event has on land use plans and regulations of a stricken community. Our information is derived mainly from interviews, review of local newspapers, and review of pertinent documents such as local plans and regulations and hazard mitigation reports. The case study reports reflect our selection of the topics which seem most interesting and pertinent. They are not rigorously structured.

Slope failures are complex natural occurrences. Reasonable postdisaster decisions require evaluation of the probability of recurrence, the areas at risk, the stability of the failed area, and the means and cost of stabilizing it. Since geotechnical expertise is needed for that, we teamed with William Cotton and Associates, Inc., a geotechnical consulting firm, to provide the needed evaluation of response from the geotechnical perspective.

This effort is, in a sense, a follow-up to a previous study, also funded by the National Science Foundation, called Post-Earthquake Land

Use Planning (PELUP). The final PELUP report, Land Use Planning After Earthquakes, contains case studies of planning response to recent U.S. earthquakes and to the Bluebird Canyon landslide in Laguna Beach, California. This study clearly shows that one of the most challenging tasks after an earthquake is deciding what to do in areas of failed ground. Recommendations from the earlier study are reviewed and modified based on insights derived from the January, 1982, debris flow cases.

We have found these cases interesting and informative, and trust the descriptions will add to the body of experiential information from which useful generalizations can be made. We hope the descriptions will be useful to other researchers, public officials in areas with debris flow hazards, and administrators of federal and state disaster assistance programs.

Martha L. Blair
Principal Investigator

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CHAPTER I

OVERVIEW

Purpose of Study

This study documents decisions pertaining to rebuilding or reuse of areas affected by debris flows in northern California in January of 1982. It is expected that such documentation will enhance understanding of recovery after debris flow incidents. With improved understanding, it is possible that federal, state and local disaster response procedures and priorities can be adjusted to foster more effective post-disaster decision making, especially with regard to land use decisions in areas of ground failure.

The study was funded under the National Earthquake Hazards Reduction Program of the National Science Foundation. Although debris flows do not necessarily accompany earthquakes, other forms of slope failure do. Previous research emphasizes the importance of land use issues in areas of earthquake-induced ground failure (William Spangle and Associates *et al.*, 1980). Better knowledge of response to slope failures, regardless of the cause, can lead to improved understanding of recovery from earthquakes.

Several facts underscore the relevance of this study to earthquake-induced slope failures:

1) Slope failures, including debris flows under some conditions, are a common effect of earthquakes (e.g., San Francisco, 1906; Anchorage, 1964; San Fernando, 1971).

2) Like the rain-induced debris flows of January, 1982, earthquake-induced slope failures are usually only part of an areawide disaster.

3) Geotechnical evaluation of the damaged areas is needed in order to reach reasonable decisions about reconstruction.

4) Changes in land use, structural design or occupancy are often needed to reduce future risk in areas of slope failure, regardless of the cause.

It is expected that by observing response to the debris flows, much can be learned about the problems of responding to slope failures that are part of an earthquake disaster.

A secondary purpose of this study is to observe the effectiveness of the FEMA procedures requiring hazard mitigation as an integral part of disaster recovery. Suggestions are made for improving the process. They apply not only to recovery from future debris flow disasters, but to disasters caused by other geologic hazards as well.

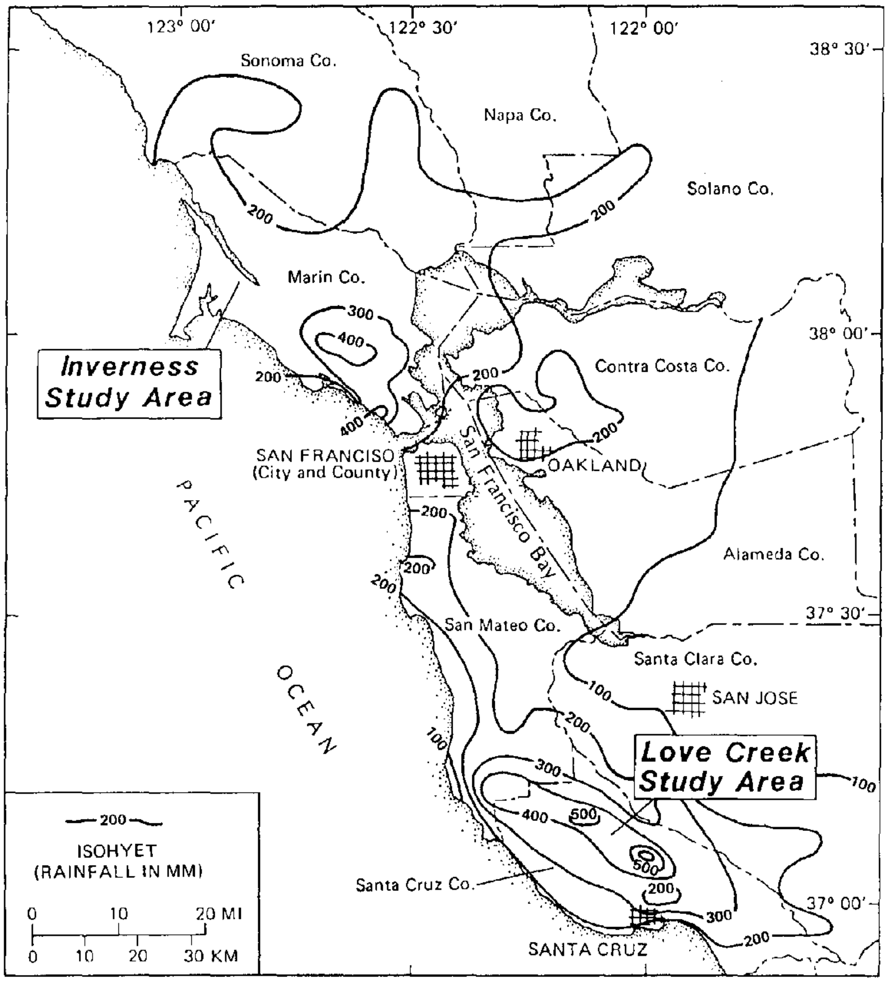
The Storm

November and December of 1981 were unusually rainy in northern California. The Santa Cruz Mountains and much of Marin County had already received over 24 inches of rain. On the afternoon of Sunday, January 3, 1982, yet another major storm system moved into the Bay Area. This storm, however, was different from the typical Pacific storm system; it was the result of a collision between a moist, tropical air mass from the south and an arctic cold front from the north. The resultant stationary, high intensity storm deluged the coastal mountains with up to 24 inches (610 mm) of rainfall in 32 hours (Figure I-1). At times, rainfall intensities were as great as one inch (25 mm) per hour.

The high rainfall intensities associated with the storm initiated literally thousands of shallow debris flow failures in the already saturated hillsides of the region (Figure I-2). Flooding was reported in Marin, Sonoma, and Santa Cruz counties as swollen streams overtopped their banks. Thousands of people were evacuated during the height of the storm, and at least 1500 needed temporary housing. Entire communities were isolated for periods of time ranging from a few hours

FIGURE I-1

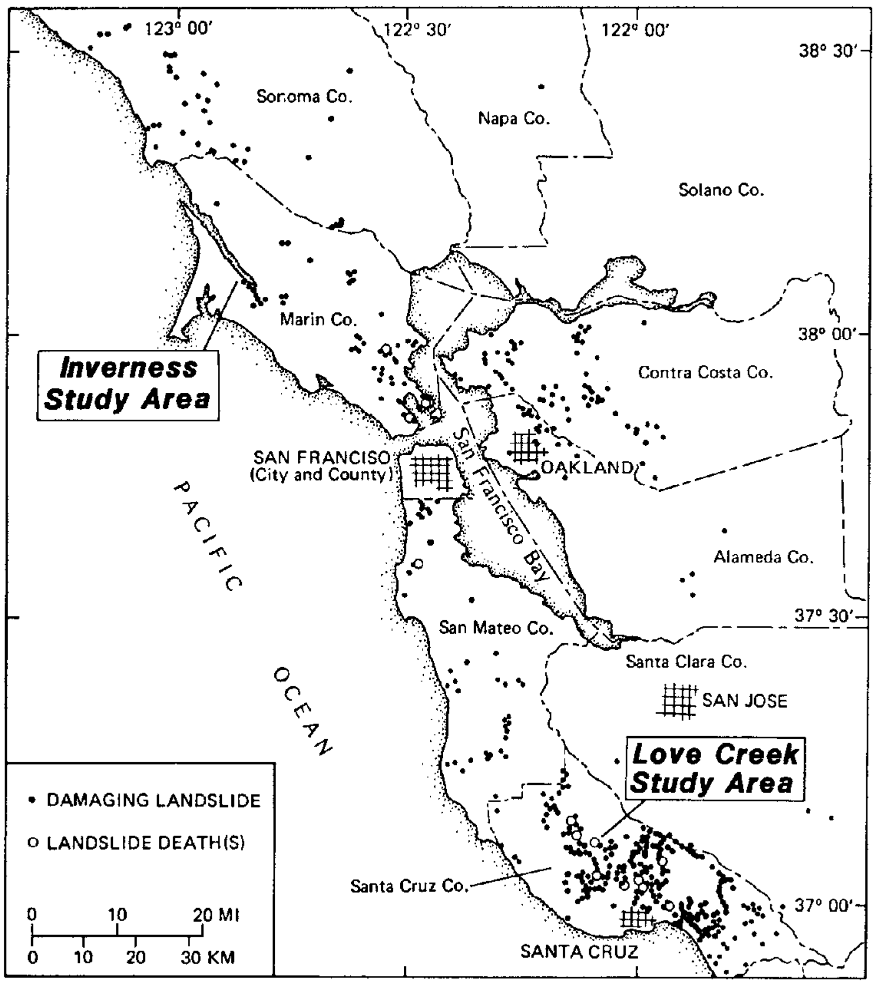
RAINFALL AMOUNTS IN MILLIMETERS FOR JANUARY 3-5, 1982, STORM PERIOD



Contours from T.C. Smith and E.W. Hart, 1982, Landslides and Related Storm Damage, January 1982, San Francisco Bay Region, in California Geology, July 1982, Vol. 35, No. 7, p. 140.

FIGURE I-2

LOCATION OF DAMAGING SLOPE FAILURES IN THE VICINITY OF SAN FRANCISCO BAY DURING THE JANUARY, 1982, STORMS



Source: National Academy of Sciences, 1984, Debris Flows, Landslides, and Floods in the San Francisco Bay Region, January 23-26, 1982, National Academy Press, Wahington, D.C., p. 18.

up to several days. Hundreds of commuters with homes in Marin County were stranded in San Francisco because of the closure of Highway 101. Santa Cruz County was officially closed to nonresidents because its major roads had been blocked by landslides and flooding. Phone and power lines were down throughout the Bay Area, and in several places water service was shut down. By the time the rain stopped, it was clear that a disaster of major proportions had occurred.

On January 6, Governor Brown declared a state of emergency and requested federal assistance. On January 7, President Reagan declared ten counties in northern California a federal disaster area because of widespread floods and rain-induced ground failures (FEMA-651-DR). Initial estimates listed 36 dead, 539 injured, and 5,389 people displaced from their homes. An estimated 232 homes and 65 businesses were destroyed, and another 6,259 homes and 1,507 businesses damaged. The loss to public property was placed at about $109 million, and to private property at about $172.4 million (San Francisco Chronicle, January 13, 1982). Marin, San Mateo and Santa Cruz counties were hardest hit, together accounting for 32 deaths and over $210 million in damages.

Slope Failures

The slope failures initiated by the storm generally consisted of swiftly moving, highly saturated masses of soil and rock debris. Once mobilized, the soil and debris masses attained velocities as high as 25 to 30 miles per hour. Because of the high velocities, the failed materials descended long distances from their source areas and did so with little or no warning. Most of the loss of life and property damage associated with the disaster was caused by these fast, liquid-like slope failures.

The losses of life and property were almost entirely sustained by people and buildings located on stable ground. The debris flows, originating in unstable materials high up on steep hillsides, devastated areas at the bases of the hillsides and along the floors of stream canyons. Damage to buildings was caused by impact and by inundation with coarse mixtures of rock, soil and vegetation. In some cases, structures were overrun, actually incorporated into the swiftly moving mass of debris, and swept downslope. Most of the people who were killed were trapped and buried in their homes by the rapidly moving debris flows.

Debris Flows Defined

The slope failures that occurred during the January, 1982, storm are fundamentally different from deep-seated landslides that are more common in northern California. Table I-1 shows a classification of slope failures by type of material and type of movement. The slope failures in the 1982 storm were derived from the thin, surficial soil cover of steep hillsides. This soil and associated debris moved downslope rapidly as a flowing mass. The term debris flow, as shown in Table I-1, is the best word to describe this phenomenon.

Landslides in northern California (block slide, debris slide, and earth block slide on Table I-1) typically consist of the relatively slow, downhill movement of a coherent block of bedrock or soil material along a well-defined, curved or planar slip surface. Such landslides cause considerable property damage, but rarely result in loss of life because there is usually sufficient warning to evacuate the failing area. Damage from deep-seated landslides is usually sustained by property located on, or immediately adjacent to, the moving ground.

Debris flows move faster than the more common landslides and tend to affect areas a much greater distance from the source of the hazard.

TABLE I-1

CLASSIFICATION OF SLOPE MOVEMENTS

(adapted from Varnes, 1978)

Note: Shaded area indicates the common type of slope failure resulting from the January 3-5, 1982, storm.

TYPE OF MATERIAL		TYPE OF MOVEMENT — GENERALLY INCREASING SPEED →					
		SLIDE			FLOW		FALL
		ROTATIONAL		TRANSLATIONAL			
TYPE OF MATERIAL	BEDROCK	ROCK SLUMP	INCREASING COHERENCE	ROCKSLIDE BLOCK SLIDE	ROCK CREEP	ROCK AVA-LANCHE	ROCKFALL
	REGOLITH (Includes soil, colluvium, and fill)	EARTH SLUMP (Debris slump)		DEBRIS SLIDE EARTH BLOCK SLIDE (Slab slide)	DEBRIS AVALANCHE DEBRIS FLOW EARTH FLOW SOIL CREEP		SOIL FALL (Earth fall) OR DEBRIS FALL

Source: National Academy of Sciences, 1984, Debris Flows, Landslides, and Floods in the San Francisco Bay Region, January 23-26, 1982, National Academy Press, Wahington, D.C., p. 22.

For these reasons, the risk to life and limb is much higher with debris flows than with landsliding. It is also more difficult to define the probability of damage from a debris flow because a given site may be subject to damaging flows from many source areas within a drainage basin. These dissimilarities clearly indicate that different approaches to mitigation, both before and after an incident, are called for. For example, on-site geotechnical evaluation, often recommended as one measure to mitigate landslide hazards, is insufficient to disclose the risk of damage from a debris flow.

Slope Stability Data Available Prior to January, 1982

Considerable technical information on slope stability is available for the San Francisco Bay Area. During the last 10 to 15 years, public awareness of the potential problems associated with urban development of hillsides has increased. The occurrence of damaging landslides has certainly contributed to increased awareness, but the geologic community has also played a role in publishing maps and reports showing the location of landslide deposits, especially in areas undergoing urbanization.

In 1970, the U.S. Geological Survey and the Department of Housing and Urban Development joined forces to fund the San Francisco Bay Region Environment and Resources Planning Study. The study produced earth science information for regional planning of the nine counties that surround the San Francisco Bay. A significant contribution of this study was a series of photointerpretation maps of landslides and surficial deposits (on a scale of 1:62,500) that were produced for parts of Alameda, Contra Costa, Santa Clara, Solano and Sonoma counties. In addition, the U.S. Geological Survey produced a set of regional slope stability maps of the entire study area (1:125,000) showing five categories of relative slope stability. The survey maps have been widely used by regional, county, and local public agencies in the San Francisco Bay Area to identify areas of potential slope stability problems in which more detailed geologic investigation is needed prior to permitting development (Kockelman, 1980).

Additionally, geologic mapping at a scale of 1:24,000 has been completed by the California Division of Mines and Geology for many areas of California, including some parts of the San Francisco Bay Area and Santa Cruz County. Some of these maps show areas that have been affected by landslides as well as other geologic hazards. As with the U.S. Geological Survey maps, these maps are typically used by public officials to uphold requirements for more detailed geologic investigation prior to approval of development in areas identified as potentially hazardous.

Use of all the products of the San Francisco Bay Region Study and the California Division of Mines and Geology was stimulated by the adoption by the State Legislature in 1975 of the requirement that all city and county general plans contain a seismic safety element. Evaluation of geologic hazards, including landslides, is required as part of the element.

A few northern California communities, such as Portola Valley, Saratoga, Milpitas, Hayward, and San Jose, have contracted for more detailed slope stability maps of their hillsides. The more detailed mapping, based on field investigations and engineering geologic analysis, are used as a basis for planning and regulating development of hillside areas. Little damage from slope failure occurred in new hillside developments in these communities during the January storm. This can be attributed, in part, to the wide variations in rainfall amounts and intensities within the region. However, the care taken in assessing stability conditions prior to approving hillside developments in these communities probably also helped to avert problems.

The maps and reports on slope stability done before the January, 1982, disaster addressed primarily the problem of deep-seated landsliding. No maps or reports dealt with shallow landsliding or debris flows. The relative slope stability maps that were available did not generally define the type of landslide, the dimensions, the nature of the earth materials involved or the history of activity. Typically, landslide deposits smaller than 500 feet in width were not mapped. Most of the debris flows that occurred in January of 1982 were too small to have been mapped under conventional mapping criteria.

The January, 1982, disaster underscored the fact that current and prospective urban development in much of northern California may be exposed to debris flow hazards. The U.S. Geological Survey, California Division of Mines and Geology, and geologists and engineers at universities are intensifying research efforts aimed at improving our ability to identify, evaluate, and mitigate debris flow hazards.

Selection of Case Studies

Two small, unincorporated communities in coastal counties were selected for the case studies--Inverness in Marin County, and Love Creek in Santa Cruz County. The regional locations of the case study communities, one north and one south of San Francisco, are shown in Figures I-1 and I-2. Both were selected primarily because they had severe and unanticipated damage from debris flows during the storm.

In both communities, initial emergency response was directed by volunteer fire departments, but the counties were responsible for longer-term recovery. Authority to plan and regulate land use, approve developments, and establish building standards rests with the counties in both cases. Both counties were hard pressed to respond effectively to problems in the individual communities, since they were handling countywide disasters and many requests for assistance. State and federal assistance was available to both areas under the same terms.

These similarities are important, mainly because they highlight the differences in recovery experiences in the two communities. By focusing on these two areas, the study team was able to observe the local influences on response and recovery. Such influences, including the intangible quality of leadership, are very important in recovery, but more difficult to identify than the federal role which was emphasized in the previous study of postearthquake land use planning. In part, the case studies document the efforts of people living in these two ostensibly similar communities as they coped with the disasters' effects.

CHAPTER II

ORGANIZATION FOR PUBLIC RESPONSE

At times of disaster, people typically turn to their public agencies for answers and solutions to urgent problems. To a great extent, the speed and degree of recovery of individuals and communities depends on the actions of public agencies. The initial public response to a disaster is made by local governments as emergency services and personnel are called into play. A local declaration of emergency precedes help from higher levels of government. A state must declare an emergency and request federal assistance prior to a Presidential Disaster Declaration. Generally speaking, the idea behind the federal disaster procedure is that response to a disaster or emergency situation should remain at the lowest level of government capable of handling it.

This chapter describes the organization and authority to respond to disaster as it pertained to the January, 1982, northern California storm, flood, and debris flow disaster. Local, state and federal mechanisms for response are outlined.

Response of Local Government

In California, cities and counties are general-purpose local governments. Counties provide some services, such as administering the courts, some social service programs, and maintaining county roads for all residents of the county. In addition, they may provide services to people in the unincorporated parts of the county, either directly or through service districts.

Both Love Creek and Inverness are unincorporated communities with governmental services provided by the county and through special purpose districts. Both communities have local volunteer fire departments. The firefighters were first on the scene after the 1982 disaster and continued to provide a focus for local response throughout the emergency period.

As the emergency period ended, both communities looked increasingly to the counties to assist with recovery. Contacts with state and federal agencies about repairs to roads, utilities, and public facilities were handled by the counties. The counties sent in crews to remove debris, open roads, reestablish utilities and shore up stream banks. The counties were responsible for issuing permits for demolition, repair, and rebuilding; building inspection; code enforcement; and establishing and enforcing development standards.

As attention turned to long-term recovery and hazard mitigation, the role of the counties in land use planning and regulation for the unincorporated communities became important. The power to determine what uses should be permitted on lands that failed, lands subject to hazards from above, and flood plains, for example, rests with the counties. Thus, to a considerable degree, the counties held the key to hazard mitigation.

All cities and counties in California are required to adopt a general scheme for future development of their planning area. The general plan must consist of nine elements--land use, circulation, open space, conservation, housing, noise, safety, seismic safety, and scenic highways. In California, the plan has "teeth." By law, a county or city zoning ordinance and subdivision regulations must be consistent with an adopted plan. Applications for development projects must be reviewed by the local planning agency for conformity with the general plan.

The general plan expresses the jurisdiction's intent regarding land use and development standards in areas of natural hazards. Because it is adopted by an elected body following required public hearings, a general plan often quite accurately portrays where a community wishes to head and its perception of risk. However, when planning for a small community is done by a county government, which is viewed as an outside authority, local informal organizations are likely to be formed in order to influence the outcome of the county efforts. In Inverness, especially, a high degree of local control over county planning was exercised by local citizens throughh groups formed for that purpose. The desire to control its own affairs and the habit of organizing to do so seemed important factors in the recovery of Inverness from the disaster. "Local" response in this case means intensive efforts of people in the community to ensure that their duly constituted local government actually responded to their needs and objectives. In the case of Love Creek, "local" response stayed at the county level, with less involvement by the affected local community.

Response of State Government

On January 6, 1982, following the storms and resulting flood and debris flow disaster, Governor Edmund G. Brown, Jr. declared a state of emergency, and requested a federal disaster declaration for the northern California counties that had sustained heavy damage. The state declaration, authorized by the California Emergency Services Act, mobilized the California Office of Emergency Services, Caltrans, the California National Guard, California Conservation Corps, Department of Water Resources, Department of Forestry, Department of Public Health, and other agencies of state government to assist the stricken areas.

