UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TOOLS TO AVOID LANDSLIDE HAZARDS AND REDUCE DAMAGE

by

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Open-file report no. 80-487

1980

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Numerous tools are available to planners and decisionmakers to avoid landslide hazards and reduce potential damage. Some of these are well known in the engineering profession, such as restraining structures; or in the planning profession, such as public acquisition of hazardous areas. Others are obvious and practical, such as warning signs and regulations, but these require consistent enforcement. Still others are innovative when applied to landslides, but have been successfully used in solving flood and soil problems. This report includes a discussion of a comprehensive array of tools under the general headings of:

Protecting Existing Development

Removing or Converting Existing Development

Discouraging Development

Regulating Landslide Areas

The tools may be used in a variety of combinations to help solve both existing and potential landslide problems. A prerequisite for the successful use of any of these tools is the availability of adequate and reliable earth-science information on the character of landslides -- including mudflows, creep, slumps, and rockfalls.

Recognition and identification of landslides are discussed by Rib and Liang in Schuster and Krizek, eds. (1978, p. 34-80). The slope stability maps prepared by Nilsen and others (1979) for the nine-county San Francisco Bay region are

examples of the types and scale of hazard maps adequate for county and regional planning and decisionmaking. The relevance and application of these maps to land-use planning are discussed on pages 55-87 by Vlasic and Spangle in the report by Nilsen and others (1979). The feasibility and cost of using a computer to prepare landslide susceptibility maps are discussed and illustrated in a report by Newman, Parodis, and Brabb (1978).

Protecting Existing Development

Development has occurred and will continue to occur in landslide areas. Such development can be protected by building structures to control the slides; by diverting mudflows; and by monitoring, warning, and evacuation if a slide occurs.

Slide control -- Loss from slides often leads to a demand for public works to provide protection for existing developments -- public or private -- through structures and other improvements. These remedial measures include (1) restraining structures such as buttresses, canopies, shear keys, fences, wire mesh, retaining walls, cables, anchors, reinforcing bars, berms, pilings, cribs, bulkheads, gabions, tensioned rock-bolts, or combinations of these; (2) water control to reduce infiltration, prevent erosion, or lower ground-water levels, such as tunnels, culverts, revegetation, trenches, subsurface drains, pumps, siphons, soil hardening, diversions, impervious surfaces, or combinations of these; or (3) excavation such as complete removal, unloading the head of the slide, slope reduction, benches, or combinations of these. Such controls are usually limited to small slides because of construction costs and the careful engineering design, inspection, and maintenance required.

Many descriptions and examples of these remedial tools appear in the engineering geology literature. For example, they may be found in "Reviews in Engineering Geology," edited by Coates (1977), "Landslides; Analysis and Control," edited by Schuster and Krizek (1978), and "Landslide Remedial Measures"

by Royster (1979). Some of these tools were evaluated and the construction costs analyzed by Martin Associates (1975) for the Allegheny County Department of Planning and Development.

Slide control can be self-defeating. As building on slide areas continues, the number of persons and the value of the property tend to increase at a rate faster than that at which protection can be provided. Development up-slope often causes trouble for down-slope developments. Grading, drainage improvements, paving, and watering, for example, may load, or cause instability of, a slide and require public expenditures for slide control.

Remedial public-works construction for slide control, such as restraining structures, may encourage development of slide areas in the expectation that additional works will be forthcoming. The public may believe that the slide problem has been eliminated, rather than simply reduced. Also, earthquake-triggered slides may not be prevented by such construction. Intelligent management and regulation of the slide areas is still required.

Mudflow diversion -- Diversion and reduction are specific types of slide control to reduce damage from mudflows. They may prevent or reduce loss to existing structures that cannot be economically removed or that need to be maintained in a mudflow area, such as roads and utilities. Specific measures include establishing a slope cover or consructing catchment basins, containment dams, channels, levees, and other such structures. The Los Angeles County Flood Control District has experience in using some of these measures (Davis, 1979).

