Chapter 4
Hazard Identification, Assessment, and Mapping

Hazard Analysis

Recognition of the presence of active or potential slope movement, and of the types and causes of the movement, is essential to landslide mitigation. Recognition depends on an accurate evaluation of the geology, hydrogeology, landforms, and interrelated factors such as environmental conditions and human activities. Only trained professionals should conduct such evaluations. However, because local governments may need to contract for such services, they should be aware of the techniques available and their advantages and limitations.

Techniques for recognizing the presence or potential development of landslides include:

- map analysis
- analysis of aerial photography and imagery
- analysis of acoustic imagery and profiles
- field reconnaissance
- aerial reconnaissance
- drilling
- acoustic imaging and profiling
- geophysical studies
- computerized landslide terrain analysis
- instrumentation

Map Analysis

Map analysis is usually one of the first steps in a landslide investigation. Maps that can be used include geologic, topographic, soils, and geomorphic. Using knowledge of geologic materials and processes, a trained person can obtain a general idea of landslide susceptibility from such maps.

Analysis of Aerial Photography and Imagery

The analysis of aerial photography is a quick and valuable technique for identifying landslides, because it provides a three-dimensional overview of the terrain and indicates human activities as well as much geologic information. In addition, the availability of many types of aerial imagery (satellite, infrared, radar, etc.) make this a very versatile technique.

Analysis of Acoustic Imagery and Profiles*

Profiles of lake beds, river bottoms, and the sea floor can be obtained using acoustic techniques such as side-scan sonar and subbottom seismic profiling. Surveying of controlled grids, with accurate navigation, can yield three-dimensional perspectives of subaqueous geologic phenomena. Modern, high resolution techniques are used routinely in offshore shelf areas to map geologic hazards for offshore engineering. Surveying and mapping standards for outer continental shelf regions are regulated by the U.S. Minerals Management Service.

Field Reconnaissance

Many of the more subtle signs of slope movement cannot be identified on maps or photographs. Indeed, if an area is heavily forested or has been urbanized, even major features may not be evident. Furthermore, landslide features change over time on an active slide. Thus, field reconnaissance is necessary to verify or detect many landslide features.

Aerial Reconnaissance

Low-level flights in helicopters or small aircraft can be used to obtain a rapid and direct overview of a site.

Drilling

At most sites, drilling is necessary to determine the type of earth materials involved in the slide, the depth to the slip surface and thus the thickness and geometry of the landslide mass, the water-table level, and the degree of disruption

***By D.B. Prior**

of the landslide materials. It can also provide samples for age-dating and testing the engineering properties of landslide materials. Finally, drilling is needed for installation of some monitoring instruments and hydrologic observation wells.

Geophysical Studies

Geophysical techniques (the study of changes in the earth's gravitational and electrical fields, or measurement of induced seismic behavior) can be used to determine some subsurface characteristics such as the depth to bedrock, zones of saturation, and sometimes the ground-water table. It can also be used to determine the degree of consolidation of subsurface materials and the geometry of the units involved. In most instances these methods can best be used to supplement drilling information. Monitoring of natural acoustic emissions from moving soil or rock has also been used in landslide studies.

Computerized Landslide Terrain Analysis

In recent years computer modeling of landslides has been used to determine the volume of landslide masses and changes in surface expression and cross section over time. This information is useful in calculating the potential for stream blockage, cost of landslide removal (based on volume), and type and mechanism of movement. Very promising methods are being developed utilizing digital elevation models (DEMs) to evaluate areas quickly for their susceptibility to landslide/debris-flow events (Filson, 1987; Ellen and Mark, 1988). Computers are also being used to perform complex stability analyses. Software programs for these studies are readily available for personal computers.

Instrumentation

Sophisticated methods such as electronic distance measuring (EDM); instruments such as inclinometers, extensometers, strain meters, tiltmeters, and piezometers; and simple techniques such as establishing control points using stakes can all be used to determine the mechanics of landslide movement and to warn against impending slope failure.

Anticipating the Landslide Hazard

One of the guiding principles of geology is that the past is the key to the future. In evaluating landslide hazards this means that future slope failures will probably occur as a result of the same geologic, geomorphic, and hydrologic situations that led to past and present failures. Based on this assumption, it is possible to estimate the types, frequency of occurrence, extent, and consequences of slope failures that may occur in the future. However, the absence of past events in a specific area does not preclude future failures. Man-induced conditions such as changes in the natural topography or hydrologic conditions can create or increase an area's susceptibility to slope failure (Varnes and the International Association of Engineering Geology, 1984).

In order to predict landslide hazards in an area, the conditions and processes that promote instability must be identified and their relative contributions to slope failure estimated, if possible. Useful conclusions concerning **increased probability** of landsliding can be drawn by combining geological analyses with knowledge of short- and long-term meteorological conditions. Current technology enables persons monitoring earth movements to define those areas most susceptible to landsliding and to issue "alerts" covering time spans of hours to days when meteorological conditions known to increase or initiate certain types of landslides occur. Alerts covering longer periods of time become proportionately less reliable.

Translation of Technical Information to Users

According to Kockelman (personal communication, 1989), the successful translation of natural hazard information for nontechnical users conveys the following three elements in one form or another:

(1) likelihood of the occurrence of an event of a size and location that would cause casualties, damage, or disruption;

(2) location and extent of the effects of the event on the ground, structures, or socioeconomic activity;

(3) estimated severity of the effects on the ground, structures, or socioeconomic activity.

These elements are needed because usually engineers, planners, and decision makers will not be concerned with a potential hazard if its likelihood is rare, its location is unknown, or its severity is slight.

Unfortunately, these three pieces of information can come in different forms with many different names, some quantitative and precise, others qualitative and general. For a product to qualify as "translated" hazard information, the nontechnical user must be able to perceive likelihood, location, and severity of the hazard so that he or she becomes aware of the danger, can convey the risk to others, and can use the translated information directly in a reduction technique.

Maps are a useful and convenient tool for presenting information on landslide hazards. They can present many kinds and combinations of information at different levels of detail. Hazard maps used in conjunction with land-use maps are a valuable planning tool. Leighton (1976) suggests a three-stage approach to landslide hazard mapping. The first stage is regional or reconnaissance mapping, which synthesizes available data and identifies general problem areas. This small-scale mapping is usually performed by a state or federal geological survey. The next stage is community-level mapping, a more detailed surface and subsurface mapping program in complex problem areas. Finally, detailed site-specific large-scale maps are prepared. If resources are limited, it may be more prudent to bypass regional mapping and concentrate on a few known areas of concern.

Regional Mapping

Regional or reconnaissance mapping supplies basic data for regional planning, for conducting more detailed studies at the community and site-specific levels, and for setting priorities for future mapping.

These maps are usually simple inventory maps and are directed primarily toward the identification and delineation of regional landslide problem areas and the conditions under which they occur. They concentrate on those geologic units or environments in which additional movements are most likely. Such mapping relies heavily on photogeology (the geologic interpretation of aerial photography), reconnaissance field mapping, and the collection and synthesis of all available pertinent geologic data (Leighton, 1976).

Regional maps are most often prepared at a scale of 1:24,000, because high-quality U.S. Geological Survey topographic base maps at this scale are widely available, and aerial photos are commonly of a comparable scale. Other scales commonly used include 1:50,000 (county series), 1:100,000 (30 x 60 minute series), and 1:250,000 (1 x 2 degree series).

Community-Level Mapping

Community-level mapping identifies both the three-dimensional limits of landslides and their causes. Guidance concerning land use, zoning, and building, as well as recommendations for future site-specific investigations, are also made at this stage. Investigations should include subsurface exploratory work in order to produce a large-scale map with cross sections (Leighton, 1976). Map scales at this level vary from 1:1,000 to 1:10,000.

Site-Specific Mapping

Site-specific mapping is concerned with the identification, analysis, and solution of actual site-specific problems. It is usually undertaken by private consultants for landowners who propose site development and typically involves a detailed drilling program with downhole logging, sampling, and laboratory analysis in order to procure the necessary information for design and construction (Leighton, 1976). Map scales vary, but are usually not larger than one inch equal to 50 feet.

Types of Maps

The three types of landslide maps most useful to planners and the general public are (1) landslide inventories, (2) landslide susceptibility maps, and (3) landslide hazard maps.

Landslide inventories

Inventories identify areas that appear to have failed by landslide processes, including debris flows and cut-and-fill failures. The level of detail of these maps ranges from simple reconnaissance inventories that only delineate broad areas where landsliding appears to have occurred (Figure 20) to complex inventories that depict and classify each landslide and show scarps, zones of depletion and accumulation, active versus inactive slides, geological age, rate of movement, and other pertinent data on depth and kind of materials involved in sliding (U.S. Geological Survey, 1982; Brabb, 1984b) (Figure 21).

Simple inventories give an overview of the landslide hazard in an area and delineate areas where more detailed studies should be conducted. Detailed inventories provide a better understanding of the different landslide processes operating in an area and can be used to regulate or prevent development in landslide areas and to aid the design of remedial measures (U.S. Geological Survey, 1982). They also provide a good basis for the preparation of derivative maps such as those indicating slope stability, landslide hazard, and land use. Wieczorek (1984) described how to prepare a landslide inventory map that can be used by planners and decision makers to assess landslide hazards on a regional or community level. The process consists of using aerial photography with selective field checking to detect landslide areas, and then presenting the information in map form using a coded format. The maps show any or all of the following: state of activity, certainty of identification, dominant types of slope movement, estimated thickness of slide material, and dates or periods of activity.

Landslide susceptibility maps

A landslide susceptibility map goes beyond an inventory map and depicts areas that have the potential for landsliding (Figure 22). These areas are determined by correlating some of the principal factors that contribute to landsliding, such as steep slopes, weak geologic units that lose strength when saturated, and poorly drained rock or soil, with the past distribution of landslides. These maps indicate only the relative stability of slopes; they do not make absolute predictions (Brabb, 1984b).