The state is responsible for preparing, with local officials, the initial estimates of damage and available local and state resources for recovery; those data then become part of the request for federal assistance. State agencies and crews helped to open up streets and highways, clear waterways, and remove debris from public property. State personnel also helped local authorities maintain order and control access to disaster sites.

State efforts supplement local response and focus on the emergency response period. As the focus shifts to long-term recovery, the state becomes a conduit for the flow of paper and funds between the federal agencies and the disaster area. State assistance at this stage may include advising local officials about how to keep records and fill out applications, providing funds for all or part of the local share of some aid programs, and administering (for the federal government) such aid programs as individual and family grants and unemployment compensation. The paperwork required for the federal funds is voluminous--characterized by some as "the second disaster"--the help of state personnel is welcomed and needed by many local officials.

The state also has a formal role in hazard mitigation under Section 406 of the Federal Disaster Relief Act of 1974 (Public Law 93-288). With local representatives, the state is responsible for preparing a state hazard mitigation plan within 180 days of the Presidential Disaster Declaration. The state is to ensure to the satisfaction of the Federal Emergency Management Agency (FEMA) that the hazard mitigation measures recommended in the plan are being followed by local jurisdictions receiving federal disaster assistance.

Response of Federal Government

In theory, a disaster area looks to the federal government for assistance in recovery if all else fails. In fact, many of the post-disaster activities of local and state government officials are determined by the requirements for federal aid. The objective is to do what is necessary to qualify for maximum assistance. The cooperation among governmental entities which typically characterizes the initial response to a disaster soon turns into attempts to pass the responsibility for funding recovery on up the governmental ladder.

On January 7, 1982, President Reagan declared a major disaster for Alameda, Contra Costa, Humboldt, Marin, San Joaquin, San Mateo, Santa Clara, Santa Cruz, Solano and Sonoma counties, all in northern California. The Federal Emergency Management Agency is responsible for coordinating the response of other federal agencies, in addition to carrying out assistance functions of its own. The authority for FEMA's actions is Public Law (PL) 93-288, which establishes several federal programs to assist disaster areas. Since 1974, numerous changes have occurred in the federal implementation of the assistance authorized by the act. These changes are embodied in regulations and administrative guidelines that govern the day-to-day operations of the agency.

Federal disaster assistance comes into play only following declaration of an emergency or major disaster by the President of the United States. Following a declaration, a federal/state damage survey team tours the disaster site with local officials and estimates the dollar value of damage, broken down into categories relevant to aid programs. The estimates become "official"--the accepted measure of the disaster's impact.

As set forth in PL 93-288, a clear distinction is made between assistance to private individuals, households, businesses, and public entities, including those operating certain quasi-public facilities such as non-profit hospitals.

Public Assistance

Section 402 of PL 93-288 provides the basis for most of the public assistance. The section authorizes federal "contributions to state or local governments to help repair, restore, reconstruct, or replace public facilities belonging to such state or local governments which were damaged or destroyed by a major disaster." The federal contribution "shall not exceed 100 per centum of the net cost of repairing, restoring, reconstructing, or replacing any such facility on the basis of the design of such facility as it existed immediately prior to such disaster and in conformity with current applicable codes, specifications, and standards" (PL 93-288, Section 402(a)).

Interpretation of this latter provision has caused considerable controversy over the years. First of all, "shall not exceed 100 per centum" has been applied differently at different times. At the time of the 1982 California disaster, the federal contribution was limited to 75%. Fiscally hard-pressed local governments were expected to contribute 25% of the cost to repair or replace damaged public facilities. The state stepped in to help with part of this expense, but a large share of the cost was borne by local public agencies.

Controversy also occurs over the issue of "design" of public facilities. The provision is difficult to interpret in specific situations. Often the local agency sees the need to repair or replace a public facility as an opportunity to upgrade it. For example, the agency may wish to install a larger storm drain or widen a street. The federal government does not pay for such improvements to local public facilities as a part of disaster assistance. Two provisions complicate the situation. First, the requirement that the repairs be in "conformity with current applicable codes, specifications, and standards" may permit federal funding of significant improvements to facilities that did not conform to local codes at the time of the disaster. This provision works in favor of communities that keep their codes and standards up to date. The other provision, contained in Section 402(f), allows for an in lieu payment of 90% of the estimated federal contribution to repair or restore all facilities owned by a public agency. The 90% can be spent to repair facilities or to build new ones which "the State or local government determines to be necessary to meet its needs for governmental services and functions in the disaster affected area." This provision gives the local agency the option of preserving greater local control over the use of disaster relief funds in exchange for a 10% reduction in the amount.

Sometimes, rebuilding a public facility according to its predisaster design and the agency's predisaster standards and codes may needlessly perpetuate vulnerability to a hazard. Opportunities to mitigate future hazards in the course of reconstruction may be lost. An attempt to deal with this problem is contained in Section 406 of PL 93-288. This section contains the authority for a hazard mitigation planning process established by regulation in 1979; this is described in the section on hazard mitigation.

Under specific Congressional authorization, other public assistance is provided by the Army Corps of Engineers, Soil Conservation Service, Department of Transportation, and Department of Education. The Soil Conservation Service cleared Love Creek for Santa Cruz County; it is one of the few agencies authorized to do work on private property. The Army Corps of Engineers did a preliminary investigation of a potential slope failure in Love Creek under a contract to FEMA. This function is distinct from the Corps-authorized function of restoring and repairing certain flood control works.

Assistance to Individuals and Businesses

Individual assistance includes 1) temporary housing provided by FEMA; 2) grants up to $5000 to individuals and families to meet emergency needs, funded 75% by FEMA and 25% by the state; 3) crisis counseling provided by the National Institute of Mental Health with FEMA funding; and 4) unemployment compensation provided through the Department of Labor with FEMA funds. The Internal Revenue Service may also speed up tax refunds for disaster-caused casualty losses.

The most extensive and controversial of the individual assistance programs is the loan program operated by the Small Business Administration (SBA) and coordinated by FEMA. Over the years, Congress has established varying terms for SBA loans. In the January, 1982, disaster, the fact that new, more stringent terms had just gone into effect led to problems. Disaster victims expected more generous terms than the agency was authorized by Congress to provide, and dissatisfaction was widespread and vocal.

At the time of the disaster, homeowners could borrow up to $50,000 for structural repairs and up to $10,000 to replace contents, with a total not to exceed $55,000. Renters could borrow up to $10,000 to replace personal property. The rates were 16% for those judged by SBA personnel as able to obtain a loan from conventional sources, and 8% for those considered unlikely to qualify for conventional financing. People with low incomes and many retired people considered poor repayment risks were refused loans altogether. FEMA personnel think that publicity about the 16% interest rates and the paperwork involved discouraged people from applying for loans (Hamner, 1982).

SBA also loans businesses up to 85% of their losses, not to exceed $500,000. Small businesses that cannot obtain funds for working capital from normal sources may be eligible for up to $500,000 in economic injury loans. Like the individual loans, the business loans have a two-tiered rate structure with rates linked to the current rate the federal government is paying to borrow on the open market. In January, 1982, 8% and 16% were common rates.

FEMA Provisions for Slope Failures

FEMA regulations covering public assistance distinguish between emergency and permanent work (44 CFR Part 205, Subpart E, August 13, 1980). Emergency work is that essential to save lives and protect and preserve property, public health and safety. Categories of eligible emergency work include debris removal, emergency protective measures, communications, and public transportation. Emergency protective measures must be justified by favorable benefits to the community at large. Protective work is eligible if it will prevent additional damage to improved property or remove health and safety hazards. With respect to landslides, the regulations permit emergency work during the incidence period. Emergency work might include "debris removal, simple drainage measures and emergency repairs to damaged public facilities. Permanent stabilization of a landslide is not attainable usually by such emergency measures" (Section 205.74 (C)(4)).

Permanent work is to repair, restore, reconstruct or replace damaged public and certain quasi-public facilities to predisaster design using applicable standards. Minor disaster-proofing not required by adopted codes may be permitted. Regarding landslides, the 1980 regulations state that:

> Section 402 of the Act provides for restoration of damaged or destroyed facilities which are man-made features or improvements. The site is the owner's responsibility. Permanent stabilization of a landslide area can be quite costly and may not produce the desired results. When the Regional Director determines that no practicable alternative exists, he may decline to provide such grant assistance for restoration of facilities within the slide area. Permanent work to stabilize a landslide is not eligible (Section 205.75(a)(17)).

Thus, FEMA will not fund any permanent landslide stabilization work, but might fund minor emergency work if there is sufficient threat of additional damage to public facilities. However, the distinction between emergency and permanent work has little meaning in this context. Rarely do minor measures prevent additional failures and, if they do, they may be considered permanent. The potential for further failure and/or stabilization usually cannot be determined without detailed geotechnical investigation. FEMA has no provision that directly authorizes expenditure for such purposes.

FEMA's Eligibility Handbook indicates that engineering and design work is usually not necessary for emergency work. Costs for basic engineering of eligible permanent work are allowed according to a curve relating such costs to total project costs. "Special engineering services" such as "engineering surveys, soil investigations, resident engineers, additional construction inspection" may be required by the Regional Director, if necessary. Geology or engineering geology reports are not mentioned.

The result of these provisions is often controversy, uncertainty and delay. FEMA staff on the scene must make decisions without adequate technical information. No way is provided or authorized to acquire the geotechnical data needed to reach a conclusion on the stability of a failed area and, in some cases, adjacent areas. Without this information, logical decisions on public assistance for repair of roads and utilities, and on private assistance for rebuilding of homes and businesses, cannot be made.

National Flood Insurance Program

The National Flood Insurance Program (NFIP) was established by the Housing and Urban Development Act of 1968. In 1969, this act was amended to include mudslides. The Flood Disaster Protection Act of 1973 established the framework for the NFIP as it presently exists. The program is a mixture of "carrots and sticks" intended to encourage local governments to regulate land use and construction practices in flood-prone areas, and to shift the costs of flood damage in part to property owners in the flood plain. The carrots include availability of flood insurance at subsidized rates to property owners in eligible communities and mapping of flood-prone areas at federal expense. The stick for the individual is mandatory purchase of flood insurance as a condition of financing from a federally regulated or insured financial institute for purchase or construction of a structure in a mapped flood-prone area. The community is required to adopt certain minimum standards of flood plain management in order for its residents and business owners to be eligible for flood insurance coverage. The inclusion of mudslides in the program has caused many problems, not the least of which is agreeing on a workable definition of mudslide. The term does not have a generally accepted technical definition. In addition, unlike flood plains which can be mapped with some precision, areas prone to mudslides are not readily predictable by commonly accepted methods.

Most of the cities and three of the counties in the 1982 disaster area had moved from the emergency to the regular phase of the flood insurance program. This means that Flood Insurance Rate Maps (FIRMs) had been provided, giving flood elevations and permitting rates to be set on an actuarial basis. Unincorporated areas of both Marin and Santa Cruz counties were still in the emergency phase of the program. Flood hazard boundary maps were available and rates were heavily subsidized. In Marin County's unincorporated area, 397 policies were in force and 33 claims were received as a result of the storm. In Santa Cruz County, there were 317 policies and 102 claims (FEMA, 1982, Appendix B).

The insurance program attempts to place responsibility for the costs of building in hazardous areas on the property owner through mandates affecting lending institutions and local governments. However, the number of policies remains quite low in relation to the number of properties at risk. Many individuals and businesses are uninsured for flood damage, and the need for disaster assistance after a flood remains strong.

The ability to purchase insurance, especially at subsidized rates, to cover flood and mudslide may encourage building and rebuilding in flood-prone areas. In recognition of this, the cost of rebuilding structures which suffered loss exceeding 50% of value is not covered. Provision is made for relocating households and businesses subject to repetitive flood losses. However, funding for this program is limited and it has been used sparingly in relation to the need. Only residents of properties insured under the program at the time of a flood are eligible for relocation assistance. Often the need is to relocate several structures, some of which may not be insured.

Hazard Mitigation

Hazard mitigation as a condition of disaster assistance is relatively new. Section 406 of PL 93-288 contains the authorizing language:

> 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.

Although this section has been in the law since 1974, implementing regulations were not issued by FEMA until 1979. The regulations established a planning process to be carried out by a federal-state-local hazard mitigation team. The team prepares recommendations for mitigating natural hazards in the areas in which disaster assistance funds are to be spent. The recommendations are advisory, although FEMA has the authority to refuse to fund rebuilding or repair projects unless mitigation is accomplished as recommended. At the time of the January disaster, the procedures and staff were in place to implement Section 406, but funding for mitigation projects was very limited.

In the case of a flood disaster, hazard mitigation requirements are more complicated. In addition to Section 406, the disaster area comes under the provisions of the NFIP, the Interagency Agreement on Nonstructural Flood Damage Reduction (December 16, 1980), and Executive Order 11988, Floodplain Management (September 9, 1980). For the January, 1982, disaster, a coordinated hazard mitigation process was worked out to meet the requirements of all these authorities.

As called for in the Interagency Agreement, a team of representatives from concerned federal agencies was formed to ensure a consistent federal policy toward mitigating flood losses through non-structural means. This Interagency Team was to issue a hazard mitigation report within 15 days of the disaster declaration. Under unusual circumstances, a 15-day extension may be allowed. The Interagency Team report was issued on February 7, 1982, 30 days after the disaster declaration. In the report, the team assessed the hazard, identified mitigation opportunities, and recommended implementing actions to federal, state and local government agencies. The report outlined key issues to be addressed by the Section 406 federal-state-local hazard mitigation planning team.

The Interagency Team report recognized the need to consider the slope failure hazards evident in the disaster with the following statement:

Mudslide and landslide hazards are directly related to storm/flood conditions in this disaster. These hazards can be reduced by an effective program of appropriate land use regulation, construction standards and emergency evacuation and warning plans.

Six "areas of special opportunity" for hazard mitigation were selected by the Interagency Team and these became the focus of the Section 406 mitigation plan. Both Inverness and the San Lorenzo Valley area of Santa Cruz County, where the Love Creek debris flow occurred, were identified as "areas of special opportunity."

The Section 406 Hazard Mitigation Planning Team is required to prepare a hazard mitigation plan within 180 days of the disaster declaration. The plan is to be submitted by the state to the FEMA Regional Director. The California Office of Emergency Services (OES) was responsible for preparing the plan following the January, 1982, disaster. The plan and a one-year update were issued in the summer of 1983. The plan, as required by FEMA, follows up the Interagency Team recommendations, and established governmental responsibility, sources of funding, and priorities for recommended hazard mitigation actions. The specific recommendations for the Love Creek and Inverness areas are discussed in the following case studies.

CHAPTER III

CASE STUDY OF THE LOVE CREEK DEBRIS FLOW

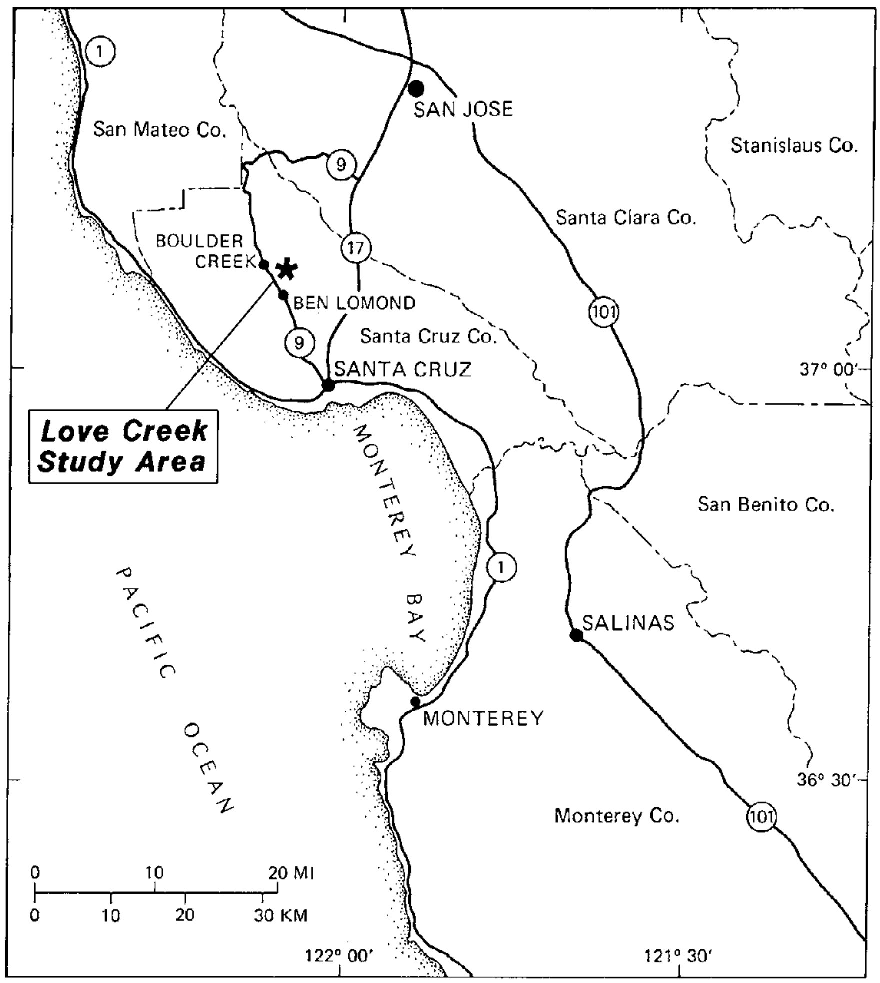
> SANTA CRUZ--Nature caused the first disaster that ravaged Santa Cruz County this year, when the heaviest one-day rainfall on record caused January floods in its redwood forested valleys that killed 22 people and caused $106 million in property damage.
>
> Government caused the second disaster, when new, and little known, federal disaster aid policies washed away the flood victims' expectations of relief.
>
> Los Angeles Times, July 6, 1982

This lead-in to a news story about the aftermath of the Santa Cruz County storm disaster illustrates one problem that ensued after the disaster. The storm brought flooding and debris flows that caused widespread damage to homes and businesses, and hardship for many of the county's residents. Though victims expected that federal aid would be sufficient for them to recoup their losses, the aid, while substantial, fell short of this expectation. Frustration and dashed hopes characterized the postdisaster period.

The Love Creek debris flow occurred in the San Lorenzo Valley area of Santa Cruz County near the town of Ben Lomond, about ten miles northwest of the City of Santa Cruz (see Figure III-1). Santa Cruz County lies along the north shore of Monterey Bay and is part of the Monterey Bay region. However, it is becoming increasingly linked economically to the nine-county San Francisco Bay region as more workers, especially in Santa Clara County, seek housing in the relatively more affordable market of Santa Cruz County. Highways 17 and 9 tie Santa Cruz County to the high-technology industrial parks of Santa Clara County. In some respects, Santa Cruz County is as much a part of the San Francisco Bay region as it is of the Monterey Bay region.

FIGURE III-1

REGIONAL SETTING OF LOVE CREEK STUDY AREA



The debris flow happened about midnight on January 4, 1982, after a day or more of intense rainfall. More than 600,000 cubic yards of rock and debris broke loose and slid toward the floor of Love Creek Canyon. Ten people were killed and nine homes were completely destroyed. The debris flow was the most dramatic event in the countywide storm.

This case study describes the debris flow in the context of the countywide storm disaster and the response of local, state, and federal public agencies. The focus is on the decisions affecting the eventual reuse of the failed area and adjacent, potentially unstable areas. A description of some relevant predisaster conditions and of the debris flow is followed by a brief outline of emergency response. Most of the study deals with the local, state, and federal actions that bear directly on future land uses in Love Creek Heights. Obtaining and using geotechnical information is emphasized.

Predisaster Conditions

Santa Cruz County's response to the flood and debris flow disaster of January, 1982, was influenced by a number of pre-disaster conditions. Some of these are outlined to provide background for the disaster and the responses that followed.

Fiscal Condition

Santa Cruz County is not fiscally strong. There is very little local industry. Tourism is economically important, but involves mostly day use of the beaches that does not generate much tax revenue. Proposition 13, California's property tax-cutting initiative adopted in June, 1978, severely affected the fiscal standing of local governments like Santa Cruz County with few other sources of revenue. At the time of the 1982 storm disaster, the county government staff had been drastically cut and all services had been pared to the bone. There was little or no fat in the county's budget to pay for the costs of disaster response.

Population, Planning and Regulation

In the years before the disaster, political debate had centered on growth/no growth issues. In 1978, the voters adopted a growth-limiting initiative (tying future growth to a percentage of statewide growth). Each year, the Santa Cruz County Board of Supervisors adopts an ordinance setting the maximum number of new housing units to be permitted during the year. However, in spite of both this limitation and water supply constraints, there is significant growth in all areas of the county. From 1970 to 1980, Santa Cruz County's population increased over 50%.

In 1980, Santa Cruz County had a population of 188,141, of which 41,483 lived in the City of Santa Cruz, the county seat, and 23,543 lived in Watsonville, the only other city in the county with 10,000 or more people. The 1980 Census shows that 55,720 people lived in cities and towns with populations between 5,000 and 10,000. The rest, 67,395 people, were scattered in small towns and settlements in the Santa Cruz Mountains and along the northern shore of Monterey Bay.

The Love Creek settlement is typical of many of the small mountain communities that were subdivided in the 1920s and 1930s. Originally it consisted primarily of seasonally used cabins, but over the years, many cabins have been converted to permanent residences and, in recent years, new primary residences have been built. Love Creek Heights, where the debris flow occurred, had about 40 homes ranging from cabins to modern homes. The main road serving Love Creek Canyon is a public road maintained by Santa Cruz County. As is common in this area of the county, most of the secondary access roads are privately owned and maintained.

The Santa Cruz Mountains are a remote, wooded environment relatively free from the constraints of urban life. Attempts by county government to control how the people use their land are often unwelcome. Building, especially remodeling and adding onto summer cabins, is often done without building permits, and county regulations are often imperfectly enforced. Cohesive community associations to support planning and regulation of development have not formed in most communities of the Santa Cruz Mountains.

In August of 1975, the county adopted a Seismic Safety Element as part of its General Plan. The provision includes a preliminary map of landslide deposits at a scale of 1" = 1,670', prepared by Cooper-Clark & Associates in 1975. The mapping was done by stereoscopic examination of 1963, 1968 and 1970 aerial photographs; no field checking was done. The map was intended to provide information for use in general planning and is not suitable for making decisions about the stability of individual sites (Cooper-Clark, 1975). Figure III-2 shows the map of landslide deposits near Love Creek. The area below the Love Creek failure is designated as a questionable landslide deposit.