Monitoring, warning, and evacuation -- Careful monitoring together with reliable and timely warnings permit temporary evacuation of people and some personal property from slide areas. Monitoring can be accomplished by patrols, electric fences, and trip wires. Other monitoring tools currently being tested are vibration meters, television, guided radar, and laser beams. In areas where

rockfalls, rapid debris flows, and submarine slides occur, such information must be relayed immediately if any savings are to result.

The responsibility to provide timely and effective disaster warnings for landslides, mudslides, and other geological catastrophies, delegated under the Disaster Relief Act by the U.S. Congress (1974a), is met by a warning system developed by the U.S. Geological Survey (1977). As a result of this system, notices of potential rockfalls, Pillar Mountain landslides, and cyclic landsliding have been given to local, State, and Federal officials in Billings, Montana; Kodiak, Alaska; and Wrightwood, California, respectively. The time, place, and magnitude of slides can be predicted only in relatively small areas in which detailed geologic and engineering studies have been conducted. However, on a large scale, some areas and geologic formations can be identified as particularly susceptible to landsliding, and the tools described below become the more appropriate ones to use.

Removing or Converting Existing Development

Recurrent damage from landslides may be avoided by permanently evacuating the slide area. Structures may be removed or converted to some use that is less vulnerable to damage by slides. The feasibility of such action depends on the value of the structures, whether they can be successfully reinforced, their potential for triggering slides, and the level of citizen concern. Tools for removal or conversion include public acquisition, urban redevelopment, abatement of a public nuisance, nonconforming-use provisions in zoning ordinances, and reconstruction of existing public facilities.

Public acquisition -- One way of removing or converting development in a slide area is for a governmental agency to acquire the land. The area could be acquired through negotiation, condemnation, tax-delinquency default, dedication, devise, or donation. The agency could then control development in the public interest. It might elect to sell or lease part or all of the acquired lands on the condition that no structures be built that would be vulnerable to slide damage. If the land can support crops or grazing, it might be leased for such uses, thus recovering part of the acquisition costs.

Acquiring less-than-fee interest in slide areas costs the public less than purchasing the land, because only certain property rights need be purchased. Such interest may be in the form of scenic easements to protect vistas, conveyance of development rights to assure the continuation of existing private parks and open spaces, or grants of public access and development rights for construction and use of park facilities. By purchasing easements or development rights, development can be limited, and the owner receives fair compensation for the release of these rights. Easement lines need not be based on accurate landslide information (such as that required for zoning) because the boundaries of the lands to be acquired can be determined by agreement. The

use of easements should include periodic inspections, and enforcement of the land-use permitted by the agency holding the easement. Easements should be obtained in perpetuity, or for as long as the slide hazard exists.

Numerous State and Federal financial aid programs are available for acquiring land for purposes (such as park and recreation uses) compatible with slide hazards. For example, the Federal Land and Water Conservation Fund Act provides grants. This program is discussed in the "Catalog of Federal Domestic Assistance" by the U.S. Office of Management and Budget (1979, p. 561).

Urban redevelopment -- Landslide areas can be redeveloped publicly or privately by purchasing land that has been determined to be blighted or to have deteriorated. State laws authorizing the creation of public redevelopment agencies usually provide for the preparation and adoption of redevelopment plans; acquisition, clearance, disposal, reconstruction, and rehabilitation of blighted areas; and relocation of persons displaced by a redevelopment project. Redevelopment agencies usually are empowered to issue bonds, receive a portion of taxes levied on property in the project, and use Federal grants or loans available under various programs of the Federal Housing and Community Development Act. These programs are discussed in the "Catalog of Federal Domestic Assistance" by the U.S. Office of Management and Budget (1979, p. 540-543).