Landslide susceptibility maps can be considered derivatives of landslide inventory maps because an inventory is essential for preparing a susceptibility map. Overlaying a geologic map with an inventory map that shows existing landslides can identify specific landslide-prone geologic units. This information can then be extrapolated to predict other areas of

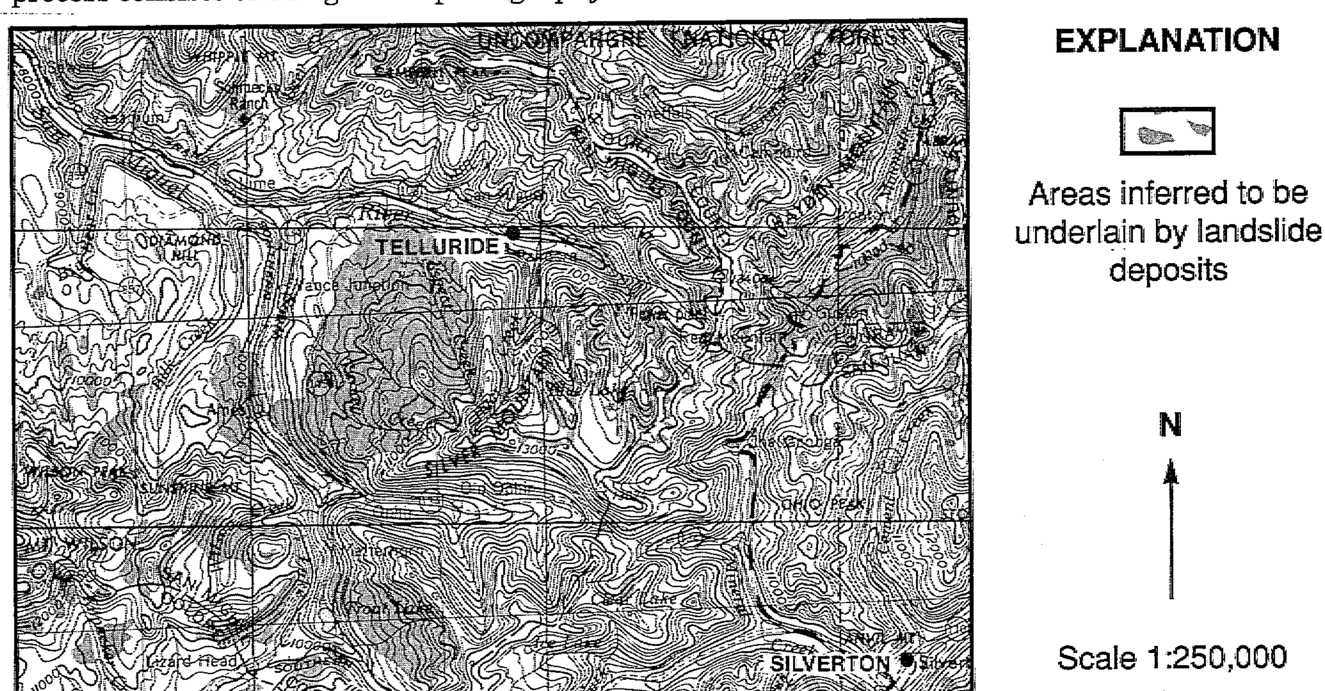

Figure 20. Detail from the landslide inventory map of the Durango 1 x 2 degree map, Colorado (Colton et al., 1975).

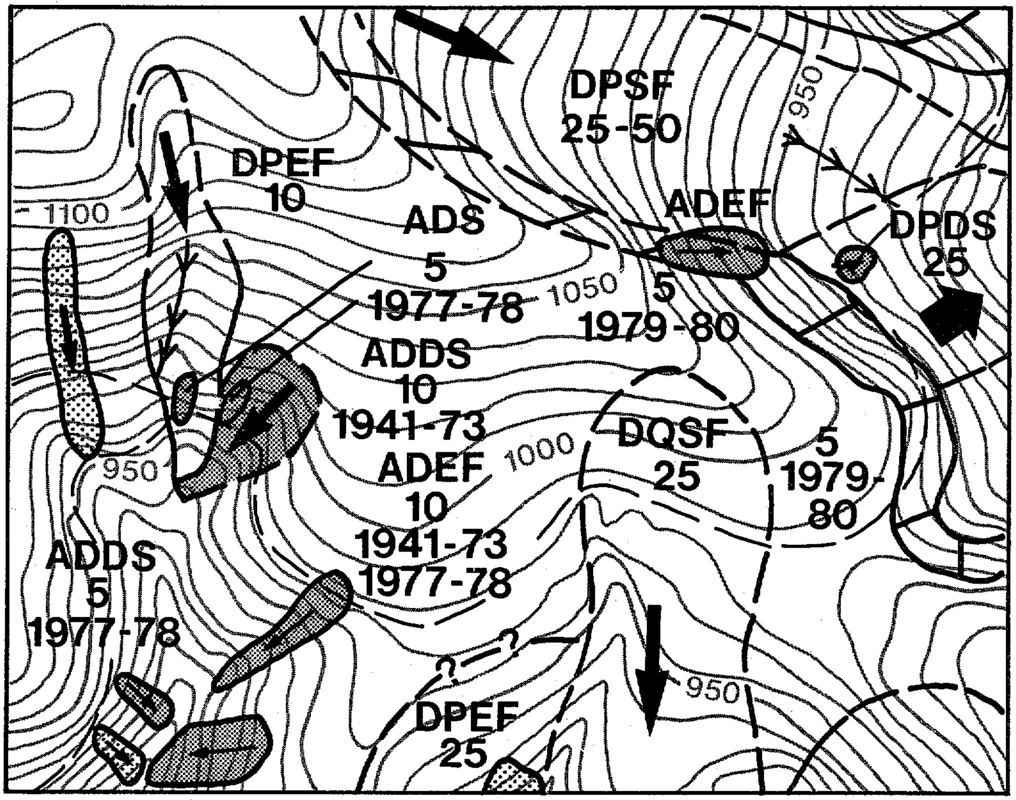

Figure 21.
Detail from map showing recently active and dormant landslides near La Honda, central Santa Cruz Mountains, California. Information shown on this map includes: state of activity, dominant type of slope movement, direction of movement, scarp location, depth and date of movement. See map for detailed explanation. (Wieczorek, 1982.)

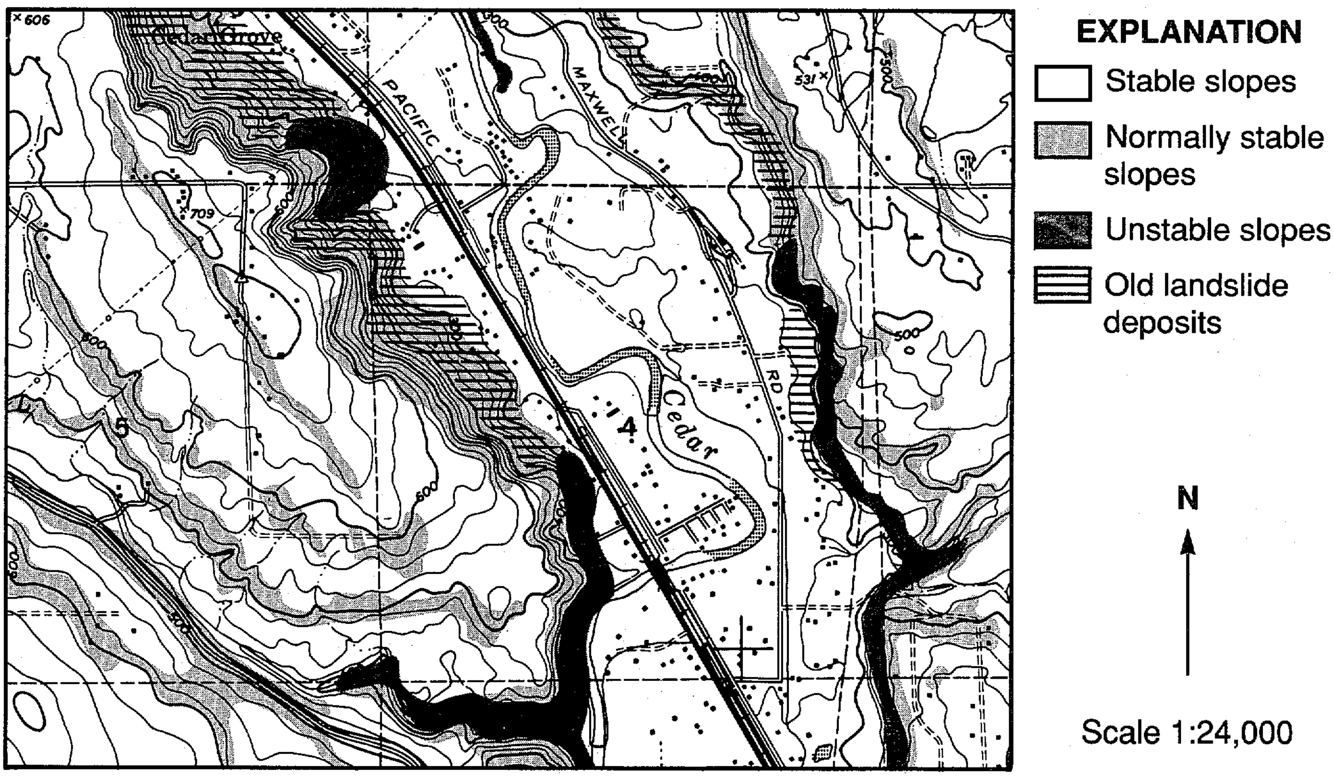

Figure 22. Detail from map showing relative slope stability in part of west-central King County, Washington (Miller, 1973).

potential landsliding. More complex maps may include additional information such as slope, angle, and drainage.