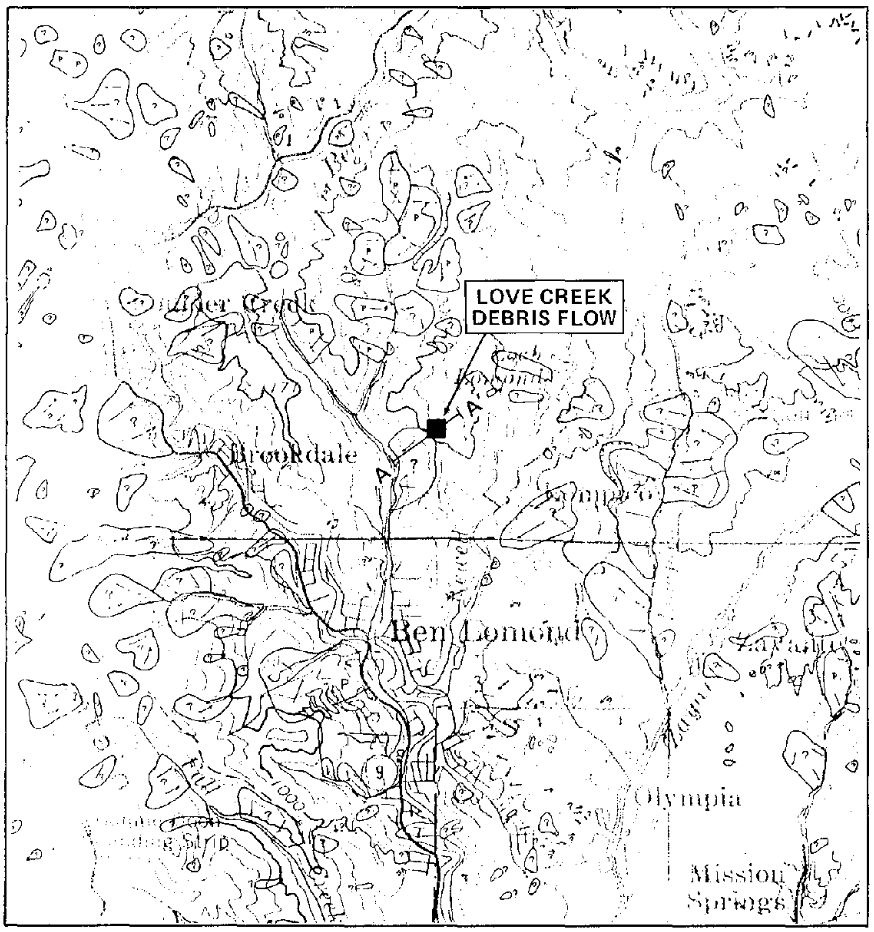
The Seismic Safety Element states that, "Landsliding is an ongoing process . . . that annually results in significant public and private costs," and that "Landslides within the county appear to be limited to those areas over 15% slope . . ." (Santa Cruz County, 1975, p. 30). Based on these and other findings, the following recommendations are made (pp. 31 and 32):

> Open space/agricultural or extremely low-density residential land use of potentially hazardous areas should be encouraged.

FIGURE III-2

PORTION OF THE MAP OF LANDSLIDE DEPOSITS IN SANTA CRUZ COUNTY SHOWING THE LOCATION OF THE LOVE CREEK DEBRIS FLOW (Cooper-Clark & Associates, 1975)

Key: As defined on the source map, P = probable landslide deposit; ? = questionable landslide deposit. Single arrow indicates small landslide deposit or gully; wiggly arrow indicates area of suspected soil creep (see Figure III-3 for geologic relationship along Section A-A').



> The staff geologist should review all proposals for development in areas over 15% slope in order to determine whether site-specific investigations are required. These investigations should assess the stability of the site under both normal and seismic conditions as well as recommend mitigation measures. If it is found that the hazards cannot be mitigated to within acceptable risk levels appropriate with the intended land use, the location of the proposed development should be denied. A public file should be kept of all site-specific investigations.
>
> The map of landslide deposits should be made readily available to the public and should be constantly updated as additional information becomes available. The map should also be used in conjunction with available geologic and slope maps to prepare a landslide susceptibility map.
>
> The public should be informed of how they can minimize slope stability problems on their own property.
>
> For every landslide that occurs in the County, a standard report form distributed by the County Planning Department should be completed by Public Works Departments, the Assessor's Office, and/or utility companies, and filed with the appropriate planning departments. This information would provide data on the annual costs, both public and private, of landsliding within the County, and would identify areas of high risk.

Work was started on a countywide landslide susceptibility map as recommended, and at the time of the Love Creek debris flow, county planners and the staff geologist were putting the final touches on a colored draft map to present to the Board of Supervisors.

Geologic Hazard Review Procedures

Prior to the 1982 disaster, the county had evolved a process for geologic review, as recommended in the Seismic Safety Element. Initially, the process was established to meet the requirements of the state Alquist-Priolo Special Studies Zones Act of 1974. This act requires local review of development applications in fault zones designated by the California Division of Mines and Geology. Santa Cruz County expanded its review to include projects on coastal bluffs, in flood plains, and in landslide-prone areas. Potential debris flows could be identified in the review of landslide- or flood-prone areas, but they are not specifically addressed in the procedures. By 1982, the county's geologic hazard review was as follows (Burns, 1984):

1. Fault Zones--A geologic hazards assessment is automatically required for all development applications, except for single family homes, in the Alquist-Priolo Special Studies Zones as well as in county-designated fault zones. Additional geologic information may be required if the assessment indicates a need. A preliminary geotechnical report is required for applications for development of a single family home in the Alquist-Priolo Special Studies Zone, but not in county-designated fault zones. The preliminary report is done by a geologist under an annual contract with the county to perform such services. Based on the preliminary analysis, additional geotechnical investigation including trenching may be required. Conditions of development approval, such as special foundation design, may also be required.

2. Coastal Bluffs--A geologic hazards assessment is required for all applications for development of parcels bordering on or directly below a coastal bluff. The staff geologist reviews the assessment and can require additional geotechnical reports if the assessment reveals a need.

3. Floodplains--A geologic hazards assessment is required for all applications for development of parcels shown on the Flood Insurance Rate Maps as being in a flood hazard area. Normally, additional geotechnical work is not required, but the staff geologist sets the conditions of development approval, such as the required elevation of structures.

4. Landslides--A geologic hazards assessment is automatically required in a landslide hazard area of the Santa Cruz Mountains identified by a consultant as the most critical of the areas shown as unstable on the Cooper-Clark maps. In addition, the sites of all development applications are field inspected by one of four county grading and erosion control inspectors to identify site design problems especially related to drainage, erosion and grading. The inspectors have been trained by the staff geologist in the rudiments of field identification of slope stability problems. When problems are identified the staff geologist can require a geologic hazards assessment and additional geotechnical work, if indicated.

Information from geologic hazards assessments and geotechnical reports is compiled on base maps as it becomes available. When geologic reports have been required and problems are indicated, the property owner is required to sign a notice stating that s/he is aware of the hazards. A waiver has been added to the notice to relieve the county of any liability from damages. The County Counsel also signs the notice, which is then recorded with the deed.

Topographic and Geologic Conditions

A look at the topographic and geologic characteristics of the Love Creek area reveals the key factors that predispose an area to slope failures: steep slopes, heavy rainfall, unstable bedrock or unconsolidated deposits, and old landslide deposits (Nilsen, 1979).

Slopes. The channel of south-flowing Love Creek is flanked by steep northwest-trending hillsides, and narrow tributary stream channels. The hillside down which the debris flow came rises approximately 900 feet from Love Creek to the ridge top. Prior to the debris flow, the upper two-thirds of the hillside had a uniform surface sloping to the southwest at inclinations of 25 to 30 degrees. In contrast, the topography of the lower third was more variable and flatter, with slope angles ranging from 5^{o} to 20^{o}. This lower area also included some relatively flat surfaces and associated closed depressions typical of terrain with old landslide deposits.

Rainfall. The mean annual rainfall for the Ben Lomond-Boulder Creek area is between 46 to 58 inches. Dense forests of coastal redwood, tanbark oak, and madrone attest to the generally high rainfall in this part of the Santa Cruz Mountains. The debris flow was preceded by unusually heavy rains; between 33 and 39 inches had fallen in November and December of 1981. The landslide came at the end of a major storm that had dropped about 20 inches of rain on the area in a 30-hour period.

Bedrock and unconsolidated deposits. The Love Creek debris flow is located within a northwest-trending structural block composed of tertiary sedimentary rocks (Clark, 1981). This block is bounded by the Ben Lomond fault on the west and the Zayante fault on the east, and is located approximately five miles southeast of the San Andreas fault. The major structural element of the block is the Scotts Valley syncline, a broad downward-arching fold in the bedrock layers between the two faults. Love Creek flows along the axis of this syncline. The bedrock structure exposed by the failure is characterized by bedding at generally consistent inclinations of nearly 30^{0} to the southwest. The parallel inclinations of the hillside and the underlying bedrock strata form a classic "dip-slope" relationship with inclination toward Love Creek Canyon (Figure III-3). This relationship is inherently unstable.

The debris flow consisted of earth materials in a thick mantle of loose, unconsolidated deposits called "regolith," which covers the more competent bedrock of the area. The bedrock is a sequence of thinly bedded sandstone and shale of the Monterey Formation, and is exposed along the upper part of the pull away zone (Figure III-3), as well as in nearby canyon bottoms and road cuts. The regolith is between 30 and 40 feet thick and is composed of a heterogeneous mixture of deeply developed soil, weathered colluvium, and broken rock debris. The earth materials that failed were derived from the bedrock through weathering and natural slope processes. The base of the regolith is sharply defined by a relatively thin layer of clay and sand. Immediately below this layer, on a very competent sandstone unit, is a southwest-sloping bedding plane that formed the basal surface for the debris flow. This bedding plane, between the bedrock and regolith, continues upslope from the headwall scarp (see Figure III-3).

FIGURE III-3

SCHEMATIC GEOLOGIC CROSS SECTIONS OF THE
LOVE CREEK DEBRIS FLOW

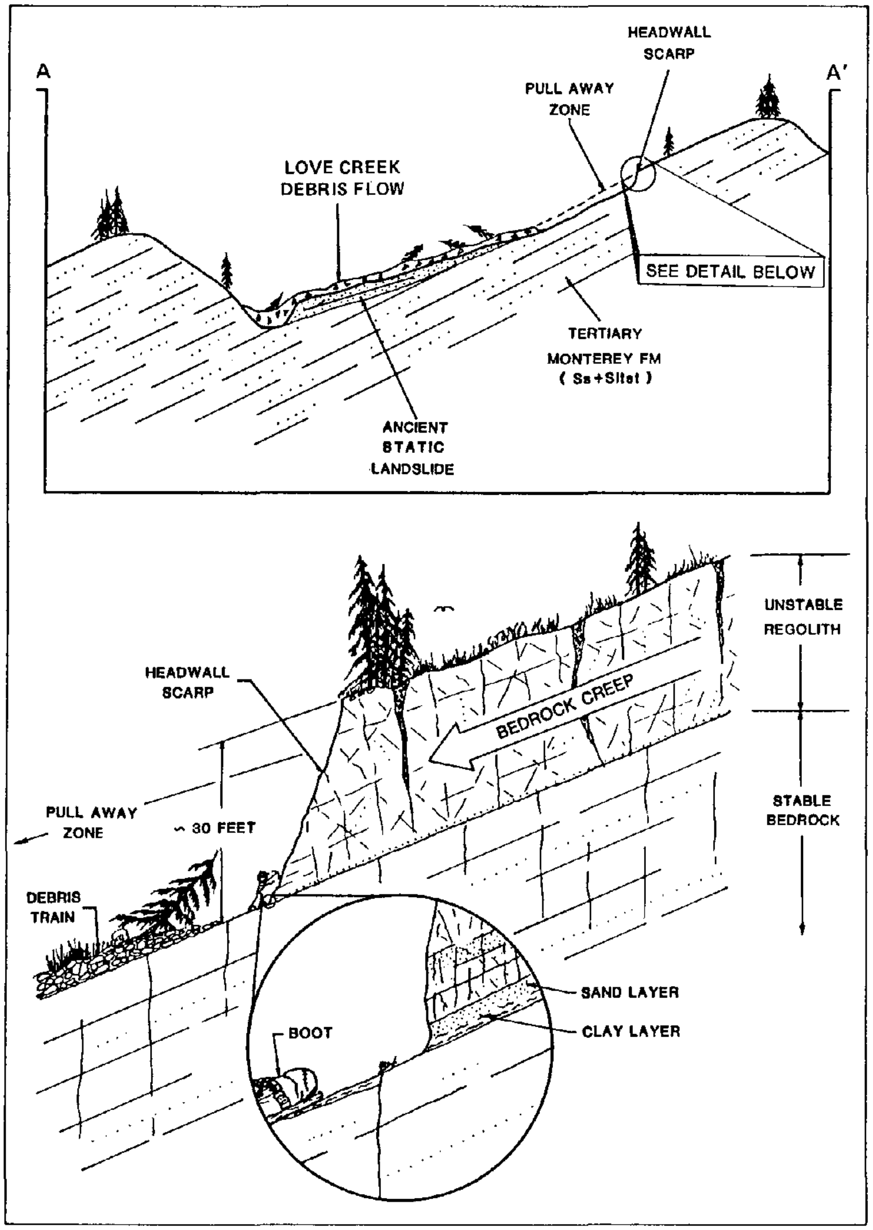
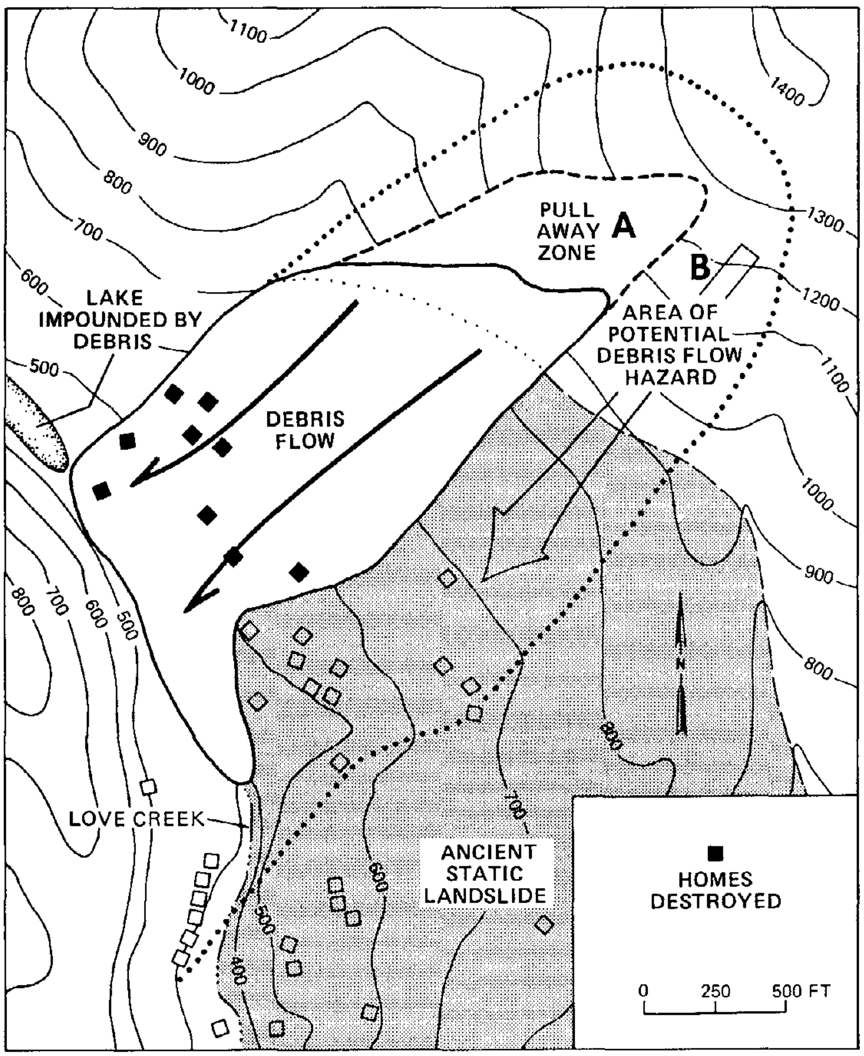


FIGURE III-4

LOVE CREEK DEBRIS FLOW

Note: Heavy dotted line outlines area subject to possible future debris flows; shaded area is the ancient static landslide deposit on which Love Creek Heights was built, and across which the Love Creek debris flow traveled.



Source: William Cotton and Associates, 1982, and Army Corps of Engineers, 1982.

Landslide deposits. Also important to understanding the Love Creek failure is the presence of an ancient landslide along the lower slopes of the hillside (Figure III-4). The configuration of this ancient, static slide suggests it is a deep-seated, rotational landslide. Its presence indicates that slope failures are a part of the geologic history of the Love Creek area. However, it is important to note that the ancient landslide did not move in the January, 1982 failure. The failure originated in the steep hillside above the ancient slide and flowed across its surface. The relatively gentle slopes of the ancient slide helped to contain the advance of the January 4 debris flow, preventing it from moving further down Love Creek Canyon.

The Love Creek Debris Flow

The debris flow was the most dramatic event in a storm and flood disaster that touched the lives of most of the county's residents. The storm of January 3-5, 1982, during which the failure occurred, was preceded by an unusually wet and stormy late fall and early winter throughout much of northern California. Many areas in the Santa Cruz Mountains had already received over 24 inches of rain and snow, and some communities in the San Lorenzo Valley (Lompico, Ben Lomond and Boulder Creek) had received from 33 to 39 inches of rain in November and December alone. This early rainfall accounted for an unusually large share of the 46 to 58 inches of mean annual rainfall. In addition, during the week just preceding the January 3 storm, a smaller storm system passed through the mountains, leaving the ground highly saturated.

Late in the afternoon of Sunday, January 3, a light rain began to fall in much of northern California. The storm system gave no early indications of what was to follow. The California Division of Mines and Geology described the storm as follows (Smith and Hart, 1982):

> Nothing about the way the storm itself formed was unusual: a low-lying cold front moving in from the north collided with moist tropical air from the south. What was unusual, was that the storm failed to move eastward as most storms do. As a result of this stalled weather system, intense rainfall fell on certain areas for up to 18 hours. According to the National Weather Service, rainfall rates of about 12 mm (0.5 in) per hour were commonly reported Sunday night and Monday morning. Sustained rainfall at that rate is unusual for most parts of the affected area. A spokesman for the National Weather Service (NWS) was widely quoted as stating that by the time NWS realized what was happening, it was too late to give any warning--flooding and landslides had already begun taking their toll.
>
> Amounts of rainfall recorded during the storm (which ended about 10:00 a.m. on January 5) ranged from less than 50 mm (2 in) in San Jose to more than 600 mm (24 in) in the Santa Cruz Mountains. Most mountainous areas in Marin, Santa Cruz, and San Mateo counties received more than about 173 mm (7 in) of rain.

In Santa Cruz County, the storm centered on the communities of Boulder Creek and Ben Lomond, on the San Lorenzo River, upstream from the City of Santa Cruz (see Figure III-1). Many residents who had left for work outside of the area on Monday morning, January 4, were unable to return to their homes later that day. Those who stayed behind were cut off from the outside world by the swollen river channels, landslides and fallen trees. Telephone and power lines were downed.

North of Ben Lomond, along Love Creek, the stranded residents of the hillside community of Love Creek heights were preparing to ride out the storm. During Monday evening, the residents busied themselves collecting water from their dripping ceilings, attempting to divert the surface runoff to control erosion around their properties, and tending their animals. Near midnight, the storm ended rather abruptly and the sky over Love Creek began clearing, with clouds yielding to a bright array of stars. The roar from the bottom of the canyon reminded anyone awake that Love Creek was still raging out of control, but most of the residents of Love Creek Heights were asleep.

Sometime between 11:30 p.m. Monday and 1:00 a.m. Tuesday, a 1,000 foot long section of the steep hillside above Love Creek Heights suddenly broke loose and more than 600,000 cubic yards of hillside debris cascaded toward Love Creek. In its path the debris flow buried nine homes and killed ten people. Most of those who perished were apparently caught in bed, attesting to the speed of the debris flow's descent into the canyon. The debris mass formed a dam in Love Creek, creating a small lake. The road along Love Creek was severed, cutting off access to homes in upper Love Creek Canyon. Telephone and power lines were downed, and the creek itself was clogged with trees, brush and debris from the failure.

Figure III-4 shows the location of the dam and an area identified as potentially hazardous soon after the failure occurred. Figures III-5 and III-6 are photographs taken in the month after the disaster, showing features of the failure and the area of devastation. The Love Creek debris flow was one of the largest and most destructive naturally induced slope failures in California history.

However, the debris flow was only part of the storm's impact on Santa Cruz County. Flooding and debris flows in the county resulted in a total of 22 deaths and 50 injuries. Highways 9 and 152 and other public and private roads, especially in the mountainous areas of the county, were closed because of debris flows. Telephone service was interrupted in several areas and 73,000 households were without electricity.

Slope failures in the mountains and along the coastal bluffs were numerous, killing at least eight people in addition to those who lost their lives at Love Creek. The San Lorenzo River, Aptos Creek and

FIGURE III-5a

OBLIQUE AERIAL VIEW OF THE LOVE CREEK DEBRIS FLOW

Note headwall scarp (white band), broad pull away zone (light area), and debris flow mass (dark area).

FIGURE III-5b

SLIDE DEBRIS LEFT ON HARD BEDROCK SURFACE IN THE PULL AWAY ZONE

Note steep headwall scarp in background.

FIGURE III-6a

DEBRIS TRAIN ON THE PULL AWAY ZONE

Note parallel relationship between dip of
hard bedrock surface and slope of hillside (background).

FIGURE III-6b

VIEW TO THE NORTHEAST FROM THE TOE AREA AT LOVE CREEK

The distance to the headwall scarp is approximately
2,000 feet; foreground is location of buried homes,
covered by 10 to 20 feet of slide debris.

Soquel Creek overflowed, causing considerable damage in their flood plains.

A week after the disaster, the California Office of Emergency Services estimated that 135 homes were destroyed and 300 homes were damaged, resulting in 400 displaced people. In addition, 10 businesses were destroyed and 35 damaged. The total loss to private property was estimated to be $50 million. An additional $56.5 million in damage was done to public facilities, mostly roads, for a total estimated countywide damage in excess of $106 million.