Public-nuisance abatement -- Buildings and structures damaged by less catastrophic slides, such as creep and swelling soils, often go unrepaired, thus initiating a cycle of deterioration. Such buildings and structures can be removed or razed by government agencies by applying their powers for public-nuisance abatement. For example, Section 203 of the Uniform Building Code, prepared by the International Conference of Building Officials (1976, p. 27), and adopted by many cities and counties, provides:

> All buildings or structures which are structurally unsafe or not provided with adequate egress, or which constitute a fire hazard, or are otherwise dangerous to human life, or which in relation to existing use constitute a fire hazard to safety or health, or public welfare, by reason of inadequate maintenance, dilapidation, obsolescence, fire hazard, disaster damage, or abandonment ... are ... unsafe buildings. All such unsafe buildings are hereby declared to be public nuisances and shall be abated by repair, rehabilitation, demolition, or removal ...

Non-conforming uses -- New or amended zoning ordinances (discussed later in this appendix) may make some existing uses of a slide area nonconforming. Nonconforming uses are those in existence at the time of the adoption or amendment of a zoning ordinance that do not conform to the use restrictions. For example, if residences in a slide area are prohibited by a zoning ordinance, residences existing in the area at the time of adoption of the ordinance become nonconforming.

Zoning ordinances may provide that nonconforming uses be continued but not extended or enlarged, and, if discontinued for some designated period, any future use must conform with the ordinance. The total structural repairs or alterations over the lifetime of a nonconforming building may be limited to a percentage of the assessed or market value. Enabling legislation may also permit eliminating nonconforming uses by providing for amortization over a reasonable period of time. The concept and practice of eliminating nonconforming uses are discussed by Scott in "The Effect of Nonconforming Land-Use Amortization" (1972). Model ordinance provisions and comments on the discontinuance of existing land uses are described in "A Model Land Development Code" by the American Law Institute (1975, p. 142-166).

Public-facility reconstruction -- Reconstructing public facilities located in slide areas (such as roads, bridges, utilities, and community facilities that are subject to rebuilding by reason of functional or structural

obsolescence) may afford an opportunity to reduce the risk of damage from landslides. This end can be achieved by reinforcing, designing to accommodate displacement, relocating in areas not subject to landslides, or bridging.[1/]

[1/] Bridging refers to the construction of spans over slide areas. It is primarily used for highways, but is expensive and consequently used as a last resort.

Discouraging Development

Several tools are available to discourage development in landslide areas. They include public-information programs, warning signs, recording, tax-assessment and credit practices, financing policies, public-facility extensions, and disclosure. Requirements for landslide insurance -- where available -- and its cost might be an additional deterrent.

Public information -- Public-information programs can help to bring landslide information to the attention of the public. Prudent citizens, when told of slide hazards, would not wish to risk property losses and expose their families to the danger and trauma of a landslide. Since any program of land-use control depends on the support of an informed public, educating the public becomes of great importance.

Preparing, announcing, and disseminating information on slide damage and susceptibility can be done through conferences, workshops, newsletters, press releases, bulletins, and letters to key officials and other users. The series of maps by Lessing and others (1976) showing five zones of landslide susceptibility for the urban and urbanizing areas of West Virginia is a good example of disseminating information. Advice for buyers, builders, and homeowners concerning "danger signals," slide-correction methods, and the legal responsibilities of State agencies are provided in the bulletin accompanying the maps.

Warning signs -- Warning signs can be used to alert land purchasers and developers who inspect sites prior to purchase of a potential hazard. Such signs will be most effective if they are readily visible to buyers, developers, and the public; if they are based upon adequate data; and if they are posted where the slide areas intersect or abut public rights-of-way. Warning signs have been erected by the U.S. Bureau of Reclamation in flood-hazard areas on the Sacramento River near Redding, California. Signs might also take other

forms, such as rubber-stamp notations on subdivision plats and on building and zoning permits, warning that the sites are in areas susceptible to slides.