Landslide hazard maps

Hazard maps show the areal extent of threatening processes: where landslide processes have occurred in the past, where they occur now, and the likelihood in various areas that a landslide will occur in the future (Figure 23). For a given area, they contain detailed information on the types of landslides, extent of slope subject to failure, and probable maximum extent of ground movement. These maps can be used to predict the relative degree of hazard in a landslide area.

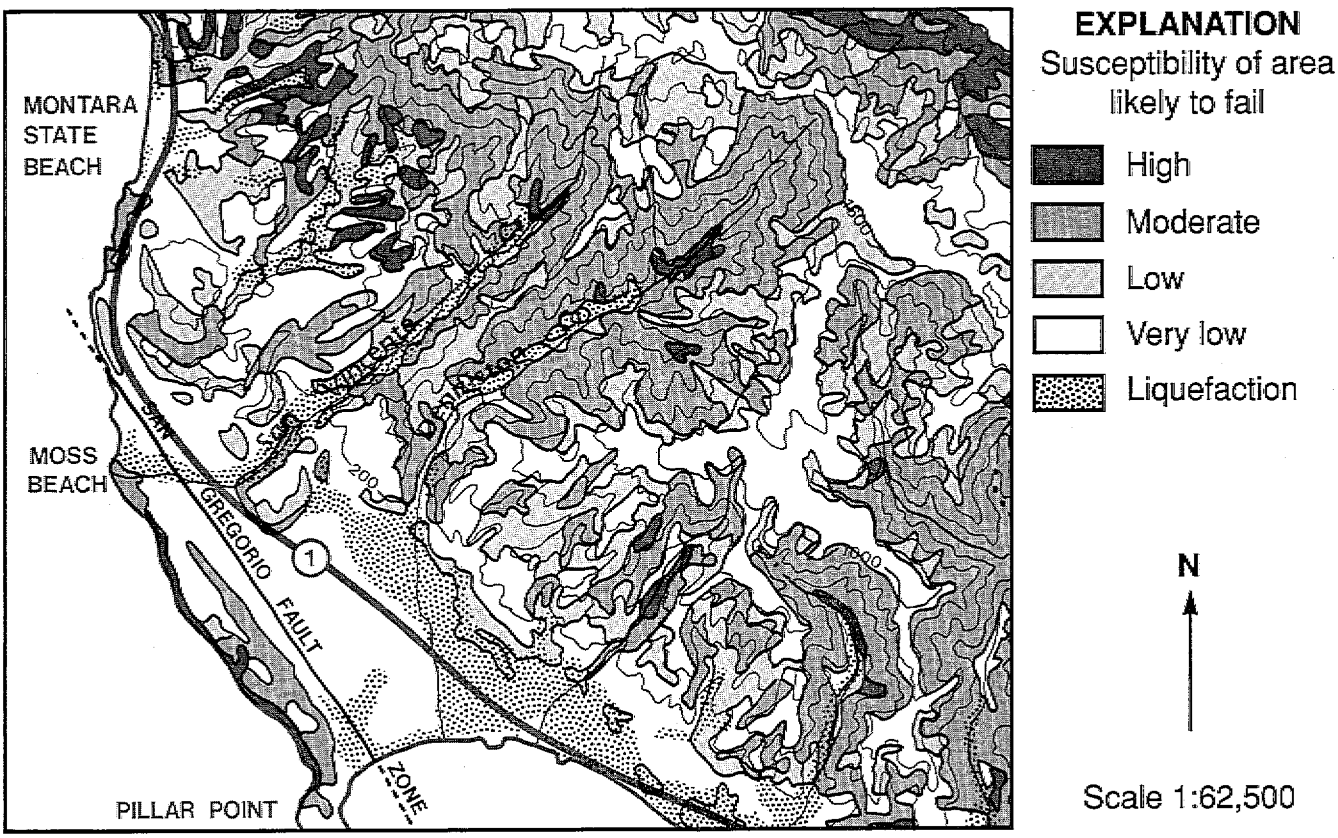

Figure 23. Detail from map showing slope stability during earthquakes in San Mateo County, California (Wieczorek et al., 1985). ❑

Chapter 5
Transferring and Encouraging the Use of Information

A major part of any effective landslide loss-reduction program must be the communication and use of technical information (information transfer). Often individuals or groups do not take mitigative action because they do not understand what to do, or lack training on how to do it. The mitigation and/or avoidance of landslide hazards and the reduction of landslide losses require that appropriate information be communicated to, and effectively used by, planners, decision makers, and emergency response personnel.

According to Kockelman (personal communication, 1989), various terms are used to describe the transfer of information to users, namely "disseminate," "communicate," "circulate," "promulgate," and "distribute." Often these terms are interpreted conservatively. For example, an agency or person might simply issue a press release on hazards or distribute research information to potential users. Such activity rarely results in the adoption of effective hazard reduction techniques.

Kockelman notes that no clear, concise definition or criteria for effective information transfer has been offered or can be found in the literature, except by inference or by analysis of what actually works for lay persons. Therefore, he uses "transfer" to mean the delivery of an understandable product in a usable format to a specific person or group "interested" in, or responsible for, hazard reduction, plus assistance and encouragement in the selection and adoption of an appropriate reduction technique. Only when all these criteria have been met have researchers, translators, and transfer agents fulfilled their objectives.

The effective use of landslide information to reduce danger, damages, or other losses depends not only on the efforts of the producers of the information, but also on (1) the users' interest, capabilities, and experience in hazard-related activities, (2) the existence of enabling legislation authorizing federal, state, and local hazard-reduction activities, (3) the availability of funds and adequate, sufficiently detailed information in a readily usable and understandable form, (4) the use of effective information communication techniques, and (5) the existence of qualified staff at all levels of government with the authority to take mitigative action.

Information Transfer

Methods for transferring and/or obtaining landslide information are listed in Table 3. These methods should be used by any landslide information collection, interpretation, and transferral program designed for planners and decision makers. Some of these services are provided by state agencies, map sales offices, geologic inquiries staffs, public inquiries offices, universities, and, in the course of ordinary day-to-day contacts with the public, by the producers of landslide hazard information. In addition, many research workers have provided such services on a limited and informal basis.

Table 3. Examples of resources available for obtaining / transferring landslide information (adapted from U.S. Geological Survey, 1982).

Educational Services

- Universities and their extension divisions through courses, lectures, books, and display materials
- Guest speakers and participants at lectures in regional and community educational programs related to the application of hazard information
- Seminars, conferences, workshops, short courses, technology utilization sessions, training symposia, and other discussions involving user groups

Table 3. Continued

- Oral briefings, newsletters, seminars, map-type "interpretive inventories," open-file reports, reports of cooperating agencies, and "official-use only" materials (released via news media)
- Radio and television programs that explain or report hazard-reduction programs and products
- Meetings with local, district, and state agencies and their governing bodies
- Field trips to potentially hazardous sites by state, local, or federal agencies, and professional societies

Information Sources

- Annotated and indexed bibliographies of hazard information and lists of pertinent reference materials
- Local, state, and federal policies, procedures, ordinances, statutes, and regulations that cite or make other use of hazards information
- Hazards information incorporated into local, state, and federal studies and plans
- User guides relating to earth-hazards processes, mapping, and hazard-reduction techniques

Users of Landslide Hazard Information

Among the potential users of landslide hazard information are people at national, state, regional, and community levels in both the public and private sectors. Three general categories can be identified: (1) scientists and engineers who use the information directly, (2) planners and decision makers who consider hazards among other land-use and development criteria, (3) developers and builders; financial and insuring organizations, and (4) interested citizens, educators, and others with little or no technical expertise. These people differ widely in the kinds of information they need **and in their capabilities to use that information**. Examples of potential users are listed in Table 4.

Table 4. Potential users of landslide hazard information (modified from U.S. Geological Survey, 1982).

City, County, and Area-Wide Government Users

City and county building, engineering, zoning, safety, planning, and environmental health departments
City and county offices of emergency services
County tax assessors
Local government geologists
Mayors, county commissioners, and city council members
Multicounty (regional) planning, development, and emergency preparedness agencies
Municipal engineers, planners, and administrators
Police, fire, and sheriff's departments
Public works departments
Road departments
School districts
Special districts (water, sanitation, urban drainage)

State Government Users*

Attorney General's Office
Department of Administration
State Buildings Division
Department of Health
Department of Highways
Department of Local Affairs
Department of Military Affairs
National Guard
Department of Natural Resources
Geological Survey
Water Conservation Board
Water Resources
Department of Public Safety
Emergency Management Agencies
Department of Revenue
State Planning and Budgeting Office

***NOTE:** Names and functions of state agencies vary from state to state and this list should be adapted accordingly.

Table 4. Continued

Federal Government Users
Department of Agriculture
Farmers' Home Administration
Forest Service
Soil Conservation Service
Department of the Army
Army Corps of Engineers
Department of Commerce
National Bureau of Standards
National Oceanic and Atmospheric Agency
Department of Housing and Urban Development
Federal Housing Administration
Department of the Interior
Bureau of Land Management
Bureau of Reclamation
Geological Survey
National Park Service
Department of the Navy
Department of Transportation
Federal Highway Administration
Environmental Protection Agency
Federal Emergency Management Agency
General Services Administration
Members of Congress and their staffs
Nuclear Regulatory Commission
Small Business Administration

Private, Corporate, and Quasi-Public Users
Civic and voluntary groups
Concerned citizens, homeowners associations
Construction companies
Consulting planners, geologists, architects, and engineers
Economic development committees
Extractive, manufacturing, and processing industries
Financial and insuring institutions
Landowners, developers, and real estate agents
News media
Utility and transmission companies
University departments (including geology, civil engineering, architecture, urban and regional planning, and environmental studies departments)

Other National Users
Applied Technology Council
American Association of State Highway and Transportation Officials
American Public Works Association
American Red Cross
Association of Engineering Geologists
Association of State Geologists
Council of State Governments
Earthquake Engineering Research Institute
International Conference of Building Officials
National Academy of Sciences
National Association of Counties
National Association of Insurance Commissioners
National Governors' Association
National Institute of Building Sciences
Natural Hazards Research and Applications Information Center, University of Colorado
National League of Cities
Professional and scientific societies (including geologic, engineering, architecture, and planning societies)
United States Conference of Mayors

Most states have professional planners, engineers, or geologists available who can make interpretations from available hazard information. Specialists from the federal government who are skilled in the translation of technical data can also assist states. As suggested in Chapter 4, the most effective use of landslide information is achieved when maps are prepared that indicate the location, severity, and recurrence potential of landslides.