Emergency Response

Search and rescue efforts in Love Creek began in the early hours Tuesday morning, shortly after the debris flow. Local residents and members of the Ben Lomond Volunteer Fire Department conducted the initial search. On Tuesday, they rescued four survivors and recovered several bodies from the debris. The search was then expanded and, with the aid of heavy equipment, crews excavated debris from areas where victims were suspected to be. Late in the afternoon of Saturday, January 9, however, the County Sheriff, at the recommendation of the County Geologist, stopped all excavation near the toe of the failure to avert possible reactivation of the debris mass. Crews continued to search the ground in hopes of finding an entire family that was still missing.

On Thursday, January 14, the County Geologist supervised the resumption of excavation in the toe of the debris flow in search of the family. Crews from the California Division of Forestry worked with a bulldozer and backhoe to drain the lake impounded by the debris. They also installed a culvert for a road crossing needed to complete an emergency access road to the upper portion of Love Creek Canyon.

Shortly before noon, two bodies were unearthed, but other victims were not located. The next day, rescue efforts were curtailed after local officials concluded there was little hope of finding any more victims. Four survivors were rescued, the bodies of six victims were removed, and four people remain missing.

During these early rescue operations, geologists with the county and in private firms became concerned about the stability of the slopes adjacent to, and downstream from, the January 4 debris flow. Cracks were discovered in the earth, indicating major stress on the hillside. Field evidence of instability led to a decision by the County Board of Supervisors on January 15 to evacuate 25 families from undamaged houses below this potential second failure area (see Figure III-4). Actions related to this potential failure continue to be a major issue in recovery.

Immediately after the storm, the Board of Supervisors declared a countywide disaster. County officers were closed to the public for a week after the storm because of the water shortage. Emergency response by the county staff was later characterized by a Grand Jury report as poorly organized. In spite of daily staff situation meetings, the initial efforts at assistance were mosty ad hoc and uncoordinated.

Staff teams, usually including a building inspector, watershed analyst and geologist, were dispatched to review field conditions. Over 600 houses were inspected and a number were posted as unfit for occupancy. Several days passed before a team went into the Love Creek area. The teams were authorized by the Board of Supervisors to issue free, 90-day construction permits for emergency work to protect property from damage from expected future storms.

On January 7, Santa Cruz County was declared a federal disaster area, and on January 11, the federal/state disaster assistance center was set up in the Veterans Building in the City of Santa Cruz. The full range of assistance to individuals and businesses authorized by the Federal Disaster Relief Act was made available to victims.

Recovery

As the immediate postdisaster emergency period passed in Santa Cruz County, local elected officials were faced with a number of serious issues. Those with most direct effect on replanning and rebuilding the Love Creek area included 1) obtaining needed geotechnical evaluation of the debris flow and adjacent areas, 2) abating houses in the potentially unstable area, 3) qualifying and applying for funds to repair and rebuild damaged public facilities, 4) helping individuals and businesses to obtain needed assistance, and 5) incorporating actions to mitigate future hazards into plans to rebuild and regulate new development. Each of these problems is discussed in the following sections.

Geotechnical Investigations

Because of the severity of the January 3-5 storm and the resulting widespread damage, almost a week passed before any official geotechnical assessment of the Love Creek failure was undertaken. The initial assessment was done primarily by Gerald Weber, Gary Griggs and Rogers Johnson, local consulting geologists. Santa Cruz County was fortunate to have two geologists on staff: Tom Burns, former county staff geologist, serving as Chief of the Environmental Planning Division of the Planning Department, and David Leslie, a newcomer to the staff as County Geologist. Leslie learned of the Love Creek failure on January 6, but did not immediately visit that site because of pressing problems elsewhere in the county. Official acknowledgment of the problem came on January 9, when Tom Burns inspected the Love Creek area with Griggs, Weber and Johnson. It was during this inspection that the cracks indicating potential failure adjacent to the debris flow were discovered. The geologists made the following recommendations to the County Administrator's Office: 1) stop all excavation (for rescue efforts) in the toe of the debris flow, 2) monitor the water level in the debris-impounded lake, 3) establish survey arrays to monitor movement of the debris mass and the potentially unstable area, and 4) evaluate the hazard to the area downslope of the potential debris flow. In addition, the geologists planned an aerial reconnaissance of the area, using a National Guard helicopter, for the following morning.

By Monday, January 11, Leslie and Burns, working closely with Griggs and Weber, had completed a ground and aerial reconnaissance of the debris flow, defined the extent of the potentially unstable area, designated the areas to be evacuated, and prepared a letter describing their observations, findings, and recommendations. Representatives of FEMA, the Army Corps of Engineers, and other federal and state agencies also conducted aerial reconnaissance and field inspections during the week following the debris flow; however, no official recommendations were made by any of them.

On January 12, the County Board of Supervisors asked the U.S. Army Corps of Engineers for help in assessing the danger still present in the Love Creek area. The Corps was asked to determine what could be done to save lives and prevent further loss of life and property during the remaining two months of the rainy season. The Corps agreed to send hydrologists and geologists to look at the Love Creek area; however, nothing was done until FEMA requested assistance from the Corps in February. During the final two weeks of January, some geologic field work was done by volunteer geologists who found their work hampered by the lack of detailed topographic maps of the area. The need for a coordinated, funded effort was apparent, but none was authorized until the following month.

On January 25, an engineer with the Federal Highway Administration inspected the debris flow area to evaluate the feasibility of constructing an access road across the toe of the failure. No report was made public, but the conclusion was apparently reached that it was reasonably safe to grade a road across the toe. Caltrans started grading before the end of January.

On Saturday, January 30, a public meeting was held at the Ben Lomond Fire Department to discuss the status of the Love Creek debris flow. Representatives of numerous local, county, state and federal agencies were present, as well as local residents and the news media. Consulting geologist William Cotton assisted Burns in the presentation of the geologic analysis to date. The need for thorough geotechnical evaluation of the area was not disputed; however, the issues of who should conduct the evaluation and how it should be paid for were not resolved. A proposal from William Cotton and Associates, Inc., to do an engineering geologic investigation for $48,500 was considered, but the general consensus was that it would be preferable to get a federal or state agency to do the work and, thereby, save local costs.

On February 4, FEMA requested the Corps of Engineers to investigate the Love Creek debris flow. The investigation, which took place on February 6 and 7, was done by engineers; not geologists. On the 8th, the engineers met with FEMA representatives and David Leslie to present their preliminary findings. These included the need for a detailed geotechnical study. However, the FEMA representatives indicated that a detailed geotechnical study of the area would not be considered necessary for emergency response and, therefore, could not be paid for by federal disaster assistance funds. By February 18, both the U.S.

Geological Survey and California Division of Mines and Geology had declined to undertake a detailed geotechnical investigation of the Love Creek debris flow.

On February 26, the Corps of Engineers presented a report on the preliminary investigation, with recommendations, to the County Board of Supervisors. The recommendations were termed unclear by some members of the Board (San Jose Mercury News, March 2, 1981). The report called for further study of the failure and potential failure areas, while at the same time concluding that there was no practical way to stabilize the slopes.

A revised report was subsequently resubmitted to the Board of Supervisors. The submittal letter explained the reason for the revisions and stated the purpose and limitations of the study:

> As a result of our meeting with the Santa Cruz County Board of Supervisors on 26 February 1982, the recommendations in the Love Creek Site Assessment have been revised as requested. The purpose of this investigation has been to assess stability of the Love Creek slide and adjacent area so that emergency decisions regarding immediate habitation of this area could be made. This study is not intended to be a definitive report on the Love Creek slide nor serve as the basis for land-use planning in this area.

The report (U.S. Army Corps of Engineers, 1982) concludes:

> The debris from the slide of 4 January has not completely stabilized. This material is in a loose condition in mounds that are steeply sloped. Settlement as well as creep of this material will take place. Heavy rains or new debris falling from above could cause this mass to move; however, movement would not be as rapid as on January 4th. As this slide debris stabilizes the Love Creek road and stream channel will require continuous maintenance. Surface drainage over this area has been disrupted and until it is reestablished, severe erosion can be expected.
>
> The potential slide area (Area B) is shown on Figure 1 [Figure III-4 of this report] and the path that the slide debris might follow is also shown. It is difficult to predict the exact path the slide will follow, but it is reasonable to assume that it will move straight downslope and some portions divert into drainage swales or gullies. The usual non-structural methods for improving hillside stability such as control of water, adjusting slope angles, and removal

> or improvement of weak spots are not realistic solutions to the Love Creek slide problem because of the nature of the hillside slopes and the type and volume of material therein. Structural methods of slope stabilization such as retaining walls would be very costly and uneconomical as well as impacting adversely on the landscape. Methods of controlling or containing slide debris would likewise be extremely costly and have a negative impact on the landscape of this area.

In spite of the caveat in the cover letter, the key recommendation of the report is clearly directed toward land use planning for the Love Creek area:

> A significant potential for additional slope failure and movement remains in both Areas A and B of the Love Creek Slide Area. It has been reported that 10 people were killed and that 9 homes were destroyed by the slide in Area A. This precedent for the loss of life and the destruction of property along with the findings of this study clearly demonstrate that prudence would dictate that the construction, repair or maintenance of any structure on the slide or potential slide areas be prohibited.

County staff agreed with the conclusions that debris flow and potential debris flow areas were clearly unsafe and too large to be stabilized through engineering techniques, but felt the need for more detailed mapping of the potential failure area showing parcel boundaries. Such a map was needed to proceed with abatement actions under discussion by the Board of Supervisors. FEMA requested the Corps to prepare a more detailed base map.

On April 16, 1982, the detailed topographic map showing the limits of the potential failure was completed by the Corps of Engineers and submitted to the county. The cost of the Corps' effort, billed to FEMA, was about $35,000 (Bazilwich, 1982). The project engineer with the Corps noted possible new movement along a crack in the potentially unstable area; this caused concern to members of the Board of Supervisors, but a field inspection on April 18 by two supervisors, David Leslie and other geologists, revealed no firm evidence of movement of the potential debris flow since January.

Since late spring of 1984, no further geotechnical work has been done at Love Creek. Because detailed, geologic engineering investigations and soils testing were not done, some uncertainty remains about the stability of the area and the possibilities of achieving stabilization by any means.

Abatement Order

Following submittal of the final Corps of Engineers report, local officials had little choice. The people evacuated from the potential debris flow area were without homes yet ineligible for SBA loans and other assistance because their homes were undamaged. The Corps' report, the only geotechnical assessment available, concluded that the debris flow and adjacent area were unstable and too large to stabilize economically. Further, Robert Vickers, Federal Coordinating Officer for FEMA, stated:

> . . . it has been determined that there are no emergency measures eligible for FEMA funding that can be undertaken to effectively stabilize or prevent future slides in Area A and B.

On April 28, 1982, the County Board of Supervisors issued abatement orders for 28 houses in the hazardous area, in accord with Section 501 of the Uniform Code for the Abatement of Dangerous Buildings. The orders were to vacate and remove the houses because of the hazardous condition. Under abatement procedures, the property owner is not compensated for the loss of property and, in fact, must pay for the demolition or removal of the structure. The county waived fees for demolition and moving permits. The removal was to be completed within 180 days of the issuance of the final demolition or moving permit. The owner was given 120 days to make a preliminary application for a permit and another 180 days to obtain a final permit. If a property owner failed to clear his or her property by the end of the time period (about 16 months), the county would do so and bill the owner for the cost.

Twenty of the twenty-eight property owners filed an appeal of the abatement order to the Building Appeals Board. The appellants argued that the orders amounted to taking of property without compensation, and that more testing of stability should be undertaken prior to condemnation (Santa Cruz County, 1982). The Board heard the appeal and continued final action on the appeal for one year to permit more technical data to be collected. In August of 1983, the Board continued the matter for another year. As of mid-1984, no new data had been collected, no final decision had been made, and the property owners were in limbo.

Public Assistance

Of the more than $106 million in storm and debris flow damages, $56.5 million was in damage to public facilities, mainly roads. Under terms set by Congress for public disaster assistance (Sec. 402 of Public Law 93-288), the federal government agrees to pay 75% of the cost to repair, restore, rebuild, or rehabilitate damaged public facilities to their predisaster condition and to currently applicable codes and standards. Santa Cruz County's biggest problem was how to raise the 25% local share of the cost to repair public facilities. In a February 2, 1982, report to the Board of Supervisors, the Director of Public Works estimated that projects to repair and restore damaged public facilities would cost $16 million.* Under the 75-25% split, the county's share would be $4 million. The state agreed to cover about one-half of the county's share to repair damage to public roads and bridges, thus lowering the county share to $2.2 million. However, after adding repairs for damage not eligible for federal assistance and providing for

*This is $40 million lower than the countywide damage estimate of $56 million. The latter figure includes damage in incorporated cities in the county.

contingencies, the staff estimated the county share would be at least $4.9 million. A significant part of this added cost was for hazard mitigation projects required by FEMA under Section 406 of Public Law 93-288 as a condition for receiving disaster assistance funds. Federal funds were not available for the mitigation projects.

In analyzing the funding alternatives available to the Board of Supervisors, the acting County Administrative Officer, George T. Newell, reached the following conclusion:

> It is with reluctance that I recommend that your Board place a special tax on the June ballot and only after determining that:
>
> - Federal disaster assistance programs are being maximized.
> - The State will provide only a portion of the local share of cost and will not participate financially in the improvements required by the Federal Government as a condition of Federal assistance.
> - The general and revenue sharing funds are facing potential deficits of $4,100,000 and $600,000 respectively and cannot absorb new costs.
> - The road fund cannot absorb the costs without eliminating all new projects and preventive maintenance from the road program and performing only emergency repairs for a period of three to five years.
>
> In developing the special tax proposal for your Board's consideration we attempted to structure the tax so it does not impose an unreasonable financial burden on the home-owners, tenants, businesses or other property interests. In order to minimize the amount levied on each parcel we are not recommending that any category of property be exempt from the special levy (1982b).

Based on this recommendation, the Board of Supervisors set an election for June 8, 1982, to authorize a special tax to raise the funds needed to qualify for federal disaster assistance funds. The election came at a time when economic conditions in Santa Cruz County were poor. The ballot measure, requiring approval by two-thirds of the voters, was defeated with only 49.6% of the voters in favor. A second election was held later in 1982 with similar results. With the failure of the tax increase elections the Board of Supervisors finally diverted funds earmarked for other purposes to the required hazard mitigation projects and cost-sharing payments. The projected impact of this diversion was to stop almost all maintenance and repair work on county roads for five years.

Another issue that created considerable frustration for county supervisors was determining what was and was not an "eligible" project. After several meetings with FEMA representatives, one frustrated supervisor expressed the feeling that the "Feds approached the disaster with the mentality of an insurance adjuster" and that after "eligibility" was defined, the cost split was more like 50-50 than 75-25 (Cucchiara, 1982). This general sense of anxiety over the local share of funds to repair public facilities influenced all decisions regarding the Love Creek area.

Love Creek Road, including a bridge over the creek, had been destroyed. Unlike many roads in the mountainous areas of the county, this is a public right-of-way and its repair was eligible, without question, for federal funds. The road provides the only public access to more than 20 residences up the canyon from the debris flow. By the end of January, Caltrans had bulldozed an emergency access road across the toe of the failure and repaired the bridge. However, only residents of Love Creek Canyon and people with a legitimate reason to be in the area were allowed access. The Board of Supervisors approved construction of a new road through the debris flow area in April of 1982. Restoration of the Love Creek channel, which was clogged with debris, was undertaken by the Public Works Department with the Soil Conservation Services (SCS); SCS assumed 100% of the cost.

The question of public assistance to fund geotechnical evaluation of the debris flow and potentially unstable areas was repeatedly raised. In a February 9 letter to FEMA, George Newell (1982a) reiterated a request for technical help:

> The County has requested technical assistance on the Love Creek slide and potential slide areas. Local effort is not sufficient to staff this program, and we are requesting a commitment for geological technical assistance on the following additional areas:
>
> Alba Road Slide
> Hubbard Gulch Slide
> Villa Del Monte Slide

The preliminary study by the Corps of Engineers was the only geotechnical assistance received.

Assistance to Individuals and Businesses

Disaster assistance was needed by those whose properties were damaged or destroyed, those who lost access to their homes, and those who were affected by the abatement order. In the emergency period, these people were assisted by such public and private organizations as Santa Cruz County, the Red Cross, and the Salvation Army. For full recovery and repair or reconstruction of damaged or destroyed property, they had to rely on personal resources, federal disaster assistance, or other private help.

In Santa Cruz County, the victims seemed to expect more assistance than was forthcoming. At the center of this problem was the SBA loan program that had been revised by Congress the preceding year. The expectation was that loans would be made at a very low interest rate (3% to 5%) for the repair of damaged businesses and homes. On January 13, in reference to the Presidential declaration of disaster, the local newspaper, the Valley Press, stated:

Under a federal emergency, homeowners suffering from disaster damage could apply for loans of up to $50,000 to restore their houses, $10,000 to replace furnishings, or $55,000 for both. The loans would carry interest rates of 9.25 to 9.5 percent.

Not only did these rates exceed expectations, they were below those actually applied in many cases in the disaster.

As noted previously, Congress had adopted a two-tiered system of rates, to be set at the time of a disaster declaration. In January, 1982, the interest rates were either 8% or 16%, depending on the financial situation of the applicant. The loans were available, at either rate, only to those whose incomes were sufficient to qualify; many retired and low-income persons found that they could not qualify for the SBA loans. Some found little advantage in a loan at 16% interest. Owner-occupants could not replace a home with the maximum loan amount of $55,000.

In response to these problems and especially the plight of the "abated" property owners, Joseph Cucchiara, Supervisor from the San Lorenzo Valley District, wrote to the County Board of Supervisors on April 19:

> As Board members know, residents of the Love Creek slide area have suffered tremendous losses due to the geological hazards resulting from the January 1982 storm. Their losses, without question, far exceed the present limits of federal, state, or local assistance. Because of the continued suffering and economic devastation Love Creek residents must endure, it seems appropriate, as a Board, to make whatever attempts we can to provide additional assistance to those in need.
>
> Therefore, I recommend that the Board of Supervisors adopt the attached Resolution requesting the President, the Governor and our local, state and federal legislators to seek out and provide extraordinary disaster relief assistance to Love Creek slide victims and to distribute the resolution as indicated accompanied by a letter of transmittal from the Chairperson of the Board of Supervisors.

This and follow-up political efforts had some short-lived success. Bills were introduced in the House of Representatives (HR 5408 and HR

5409) to lower the interest rate to 3% and to increase the amounts available under the SBA program to 100% of the amount needed to restore property. However, these bills did not pass.

The residents of the 28 homes in the potentially unstable area were in a particularly difficult position: they were evacuated from their homes, but did not qualify for SBA loans or other assistance beyond the emergency period because their homes were undamaged. The abatement order was helpful in that it qualified them for temporary housing assistance and the other forms of aid. About two years after the disaster, SBA decided to consider loan applications from residents of the abated properties.

Hazard Mitigation

The San Lorenzo Valley was selected by the Interagency Hazard Mitigation Team as one of the "areas of special opportunity" for hazard mitigation. In the report issued 30 days after the disaster declaration, the team offered this conclusion:

> The team is very concerned about the safety of developments in San Lorenzo Valley and concluded that the hazards, their severity and likelihood of occurrence must be determined before further development is allowed. Once the hazards are evaluated, new development and reconstruction should only be allowed if they can be reasonably safe from damage. Since most of the deaths in this disaster occurred in San Lorenzo Valley, the county should implement a warning and evacuation plan (FEMA, 1982).

All the recommended work elements were directly related to carrying out the hazard evaluation and regulating new development according to the risk. The State Hazard Mitigation Plan, prepared by the California Office of Emergency Services with assistance from local and federal representatives, outlined a series of action items to address specific hazard mitigation problems in the San Lorenzo Valley. Eight mitigation measures addressed the slope failure hazard; these are quoted below, with the status one year later noted in parentheses after each.

1) The county should contract with the U.S. Geological Survey to develop a reliable map for designating areas where failures occurred during the January 1982 storms (completed).

2) Based on maps developed in #1, above, the county should expand its landslide review procedures to include those areas prone to slope instability (underway).

3) The county should revise current geologic report guidelines to require that geologic evaluations include areas beyond geologically unstable property or project boundaries in order to ensure accurate assessment of all known and potential hazards (completed).

4) The county should establish a program for compiling all information from geologic reports onto county-wide base maps (underway).

5) The county should explore alternative methods, including the legal impact of each alternative, for geologic hazards notification to future purchasers of homes in hazardous areas (underway).

6) Determine and implement policies, as appropriate, for prohibiting or limiting building on existing lots of record within high hazard areas (deferred; the county analyzes new development and reconstruction on a lot-by-lot basis as building permits are applied for).

7) Evaluate the causes of road damage to determine whether alternative design criteria would have prevented or reduced road damage. Where appropriate, enact policies to implement improved design criteria (underway).

8) Establish guidelines for forming road maintenance associations, including necessary agreements as a condition of development approvals (completed).

All of the measures required action, funding, and staff time by the county. The measure most directly related to replanning the Love Creek area is #6. Although the report lists it as "deferred," county staff consider that their provisions for reviewing development applications satisfy this measure. None of the mitigation measures are particularly costly and most represent normal practice in many California communities. The revision of geologic report guidelines to ensure evaluation of hazards beyond the project boundaries is particularly important. In most cases,there was damage to parcels that were not themselves unstable but happened to be above or below unstable slopes.

Status Two Years Later

The following statement of potential hazards published in July of 1982 raises many questions that still were unresolved in May of 1984:

> Considering the Love Creek landslide disaster and the existing slope conditions above the Love Creek Heights area, it seems clear that the probability for catastrophic failure of these slopes is high. This is especially true for the unsupported slope above the headwall scarp and the landslide mass adjacent and southeast of the Love Creek landslide (Figure 2 [Figure III-3 of this report]). Preliminary estimates indicate that approximately 1,000,000 cubic yards of potentially unstable earth materials still exist above this portion of the Love Creek drainage. Nearly 30 homes located below these hazardous slopes have been evacuated because they are believed to be in jeopardy of a landslide event similar to the January 5th disaster. Unfortunately, it is not possible to accurately predict the time, exact location or pattern of the next failure. However, in a geologic fram of reference, there is little doubt that the slope will fail (Cotton and Cochrane, 1982, p. 153).