Recording the hazard -- Public records on land ownership provide a means for alerting land purchasers, local assessors, and lenders to potential slide hazards. Such records can be made by filing maps of slide areas with the appropriate register of deeds, together with listings of the subdivisions or the sections (as identified under a public survey system),and requesting entry onto tract indexes. Abstracts of titles for affected properties and subsequent conveyances then would contain an entry referencing the hazards. Adopting subdivision ordinances that require that slide areas be shown would automatically result in the filing of the information with a register of deeds.

If the geologic report required by the Santa Clara County Board of Supervisors (1978) indicates unusually severe geologic constraints, development is allowed to proceed only after the property owner signs a statement acknowledging he has been told of the hazards, accepts the risks, and relieves the county of liability. The statement is recorded in the county recorder's office and may be expunged if subsequent information -- approved by the county geologist -- indicates that the hazard no longer exists or has been reduced. However, no new structures for human occupancy can be located on active landslides that have not been stabilized by acceptable engineering practices.

Tax assessment and credit practices -- Some form of tax relief can be considered for lands subject to slide hazards in order to encourage non-vulnerable uses of these areas. A low assessment value on lands retained in open use by private owners could provide a property tax rate to compensate for the profit that might be realized through other types of development. At the same time, slide areas that are developed contrary to the adopted plan could be assessed and taxed at a rate high enough to recover the cost to the

public of protecting the development. Such assessment practices usually require both statutory and constitutional amendments.

If the construction of public works for the control or prevention of slides becomes necessary, the costs could be assessed in whole or in part against the lands that will benefit from the construction. Although this is not commonly done, the posssibility of an unexpected assessment against the property could be reflected in their assessed value.

The use of State farmland preservation laws can discourage development in slide areas. For example, the Wisconsin Legislature (1977) provides for a State income tax credit of up to $4,200 annually as an incentive to farmers to preserve farmland. The credit doubles in 1982 if the county creates an exclusive agricultural zone.

Financing policies -- If private lenders and government agencies were to deny loans or loan insurance for construction in slide areas, development in hazardous areas would be reduced. Almost all construction today involves loans or mortgages by private lenders, many of which are insured by government agencies. The U.S. Department of Housing and Urban Development (1973) has adopted property standards which define the minimum level of acceptability of design and construction for federally assisted housing and housing eligible for federally insured mortgages. These standards require that development proposals take note of natural hazards such as slides.

Public-facility extensions -- Metropolitan and municipal utilities could design and install water-supply and sanitary-sewer systems that would not have the capacity to serve urban developments in slide areas. The availability of roads, utilities, and other community facilities in slide areas attracts subdividers, developers, and home purchasers. Government agencies could adopt policies and announce that they will not accept, authorize, finance, or

construct community facilities (such as roads and schools) to serve areas subject to slides. These actions should be taken well in advance of developmental plans and could be used in conjunction with removal and regulatory tools.

Disclosure -- Presenting landslide-hazard information in layman's language and enacting Federal, State, and local hazard-disclosure laws can make people aware of slide hazards. Disclosing such hazards at the time of purchase alerts property owners to the potential dangers.

For example, to provide for protection against flood losses through a federally subsidized flood-insurance program, the U.S. Congress (1974b) requires lenders to notify prospective borrowers that the real estate being mortgaged is located in flood-hazard areas, as identified by the Federal Insurance Administrator.

When providing for the public safety from fault rupture through the use of the Special Studies Zones Act, the California Legislature (1972) requires a seller or his agent to tell the prospective buyer that the real estate is located within a fault-rupture zone, as delineated by the State Geologist.

In the ordinance enforcing on-site geologic investigations prior to construction, the Santa Clara County Board of Supervisors (1978) also requires all sellers of real estate lying partly or wholly within the county's flood, landslide, and fault-rupture zones to provide the buyer with a written statement of the geologic risk.