Developing an Information Base: Sources of Landslide Hazard Information

Some of the organizations that produce or provide landslide hazard information are listed in Table 5.

Table 5. Examples of producers and providers of landslide hazard information (adapted from U.S. Geological Survey, 1982).

American Institute of Professional Geologists
American Society of Civil Engineers
Association of Engineering Geologists
County extension agents
Educators (university, college, high school)
Museum of Natural History
State Department of Highways
State Geological Survey
Hazard researchers, interpreters, and mappers
International Conference of Building Officials
Journalists, commentators, editors, and other news professionals
Local seismic safety advisory groups
National Governors' Association
Natural Hazards Research and Applications Information Center, University of Colorado
Public information offices (federal and state)
U.S. Army Corps of Engineers
U.S. Bureau of Land Management
U.S. Bureau of Reclamation
U.S. Forest Service
U.S. Geological Survey
U.S. Soil Conservation Service

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Chapter 6
Landslide Loss–Reduction Techniques

A significant reduction in landslide losses can be achieved by preventing or minimizing the exposure of populations and facilities to landsliding; by preventing, reducing, or managing the actual occurrence of landslides; and by physically controlling landslide-prone slopes and protecting existing structures.

Subsidized insurance is not considered a loss-reduction technique because it does not prevent or reduce losses but merely transfers the loss to other segments of the population. Indeed, it may encourage lenders to develop hazardous lands because they are indemnified by uninvolved taxpayers. The insurance industry could become a strong promoter of hazards reduction if it would establish its rates to reflect relative risks. Most homeowners' insurance policies exclude coverage for ground movements, including landslides.

Preventing or Minimizing Exposure to Landslides

Vulnerability to landslide hazards is a function of a site's location, type of activity, and frequency of landslide events. Thus, the vulnerability of human life, activity, and property to landsliding can be lowered by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can accomplish this by adopting land-use regulations and policies and restricting redevelopment.

Land–Use Regulations

Land-use regulations and policies are often the most economical and effective means of regulation available to a community—particularly if enacted prior to development. However, where potentially hazardous land is privately owned with the expectation of relatively intense development and use, or where land optimally suited for development in communities is in short supply, there is strong motivation and pressure to use the land intensively. Land-use regulations must be balanced against economic considerations, political realities, and historical rights.

Various types of land-use regulations and development policies can be used to reduce landslide hazards. Some of these methods are listed in Table 2, Chapter 2. Responsibility for their implementation resides primarily with local governments, with some involvement of state and federal governments and the private sector.

Reducing the Occurrence of Landslides and Managing Landslide Events

As discussed in Chapter 3, many landslides occur as a direct result of human activities. The excavation and grading associated with the construction of buildings, highways, transmission lines, and reservoirs can create conditions that will ultimately result in slope failure. The development and enforcement of codes for excavation, grading, and construction can prevent such landslides. A review of the state of the art and standards of performance of hillside and flatland urban development from the 1950s to the early 1980s is available in a training manual (Scullin, 1982). This manual describes the mitigation of several geologic hazards: landsliding, subsidence, expansive soils, drainage, and earthquakes. The concepts and technical applications described in this book may be applied in short-or long-term planning regarding geologic risks anywhere.

Building and Grading Codes

Design, building, and grading codes are regulatory tools available to local government agencies for achieving desired design and building practices. They can be applied to both new construction and pre-existing buildings. In rare cases, such as those involving large offshore structures, the effect of landslides can be considered explicitly as part of the design, and the facility can be built to resist landslide damage. In some cases, existing structures in landslide-prone areas can be modified to be more accommodating to landslide movement. The extent to which this is successful depends on the type of landsliding to which the structure is exposed. Facilities other than buildings (e.g., gas pipelines and water mains) can also be designed to tolerate ground movement. Codes and regulations governing grading and excavation can reduce the likelihood that construction of buildings and highways will increase the degree to which a location is prone to landslides. Various codes that have been developed for federal, state, and local implementation can be used as models for landslide-damage mitigation. A fundamental concern with design and building codes is their enforcement in a uniform and equitable way. (Committee on Ground Failure Hazards, 1985, p. 15).

Emergency Management

Emergency management and emergency planning contribute to landslide loss reduction by saving lives and reducing injuries. Such planning can also protect and preserve property in those cases where property is mobile or where protective structures can be installed if sufficient warning time is available.

Emergency management and planning consist of identifying potential hazards, determining the required actions and parties responsible for implementing mitigation actions, and ensuring the readiness of necessary emergency response personnel, equipment, supplies, and facilities. An important element of emergency management is a program of public education and awareness informing citizens of their potential exposure, installation of warning systems, types of warnings to be issued, probable evacuation routes and times available, and appropriate protective actions to be taken.

A warning system may include the monitoring of geologic and meteorologic conditions (e.g., rates of landslide movement, snowmelt runoff, storm development) with potential for causing a catastrophic event or the placement of signs instructing people within a potentially hazardous area of proper procedures (Figure 24). Automatic sensors, located within landslide-prone areas, with effective linkages to a central communication warning facility and, thence, to individuals with disaster management responsibilities, are also sometimes used. Warning systems can be long-term or temporary—used only when high risk conditions exist or while physical mitigation methods are being designed and built (Figure 25).

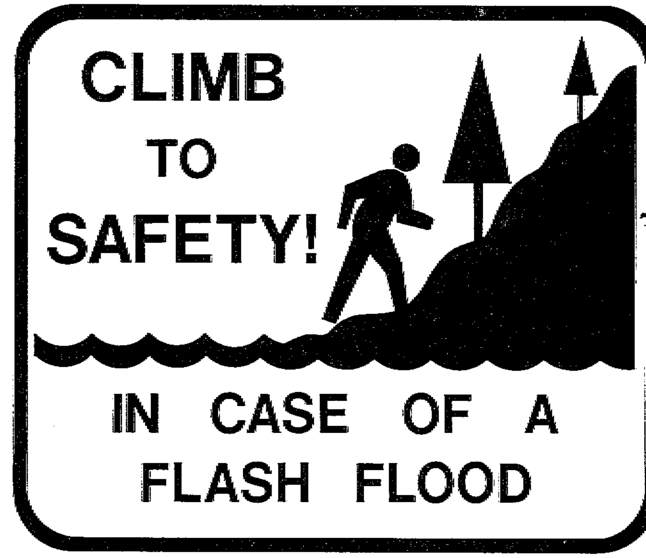
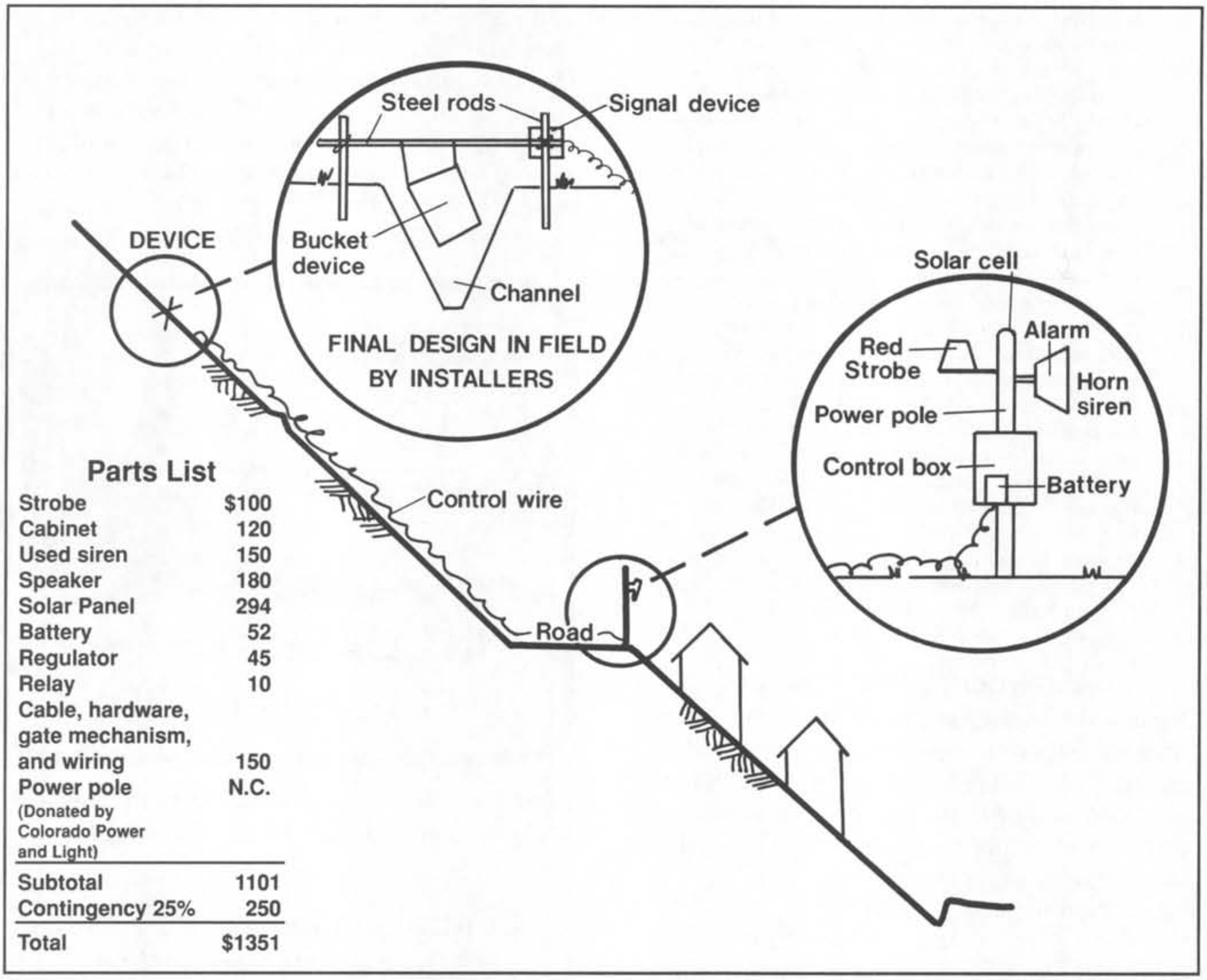