The winter of 1983 was also unusually stormy, but there was no movement in the potential failure area. As time passes and the land does not move, holding to the abatement order becomes more and more difficult.

Geotechnical data are essential to long-term hazard mitigation planning, but there has never been provision for funding data collection at any governmental level. The protracted uncertainty over which agency would fund the field investigations significantly delayed necessary data collection; uncertainty resulting from that delay has most directly affected those residents of the potentially unstable area. Their lives have been disrupted and they have not had the technical advice needed to determine the wisest course of action.

As of mid-1984, the stability of the mass downstream from the debris flow was still uncertain. No geotechnical work had been done since the Corps completed the topographic map in April, 1982. Slope stability mapping of parts of Santa Cruz County is expected as part of a statewide mapping effort authorized by the state legislature in the fall of 1983. The Love Creek drainage channel has been cleared and restored, and the access road has been re-established over the debris flow mass.

The future uses of the land have not been formally decided. However, the county planning staff considers it extremely unlikely that the Board of Supervisors would approve any rebuilding on the debris flow (Burns, 1984). Property owners have been offerred rapid processing of permits to build elsewhere in the county if they are willing to declare their Love Creek lots unbuildable. The delarations become part of the deeds. Owners of property in both the debris flow and potential debris flow areas have received relief from property taxes. The county is apparently unwilling to acquire title to any of the parcels because of possible liability problems (Burns, 1984).

No one is living in the abatement area (at least not legally) and several houses have been removed; one burned down. Property owners are still looking for help out of their difficult situation and are expected to seek further delay in carrying out the abatement order (Burns, 1984).

The geologic hazard review procedures in place prior to the disaster are seen by county staff as a good start on mitigating hazards in new development. The staff recognizes that much existing development is at risk from debris flows and other forms of slope failure. In anticipation of possible problems, contracts have been executed with local geologists to provide immediate assistance in the event of another disaster like the January, 1982, event.

CHAPTER IV

CASE STUDY OF THE INVERNESS DEBRIS FLOWS

The winter storms that hit the San Francisco Bay Area in the winter of 1981-82 were particularly severe in Marin County. The storm sequence that began on January 3rd reached a climax on January 4th in a deluge that dropped up to 14 inches of rain in a 36-hour period in parts of Marin County. There were widespread floods and numerous debris flows throughout the county.

The community of Inverness, on the west shore of Tomales Bay, was hard hit by both flooding and debris flows. The distinction between the damage from debris flows and from flooding is not easy to make in this case. Water, mud, and debris coursed through the narrow valleys of Inverness Ridge, damaging buildings, roads, bridges--everything in the path. Some buildings were flooded, some filled with mud, and some were partially demolished by the branches and large debris carried by the water and mud. Definition is important because flood and mudslide damage is covered under the National Flood Insurance Program, but damage from other forms of slope failure is not. Actions to mitigate future risk may also differ depending on whether the hazard is flooding or debris flows.

This case study is organized into four major sections: the first gives relevant background on the community, physical setting, plans and regulations, and emergency preparedness; the second is a description of the disaster and a brief discussion of emergency response; the third section outlines local recovery actions; and the fourth describes assistance from outside the community.

Pre-Storm Conditions

Population

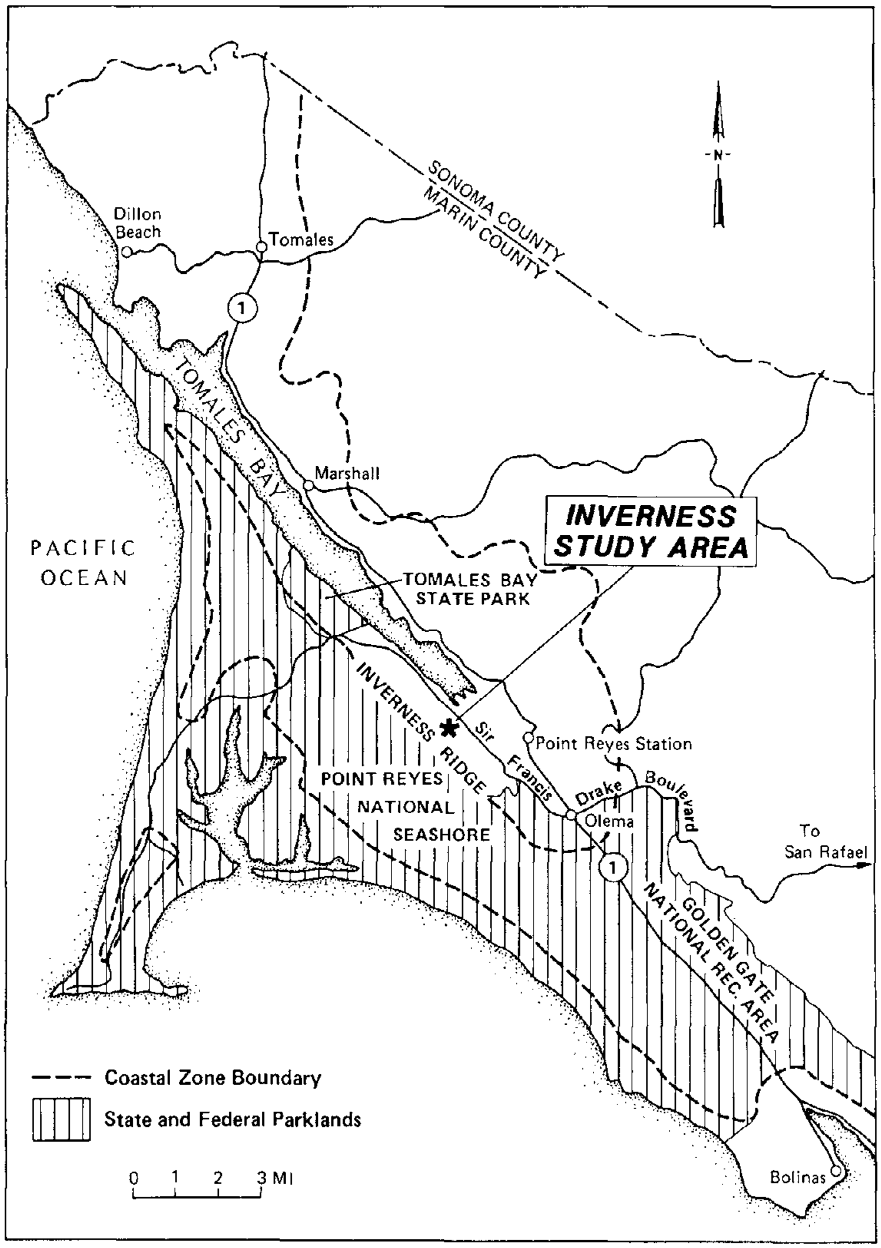
Marin County is located across the Golden Gate Bridge from San Francisco, and has evolved as a fashionable suburb of the city. Per capita and median household incomes are the highest of all California counties. Housing is primarily single-family and the population is overwhelmingly white. The county is blessed with some of the most beautiful and varied scenery in California; Mt. Tamalpais, Muir Woods, Stinson Beach, and the Point Reyes National Seashore attract visitors from all over the world. In 1980, the county had 222,568 people in 88,723 occupied housing units. About 72% of the people lived in 11 incorporated cities ranging in size from 2,300 to 44,000 people. The rest (about 62,000 people) were in unincorporated areas of the county.

Inverness is one of several small communities or subdivisions located on the northeast side of Inverness Ridge between Tomales Bay and the Point Reyes National Seashore. It is 60 miles north of San Francisco and 30 miles west of San Rafael, county seat for Marin County. Figure IV-1 shows the location of Inverness Ridge and the surrounding land uses. Parklands and Tomales Bay virtually surround the ridge, leaving little or no space for additional urban expansion. The only access to the ridge is Sir Francis Drake Boulevard, which is also the main access road to the National Seashore. Commercial establishments serving both residents and visitors are clustered along this highway.

Inverness is the oldest of the ridge communities and is more densely developed than the more recently subdivided areas. The community contains almost half of the ridge's population. Inverness was originally settled as a vacation community with a seasonal population and cottage-type housing. Over the years, it has evolved into a

FIGURE IV-1

INVERNESS RIDGE AND SURROUNDING LANDS



permanent, year-round community and many of the original houses have been modified and expanded. A majority of the people live in the community full-time and many commute to jobs in San Rafael, San Francisco or other Bay Area locations.

Inverness Ridge is a cluster of neighborhoods defined by the Marin County Planning Department as a planning area. The planning area consists of about 3500 acres, with a 1980 population of 1,293 living in 781 housing units. Under existing zoning, the development potential of the privately owned parcels on the ridge is 1,266 housing units, allowing for construction of about 485 additional houses (Marin County Planning Department, 1979). Well over half the planning area has slopes in excess of 30% (Cooper-Clark & Associates, 1978). All of the ridge neighborhods had some damage in the storms of January, 1982, but much was concentrated in Inverness, which suffered from flooding and debris flows in two major canyons called First and Second valleys.

Topographic and Geologic Setting

The topography of the Inverness region is typical of that of the California Coast Ranges. The community of Inverness is located in an area of densely forested hillside terrain situated between Inverness Ridge and the western shoreline of Tomales Bay. The hillside terrain between the ridge and the bay typically exhibits steep slope inclinations and is well dissected by narrow stream channels. The stream channels divide the terrain into a system of steep-sided, northeast-southwest trending valleys. The majority of the development in Inverness is in three of the larger valleys, although several of the intervening ridges are also developed. Commercial activity is restricted primarily to the gentle shoreline of Tomales Bay along Sir Francis Drake Boulevard.

The Inverness area is entirely underlain by granitic bedrock materials composed chiefly of coarse-grained quartz diorite which has been highly sheared and fractured. Throughout most of the area, bedrock is exposed at the ground surface only along creek beds and in road cuts or other excavations. Elsewhere it is covered by a mantle of unconsolidated soil materials resulting from deep weathering of the underlying bedrock.

The surficial colluvial deposits are composed of an unsorted, heterogenous mixture of weathered bedrock fragments in a coarse, clayey sand matrix. The upper horizon is locally composed of a more soil-like material. Because these deposits represent the accumulation of soil and rock debris by soil creep and shallow slope movement processes, they generally thicken in the downslope direction. Thicknesses may range from a few inches to a foot or so along ridge tops, to tens of feet along the base of hillside slopes. In general, these colluvial materials are found in a loose and uncompacted state and, as a consequence, are subject to erosion and shallow sliding where natural or human processes upset their fragile equilibrium.

In addition to the surficial colluvial deposits, the bedrock along the beds and banks of existing stream courses is overlain by alluvial deposits. These materials represent the depositional products of recent stream activity and range from a few feet to several tens of feet in thickness. The alluvial deposits consist of unconsolidated, crudely stratified layers of gravel, sand, silt, and clay combined in widely varying proportions. These materials are easily eroded and transported during periods of high stream flow.

Geotechnical Information Available Prior to the Storm

Prior to the January, 1982 storm, two regional geologic and topographic maps covering the Inverness area were available. Although the scale and content of these maps were not adequate for site-specific planning, the maps did identify the general problem of slope stability along Inverness Ridge. Geology for Planning in Western Marin County, California (Wagner & Smith, 1977), published by California Division of Mines and Geology, addresses geology, seismicity, and slope stability of the general area surrounding Tomales Bay. Figure IV-2 shows a portion of a slope stability map included as a plate in the CDMG report. As shown on the map, steep, potentially unstable slopes exist throughout the Inverness area.

Four stability zones are mapped as follows:

Zone 1 The most stable category. This zone includes resistant rock that is either exposed or covered only by shallow colluvium or soil. Also included in this zone are broad, relatively level areas along the tops of ridges or in valley bottoms that may be underlain by material that is quite weak (such as Franciscan melange matrix and alluvium). However, landslide masses may enter Zone 1 from nearby slopes.

Zone 2 Includes narrow ridge and spur crests that are underlain by relatively competent bedrock but are flanked by steep, potentially unstable slopes.

Zone 3 Areas where the steepness of the slopes approaches the stability limits of the underlying geological materials. Some landslide deposits that appear to have relatively more stable positions than those classified within Zone 4 are also shown here.

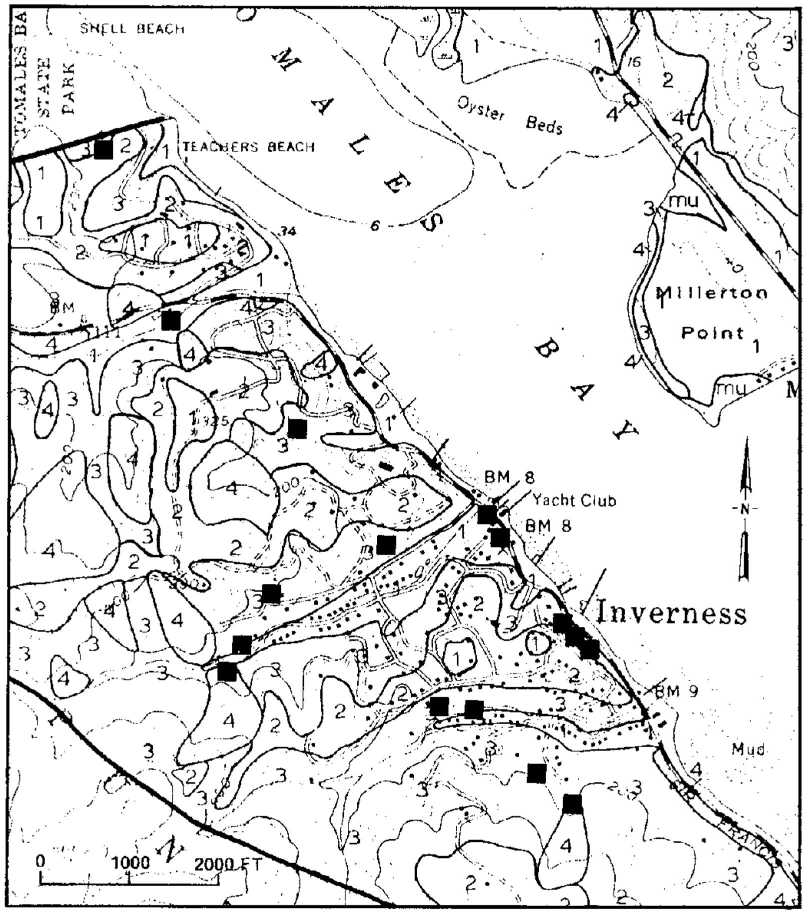
Zone 4 The least stable category. This includes most landslide deposits in upslope areas, whether presently active or not, and slopes on which there is substantial evidence of downslope creep of the surface materials. These areas should be considered naturally unstable, subject to potential failure even in the absence of man's activities and influences. Banks along deeply incised streams are also included in Zone 4 (Wagner and Smith, 1977).

The mapping does not extend into Tomales Bay State Park or the Point Reyes National Seashore lands, although most of the debris flows along the Inverness Ridge originated in these public lands. The report recommends that geotechnical investigations be required prior to tract

FIGURE IV-2

PORTION OF THE SLOPE STABILITY MAP SHOWING INVERNESS
(Wagner and Smith, 1977)

Key: ■ = approximate location of damaged houses; numbers 1 through 4 are stability zones.



development, and that grading ordinances be enacted to minimize the impact of development in the Inverness area. The information in the report is the basis for geotechnical report requirements enacted by the county after the January, 1982 disaster.

A study entitled Cumulative Impact Study of Septic Tank Disposal Systems in the Inverness Area of Marin County, completed in 1978 by the firm of Cooper-Clark & Associates, was commissioned to evaluate the impacts of long-term septic tank use in the Inverness area. A brief overview of the geotechnical characteristics of the area was provided by that report.

Some geotechnical information addressing potential geologic hazards was available for the Inverness area prior to the January, 1982 storm; however, the information is considerably less detailed than that available for many hillside communities around the San Francisco Bay Area. The two studies that were done provided strong indication of potential slope stability problems in the Inverness area, but did not specifically assess the debris flow hazard. Both studies were done in the late 1970s after most development had already occurred, but the information was sufficient to alert the county to potential problems to be addressed in reviewing development applications for new development.

Marin County Plans

Marin County is responsible for planning for the Inverness area. Most pertinent to the Inverness storm response are the Marin Countywide Plan, adopted April, 1982, and the Inverness Ridge Communities Plan, adopted in 1979. Although the Countywide Plan was adopted after the January storm, it was essentially complete prior to the storm and represents pre-storm objectives and policies. Most of Inverness Ridge is in the California Coastal Zone and, as required by the California Coastal Act of 1976, is subject to a Local Coastal Plan (LCP) which was certified by the State Coastal Commission in 1981. The LCP policies relevant to hazard mitigation have been fully incorporated into the Marin Countywide Plan; therefore, the LCP is not discussed separately in this section.

The Marin Countywide Plan, April 1982. This document updates the 1973 Marin County General Plan, and recognizes that the future develoment of Inverness Ridge is geographically constrained by public lands to the north, south and west and Tomales Bay to the east. Development is further limited by the need to protect the watersheds, the existence of old paper subdivisions with non-conforming lots, and the presence of flood and seismic hazards (p. 5-25, Table 5.1).

Policies of the Marin Countywide Plan most relevant to recovery decisions in Inverness are those dealing with stream corridors and geologic hazards. In the coastal zone, all streams and 100 feet on either side are designated as Stream Conservation Areas (SCAs). Land uses in these areas are restricted in order to protect water and water-dependent resources, and to preserve the county's perennial and intermittent streams in as natural a condition as possible. Existing structures are permitted to remain in the SCAs and may be repaired or rebuilt in the event of damage.

Other policies pertaining to SCAs which are related to disaster recovery and hazard mitigation include:

> Before any stream alterations are permitted, the minimum water flows necessary to protect fish habitats, water quality, riparian vegetation, groundwater recharge areas, and downstream users should be determined in conjunction with the State Water Resources Control Board.
>
> Filling, grading, excavating, obstructing the flow, or altering the bed or banks of the stream channel and riparian systems should be allowed only under emergency conditions or where no reasonable alternative is available, by permit granted by the Environment Protection Committee, which should include possible mitigation measures.

Damaged portions of SCA's should wherever possible be restored to their natural state. Portions of the channels that have been significantly altered for flood control have potential for urban open space uses as landscaped areas and paths.

An ordinance for floodplain management in compliance with regulations for the National Flood Insurance Program should be adopted (p. 2-14-16).

The county plans to implement the SCA policies through its established permit review process. Applicants for a building, excavation, or grading permit must provide information to determine whether a proposed development falls within an SCA. If the project is within an SCA, the county staff will determine whether the proposed use is consistent with the stream conservation policies. Proposals that do not conform to the SCA policies, and that cannot be modified or mitigated so that they do conform, are to be denied. All the stream corridors of Inverness Ridge are designated as SCAs. Permits for repairs to damaged structures within the corridors were issued by the county in accordance with the exclusion in the policies pertaining to existing buildings.

The Marin Countywide Plan also contains policies on seismic, geologic, fire and flood hazards. The plan recognizes the need for geotechnical expertise on the county staff in the following statements (p. 8-20-23):

Recognize the continuing need for engineering geologic expertise in County and local government, and develop a workable proposal to meet this need. Such a staff or consultant engineering geologist would:

develop accurate detailed information on geologic hazards in areas subject to planning studies;

review and approve for adequacy all geologic reports required as part of the environmental and development review process.

formulate appropriate measures to mitigate geologic hazards in development.

Continue to support scientific geologic investigations to refine, enlarge and improve the knowledge about active fault zones, areas of instability, severe ground shaking and similar hazardous conditions in Marin County.

Consider creating a Geotechnical Review Board composed of qualified engineers, architects, geologists, seismologists, and relevant County officials to formulate, direct and define the procedures proposed herein.

Consider developing a method whereby prospective property owners can be informed of potential safety hazards.

Policies directly confronting the presence of natural hazards include (p. 8-20-23):

Construction shall be located and designed to avoid or minimize the hazards from earthquake, erosion, landslides floods and fire.

Applications for developments proposed to be sited on landslide deposits, non-engineered fill, or bay mud shall be accompanied by a geotechnical engineering investigation directed to the problem of ground shaking and ground failure. The engineering geologist and civil engineer shall submit recommendations regarding site development, structural engineering, drainage, etc.

No structure which is necessary for public safety or for the provision of needed emergency services shall be built in an area subject to ground failure and consequent structural failure unless the only alternative sites would be so distant as to thereby jeopardize the safety of the community served.

Policies related to slope failure hazards include (p. 8-24):

Projects proposed for slopes rated 3 or 4 in stability classification (CDM&G...) shall be evaluated for stability prior to consideration of site design or use. The evaluation should include the structural foundation engineering of the actual site and should include possible impact of the project on adjacent lands. Where, in the course of land development review, it is determined to be necessary, this evaluation shall also apply to construction on existing single family lots.

In projects where such evaluations indicate that state-of-the-art measures can correct instability, the County should require that the foundation and earth work be supervised and certified by a geotechnical engineer and where deemed necessary, an engineering geologist.

> Known landslides and landslide-prone deposits on steep slopes should not be used for development except where engineering, geologic site investigations indicate such sites are stable or can be made stable providing appropriate mitigating measures are taken. In such cases, it must be shown to the satisfaction of the County that the risk to persons or property or public liability can be minimized to a degree acceptable to the County.

The policy framework established in the Marin Countywide Plan to address natural hazards is comprehensive, except for the lack of specific discussion of debris flows. Hundreds of debris flows occurred in the county in January of 1982. At the time of the 1982 disaster, several of the policies, especially pertaining to acquiring staff geotechnical expertise, had not been implemented.

Inverness Ridge Communities Plan. This plan was adopted by the Marin County Board of Supervisors on March 20, 1979, as a part of the Marin Countywide Plan. Community goals as listed in the plan are (p. v):

1) Preserve, to the extent possible, the Inverness Ridge for both scenic and watershed purposes.

2) Retain and maintain the established characters of the neighborhood components located within the Planning Area.

3) Recognize the diversity of the individual lifestyles and provide means for their continuance.

4) Provide reasonable opportunities for further residential and commercial development.

5) Conserve the land and water areas along the shores of Tomales Bay.

6) Recognize the unique physical setting of the Planning Area and design development in a fashion consistent with such character.

7) Provide opportunities for pedestrian, equestrian, bicycle and transit uses to minimize reliance on the use of the private automobile.

The main thrust of the 1979 plan is to control and in some places reduce, residential density and, thus, development potential of the Inverness Ridge. Environmental problems and natural hazards are recognized and become part of the rationale for reducing building potential in the undeveloped areas of the community.