To assist Realtors in complying with these Federal, State, or county laws, five local boards of Realtors in the San Francisco Bay region had street index maps colored to show some or all of the flood, landslide, and fault-rupture zones. The five maps cover one entire county and parts of three others and include more than 50 cities. In addition, the San Jose Board of Realtors (1978) has designed a form to be attached to a real-estate contract to comply

with the county's disclosure ordinance. This example of disclosure is discussed and illustrated in "Examples of the Use of Earth-Science Information by Decisionmakers" (Kockelman, 1980, p. 58-72).

Insurance costs -- A combination of occupancy charges and landslide insurance can be used to discourage development in slide areas or to create economic incentives to select uses that are less subject to damage. The National Flood Insurance Program attempts to discourage development in mudflow areas. The U.S. Congress (1973) amended the program to require the purchase of flood insurance as a condition for receiving any form of Federal financial assistance for construction or acquisition in identified mudflow-hazard areas.

Inexpensive landslide insurance is not usually available from private sources in known slide areas because the slides lack the random nature necessary for a sound insurance program. In some respects, known slide areas are similar to known flood areas upon which the American Insurance Association (1956) reported that:

> flood insurance covering fixed-location properties in areas subject to recurrent floods cannot feasibly be written because of the virtual certainty of loss, its catastrophic nature, and the reluctance or inability of the public to pay the premium charge required to make the insurance self-sustaining.

Therefore, insurance in slide areas can only be provided at reasonable rates if subsidized. Unless premiums are related to the risk involved, and development is regulated, slide insurance must be considered a form of taxation. Government subsidies of property owners who suffer slide damage may lead to highly undesirable and unwarranted development of slide areas in anticipation of indemnification of their loss.

Regulating Landslide Areas

It is costly to construct public works for the protection of development, difficult to remove or convert existing development, and probably unrealistic to assume that all future development in landslide areas will be discouraged in indirect ways. Prohibiting and regulating uses susceptible to slide damage or capable of triggering slides, however, provides an efficient and economical method for avoiding the hazards and reducing their damage.

Generally, slide areas should be restricted to such open-space uses as parks, grazing, or some types of agriculture, and to such roads and utilities as must be located in slide areas. Tools for prohibiting or regulating development in slide areas include establishing zoning districts compatible with the hazards involved, and incorporating special regulations in zoning, subdivision, sanitary, and grading ordinances.

Zoning Districts -- Zoning is an accepted and effective technique for controlling development. It can provide direct benefits by restricting future development of vacant lands in slide areas and by limiting the expansion of existing development in those areas.

The most common zoning districts which are compatible with slide hazards are agricultural, open-space, conservancy, and park districts. These districts permit such uses as grazing, woodlands, wildlife refuges, and public and private recreation. The district regulations can be supplemented by incorporating regulations to prohibit those agricultural, open-space, conservancy, and park uses that would be vulnerable to slide damage or that would trigger slides, for example, farm dwellings, off-road vehicles, irrigation, and the permanent sheltering or confining of animals. The district regulations can also reduce the density of development. For example, the San Mateo County Board of Supervisors (1973) created a resource management zoning district

especially designed to carry out the objectives and policies of their open-space and conservation plans. The district regulations limit the number of dwellings in slide areas to one unit per 40 acres. However, the number of dwellings permitted may be accumulated over large areas and clustered in the nonhazardous areas.

The Pacifica City Council (1973) created a hillside preservation zoning district which required a percentage of each parcel to be retained in a natural or undisturbed state. In addition, the city prohibited all development on slopes exceeding 35 percent. The purpose of slope-density regulations and examples of regulatory techniques throughout the United States are discussed in detail by Thurow, Toner, and Erley (1975) in "Performance Control for Sensitive Lands."