Figure 24. Sign placed in some of the hazardous mountain canyon areas of Colorado.

Controlling Landslide-Prone Slopes and Protecting Existing Structures

Physical reduction of the hazard posed by unstable slopes can be undertaken in areas where human occupation already poses a risk, but where measures such as zoning are precluded by the cost of resettlement, value or scarcity of land, or historical rights. Physical measures can attempt to either control and stabilize the hazard or to protect persons and property at risk.

It is not possible, feasible, or even necessarily desirable to prevent all slope movements. Furthermore, it may not be economically feasible to undertake physical modifications in some landslide areas. Where land is scarce, however, investment in mitigation may increase land value and make more expensive and elaborate mitigation designs feasible.



Parts List

Strobe	$100
Cabinet	120
Used siren	150
Speaker	180
Solar Panel	294
Battery	52
Regulator	45
Relay	10
Cable, hardware, gate mechanism, and wiring	150
Power pole (Donated by Colorado Power and Light)	N.C.
Subtotal	1101
Contingency 25%	250
Total	$1351

Figure 25. Schematic of a warning system (by Robert Kistner, Kistner and Associates).

Landslide control structures can be costly and usually require considerable lead time for project planning and design, land acquisition, permitting, and construction (Figure 26). Such structures may have significant environmental and socioeconomic impacts that should be considered in planning.

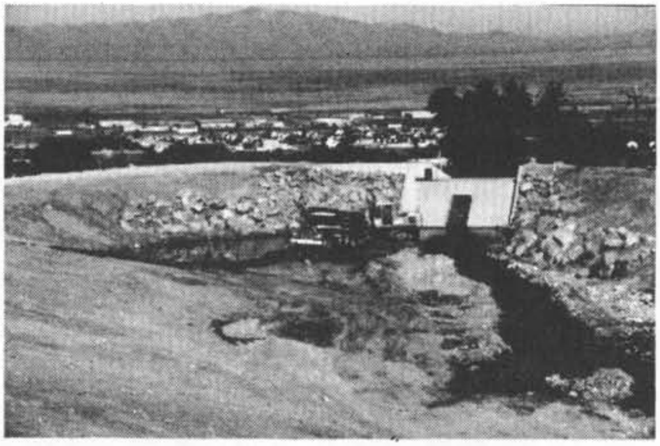


Figure 26. Rudd Creek debris basin in Farmington, Utah constructed in 1983–84 (photograph by Robert Kistner, Kistner and Associates).

Precautions Concerning Reliance on Physical Methods

Although physical techniques may be the only means for protecting existing land uses in hazard areas, sole reliance on them may create a false sense of security. An event of greater severity than that for which the project was designed may occur, or a structure may fail due to aging, changing conditions, inadequate design, or improper maintenance. The result could be catastrophic if the hazard zone has been developed intensively.

Design Considerations and Physical Mitigation Methods

When designing control measures, it is essential to look well beyond the landslide mass itself. A translational slide may propagate over great distances if the failure surface is sufficiently inclined and the shear resistance along the surface remains lower than the driving force. Debris flows can frequently be better controlled if mitigation efforts emphasize stabilizing the source area along with debris containment in the runout area. An understanding of the geological processes and the surface- and ground-water conditions, under both natural and human-imposed conditions, is essential to any mitigation planning.

Some factors that determine the choice of physical mitigation are:

- type of movement (e.g., fall, slide, avalanche, flow);
- kinds of materials involved (rock, soil, debris);
- size, location, depth of failure;
- process that initiated movement;
- people, place(s), or thing(s) affected by failure;
- potential for enlargement (certain types of failures [e.g., rotational slides, earthflows, translational slides] will enlarge during excavation);
- availability of resources (funding, labor force, materials);
- accessibility and space available for physical mitigation;
- danger to people;
- property ownership and liability.

The physical mitigation of landslides usually consists of a combination of methods. Drainage control is used most often; slope modification by cut and fill and/or buttresses is the second most frequently used method. These are also, in general, the least expensive techniques (Figure 27).

Various types of physical mitigation methods are listed in Table 6.

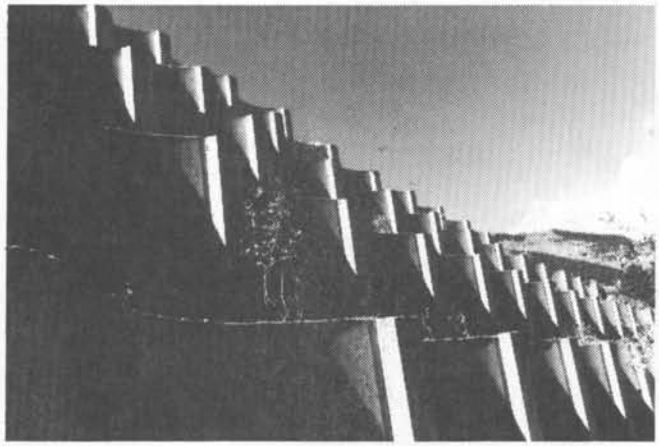


Figure 27. Retaining wall, Interstate 70, near Vail, Colorado (photograph by Colorado Geological Survey).

Table 6. Physical mitigation methods (Colorado Geological Survey et al., 1988).

A. Physical Mitigation Methods for Slides and Slumps
   1. Drainage
      a. Surface drainage
         1) ditches
         2) regrading
         3) surface sealing
      b. Subsurface drainage
         1) horizontal drains
         2) vertical drains/wells
         3) trench drains/interceptors, cut-off drains/counterforts
         4) drainage galleries or tunnels
         5) blanket drains
         6) electro-osmosis
         7) blasting
         8) subsurface barriers
   2. Excavation or regrading of the slope
      a. Total removal of landslide mass
      b. Regrading of the slope
      c. Excavation to unload the upper part of the landslide
      d. Excavation and replacement of the toe of the landslide with other materials
   3. Restraining structures
      a. Retaining walls
      b. Piles
      c. Buttresses and counterweight fills
      d. Tie rods and anchors

Table 6. Continued

- e. Rock bolts/anchors/dowels
- 4. Vegetation
- 5. Soil hardening
  - a. Chemical treatment
  - b. Freezing
  - c. Thermal treatment
  - d. Grouting

B. Physical Mitigation Methods for Debris Flows and Debris Avalanches
- 1. Source-area stabilization
  - a. Check dams
  - b. Revegetation
- 2. Energy dissipation and flow control
  - a. Check dams
  - b. Deflection walls
  - c. Debris basins
  - d. Debris fences
  - e. Deflection dams
  - f. Channelization
- 3. Direct protection
  - a. Impact spreading walls
  - b. Stem walls
  - c. Vegetation barriers

C. Physical Mitigation Methods for Rockfalls
- 1. Stabilization
  - a. Excavation
  - b. Benching
  - c. Scaling and trimming
  - d. Rock bolts/anchors/dowels
  - e. Chains and cables
  - f. Anchored mesh nets
  - g. Shotcrete
  - h. Buttresses
  - j. Dentition
- 2. Protection
  - a. Rock-trap ditches
  - b. Catch nets and fences
  - c. Catch walls
  - d. Rock sheds or tunnels

❑

Chapter 7
Plan Preparation

Determining the Need for a State Plan

In order to determine the need for a state landslide hazard mitigation plan, individual states must first assess the vulnerability of their present and future population to the hazard. **Vulnerability** is the susceptibility or exposure to injury or loss from a hazard. People, structures, community infrastructure systems (transportation, water supply, communications, and electricity), and social systems are all potentially vulnerable.

An assessment of statewide vulnerability to geologic hazards is a product of the technical assessment of the problem, based on scientific studies and investigations, and an assessment of capabilities, in the public and private sectors, to respond to and mitigate the hazards and potential impacts identified. Before resources are invested in hazard mitigation measures, the social and economic costs and impacts associated with landsliding need to be determined and put into perspective.

The next step in recognizing the overall vulnerability of the state to the landslide hazard is the identification of specific communities, areas, and facilities at risk. The existence and effectiveness of local programs and systems for mitigating landslide problems in communities experiencing actual or potential impacts must then be determined.

Although landslides can potentially affect entire regions or states, the hazards themselves are local problems first, and local governments remain on the "front lines" of the battle to reduce losses.

> Landslide loss reduction in the United States is primarily a local responsibility. While the federal government plays a key role in research, in the development of mapping techniques, and in landslide management on federal lands, the reduction of landslide losses through land use management and the application of building and grading codes is essentially a function of local government (Sangrey and Bernstein, 1985, p. 9).