Recommendations include preserving the ridge watershed and scenery by controlling density, building heights, and site design (e.g., clustering). Permits to increase density are recommended only when it can be demonstrated that adequate water and fire protection can be provided, soils and slopes are suitable for septic systems, and no adverse impact on a stream will result. Also to be preserved are the existing neighborhoods. Among the factors to be considered in setting residential densities are neighborhood distinctiveness, utility availability, access, topography, slope, soil condition, vegetation, and streams.

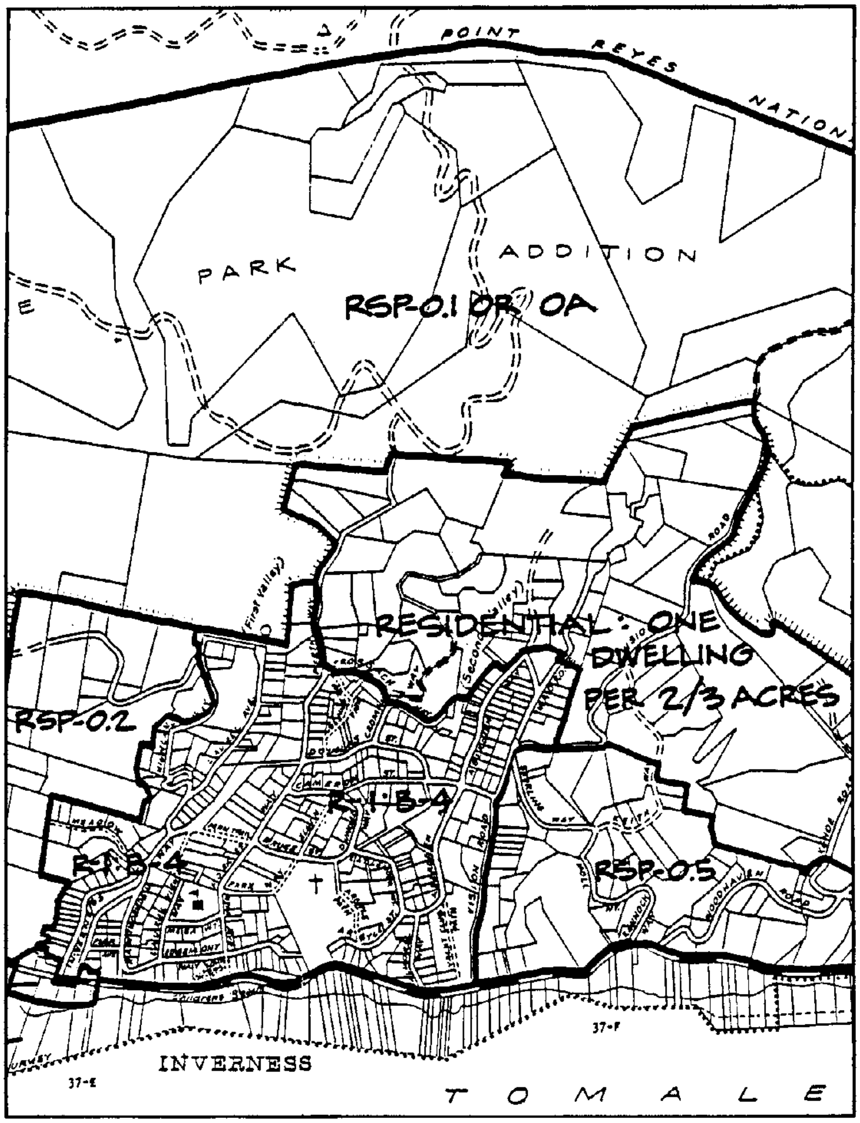
The plan cites the lack of adequate services, especially water and sewage treatment, as the biggest constraint to development. The most undesirable impacts of additional development are seen as increased traffic and decreased water quality in Tomales Bay. The plan acknowledges that the San Andreas Fault passes nearby and that many of the slopes are potentially unstable. To address these problems, the plan proposes reducing residential density, merging lots, and adding some lands to Tomales Bay State Park.

Marin County Regulations

Marin County is responsible for adopting and enforcing land use and development regulations affecting Inverness Ridge. The regulations most directly related to rebuilding and to hazard mitigation include the zoning ordinance, and authorizations for geologic review contained in several parts of the County Code.

FIGURE IV-3

ZONING DESIGNATIONS IN INVERNESS
SHOWN IN THE 1979 INVERNESS RIDGE COMMUNITIES PLAN



Zoning regulations. Figure IV-3 is a map showing the zoning designations for Inverness, as set forth in the Inverness Ridge Communities Plan. All the residential portions of Inverness are zoned either R-1 (one-family residence district), or RSP (one-family planned residential district). Uses permitted in both zoning districts are single family dwellings and the usual ancillary uses. Certain public and quasi-public uses and non-commercial recreational uses are allowed with a use permit. Building height is limited to 35 feet. The R-1 districts have a minimum lot-size of one acre and specific setback requirements.

The RSP district allows single family developments to be designed without specific setback restrictions. Permitted uses are the same as in the R-1 districts. Maximum number of units per gross acre ranges from 1 unit per acre to 0.1 unit per acre (1 unit per 10 acres). All developments proposed for RSP districts are subject to design requirements. The requirements specify minimum grading, control of erosion, road grades under 15%, minimum surface coverage with impervious materials, protection of trees, rare plant communities and wildlife habitats, and fire protection measures. Projects in the Inverness Public Utilities District watershed areas are referred to the district for comment.

With respect to geologic hazards, the design requirements are:

> Construction shall not be permitted on identified seismic or geologic hazard areas such as on slides, on natural springs, on identified fault zones, or on bay mud without approval from the Department of Public Works, based on acceptable soils and geologic reports (Marin County Zoning Ordinance, Section 22.47.024).

Other requirements cover clustering, ridge lines, landscaping, utilities, building height, building materials and colors, noise, on-site public facilities, open space dedication, maintenance and use. The provisions most pertinent to hazard mitigation in the Inverness area are that, generally, building should be clustered on the "most geologically stable portion or portions of the site . . ." (Section 22.47.024 2a), and no construction shall be ". . . permitted on top or within three hundred feet horizontally, or within one hundred feet vertically of visually prominent ridge lines . . . " (Section 22.47.024 2b).

Geologic review. Soils and geologic report requirements appear in several titles of the Marin County Code. As described in the Countywide Plan, the procedure works as follows (p. 8-23):

> The Planning Department requires submission of soils and geologic reports with master plan applications, soils reports with subdivision applications, and may require geologic reports with latter. The Department of Public Works reviews submitted reports to determine adequacy of hazard mitigation in proposed develoment. The Department of Public Works may also require soils or geologic reports for any excavation, grading or filling. similarly, the Building Inspection Department may require soils or geologic engineering reports for any permit application.

The county staff does not include a geologist or engineering geologist to review the submitted reports. Review of required geotechnical reports falls to Public Works Department engineers. In addition, there is no requirement that geologic reports be done by a registered engineering geologist. A further problem is the lack of readily available mpas identifying hazardous areas that can alert potential developers of the need to consider hazards in designing projects.

Emergency Preparedness

Prior to the January storm, the community of Inverness had drafted a disaster plan geared to preparing and responding to a damaging earthquake. The plan recognized that, although Marin County is responsible for disaster response in Inverness, the chances were high that the community would be cut off from the rest of the county and, for some period of time after a disaster, forced to manage on its own resources.

The Inverness Volunteer Fire Department (IVFD) took on the responsibility for planning. The community's food supplies, beds, and medical personnel were inventoried, and lists were made of the homes occupied by elderly or handicapped people who might need special assistance. The fire department distributed information to residents about supplies they should have available and about what to do in the event of an emergency. Individual firefighters were assigned specific responsibilities for patrol, medical aid, transport, housing, food, communications and water supply. People were advised to report to the firehouse in an emergency.

The Storm and Initial Local Emergency Response

The large and ominous storm system that moved into the San Francisco Bay Area on January 3, 1982, caused only light rainfall in the Inverness area at first; however, as the evening hours passed, the intensity of the rainfall increased. Heavy rainfall continued on through the night, and on the morning of January 4, the storm unleashed its full fury on the Inverness area. Between 7:00 and 11:00 a.m., there were rainfall intensities approaching one inch per hour. By the end of the 36-hour storm period, 9 to 14 inches of rain had fallen in the Inverness area.

Above-average rainfall had already fallen over most of western Marin County; indeed, during the preceding month alone, over 10 inches of rainfall had been recorded in the immediate vicinity of Inverness. Therefore, the ground was already well-saturated when the rains began to fall.

Debris Flows, Flooding and Damage

The intense and prolonged rainfall served as a triggering mechanism for flash flooding and large, rapidly moving debris flows. The topographic, geologic, and hydrologic conditions in the upper reaches of the narrow stream valleys are highly conducive to shallow slope failures. The failures ranged in size from small creek-side slumps to large debris flows that originated high up the steep canyon slopes. The smaller slope failures contributed sediment and debris to the stream flow, while the larger debris flows swept rapidly down the long narrow valleys destroying everything in their path. Although debris flows were by far the most destructive events, damage from floodwaters heavily freighted with sediment--the aptly named "mud flood"--was far more widespread.

As a result of the floods and debris flows, many residences, roadways, and drainage improvements throughout the Inverness area were damaged. Although there were slope failures and flooding in all of the 11 watersheds on the ridge, most of the damage was in the more intensively developed neighborhoods of Inverness, Redwood Canyon, and Inverness Park.

In the First and Second Valleys of Inverness, large debris flows originating high in the steep headwall areas of the canyons swept rapidly down the tributaries. These catastrophic failures happened on the morning of January 4, and were closely associated with the period of greatest rainfall intensity. In the uppermost developed reaches of each canyon, several houses were destroyed or severely damaged by the debris flows. Residences located in the lower reaches of the valley were damaged primarily by the surge of floodwater and sediment associated with the debris flows. The people in the valleys had little or no warning of the debris flows. On the morning of January 4, many watched the streams rising rapidly and some were taking actions to avert flood damage. Narrow escapes were the rule when the debris flows came, as illustrated in the following two accounts (Carroll, 1982):

> About three-quarters of the way up Second Valley, Howard Benedict, a retired shop teacher and building contractor, looks outside with his wife and a couple who's visiting. The four watch with concern the stream outside the house expand until it's lapping at the door. They hear a rumble.
>
> "Run!" Benedict yells, and he and his friend's wife race to the back door, assuming the other two are behind them. But Benedict's wife hesitates and falls as the mud bursts through the door and swoops into their home. His friend grabs her. "I was holding the back door, hollering for them to get out of there while I was watching the mud go across my feet. They finally got out and we ran up the hill."
>
> In First Valley, Hunn finishes packing some possessions into his car trunk, and decides to go back to the house to retrieve another load. As he walks back, he sees a wall of water with trees on top rolling toward him. "I ran like hell down the street and yelled for other people I saw to run, too," Hunn says. As the flash flood bears down on him, he clambers up a hill and takes refuge in a house. He watches a raging mass of water, mud, sand, logs and parts of houses rush by.

Along Sir Francis Drake Boulevard, numerous shallow failures originated on and above cut slopes adjacent to the roadway. Many of these failures inundated the road surface with viscous lobes of debris, effectively blocking the highway. Additionally, many culvert crossings below the roadway became plugged with sediment resulting in localized flooding of the road.

By the second week in January, the following damage estimates were reported for Marin County (San Francisco Chronicle, January 13, 1982):

5	dead
379	injured
370	people displaced
28	homes destroyed
2,900	homes damaged (includes four apartment complexes)
25	businesses destroyed
800	businesses damaged
	$65.1 million in private damages
	$15 million in public damages

In Inverness, three houses were destroyed, 50 houses severely damaged or filled with mud, 60 people evacuated and all businesses closed except the Inverness Store. The water system was destroyed, phone and power lines were down, roads were blocked, and the emergency communications system at the fire station was inoperable. Everywhere there was debris, tons of debris washed down from the ridge. Miraculously, there were no deaths or serious injuries. Figure IV-4 shows photographs taken in the first week after the disaster of the devastation in First and Second valleys.

Emergency Response

In the first 48 hours after the storm passed through, Inverness was effectively cut off from the rest of the world. The community's response during the initial hours and days was remarkably effective, and illustrates both the tendency of people to "rise to the occasion," and the value of having a disaster plan. An excellent detailed description is contained in the California Living Magazine of the San Francisco Sunday Examiner & Chronicle, February 21, 1982 (Carroll).

Sir Francis Drake Boulevard. Ranchers from Point Reyes began bulldozing debris from Sir Francis Drake Boulevard in an attempt to get through to Inverness from the north. The Marin County Fire Department was working from the south. In the middle, volunteer firefighters and residents in Inverness were cutting away debris and clearing the road as best they could. At about 7:00 p.m., Tuesday, January 5, the ranchers broke through with a front-end loader and by January 7, Sir Francis Drake Boulevard was open to one-way traffic which was led in convoys over the worst stretches.

The water system. The Inverness Public Utilities District (IPUD) had taken over the Inverness water system in December of 1979. At the time of the disaster, a major project to replace old pipes was

FIGURE IV-4a

REMAINS OF INVERNESS PUBLIC UTILITIES DISTRICT WATER SYSTEM FILTER PLANT NEAR HEAD OF FIRST VALLEY

FIGURE IV-4b

HOUSE DESTROYED BY FIRE NEAR TOP OF SECOND VALLEY.

Apparently a Propane Tank Carried by a Debris Flow Crashed into the House, Igniting It.

underway. A work crew and equipment were in the area and available to help in restoring water service. For two days after the storm, the pipeline crew, IPUD directors and manager, and volunteers walked the lines to assess the damage. At a meeting on Wednesday night, two alternatives were discussed: 1) lay temporary pipes above ground to Drakes Estates, two miles away, to tap into the North Marin Water District supply; and 2) find a new water source in one of the valleys and pump water through portable filters into the distribution system, which was still mostly intact. The group decided to try both, and a race was on to see which team could deliver water first. A small dam was built in the First Valley stream to create a new intake. The first water flowed into Inverness homes from this source on Sunday morning, January 10.

Emergency Operations Center (EOC). As recommended in the community's disaster plan, people converged on the firehouse on the morning of January 4, as conditions grew worse. Some time between 9:00 and 10:00 a.m., a wall of trees, debris, and mud pushed by water crashed down the First Valley canyon, leaving the valley floor covered with one to three feet of mud, sand, rocks and debris. About two feet of water poured into the firehouse. It left a six-inch blanket of mud, and made it clear that the firehouse was vulnerable to more rain and debris flows and was in no shape to use as a command center.

An immediate shift was made to the nearby, three-room Inverness School. Medical aid, hot food, water, temporary shelter and, above all, a central place for information and coordination of emergency response efforts were quickly available. Volunteer firefighters reported to the EOC and, with many volunteers from the community, proceeded to carry out both their preassigned tasks and others that were obviously needed.

Food and shelter. St. Columba's Episcopal Church and Retreat House was planned as the primary emergency shelter facility and it served as that throughout the emergency period. The Coast Guard supplied a portable generator for power to refrigerate food; cooking was done with propane gas. People from all over town brought the contents of their powerless freezers to St. Columba's. There are reports of evacuees and emergency workers subsisting on venison, lobster and prime rib. The work, mostly clearing debris, was hard; the food was good and most welcome. In the initial days, the staff prepared 150 breakfasts and dinners and 500 lunches. Lunches were prepared at the church and delivered to work crews in the field.

Debris clearance. Literally tons of debris had to be cleared away to open up roads and reestablish stream channels (Figure IV-5). The job was urgent because of the strong possibility of more rain. Initially, residents tackled the job with small chain saws and whatever equipment they could find. Once Sir Francis Drake Boulevard was opened up, the California National Guard arrived with earth movers and dump trucks. Sixteen work crews from the California Conservation Corps (CCC) and the Department of Forestry also arrived. They helped first with the job of shoring up damaged structures to prevent further damage and preventive sandbagging, and then turned to clearing the debris. As of late September, 1982, debris removal was still not complete.

Handling the media. The first outsider to reach Inverness was a news reporter in a Sacramento TV station helicopter. He was told by the volunteer firefighters, bothered by the vehicle hovering over them, to "help or leave." The helicopter left. Helicopters from several San Francisco TV stations showed up and got the same message. Station KGO followed through, returning with food from Safeway and sandbags from the San Francisco Department of Public Works. KRON brought in backhoe

FIGURE IV-5

NATIONAL GUARD REMOVING DEBRIS IN FIRST VALLEY

parts. Later, an NBC helicopter was met by a volunteer in a four-wheel drive vehicle, and the reporter aboard was given a tour. Requests for an interview by two-way radio were refused in the initial days because the radio was the only reliable means of communicating out of town (Carroll, 1982).

Recovery--A Local Story

As Inverness began to dig out from under the mud and debris, attention turned to making permanent repairs to roads, houses, water systems, and other facilities. The possibility of more rain was on everyone's mind during the early weeks and months of recovery. Individuals and organizations were asking, "what can we do to prevent this from happening again or getting worse?" The answers were not self-evident; local residents used a variety of approaches to find answers and to move toward recovery. Some of the approaches are described below.

Obtaining Geotechnical Advice

The formation of the Point Reyes-Inverness Organization for Reconstruction (PRIOR) was one of the most significant local responses to the storm disaster. The organization arose in response to the need of property owners for technical assistance in deciding what to do with damaged or threatened property. Local building contractors found themselves almost immediately caught up in trying to answer questions involving geology, soils, and structural engineering. The answers were not forthcoming from county engineers who were concentrating on damaged public property. Homeowners with damaged foundations or cracks in the hillside near their houses felt they had nowhere to turn for reliable advice.

Doug Elliott and Jim Campe, two local contractors, spearheaded formation of a group to fill this need. They offered free advice in the Point Reyes Light, a local newspaper, and were immediately swamped with more than 85 calls. Recognizing the need for organization, they joined with several prominent local residents and businesspeople, requested and received $2,500 in start-up funding from the San Francisco Foundation. Thus, PRIOR was launched to help owners assess their damage and determine what needed to be done. A filing system was established and a form devised for recording information about each property. Elliott, Campe, and Phil Drath, another local contractor, visited each property and recorded information on the forms, called Property Damage Assessment Reports. From January 12 to January 20, 63 properties were visited by the three men. In each case, the condition was described, a Polaroid picture of the damage was taken and attached to the report, and recommendations concerning the kind of expertise needed were recorded. In some cases the recommendation was to contact the CCC for help in debris removal; in others, it was clear that soils and/or structural engineering help would be needed.

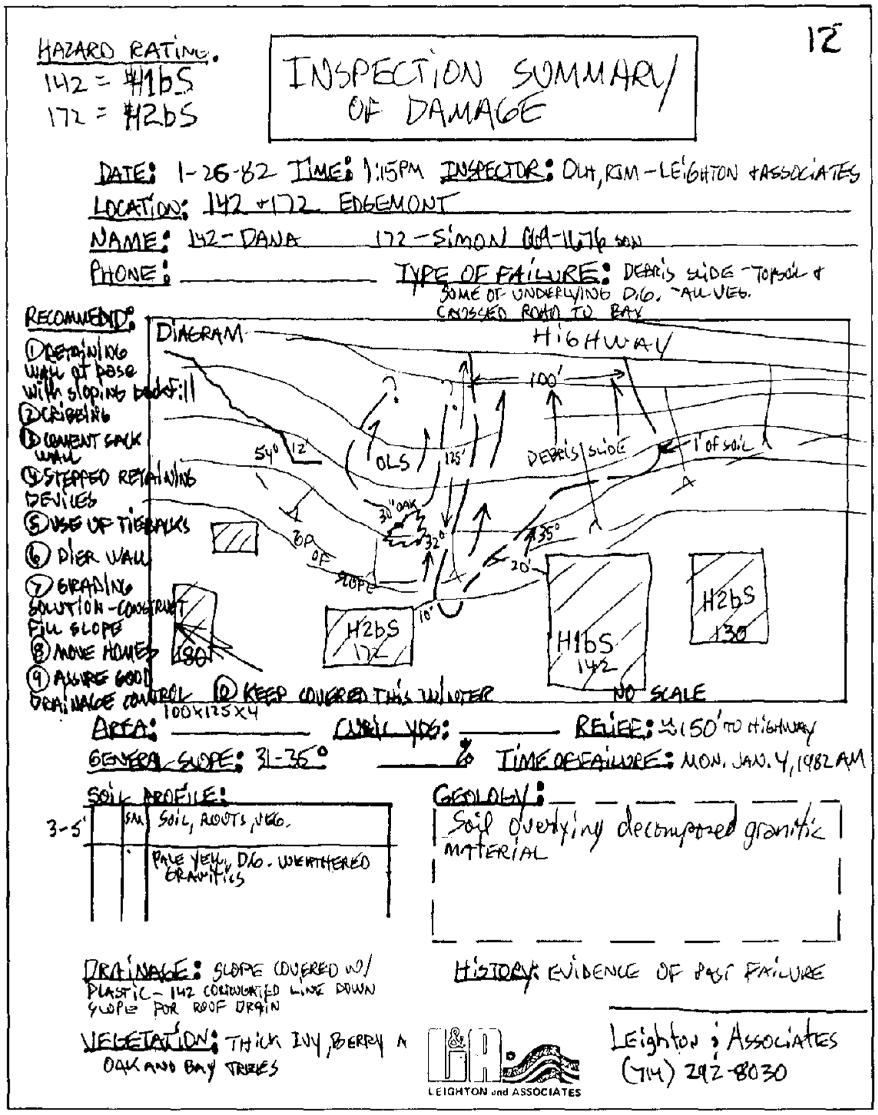
A PRIOR board member whose house was threatened by a landslide contacted the southern California geotechnical firm of Leighton and Associates for help. Two engineering geologists for the firm, Dennis Hannan and Richard McCarthy, arrived in Inverness and were drawn into the PRIOR effort. As volunteers, they worked with PRIOR on January 25, 26 and 27, providing direct advice on next steps to property owners who, according to the initial screening by the contractors, needed engineering assistance.

PRIOR served as intermediary between the engineering geologists and the property owners. Site inspections were kept to approximately one-half hour. Again, a form was devised to record information and a rating system was developed to characterize the problem (see Figure IV-6). The rating for each property visited was also recorded on a map. A portion of this map is shown in Figure IV-7; it provides a clear indication of the distribution of various kinds of problems throughout the Inverness Ridge area.