Special slide-area regulations -- Land-use regulations concerning the use of slide areas can supplement the basic use and site regulations in zoning ordinances, and can be designed to:

1. Preserve vegetation, maintain drainage, control off-road vehicles, establish vibration-performance standards, avoid the most hazardous slide areas, require clustering of dwellings, and reduce development densities.
2. Prohibit certain operations,such as filling, irrigating, disposing of solid and liquid wastes, and cutting away the toe of the slide, which increase loads, reduce slope support, or otherwise cause instability.
3. Prohibit certain uses such as the storing of radioactive, toxic, flammable, and explosive materials, that could cause health and safety hazards.

The Portola Valley Town Council (1974) adopted a resolution containing criteria concerning unstable or potentially unstable areas. Land uses that include roads, houses, utilities, and water tanks are prohibited in areas that are sliding or

have the potential for sliding. The resolution also requires that the same criteria be used in administering the town's subdivision, site development, and building ordinances. Later, the Town Council (1979) adopted regulations that reduce the maximum number of dwellings permitted in areas of potential sliding.

Subdivision ordinances -- Regulating the design and improvement of subdivisions is another method for controlling the development of landslide areas. A dilemma occurs when government officials approve a subdivision, accept public rights-of-way, extend utilities, and then attempt to apply zoning and other regulations that would prohibit further development. This dilemma can be avoided by adopting a subdivision ordinance designed to:

1. Require the delineation and designation of slide areas on subdivision plats and certified survey maps.
2. Require dedication or reservation of slide areas for public or private parks or other community purposes; and require dedication of, or easements along, those waterways necessary for adequate drainage.
3. Require that public and private roads, bridges, utilities, and other facilities be located or designed and constructed to avoid slide areas, or to withstand anticipated movement.
4. Select road and utility alinements and grades to minimize cuts and fills.
5. Prohibit the creation and improvement of building sites in slide areas.

Regulations similar to the soil and geologic regulations in the model ordinance prepared by SEWRPC (Southeastern Wisconsin Regional Planning Commission, 1969, Appendix F) would be effective. The model ordinance has been adopted by many local units of government, and some have been in effect for over ten years without successful legal assault.

Sanitary ordinances -- In addition to triggering slides, on-site soil-absorption sewage-disposal systems -- septic tanks, absorption fields, and seepage beds and pits -- become inoperative if disrupted by slides. Sanitary ordinances can be used to eliminate some of the problems caused by the disruption of private sewage-disposal systems or the contamination of private water-supply systems. The problems can be avoided by a sanitary ordinance designed to:

1. Require a permit prior to installing any such system, and require the application for such permit to show the boundaries of the slide areas.
2. Prohibit on-site soil-absorption sewage-disposal systems and private water-supply systems on lands subject to slides.
3. Require the replacement of on-site soil-absorption sewage-disposal systems in slide areas with alternate systems, such as public sanitary sewerage or holding tanks.

Regulations similar to the model soil and geologic regulations prepared by SEWRPC (1969, Appendix H) for incorporating into sanitary, health, and plumbing ordinances would be effective. These model regulations have been adopted by many local units of government and some have been in effect over ten years without successful legal assault.

Grading ordinances -- Grading ordinances can be used to ensure that the excavating, cutting, and filling are designed and conducted in such a way as to avoid overloading, cutting into the toe of the slide, or otherwise reducing its stability. Such goals can be obtained by a grading ordinance designed to:

1. Require a permit prior to scraping, excavating, filling, or cutting any lands.
2. Regulate the destroying of vegetation and disrupting of drainage patterns.

3. Provide for the proper design, construction, and periodic inspection and maintenance of drainage-ways including culverts, ditches, gutters, and diversions.
4. Prohibit, minimize, or carefully regulate the excavating, cutting, and filling activities in slide areas.
5. Provide for proper engineering design, placement, and drainage of fills including periodic inspection and maintenance.

The success of the City of Los Angeles' slide reduction program is discussed in a recent issue of the APA Journal by Fleming, Varnes, and Schuster (1979, p. 434-437).

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