The purpose of a state landslide hazard mitigation plan is to encourage and support local mitigation efforts and address serious landslide problems, beyond local capability, that threaten lives and property and have potential regional or statewide implications. Strategies and projects developed in the planning process are therefore based on an assessment of what can be accomplished locally and the level of supplemental assistance that will be required to lessen the problem. State and federal assistance picks up where local efforts stop; generally local resources must first be exhausted.

A key element in the planning process and a major recommendation of this guidebook is the establishment of a permanent state organization, representing the various levels and responsibilities of government, to focus the attention of state government on natural hazard mitigation issues.

Federal Disaster Relief and Emergency Assistance Act (Section 409)

In presidentially-declared disasters, the preparation of a state plan that identifies and evaluates hazard mitigation opportunities is mandated by Section 409 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Public Law 93–288, as amended) as a condition of receiving federal disaster assistance. This requirement was originally enacted in 1974 under Section 406 of the Disaster Relief Act to encourage identification, evaluation, and mitigation of hazards at the state and local government levels. The requirements of Section 409 are triggered by a major disaster or emergency declared by the President and apply to all types of declared emergencies and disasters. A hazard mitigation clause is incorporated into the FEMA/State agreement for disaster assistance, thereby establishing the identification of hazards and the evaluation of hazard mitigation opportunities as a condition for receiving federal assistance.

The Federal Emergency Management Agency (FEMA) is responsible for administering the Section 409 requirements and has prepared implementing regulations (44 CFR 206, Subpart M) that specify federal, state, and local responsibilities under Section 409. Under the regulations, a state hazard mitigation coordinator is designated by a governor's authorized representative to prepare a hazard mitigation plan and to ensure its implementation. States may establish a group of individuals from state and local agencies to assist in preparing the "409 plan," which must be completed and submitted to FEMA within 180 days after the presidential declaration.

With the passage of the Stafford Act in 1988, a hazard mitigation funding program was authorized for the first time under Section 404 of the Act. This mitigation-measures funding program provides up to 50 percent federal funding for activities identified under Section 404, thus making preparation of a good hazard mitigation plan more important than ever before. The identification of mitigation opportunities under this program follows the evaluation of natural hazards under Section 409. Total federal funds available under Section 404 are limited to 10 percent of the permanent restorative work funded under FEMA's Public Assistance Program. Implementation regulations for Section 404 can also be found in 44 CFR 206, Subpart M.

In state-declared disasters, some states require the development of local hazard mitigation plans as an eligibility requirement of state emergency relief.

The Planning Team

States undertaking plan development should first consider assembling a state planning team to manage the research and writing of the plan. The planning team could be in the form of a working group, directed by state representatives and supported by representatives of local government, the private sector, and academia. Typically, the group would gather, interpret, and assemble the technical information that forms the basic structure of the landslide hazard mitigation plan.

The interagency efforts of post-disaster hazard mitigation teams in presidentially-declared disasters have demonstrated that such working groups representing a broad range of state and federal agencies can successfully develop a host of innovative and cost-effective mitigation ideas.

The planning team should include individuals knowledgeable about geology, engineering, emergency management, and community development and planning. Depending on the nature of landslide problems, the team might also include individuals involved in natural resources management, highway construction and maintenance, state and regional planning, and others as conditions warrant.

The responsibilities of individual team members would include researching and writing those sections of the plan that relate to their area of expertise. Team members would also participate in meetings with planners, emergency managers, policy makers, and elected officials in local and state government and, to the extent possible, seek the input and participation of private industry, professional and volunteer organizations, and interested citizens. An initial analysis of existing mitigation plans and emergency management capabilities in landslide-impacted jurisdictions will enable the planning team to identify the most serious problems and to develop projects that build on efforts already in progress. This assessment of local landslide conditions and local capabilities to deal with them should identify a wide variety of practicable mitigation solutions. This will facilitate the coordination of state support and the identification of unmet local needs that can be presented for possible state action.

Local jurisdictions impacted by landslides should be encouraged to form their own local planning teams—composed of decision makers, planners, emergency managers, engineers, geologists, and officials from law enforcement, fire safety, and emergency medical services—to formulate local plans and mitigation strategies.

The Planning Process

The planning process recommended for the development of a landslide hazard mitigation plan follows a series of steps that are basic to mitigation planning:

(1) analysis of the types of landslide hazards in the state and a general assessment of the vulnerability of people and property to the state's landslide hazards;
(2) identification of specific areas of the state where landslides have the most serious or immediate potential impacts and a detailed analysis of their vulnerabilities;
(3) translation and transfer of technical information on hazards and vulnerabilities to users such as decision makers, community planners, and emergency management officials;
(4) assessment of resources and mitigation programs available in the public and private sectors to deal with the identified potential impacts;
(5) determination of local capability shortfalls and unmet needs in order to apply technical and financial assistance where it can best contribute to the reduction of future losses;
(6) formulation of goals and objectives for state and local landslide hazard mitigation plans, and the development of cost-effective mitigation projects that address identified vulnerabilities;
(7) establishment of a permanent state hazard mitigation system to prioritize and promote mitigation goals and objectives and to secure and direct funding for implementation;
(8) periodic evaluation and modification of the plan and planning process.

Step 1—Hazard Analysis

A complete hazard analysis is the result of the identification of the state's landslide hazard areas, the identification of the most vulnerable locations, and the assessment of potential impacts on people and property in vulnerable areas. Where possible, the hazard analysis should provide planners with information about hazard location, description, frequency, history, existing impacts, potential impacts, and, to the extent possible, probability of occurrence.

The use of land-use maps in conjunction with detailed maps exhibiting the extent and severity of landslide hazards in an area helps officials to determine vulnerability to landslides, mitigation priorities, and the most appropriate mitigation measures.

> Appropriate land use management, effective building and grading codes, the use of well-designed engineering techniques for landslide control and stabilization, the timely issuance of emergency warnings, and the availability of landslide insurance can significantly reduce the catastrophic effects of landslides. All of these approaches require, as a starting point, the identification of areas where landslides are either statistically likely or immediately imminent, and the representation of these hazardous locations on maps (Committee on Ground Failure Hazards, 1985, p. 2).

The planning team should assemble existing mapped landslide susceptibility data that portray the distribution of various types of landslides and the likelihood of their occurrence. The team will need maps sufficiently detailed to determine the character, location, and magnitude of landslide problems.

Step 2—Identification of Impacted Sites

Once the nature and distribution of the hazard and the vulnerability to landsliding of various communities, areas, and facilities has been determined, site-specific evaluations of the potential impacts of landsliding should be performed. Based on the hazard analysis, those sites determined to present the greatest threat to lives and property should be subject to further site analysis and mitigation planning.

Impact is the effect of a hazard event on people, buildings, and the infrastructure. The impacts of landsliding range from the inconvenience of debris cleanup to the life-threatening failure of a landslide-formed dam. The simultaneous or sequential occurrence of other hazards such as flooding or earthquakes with landsliding can produce effects that are greater or qualitatively different from those produced by landsliding alone.

Step 3—Technical Information Transfer

As discussed in Chapter 5, individuals or groups often do not take mitigative actions because they do not understand the significance of the threat, what to do to reduce it, or lack information and training on how to do it. Therefore, once landslide hazard information has been gathered, it must be communicated to planners, policy makers, emergency response personnel, and the public. Maps are one of the best methods of transferring such information. Landslide information can be used in the development, review, and approval of land-use plans, community development plans, emergency management plans, and hazard mitigation plans. In order for landslide information to be more widely incorporated into community planning and planning for landslide mitigation, the technical staff that produces the information must tailor it so that it is understandable and usable by the various parties involved in the development process. Producers of information should also ensure that potential users are aware of available data, as well as research planned or in progress. Conversely, nontechnical users of landslide information should take steps to improve their skills in interpreting and applying the information.

The difficulty of translating technical information for nontechnical users highlights the importance of retaining the services of qualified technical experts throughout the planning process. According to Fleming and Taylor (1980, p. 4), "solutions to the technical problems are only a part of the process of achieving landslide hazard reduction. The political problem of transferring the information into a governmental system to reduce hazards and damages is perhaps more formidable than the technical one."

Step 4—Capability Assessment

Capability assessment is a determination of public, private, and volunteer resources in a community that are available to support emergency management and hazard mitigation activities designed to reduce losses from a particular hazard. Resources include not only equipment, supplies, and materials, but, more importantly, people, expertise, plans, programs, and cooperative agreements with other jurisdictions and private industry. Private companies have a vested interest in the mitigation process because private losses often exceed public losses in natural disasters, and also because private firms may receive insurance benefits (lower premiums, reduced liability) for a demonstrated commitment to reducing future losses.

The assessment of local capabilities should identify the most vulnerable elements of the community, the current level of mitigation activity, the status of emergency management planning, and opportunities for state and federal mitigation assistance.

The checklist provided in Table 7 can assist local jurisdictions in preparing plans for landslide hazard mitigation and emergency management as well as assisting state planning teams in assessing local mitigation efforts.

Table 7. Types of information that should be considered in an assessment of a community's landslide hazards and capabilities (modified from Weber et al., 1983).