As the evaluations by Leighton and Associates proceeded, the PRIOR group became increasingly convinced of the need for follow-up work, and of the difficulty individuals were having in obtaining it. The group prepared a proposal to the San Francisco Foundation asking for $200,000 to continue PRIOR and to fund detailed geotechnical investigations for about 50 properties. By contracting for the work as a group, the proposal argued, the total cost would be considerably less than if each property owner contracted separately for his own investigation. Doug Elliott (1982) hoped the organization would evolve into a construction

FIGURE IV-6

HAZARD RATING FORM USED BY ENGINEERING GEOLOGISTS
DURING EMERGENCY FIELD SURVEYS (Leighton and Associates, 1982)


12

HAZARD RATING.
142 = #1bS
172 = #2bS

INSPECTION SUMMARY/ OF DAMAGE

DATE: 1-26-82 TIME: 1:15PM INSPECTOR: OLH, KIM - LEIGHTON + ASSOCIATES
LOCATION: 142 + 172 EDGEMONT
NAME: 142 - DANA 172 - SIMON
PHONE: TYPE OF FAILURE: DEBRIS SLIDE - TOPSOIL + SOME OF UNDERLYING D.G. - ALL VEG. CROSSED ROAD TO BAY

RECOMMEND:
① RETAINING WALL AT BASE WITH SLOPING BACKFILL
② CRIBBING
③ CEMENT SACK WALL
④ STEPPED RETAINING DEVICES
⑤ USE OF TIEBACKS
⑥ PIER WALL
⑦ GRADING SOLUTION - CONSTRUCT FILL SLOPE
⑧ MOVE HOMES
⑨ ASSURE GOOD DRAINAGE CONTROL
⑩ KEEP COVERED THIS WINTER

AREA: 100x125x4 CUBIC YDS: RELIEF: ≃150' TO HIGHWAY
GENERAL SLOPE: 31-35° TIME OF FAILURE: MON. JAN. 4, 1982 AM

SOIL PROFILE:

3-5'		SM	SOIL, ROOTS, VEG.
			PALE YELL. D.G. - WEATHERED GRANITICS

GEOLOGY: Soil overlying decomposed granitic MATERIAL

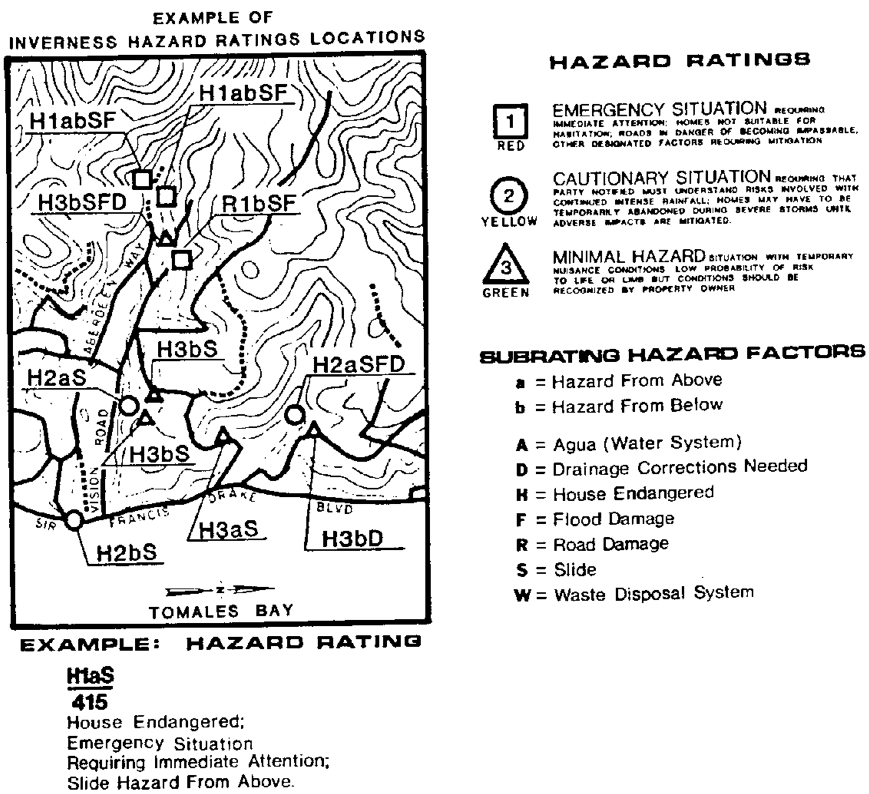
DRAINAGE: SLOPE COVERED W/ PLASTIC - 142 CORRUGATED LINE DOWN SLOPE FOR ROOF DRAIN

HISTORY: EVIDENCE OF PAST FAILURE

VEGETATION: THICK IVY, BERRY + OAK AND BAY TREES

LEIGHTON and ASSOCIATES

Leighton & Associates
(714) 292-8030



Source: National Academy of Sciences, 1984, Debris Flows, Landslides, and Floods in the San Francisco Bay Region, January 23-26, 1982, National Academy Press, Wahington, D.C., p. 42.

FIGURE IV-7

PORTION OF THE INVERNESS HAZARD RATING MAP AND EXPLANATION
(Leighton and Associates, 1982)

management group to assist the property owners in the ridge communities to rebuild. The proposal was not funded by the San Francisco Foundation, however, and by March the organization was dissolved. Its records were turned over to the Storm Damage Counseling Center, a countywide group funded by the San Francisco Foundation, to assist with rebuilding.

PRIOR is an excellent example of an innovative local effort to address an obvious need not met through the disaster relief system. Geotechnical investigations on private property are not funded under any existing disaster relief program. Yet, without the investigations, critical questions about the stability of some lots and the risk of rebuilding or repairing damaged structures cannot be answered.

As a result of the site inspections and review process, the engineering geologic team formulated a series of recommendations for future land use planning:

1) Regional large-scale mapping and geotechnical studies to delineate areas of existing and potential shallow slope failures;

2) Adoption of building and grading codes to protect the public from potentially hazardous sites and poor construction practices;

3) Realtors should inform buyers of potential slope failure hazards; and

4) Community programs aimed at educating the public about slope failure hazards.

The contribution of PRIOR and Leighton and Associates was significant and very unusual. Although Leighton and Associates may not have been motivated solely by altruism, the fact remains that many hours of professional time were donated to help victims in the Inverness area. The help was given in spite of potential professional liability for judgments made quickly which might later prove to be unsound. The effort clearly demonstrates the ability of the geotechnical community in California to meet the need for geotechnical information in the postdisaster context. Perhaps more important, Hannan and McCarthy helped to educate a population with surprisingly few earth scientists and engineers in its midst about the geologic processes at work within the community.

The Boxer Resolution

Soon after the disaster, County Supervisor Barbara Boxer introduced a resolution to the Board of Supervisors making geologic reports mandatory prior to issuance of building permits for any rebuilding or new construction, even of single-lot, one-family homes in stability zones 3 and 4, as mapped by the California Division of Mines and Geology (see Figure IV-2). The resolution represented a considerable change from the predisaster practice that required no reports for construction of a single family home, and county staff discretion on reports for other uses.

The resolution, supported by PRIOR and the engineering geologists working in Inverness, was enacted as an emergency measure over much opposition. The major argument against the measure was the cost, especially in view of the rebuilding fees people were already facing. The resolution did, however, confront the fact that more careful attention to development practices could have averted some of the damage.

Rebuilding the Water System

The emergency patch-up of the water system accomplished by January 10 was only the beginning for the Inverness Public Utilities District (IPUD). Permanent, reliable sources of water needed to be established, water quality ensured, and the distribution system rendered less prone to failure. IPUD had taken over the dilapidated water system from Citizens Utilities in 1979 in the hope of upgrading the system and providing better service to the customers. Governed by an elected board and run by a full-time water systems manager with a half-time assistant, IPUD was faced with an enormous task and limited resources.

IPUD was the only local public agency in Inverness eligible to apply for federal assistance under Section 402 of Public Law 93-288.

FEMA was contributing 75% of the total cost to repair public facilities, on the basis of predisaster design. However, because IPUD was in the process of upgrading the water system, it made no sense to rebuild it according to its predisaster design. Therefore, the District opted for a 90% "in lieu" grant and redesigned the system to better meet present and future needs.

The filter plant was relocated and redesigned, and new raw water lines were constructed. The system was built so it could be back in operation within 72 hours of any failure or destruction of any portion of it. In addition, a permanent connection to the North Marin Water District System was built and a mutual aid agreement reached for an emergency back-up source of water for both districts.

Everywhere in the damaged area after the storms, complaints were heard about the burden of paper work to be done to apply for federal assistance for repair of public facilities. John West, president of the IPUD Board of Directors, made the following comments in a letter written about one month after the disaster:

> We will get Federal assistance for 75% of our losses--but the money doesn't come at the push of a button. We must describe the losses by type and location, produce evidence of actual cost, and in all give a precise and detailed description of everything we ask for. This is very reasonable, but it is also very time-consuming. One of our IPUD Board members is a retired engineer, and he has been giving virtually full time to all these problems. I shudder to think how we could cope without him.

IPUD was the first public agency in Marin County to receive a check from FEMA, as a direct result of a competent volunteer effort to do the necessary paperwork.

Village Disaster Council

One important local response to the disaster was to take steps to improve community preparedness for another disaster. The residents learned firsthand what it meant to be cut off from outside help, and knew that the community must be prepared to survive on its own resources for many days after an earthquake or another major countywide storm and flood disaster. The disaster plan in force at the time of the disaster was generally perceived as effective, but in need of revision.

The focus of preparedness is St. Columba's Church, which had functioned as the Village Disaster Center. A group composed of representatives of the Inverness Association (a local organization of property owners, residents and interested individuals which often functions as the local voice vis-a-vis the county, Coastal Commission or other governing board), St. Columba's Church, IPUD, and the community at large was formed to oversee preparedness activities at the church. Called the Village Disaster Council, the group established four priorities: 1) provide an emergency generator at St. Columba's, 2) install permanent containers to store emergency food and supplies, 3) acquire a new 500-gallon propane tank, and 4) provide for storage of water for emergency use at the church.

As word of its role in the emergency response spread, St. Columba's received donations from many sources, including other Episcopal churches. PRIOR also turned some donations over to the church for emergency relief. When the emergency passed, the church still had some funds left which it committed to the preparedness projects. The Inverness Association raised a share of the cost and the San Francisco Foundation made a grant for the projects.

While in Inverness, the Leighton and Associates engineering geologists briefly reviewed the church site to identify any hazardous condition that would preclude its use as a disaster center. None was found. The church sits on a natural plateau between valleys, well above the flood plain. The only problem during the storms was a leaky roof. By September, a foundation for the new generator was under construction, the propane tank was installed, and two surplus cargo containers were being placed near the parking area. Fire Chief Mike Meszaros and other volunteers were assembling tools, shovels, wheelbarrows, medical supplies, food for 200 people for eight days, bedding, cots, a small portable generator, camping lanterns, and other supplies to be stored.

Restoration of First Valley Creek

Flooding and debris flows combined to alter completely the nature of First Valley Creek. The creek changed course near the firehouse and the "village green," an area to the west of the firehouse variously used as a playground and parking lot. The channel was clogged with branches, wreckage and all forms of debris. Vegetation was scoured from the valley sides in the path of a debris flow which careened side-to-side down the valley. Bridges and culverts washed out, banks collapsed and eroded, and flood waters topped the banks at many spots.

First Valley Creek is the only publicly owned creek in the area, having been deeded to the county years ago. The Inverness Association had assumed responsibility for maintaining the channel. As a public creek, funds were available through the federal government for debris clearance and restoration of the creek to its predisaster condition. In this case, that meant returning the creek to its original channel. Several creekside residents objected and a small group formed to develop an alternative plan for creek restoration, leaving the creek in its newly formed channel. It was clear that a compromise would be needed between the objectives of reducing the flood risk and enhancing the aesthetics of the creek.

As the plan evolved, the balance leaned to the side of aesthetics. For the creek to carry the 100-year flood flow, the channel would have to be completely reconstructed, widened and deepened. Even at that, there was no reasonable way the channel could be made large enough to handle debris from potential failures originating at the headwaters. The risk of a repeat of the experience just past was accepted by the citizens committee, and the overwhelming preference was for a natural channel.

Drawing on the expertise of local residents in ecology and native landscaping, the committee developed a plan and applied for a Community Development Block Grant to fund the needed work. In June of 1982, the grant was approved to survey the stream, reshape the banks to increase capacity, and plan for revegetation. The plants and labor for restoration were donated. A former resident who is a creek naturalist provided advice, the local garden club donated plants and time, and school children raised seedlings. The value of the effort was estimated at $42,000, with $31,000 consisting of volunteer labor and donated materials. On the basis of this record, the State Coastal Conservancy has contributed $125,000 to the next phase of additional channel improvements and work on the other streams on the ridge (Sunset Magazine, 1983).

The Planning Group

Direct local participation in preparing the 1979 Inverness Ridge Communities Plan was provided by a committee called the Planning Group. This group was originally associated with the Inverness Association, but later detached and broadened to include representatives from all the major neighborhoods along the ridge. Soon after the January, 1982, disaster, one of the group's original members, Lorie Chase, organized an effort to reevaluate the plan in light of the flood and debris flow disaster.

During the second week in February, a little over a month after the disaster, residents of the various ridge neighborhoods prepared a series of reports summarizing the damage that occurred and any land use or related policy issues raised by the experience. Most reports cited the need for emergency access-egress at the neighborhood as well as community level. Other issues included drainage, sewage disposal, stream maintenance and restoration, road standards, land use and road construction practices in the public lands, geologic reports on new construction, community development policy and standards, historic preservation, and growth management. The reports were forwarded to the Marin County Planning Department on February 15, as part of a local effort to spur the county into a plan-revision program.

The Planning Group also prepared a questionnaire and distributed it in April of 1982 to residents and property owners in the planning area. About 1,100 questionnaires were distributed and responses were received from 334 households. In general, the responses indicated satisfaction with predisaster conditions and a desire to reestablish them. For example, more people thought that both county-maintained roads and unpaved access roads in the watershed should be repaired to their predisaster condition than thought the roads should be upgraded. And, while problems with sewage disposal and water supply were acknowledged, measures such as establishing a septic tank maintenance district or constructing a permanent link to the North Marin Water District water supply received little support.

The questionnaire revealed strong community support for watershed management and creek restoration. A majority of the respondents considered the creeks a community resource and resposibility, and thought that restoration should be guided by a local committee rather than government agencies or individual property owners. The questionnaire responses also revealed the community's ambiguity about reducing the risk of damage from floods and debris flows at the expense of natural creek channels. The responses to a list of options for the creeks were:

	Agree	Disagree	Undecided
a. left alone	62	115	53
b. returned to former condition	111	76	68
c. planted with native vegetation	215	24	43
d. banks reinforced	139	108	72
e. planted with typical garden plants	15	162	50
f. parking banned near creekbanks	112	77	66
g. wooden bridges	144	44	70
h. provided with culverts	146	40	79

Except for the near unanimity on the issue of native vegetation, the responses show significant disagreement on all the approaches, especially the question of reinforcing the creek banks. Normally, public actions to reduce risk are most strongly supported right after a disaster; as the survey indicates, other community objectives were still important and even overriding.

The Planning Group recognized the need for a plan revision and, armed with the neighborhood reports and survey results, helped to convince the county to undertake the project. The group also provided the vehicle for the community to make its wishes heard as the county staff worked on the revision.

Geotechnical Study

Another effort that contributed directly to the replanning following the 1982 disaster in Inverness was a geotechnical study done by Woodward-Clyde Consultants for Marin County. The objectives of the study were 1) to develop final repair recommendations for public roads and drainage structures, 2) to evaluate storm hazard mitigation measures and the potential impact of implementing them, and 3) to review the Inverness Ridge Communities Plan for possible changes to reduce future storm damage.

The study report was released in May of 1982. It recommended repairing the damaged public roads and improving surface and subsurface drainage along the ridge; however, most of the report described and evaluated hazard mitigation measures. The report focuses on the flood hazard; the ways to reduce damage from the 100-year flood are quite clear. The debris flow hazard is harder to address because of the uncertainty about the areas at risk and the probability of occurrence. In addition, the most likely source areas for debris flows are on federal and state land, outside the direct planning jurisdiction of the county. The apparent conclusion was that little could be done to mitigate the debris flow hazard. In many places it is difficult to modify channels and culverts to carry the 100-year flood flow, let alone the 100-year flood flow plus debris.

Non-structural mitigation options recommended for Inverness Ridge include the following:

1) developing and implementing storm emergency plans to ensure public safety;

2) educating the general public about the emergency plans and various mitigation measures;

3) requiring a licensed civil engineer or engineering geologist to evaluate future development of hillside parcels, giving special consideration to steep hillsides in the upper reaches of First and Second valleys, the full length of smaller valleys, and the ridges next to uphill cut slopes along Sir Francis Drake Boulevard;

4) identifying flood hazard areas and establishing a flood control zone with taxing authority to fund flood control and watershed management programs;

5) identifying and improving emergency access routes;

6) restricting new development or reconstruction within high debris flow hazard areas through transfer of development rights or other mechanisms to shift development to safer sites;

7) rebuilding and retrofitting the domestic water supply system to ensure uninterrupted service during storm emergencies;

8) rebuilding or retrofitting septic systems to meet updated county standards;

9) planning future growth to establish realistic development densities for hillside areas; and

10) rebuilding damaged structures to incorporate remedial measures designed to mitigate flood and debris flow hazards.

Several structural measures, such as elevating buildings and improving stream channels and culverts, are suggested for mitigating the flood hazard. The only structural measure listed for reducing the debris flow hazard is the construction of debris barriers to protect residences which are threatened. Each of the mitigation measures is evaluated in terms of its impact on emergency effectiveness, post-emergency effectiveness, effects on the community, and public and private costs.

The report was immediately useful as repair of roads and culverts in the Inverness area got underway. As intended, the work defining mitigation measures provided background information which was used in revising the Inverness Ridge Communities Plan. Many of the measures were incorporated directly into the plan, and into the Hazard Mitigation Plan prepared by California Office of Emergency Services for FEMA. Some of the measures have been implemented and others have not, largely because of high costs or potential negative impacts on the character of the community.

Revised Inverness Ridge Communities Plan

The efforts of the Planning Group and Woodward-Clyde Consultants fed directly into Marin County's project to revise the Communities Plan. The revision was undertaken in direct response to the flood and debris flow disaster to identify any changes in community development that could reduce damage from future events. It seemed obvious as the studies progressed that the residents of Inverness valued the natural amenities of the area, and that structural solutions to the flooding and debris flow problems would be costly and unacceptable to the community. Under these circumstances, planning and regulation, especially of new develoment in the community, seemed to be the most promising way to reduce risk.

The revised plan, adopted by the Marin County Board of Supervisors in the fall of 1983, added a new goal:

> Recognize natural hazards from seismic, flood and soil instability factors and provide mitigations against future property damage and to assure personal safety.

A long description of the January, 1982, storm and resulting damage extracted from the Woodward-Clyde report is added to the plan, along with a set of "post-storm policies" restating some of the mitigation measures from the report. The policies support flood plain management requirements, geologic report requirements (as set forth in the Boxer Resolution) and the enforcement of the Stream Conservation Area setbacks. The policies are consistent with the Marin Countywide Plan adopted in April of 1982 and have, for the most part, been implemented countywide.

As recommended in the Woodward-Clyde report, the revised plan favors geologic report requirements for developments on the steep hillsides of the larger valleys, all of the smaller valleys, and next to uphill cut slopes of Sir Francis Drake Boulevard. The parking lots next to Inverness Store and the elementary school are cited as possible helicopter landing areas, since the only way in or out of the community in an emergency could be by air. No acceptable alternative to Sir Francis Drake Boulevard was found for emergency egress and access by car.

The revised plan does not recommend changes in residential densities as a way to reduce risk from natural hazards. Nor does it support the notion of transfer of development rights as proposed in the Woodward-Clyde report. The problem with transfer of development rights was the inability to find acceptable parcels within the ridge to which development could be transferred, since most of the undeveloped parcels are steep or otherwise less than desirable for development. The people of Inverness are aware of the irony in the firehouse being located within the 100-year flood plain, but no safer, available, alternative site could be found.

The most significant change in the revised plan is a recommendation to rezone the R-1 residential districts to RSP, single-family, planned residential. This means that all new residential development will be subject to the design review requirements of the Marin County Code. Under these requirements, the characteristics of the site and potential for damage from on- and off-site hazards can be fully evaluated prior to approval of any development, and the risks to new development can be reduced.

San Francisco Foundation Role

The San Francisco Foundation played an unusual and important role in Marin County's recovery from the 1982 disaster. The Foundation administers a very large legacy from the Buck estate, the proceeds from which can be spent only in Marin County. At the time of the disaster, the foundation was funding a reverse annuity mortgage program in Marin County conducted by the San Francisco Development Fund, a California non-profit corporation created in 1963 to manage short-term demonstration programs in housing and community development.

Within two or three days of the disaster, the San Francisco Development Fund was distributing Buck money in the form of emergency grants to non-profit organizations. The $2,500 start-up grant to PRIOR was made during this period. The Inverness Public Utilities Department also received a grant of $28,000 for immediate use. As the magnitude of the disaster became apparent, the Development Fund devised a program to assist individual victims and a second program to assist public agencies. To administer the individual assistance program, the Fund established the Storm Damage Counseling Center with offices in Mill Valley; the Center dispensed about $1 million of Buck money through three grant and loan programs:

> Deferred Payment Loans--are available to owner occupants of 1-4 family dwellings and to owner/lessees of small businesses. All loans will be secured by a deed of trust and are for real property improvements. The maximum loan is $5,000, with repayment due at the end of ten years or when title to the property is transferred (whichever occurs first). The interest rate is 4% simple.
>
> Catastrophic Damage Grants--are available to owner occupants of 1-4 family dwellings and to owner/lessees of small businesses. The maximum grant is $15,000 and can be used for emergency health and safety repairs, down payment on a new home, etc. These are awarded on a case by case basis.
>
> Lender Loan Pool--consists of below market interest rate loans from banks and savings and loan associations. These loans are available to owner occupants of 1-4 family dwellings and to owner/lessees of small businesses. The maximum loan amount is $20,000 which can be used for real property improvements. The maximum term will be up to 20 years. All loans will be secured by a deed of trust; the Fund will subsidize these loans. The amount of subsidy will vary (Storm Damage Counseling Center, 1982).

The public works program funded by the San Francisco Foundation had two parts. First, about $2 million was allocated to help public agencies pay the 25% local share to qualify for federal assistance to repair or rebuild public facilities. Second, about $1.5 million was disbursed to cover "special needs." This latter distribution came about when it was found that some public losses were not eligible for federal funding and that, because of methods of estimating damages and determining replacement or repair costs, less than 75% of the costs of some eligible projects was paid by FEMA. This assistance probably explains why public officials in Marin County complained less about the terms of federal aid than did public officials in the other disaster-stricken counties. The IPUD received a grant to cover its 25% and the board president felt it was a "godsend" (West, 1984).

In April of 1982, the Storm Damage Counseling Center joined with the Marin County Housing Authority to fund geotechnical review of damaged property. This effort arose out of the difficulties the county housing rehabilitation and inspection staff was having in deciding whether or not to red tag damaged houses. Advice was needed which was not provided by the usual contractors, public works officials, or building inspectors. The program that evolved funded the full cost of a geotechnical review of an owner-occupied home to determine the need for a detailed investigation. Loans were available to help pay the cost of detailed investigations, if they were needed. Rental properties were included if they were affected by a failure that also endangered other properties. An effort was made to conduct single investigations of slope failures that affected or potentially affected multiple properties.

The Marin County Housing Authority compiled a list of geotechnical engineering firms willing to do the preliminary engineering evaluation and detailed investigations. The property owner could choose any qualified firm, or the work was assigned on a rotating basis to the firms on the list. About 720 requests for assistance were received. The PRIOR records with the hazard ratings were turned over to the Storm Damage Counseling Center after PRIOR's application for additional funding was turned down. The records were used to establish priorities in assigning engineers to the Inverness area.

The San Francisco Foundation money provided flexibility to respond to needs as they arose. Unlike FEMA, the Foundation did not have to await authorization from Congress to change direction or try a new approach. They recognized the need for geotechnical engineering information to help make decisions about rebuilding and repair, and the program that developed is an interesting model.

Hazard Mitigation--FEMA and OES

The Interagency Flood Hazard Mitigation Report, issued on February 7, 1982, designated Inverness as one of six "areas of special opportunity." The basic recommendation was that "reconstruction should not take place until the hazards and their likelihood of recurrence are determined. Once these are established, new development and reconstruction should only be allowed that can withstand the effects of the hazards. The county should also implement a warning and evacuation plan for the safety of the canyon residents" (p. 31). To acomplish this, the Interagency Team recommended that the FEMA/State/Local Hazard Mitigation Survey Team:

1) Identify significant hazards in Inverness
2) Evaluate the impacts of these hazards
3) Review and evaluate applicable land use regulations, construction standards and other existing hazard mitigation measures
4) Recommend appropriate mitigation measures.

The Mitigation Team suggested three approaches to reducing damage from the combined flood-debris flow hazards in the developed valleys: flood insurance, regulation of new development and rebuilding, and relocation using transfer of development rights or some form of land swap. Flood Insurance Rate Maps (FIRMs) for Inverness indicate that the canyons are in zones C (areas of minimal flooding) and D (areas of undetermined, but possible flood hazards). Flood insurance is available at rates pertaining to those zones--lower than if the maps reflected the true hazard as revealed in January of 1982.

Marin County has adopted various measures requiring evaluation of hazards in considering new development. In addition to the Boxer Resolution and geotechnical report requirements pertaining to certain areas in Inverness, the county adopted flood plain management regulations after the disaster. The regulations (Marin County Code Chapter 23.09 and Resolution 82-16) require at least the following in flood-prone areas:

1) Anchoring of structures

2) Use of materials and utility equipment to resist flood damage

3) Maintaining the elevation of the lowest habitable floor above base flood elevation

4) Anchoring butane tanks

5) Requiring that preliminary subdivisions/land divisions identify the flood-hazard area and the elevation of the base flood.

In addition, under the proposed rezoning from R-1 to RSP, all new development in the ridge is subject to design review so that siting of buildings consistent with the risk can be required.

The State Hazard Mitigation Plan, issued by the Office of Emergency Services in mid-summer 1983, contains a statement of recommended mitigation measures and a one-year update of mitigation efforts. This plan provides an excellent summary of the various mitigation actions that began immediately after the disaster in Marin County. Most of the measures come directly from the Woodward-Clyde report and many have been incorporated into the revised communities plan.

The problems of mitigating hazards to existing development are formidable. The proposal to use transfer of develoment rights or some form of land swap to permit relocation of particularly vulnerable buildings was found to be unworkable because of the lack of acceptable "receiver" sites in the Inverness area. The decisions regarding restoration of First Valley Creek represent the choice of the community to accept a higher level of risk for existing development than for new development. Channel capacity has been increased, but not sufficiently to prevent damage in case of a recurrence of the January, 1982, conditions.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations are grouped according to a rough chronological order.

Postdisaster Geotechnical Evaluation

1) It is important to obtain the right expertise for the task at hand. When debris flows or other forms of slope failure occur, the site should always be inspected by a geologist, an engineering geologist, or a professional with a background in geotechnical engineering. If structures have been damaged or are threatened, the advice of foundation and/or structural engineers should be sought.

2) Current procedures for federal disaster relief do not provide for geologic evaluation of areas subject to debris flow hazards. However, without geologic evaluation, decisions about rebuilding in areas damaged by debris flows are often made without regard for risk of future failures.

3) Professional organizations, such as the Association of Engineering Geologists and the American Society of Civil Engineers, should assume responsibility for training interested and qualified members in procedures to provide emergency geotechnical assistance following debris flows and other geologic disasters. The associations could maintain a registry of trained professionals who have agreed to serve in an emergency situation, preferably in localities where they are familiar with geologic conditions. If concern about professional liability is found to be a barrier to participation in such an effort, the associations may wish to seek legislation specifically defining the limits of liability for work done on an emergency basis.

4) Volunteer geologic assistance was available in both cases. However, in neither case was it sufficient to provide the information needed to make decisions about recovery. Planning for the use of volunteers could significantly increase the effectiveness of the efforts.

   Santa Cruz County was fortunate to have two geologists on staff at the time of the disaster. They were able to convey to the decision makers an awareness of the nature of the problem, the need for information, and the kind of expertise needed. They have provided leadership in improving definition and administration of the county geologic hazards review procedures, and in ensuring that local geologic expertise will be available in the event of another disaster.

   The lack of any person with geologic training on the Marin County staff is a serious impediment to effective administration of the county's geologic investigation requirements. It may also have something to do with the fact that the disaster was treated as a flood problem, with relatively little attention paid to mitigation of the debris flow hazard.

5) After a debris flow or other slope failure, a geologist or engineering geologist is needed to identify the type of failure, mechanics of failure, probable cause of failure, and the potential for renewed movement. These must be determined in order to determine the technical feasibility of any engineering scheme to reduce future risk.

6) It is probably ineffective to attempt to deal with a debris flow problem separately from a flooding problem for the following reasons:

   a) Debris flows almost always occur during, or immediately after periods of heavy rainfall, which is also likely to cause flooding.

   b) Stream channels are the most common paths for debris flows.

   c) Debris flows can significantly aggravate flood conditions by blocking channels and causing floodwaters to overflow in areas outside of the 100-year flood plain.

   d) Many structures damaged by debris flows are in the 100-year flood plain. Mitigation of the debris flow hazard will usually also address the flood hazard.

   However, it is important to recognize that debris flows are distinctive geologic processes and not simply types of erosion or flooding.

7) A program to map areas of potential debris flows should be instituted in areas where urban growth is occurring at the base of or in steep hillside terrain.

8) The recent work done by the U.S. Geological Survey in mapping terrain types and evaluating each for potential as a source of debris flows is an excellent start in characterizing risk from debris flows. However, much technical work needs to be done before the potential for occurrence can be established with sufficient certainty to serve as the basis for regulating the use of land.

9) It is surprising and regrettable that no regional map showing the debris flows that occurred in the January, 1982, disaster has been produced. Collecting perishable information about the incidence, nature and characteristics of debris flows is very important in the aftermath of a disaster, particularly since so little is known about predicting the potential for debris flow occurrence.

10) Assembling the geological information needed for response to debris flows requires the following steps:

   a) Obtaining information needed in the immediate aftermath of the disaster to make decisions regarding evacuation and immediate reoccupancy of areas near debris flow sites. Although the way in which such information is provided varies a great deal, often involving the efforts of volunteers, the information does seem to be generated and the decisions are made. Procedures for improving information provision at this stage might well be developed by the professional associations in cooperation with FEMA or other agencies that might fund such an effort.

b) Obtaining the information needed to evaluate potential for future failure in order to make decisions about rebuilding and repairs. In most cases this requires detailed geologic and engineering geologic investigations. The information must be credible and the conclusions as clear as possible because the implications of the information are critical to those owning property in the affected areas. Because most incidences of debris flows involve both private and public property, obtaining the information needed to decide the use or reuse of the affected areas is logically a responsibility to be shared by public entities and private property owners. At a minimum, public agencies have a responsibility to obtain sufficient information to be reasonably sure that funds spent for rebuilding or repairing public facilities, such as roads, are wisely spent.

c) Obtaining information needed to determine if an area which has been found to be unstable in Step b can be stabilized to a reasonable (acceptable) level of safety at a cost that is reasonable in relation to the value of the potential uses. This typically requires detailed analysis of the site and is justified only if the preceding evaluations have indicated the possibility of stabilization, diversion or other engineering solutions to the stability problem.

11) Slope stability mapping based on identification of deep-seated landslide deposits, which has become quite common in California, is not a reliable guide to areas of potential debris flow.

Much basic research is still needed to identify potential debris flow areas, recurrence intervals and/or probability of occurrence, and to define, with precision comparable to the definition of the 100-year flood plain, areas susceptible to damage from the hazard.

12) Geotechnical assistance in a postdisaster situation is most efficiently provided by local geotechnical experts familiar with local conditions.

The U.S. Geological Survey, most state geological surveys, and other governmental agencies are not presently organized to provide post-disaster geotechnical assistance. Unless there is a change in the nature of their missions, these agencies should not be looked to for the kind of site-specific evaluation that is needed following a debris flow incident.

Hazard Mitigation as a Part of Recovery

1) Options for mitigating risk in rebuilding after debris flow incidents include:

   a) Requiring geotechnical site investigation before permitting reuse of the failed area, adjacent slopes or flow path.

   b) Prohibiting building or rebuilding on or below any areas identified as potentially unstable. Establish building setbacks from source areas, flow paths and deposition areas.

   c) Improving stability by installing surface/subsurface drains, removing unstable material, constructing buttresses or other retaining structures.

   d) Protecting structures by building diversion structures, debris retention basins and/or designing structures to resist impact of debris flows.

   Carrying out any of the mitigation actions listed in Options b, c, and d is predicated on the investigation results listed as Option a. Nothing sensible is likely to occur without the information characterizing, in as much detail as possible, the nature of the hazard and associated risk.

2) Federal and state funding of repair or reconstruction in areas damaged by debris flows or other slope failures should be predicated on specific geotechnical evaluation of postdisaster stability and risk of recurrence.

3) Both case study areas were designated by FEMA as "areas of special opportunity" for hazard mitigation by the Interagency Task Force. Suggested mitigation actions were, for the most part, limited to those actions that the two counties had either already undertaken or were in the process of undertaking. No funds were made available to assist in carrying out any of the mitigation proposals. If mitigation is to be a meaningful part of the federal response to natural disasters, then funding must be provided to implement the recommended mitigation measures. The cost of mitigation can reasonably be considered a shared responsibility just as the cost of disaster recovery is in fact a burden shared by the various levels of government and the private sector.

4) Funds to carry out the recommendtions of the Hazard Mitigation Team should be authorized by Congress as a regular part of the disaster assistance function. In particular, it is important that funds be provided for relocation of housing units and businesses from areas of potential instability in cases in which the cost of relocation is less than engineering works needed to achieve an acceptable level of stability.

5) Procedures to determine when rebuilding should not be permitted, combined with procedures and funding for relocation of structures, are essential if migiation is to be effective and if federal funds for rebuilding or repair are to be withheld in hazardous areas.

6) Hazard mitigation after a debris flow or slope failure incident should always include instituting local requirements for geotechnical review of applications for new construction in areas of potential instability. Local governments should be made aware of the necessity of having geotechnical expertise at hand to help develop and administer geotechnical review procedures.

Effectiveness of Recovery

1) Local leadership, ability to organize, and determination to influence the decisions of governmental entities affecting local recovery are essential attributes for fast and effective recovery from debris flow disasters, as well as from other disasters.

2) Encourage local government officials who have had the experience of coping with recovery from a major disaster, including debris flows and other slope failures, to share that experience with other local officials. Professional organizations such as the National League of Cities, City Managers Association, and American Association of Planners have a strong potential role in developing networks for such exchange.

3) In both of the case study areas, outside funds were essential to recovery from the debris flow disasters. In Santa Cruz County there was heavy dependence on federal aid for recovery and, especially, repair of roads, bridges and public facilities. In Marin County, the dependence on federal funds was reduced by the operation of the San Francisco Foundation, a private foundation that made significant contributions to recovery in the county.

4) Reducing risk is only one of many community objectives that come into play in rebuilding after a disaster. The desire to return to normal is very strong and other objectives, such as environmental protection and aesthetic considerations, often are as important, or more important, to the community as reducing risk. If potential for future damaging events is fully considered in the process of deciding about rebuilding and repairs, the resulting actions can be considered an expression of the community's concept of acceptable risk.

5) Both individuals and public agencies can easily be daunted by the sheer volume, let alone the complexity, of paperwork necessary to apply for federal disaster assistance. A loose-leaf binder several inches thick was passed out to public officials by FEMA representatives. The binder contains the instructions for applying for disaster assistance and all the laws and regulations that pertain to public assistance. Shorter, simpler application forms and profedures are essential.

6) The paperwork itself is a major postdisaster problem. Similarly, the two-tiered interest rate system presently used for Small Business Administration loans should be reviewed. the gains would have to be substantial to make up for the problems caused by the system.

7) No amount of information can relieve the local general purpose governmental agency of the responsibility of making decisions about the use of land in areas of debris flows and potential debris flows. Help in meeting this responsibility is provided by a planning process designed to integrate the many community concerns and objectives into a coherent, internally-consistent set of planning policies and regulations. The revision of the Inverness Ridge Communities Plan is an excellent example of this process. It is noteworthy that the planning effort was initiated by the local community and specifically timed to respond to geotechnical information derived from the Woodward-Clyde study.

8) Planning for recovery after debris flows or other slope failures, if at all possible, should be carried out within the context of the normal comprehensive planning process for the community.

9) The worst of all possible situations is the failure to reach decisions about future uses of land in debris flow areas. A firm decision that removes ambiguity is preferable to no decision. The problem of deciding what uses are appropriate on the Love Creek slide mass will not go away.

REFERENCES

Bazilwich, Paul, Jr.
1982 Letter to T. C. Hamner, Acting Regional Director of FEMA Region IX, March 18. U.S. Army Corps of Engineers

Blair, Martha L. and William E. Spangle
1979 Seismic Safety and Land Use Planning. U.S. Geological Survey Professional Paper 941B.

Burns, Tom
1984 Personal communication to the author. Chief, Environmental Planning, Santa Cruz County.

California Division of Mines and Geology
1982 California Geology 35 (#7). Issue devoted to the January 1982 floods and debris flows.

California Office of Emergency Services
1983 State Hazard Mitigation Plan and One Year Update. A report in response to the January 7, 1982 Disaster Declaration (FEMA-651-DR-CA).

Campbell, R. H.
1975 Soil Slips, Debris Flows, and Rainstorms in the Santa Monica Mountains and Vicinity, Southern California. U.S. Geological Survey Professional Paper 851.

Carroll, Jane
1982 "How a Community Pulled Together." California Living, magazine of the San Francisco Sunday Examiner and Chronicle, February 21.

Clark, J. C.
1981 Stratigraphy, Paleontology, and Geology of the Central Santa Cruz Mountains, California Coast Ranges. U.S. Geological Survey Professional Paper 1168.

Cooper-Clark and Associates
1975 Preliminary Map of Landslide Deposits in Santa Cruz County, California.

1978 Cumulative Impact Study of Septic Tank Disposal Systems in the Inverness Area of Marin County. Report prepared for Marin County Planning Department.

Cotton, W. R. and D. A. Cochrane
1982 "Love Creek Landslide Disaster January 5, 1982." California Geology 35 (#7), pp. 153-157.

Cotton, William and Associates
1982 Geotechnical Investigation and Planning Studies, Love Creek Landslide Area, Santa Cruz County, California. A proposal to Santa Cruz County, January 22.

Cucchiara, Joseph
1982 Memorandum to the Board of Supervisors, Santa Cruz County, April 19. Love Creek District Representative.

Ellen, Stephen *et al.*
1982 Map Showing Areas Susceptible to Different Hazards from Shallow Landsliding, Marin County and Adjacent Parts of Sonoma County, California. U.S. Geological Survey Miscellaneous Field Studies Map MF 1406.

Elliott, Doug
1982 Personal communication to the author. Point Reyes Station: Elliott Construction.

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

Federal Emergency Management Agency (FEMA)
1982 Interagency Flood Hazard Mitigation Report. February 7. Washington, DC.

Galloway, A. J.
1966 "Field Trip Point Reyes Peninsula and San Andreas Fault Zone." Pages 429-440 in Geology of Northern California, California Division of Mines and Geology Bulletin 190.

Hamner, T. C.
1982 Personal communication to the author. San Francisco: Acting Regional Director, FEMA Region IX.

Kockelman, W. J.
1980 Tools to Avoid Landslide Hazards and Reduce Damages. U.S. Geological Survey Open-File Report 80-487.

Los Angeles Times
1982 July 6.

Marin County
n.d. Zoning Ordinance in Title 22, County Code.

n.d. Flood Plain Management, in Title 23, County Code.

Marin County Planning Department
1979 The Inverness Ridge Communities Plan, adopted 1979, revised, 1983.

1980 Local Coastal Program Unit 2, certified by the California Coastal Commission on April 1, 1981.

1982 Marin Countywide Plan, adopted April.

Mark, R. K. *et al.*
1982 Rainfall Associated with the January 1982 Rainstorm in the San Francisco Bay Region, California. U.S. Geological Survey Open-File Map, OF-83-16.

National Academy of Sciences, Committee on Natural Disasters
1984 Debris Flows, Landslides, and Floods in the San Francisco Bay Region, January 1982. Overview and Summary of a conference held at Stanford University, August 23-26, 1982. Washington, DC: National Academy Press.

National Academy of Sciences, National Research Council
1982 Selecting a Methodology for Delineating Mudslide Hazard Areas for the National Flood Insurance Program. Washington, DC: National Academy Press.

Newell, George T.
1982a Letter to FEMA, February 9. Chief Administrative Officer, Santa Cruz County.

1982b Memorandum to the Board of Supervisors, Santa Cruz County, February 22. Chief Administrative Officer, Santa Cruz County.

Nilsen, Tor H. *et al.*
1979 Relative Slope Stability and Land-Use Planning in the San Francisco Bay Region. U.S. Geological Survey Professional Paper 944.

Pacific Data Resources
1984 California Almanac, 1984-1985. Novato, California: Presidio Press.

Rubin, Claire B.
1981 Long Term Recovery from Natural Hazards: A Comparative Analysis of Six Local Experiences. Washington, DC: Academy for Contemporary Problems.

1983 Case Studies of Communities Recovering from Natural Disasters, Year II Final Report. Washington, DC: George Washington University.

San Francisco Chronicle
1982 January 13.

San Jose Mercury News
1981 March 2.

Santa Cruz County
1975 Seismic Safety Element. Santa Cruz, California.

1982 Memorandum to Board of Supervisors from Building Appeals Board. Santa Cruz, California.

Smith, T. C. and E. W. Hart
1982 "Landslides and Related Damage January 1982, San Francisco Bay Region." California Geology 35 (#7), pp. 139-152.

Spangle, William and Associates, Inc. *et al.*
1980 Land Use Planning After Earthquakes. Portola Valley, California.

Storm Damage Counseling Center
1982 Flyer describing programs.

Sunset Magazine
1983 "Community Action: They Regraded and Replanted a Storm-Gulleyed Meadow." (November), pp. 308-309.

Terzaghi, K.
1950 "Mechanism of Landslides." Pages 83-123 in S. Paige, editor, Application of Geology to Engineering Practice. Boulder: Geological Society of America.

U.S. Army Corps of Engineers
1982 Love Creek Slide Site Assessment and Evaluation. Report prepared for the Federal Emergency Management Agency.

Valley Press
1982 January 13.

Varnes, P. J.
n.d. "Slope Movement Types and Processes." Pages 11-33 in R. L. Schuster and R. J. Krizek (eds.), Landslides, Analysis and Control. Transportation Research Board Special Report 176. Washington, DC: National Academy of Sciences.

Vickers, Robert
1982 Personal communiction. San Francisco: Regional Director, FEMA Region IX

Wagner, D. L. and T. C. Smith
1977 Geology for Planning in Western Marin County, California. California Division of Mines and Geology.

West, John
1982 Personal communication, January 22. President of the Board, Inverness Public Utilities District.

1984 Personal communication, July. President of the Board, Inverness Public Utilities District.

Woodward-Clyde Consultants
1982 Storm Damage Assessment and Evaluation, Inverness Area, Marin County, California. Report prepared for Marin County Planning Department.

Wieczorek, Gerald F.
1984 "Preparing a Detailed Landslide-Inventory Map for Hazard Evaluation and Reduction." Bulletin of the Association of Engineering Geologists 21 (#3), pp. 337-342.

Monograph Series
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Boulder, CO 80309

The following monograph papers may be obtained from the Natural Hazards Research and Applications Information Center, located at the above address. The monographs may be purchased on an individual basis ($8.00 each) or as part of a subscription ($7.00 each).

#023 Farhar, Barbara C. and Julia Mewes. Social Acceptance of Weather Modification: The Emergent South Dakota Controversy. 1975, 204 pp.

#024 Farhar, Barbara C., Ed. Hail Suppression: Society and Environment. 1977, 293 pp.

#025 Kates, Robert, Ed. Managing Technological Hazard: Research Needs and Opportunities. 1978, 175 pp.

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The following publications in the monograph series may be obtained from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

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#017 Assessment of Research on Natural Hazards staff. *Snow Avalanche Hazard in the United States: A Research Assessment*. PB 242 980; $5.25.

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