A. Maps
   1. Base map
   2. Landslide inventories
   3. Landslide susceptibility maps
   4. Landslide hazard maps
B. Physical (Geologic) Information
   1. Scope (boundaries of areas subject to landslides)
   2. Frequency (historical occurrences by date, location, description, and impacts)
      a. Reports
      b. Newspaper articles
      c. Eyewitness accounts
   3. Hazard characteristics
      a. Predictability
      b. Potential speed of occurrence
      c. Potential impact forces
      d. Magnitude
      e. Worst-case scenario
C. Social (Human) Information
   1. Land Use
      a. Existing (map)
      b. Future (map)
      c. Zoning (map)

Table 7. Continued

2. Population at risk
   a. Number of people/total dwelling units
   b. Variability (difference in day/night populations)
3. Property at risk (infrastructure)
   a. Use/function
   b. Assessed value
4. Economic activity at risk (commercial, industrial, tourism)
   a. Employment
   b. Gross revenues
5. Critical services and facilities at risk
   a. Access
   b. Police
   c. Fire
   d. Communications
   e. Schools
   f. Health care (hospitals, nursing homes)
   g. Utilities
   h. Emergency management facilities
   i. Transportaion
6. Aggravating influences (roads, structures, landscaping, removal of vegetation, or other land uses that contribute to landslide hazard)

D. Landslide Hazard Management Capabilities
1. Landslide hazard mitigation activities
   a. Land-use regulations
   b. Land-use plans
   c. Building and grading codes
   d. Design and location standards
   e. Development and redevelopment plans
   f. Landslide control structures
   g. Monitoring/instrumentation
   h. Acquisition and relocation projects
   i. Public utility extension guidelines
   j. Planning team formation
   k. Land exchanges
   l. Real estate disclosure requirements
   m. Lending and financing policies
   n. Additional public works
   o. Private sector involvement
   p. Special assessment districts
   q. Tax adjustments
2. Emergency management activities
   a. Warning systems
   b. Emergency plans (life-saving, evacuation, facility-specific)
   c. Public education/hazard awareness campaigns
   d. Training exercises
3. Local financial capabilities and needs
   a. Funds available
   b. Major resource shortfalls
   c. State and federal programs and grants
   d. State and federal technical assistance

By comparing local risks and possible impacts with the capability of a jurisdiction to respond to those risks, a state planning team can identify major resource deficiencies, or unmet needs, that become the basis for projects in the state plan. Unmet needs are technical and financial resource needs that exceed the capabilities of the communities at risk. In many cases, these resource shortfalls represent substantial obstacles to reducing the impacts of future landslides on people, property, and essential services.

Step 5—Determination of Unmet Local Needs

Based on the analysis of local capabilities, unmet needs that should be considered by state and federal governments are identified and a state mitigation assistance strategy is formulated. In order to determine unmet needs, specific human activities should be examined to evaluate potential impacts on public health and safety, public and private property, commerce, and the community at large. Group meetings and individual interviews can yield sufficient information to determine the most critical needs of local governments and to develop priority mitigation projects for state action. Less urgent needs can be addressed in future projects. The state planning team should also identify existing local mitigation projects so that state projects can be coordinated to support their efforts.

Step 6—Formulation of Goals and Objectives

Fundamental to a mitigation program is the establishment of a system for landslide mitigation planning and management at the state and local government levels. The establishment of a permanent state system to effect mitigation projects should be considered. This management system would help ensure that:

- existing hazardous conditions are dealt with expeditiously,
- new landslide hazards are assessed and prioritized,
- new options are developed and evaluated,
- intergovernmental and interagency technical advice and mitigative action can be coordinated,
- priorities are established for high- and moderate-risk situations that are beyond local government capability,
- decisions are made and funding obtained and spread over a period of time that is commensurate with state fiscal capabilities,
- feedback is evaluated and needed program adjustments made, and
- a systematic approach to mitigation is established.

Local Landslide Hazard Mitigation

Local jurisdictions should institute mitigation programs that coordinate landslide hazard information and mitigation needs with state government and the private sector. Local mitigation systems should effectively employ state assistance and be ready to take on new problems as solutions to old problems are found. Local mitigation plans need to be in place so that work on mitigation projects can begin as soon as funds become available.

Effective local systems are important to state planning because they provide direction for state action. A comprehensive local hazard mitigation program should be based on community consensus, developed through local planning committees with citizen support and involvement, and should conform to local goals and objectives and budget constraints. Local governments involved in landslide hazard mitigation face a number of important planning challenges, including: (a) the preparation of emergency management plans that ensure the timely warning and evacuation of people in high-risk areas; (b) the formation of local planning committees to identify unmet local needs and schedule the implementation of mitigation projects; (c) the coordination of public, private, and volunteer resources; and (d) the integration of landslide hazard information into community development plans in order to protect existing development and guide, discourage, or restrict future development in landslide-prone areas.

Local hazard mitigation and emergency planning are generally carried out separately from the basic planning of local government. Integrating hazard information into the comprehensive or master plan of a community, however, better enables a jurisdiction to guide the activities of builders, investors, and developers in areas known to be hazardous. Communities that have an adequate base of technical information about local landslide problems, and that have succeeded in applying this information to development and planning decisions, have met an important precondition to most types of mitigation. Land-use plans that consider available hazard information demonstrate to developers and to the public that public health and safety concerns are important factors in community development. According to Olshansky and Rogers (1987, p. 957), "By incorporating landslide hazard information into long-term local plans, local governments give developers advance notice of land use policies and the reasons for those policies."

Development of Mitigation Projects

The identification of areas in the state that are vulnerable to catastrophic landslide losses will enable the planning team to formulate the goals and objectives of the state plan, which may be expressed in the plan in the form of prioritized mitigation projects. With the support of the planning, technical, and policy-making staff of state and local agencies that have resources, capabilities, or statutory responsibilities relating to landslide hazard management, the planning team should be able to develop an initial group of projects.

A wide range of project ideas and opinions, representing the perspectives of planning, geology, engineering, emergency management, private industry, elected leadership, and others, should be solicited to enable the planning team to determine the cost effectiveness, feasibility, and political and social implications of each possible approach. The highest initial priority should be assigned to those projects that establish a permanent system in state government for continuous support of state hazard mitigation opportunities. A second priority should be state support to long-term mitigation programs in local government and the private sector. Another ongoing priority should be the identification of and participation in state and federal programs that can provide funding support for mitigation initiatives.

Although implementation of many recommendations may be difficult if financial resources are limited, government agencies should be encouraged to use the plan and its identified projects as a resource in formulating annual work programs, budgets, and policy statements concerning landslides. Projects that modify existing programs or improve coordination are usually relatively low-cost and stand the best chance of being implemented first. Funds to implement the more costly projects should be aggressively sought from state legislatures, the federal government, and the private sector.

Projects recommended in the state plan should include a brief statement of the problem, a general statement of the recommended solution, a description of short- and long-term initiatives, a designated lead agency, and a preliminary estimate of cost effectiveness, where possible. Projects should contribute toward an effective and coordinated state/local landslide management system, and should be flexible both in content and priority to allow for modification during the implementation process. Local jurisdictions should report their accomplishments and important unmet needs to the state mitigation organization so that new state/local strategies can be developed. New projects should be introduced into the system as new landslide threats are identified and as new approaches to old problems are found.

Step 7—Establishment of a Permanent State Hazard Mitigation Organization

A permanent state hazard mitigation organization should be created to coordinate the resources of state, local, and federal agencies with landslide hazard mitigation responsibilities and authorities. For states with serious landslide problems, establishment of a permanent organization institutionalizes in state government the consideration of opportunities to reduce landslide losses. In Colorado, this has been accomplished by an Executive Order (Figure 28) that formalizes landslide hazard mitigation planning within a natural hazards mitigation council.

States with no existing system for hazard mitigation should consider establishing an organization that also addresses and promotes the mitigation of other hazards impacting the state. Most of the public agencies involved in landslide hazard mitigation—those concerned with geology, natural resources, highways, climatology, water resources, emergency management, and others—are also involved with problems of flooding, drought, and, depending upon location, hurricanes, and earthquakes. Although the focus and extent of short-term mitigation activities at any given time may depend upon the prevailing threats, the organization should maintain a broader, long-term perspective on all of a state's natural hazards. An all-hazards approach should result in an efficient, multi-purpose process that can gain the support and approval of state leadership and the public.

The role of the state mitigation organization should essentially be a continuation of the activities performed by the state planning team and those coordinating agencies with a role in landslide mitigation that participated in the development of the plan. One type of organization might consist of a state mitigation council supported by working groups. The council would be made up of decision makers selected from key state, local, and federal agencies and could include representatives from the governor's office and the state legislature. Representatives from local and regional governments and academia may also be included in working groups.

STATE OF COLORADO

EXECUTIVE CHAMBERS
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B 044 89

Roy Romer
Governor

EXECUTIVE ORDER

ESTABLISHING A COUNCIL FOR THE IMPLEMENTATION OF
STRATEGIES TO MANAGE MITIGATION OF NATURAL HAZARDS IN COLORADO

WHEREAS, various natural hazards have caused physical and financial impacts in Colorado and will continue to do so; and

WHEREAS, these impacts have resulted in unexpected costs to state and local governments as well as degradation of the state's health, safety, environment, infrastructure and economy; and

WHEREAS, the opportunities to significantly manage floods, landslides, wildfires and other natural hazards are identifiable and should be executed as funding is available; and

WHEREAS, mitigation recommendations can be effectively prioritized and managed by a state council, supported by interagency working groups; and

WHEREAS, a need exists to provide formal recognition, authority and responsibilities to this organizational structure;

NOW, THEREFORE, I, Roy Romer, Governor of the State of Colorado, by virtue of the authority vested in me under the constitution and laws of the State of Colorado, including the Colorado Disaster Emergency Act of 1973, 24-33.5-701, et seq., hereby Order:

1. The Colorado Natural Hazards Mitigation Council is hereby created. The council will be chaired by the Colorado Department of Natural Resources and consist of as many as 25 representatives. The following organizations or groups shall be appointed by the Governor:

- The Governor's Office
- State departments of Natural Resources, Highways, Local Affairs, Public Safety, Health and Agriculture
- The Colorado Municipal League and Colorado Counties, Inc.
- The Natural Hazards Center, University of Colorado
- Business community
- The Federal Emergency Management Agency (Region VIII) and the National Weather Service (National Oceanic and Atmospheric Administration)
- U.S. Army Corps of Engineers
- Elected local officials from areas of the state with high-risk natural hazards
- The general public

Executive Order
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The Speaker of the House of Representatives, the President of the Senate, the Minority Leader of the Senate and the Minority Leader of the House of Representatives may each appoint one legislative representative. All members will serve for a term of two years with reappointments permitted at the pleasure of the Governor. The Governor will appoint the chairperson.

2. The chairperson will appoint a steering committee and an executive secretary to carry on the administrative activities of the council.

3. The responsibilities assigned to the council are to:

a. Identify vulnerability to various natural hazards and evaluate the options available to mitigate such risks.

b. Review current mitigation plans for such hazards as wildfires, droughts and avalanches.

c. Develop a unified management strategy with recommendations concerning state, federal or local mitigation responsibilities.

d. Prioritize hazards statewide.

e. Assist local government in seeking funding to implement hazard mitigation recommendations.

f. Meet at the call of the chairperson, but no less frequently than once a year.

g. Prepare an annual work program and status report covering progress achieved and provide periodic updates to the Governor and the state legislature.

h. Inform local government and the general public of the activities and recommendations of the council.

The council is directed to place high priority on use of the Colorado Flood Hazard Mitigation Plan and Landslide Hazard Mitigation Plan, and should coordinate and prioritize the projects contained in these plans and any other plans dealing with natural hazards.

Given under my hand and the Executive Seal of the State of Colorado, this 23rd day of March, 1989.

Roy Romer

Roy Romer
Governor

Figure 28. Executive Order establishing Colorado Natural Hazards Mitigation Council.

The council should be responsible for prioritizing strategies and projects, securing and directing funding, and monitoring overall program effectiveness to ensure that policies and directed measures are implemented in a timely and efficient fashion. Since funds for the implementation of many of the recommended projects will not likely be immediately available, an ongoing and aggressive search for funding sources will be a major role of the council. State and federal support should be obtained immediately for those projects that address landslides where potentially catastrophic or serious economic impacts have been identified.

The responsibilities of the working groups will be to: (1) review risks and options and provide additional information to the council once projects have been selected from the plan for implementation, (2) monitor identified landslide areas and collect and interpret information about emergency situations as they occur, (3) prepare new projects as needed to meet changing conditions, (4) implement projects as funding becomes available, (5) recommend projects for funding by government and the private sector as specific needs arise, and (6) provide technical support to the council, including recommendations on project priority.

Step 8—Review and Revision

A continuous process for evaluating mitigation progress and for making adjustments to the program should be a part of any hazard mitigation system. Procedures for review and revision of plans and the planning process are discussed in the following chapter. ❑

Chapter 8
Review and Revision of the Plan and the Planning Process

In order to ensure the timely implementation of mitigation projects recommended in the state landslide mitigation plan, the proposed state hazard mitigation organization will need to establish an ongoing system for evaluation and modification of the planning process. In addition to tracking progress of the program and providing a record of local and state mitigation achievements, a review process permits the adjustment of program priorities. It allows the state mitigation organization to monitor and become familiar with the types of problems that are likely to be encountered in future projects, so that planning strategies can be developed.

> The criteria, decisions, and methods used in applying the landslide research findings to planning and decision making can be of value to other jurisdictions in which similar hazards exist, and for which adequate landslide information is available. The adaption to, and adoption by, other jurisdictions depends upon the presence of similar public awareness, enabling legislation, hazard issues, priorities, community interest, innovative decision makers, and staff capabilities (U.S. Geological Survey, 1982, p. 44).

While the exact nature of the evaluation system should be determined by the mitigation organization in each state based on specific needs, it is recommended that any system for evaluating the success of state landslide hazard mitigation programs include the following components:

- an inventory of landslide costs,
- an evaluation of mitigation projects and techniques,
- cost-benefit analyses of local mitigation programs.

Inventory of Landslide Costs

An effort should be made to document all landslide-related losses in the state as they occur, particularly direct damage to roads and highways, homes and businesses, and facilities and services, so that decisions can be made regarding the level of mitigation assistance required to reduce losses in an area and so that the cost-effectiveness of individual projects can be determined. The inventory should provide a summary of landslide incidents and associated financial impacts on individuals, companies, municipalities, and local, state, and federal governments. The inventory should include a list of occurrences, the location, type of event, cause of event, facilities damaged, total costs of damages and/or repair and replacement, and maps and photographs of affected areas. To the extent possible, an estimate of indirect damages should also be made.

> Understanding the cost and significance of natural disasters allows officials at all levels of government to make decisions about how much money should be allocated to disaster prevention rather than to the repair of damaged facilities and disaster relief after an event (Fleming and Taylor, 1980 p. 1).

Evaluation of Mitigation Projects and Techniques

The state hazard mitigation organization should establish procedures for the periodic review and evaluation of the status of individual mitigation projects, those proposed, completed, and in progress. The effectiveness of landslide hazard mitigation efforts varies according to the physical, economic, and political conditions existing in the local areas. According to Kockelman (1986, p. 47), "Very few systematic evaluations have been made of hazard-reduction techniques, even fewer for landslides specifically." A careful assessment of the cost effectiveness of each project will help guide decisions of the state hazard mitigation organization about the implementation of future projects.

The occurrence of actual landslide disasters and the identification of new landslide threats will also necessitate an adjustment of planning priorities. Maintaining flexibility in the system will enable the state organization to apply limited funds and resources to efforts that are most likely to contribute to the reduction of future losses.

Examples of Innovative Mitigation Approaches

The evaluation process will produce a record of both mitigation achievements and failures, each of which will help educate officials involved in solving landslide problems. Examples of innovative mitigation techniques that have been successfully implemented are not only of value as guidance in other jurisdictions, but will also provide justification for gaining funds and support for new projects. Additionally, promoting mitigation success stories increases public education and awareness of landslide hazards, as well as public confidence in government hazard mitigation programs.

Analyses of Local Mitigation Programs

A critical feature of the proposed planning process is the development and maintenance of lines of communication between local and state mitigation systems and between state and federal systems. In order for state mitigation assistance to adequately support local efforts, local programs must periodically report to the state their unmet needs, i.e., desired projects that are determined locally to be needed, but are beyond local resource capabilities.

Local reports of mitigation needs and activities in progress will help state officials determine program effectiveness and funding priorities. Landslides that present potentially catastrophic impacts and local mitigation programs that have demonstrated the ability to produce mitigation results should be among the top priorities considered for state or federal assistance. ❑

Chapter 9
Approaches for Overcoming Anticipated Problems

The process of developing and implementing long-term state and local landslide hazard mitigation programs is beset with certain obstacles to success. The most significant problem is generating the resolve and motivation to organize, implement, and fund such a broad-scale effort. The expenditure of the time and money necessary to derive long-term benefits is not always attractive to state or local leaders. Unfortunately, sometimes only an actual disaster will provoke action. Developing creative approaches to financing and obtaining leadership support for mitigation projects is an ongoing challenge to mitigation proponents. Nevertheless, it is clear that the ultimate costs to taxpayers are likely to be significantly increased when mitigation activities are postponed.

Organizational Problems

The need for the plan preparation team and subsequent permanent hazard mitigation organization to be broadly representative, multidisciplinary, and intergovernmental presents some immediate organizational and coordination problems. An important first step in organizing such a group is to ensure that all elements of the team concur with their roles and assignments before work begins. This agreement should be formalized in a contract, memorandum of understanding, or some other document. A further recommendation is that a project manager be appointed early on to schedule meetings, tend to administrative and financial details, ensure deadlines are met, and direct and coordinate the effort.

The project manager should be selected from the state organization designated as the lead agency and one of his or her first tasks is to integrate the broad range of technical, planning, community, and organizational expertise available into an effective working team. Eliminating jargon and arriving at acceptable terminology for planning may require some compromise among team members. On-site visits to selected landslide areas within the state and the collection of pertinent reports and literature are important steps that the planning team should undertake. It may also be useful to organize a technical advisory committee that would meet occasionally to review draft plan material and to provide overall guidance and recommendations.

Management Problems

The research and writing efforts involved in creating a state plan will involve geologists, engineers, planners, emergency managers, elected officials, and interested citizens. The integration of these many points of view is a difficult management task but necessary if the plan is to be practical and usable for the management and mitigation of landslide hazards. The project manager, with guidance and help from other members of the team, must manage this work and establish tasks, assignments, and completion dates. In order to obtain a clear and consistent document, an editor with some background in natural hazards, earth sciences, planning and/or mitigation technology should be employed.

Financial Problems

Regardless of the source or sources of funding for development of the plan, careful management of a budget will be required to ensure all project expenses are accommodated (staff costs, travel expenses, fees for editing, printing, graphics, etc.). Since the planning process will involve several agencies working on independent tasks, periodic reviews of the budget should be conducted to prevent overruns.

Coordination Problems

Because of the difficulty involved in managing such a comprehensive effort, it is important to set realistic deadlines and to allow sufficient time for necessary coordination of involved agencies and integration of the various work elements. The involvement of all levels of government will necessarily affect progress in plan preparation, and time must be allowed for obtaining concurrence and approval from governmental agencies contributing to the mitigation process. In addition, executive and/or legislative leadership that will formally approve the plan should be kept informed of the work and made aware of the plan well in advance of publication.

Finally, in order to produce a single, clear draft of the plan, it is also necessary to coordinate the word processing systems of the participating agencies. If compatibility between computer systems is not possible, the various elements of the plan may have to be re-entered into one system. The time and expense of plan publication (typesetting, printing, distribution) should also be determined as soon as possible to permit identification of realistic deadlines. ❑

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