Estimating the Costs of Landslide Damage in the United States

GEOLOGICAL SURVEY CIRCULAR 832

COVER: Views of landslide damage that occurred in the San Francisco Bay region during the winter 1968–69. (Fred Taylor photos.)

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ABSTRACT

Landslide damages are one of the most costly natural disasters in the United States. A recent estimate of the total annual cost of landslide damage is in excess of $1 billion (Schuster, 1978). The damages can be significantly reduced, however, through the combined action of technical experts, government, and the public.

Before they can be expected to take action, local governments need to have an appreciation of costs of damage in their areas of responsibility and of the reductions in losses that can be achieved. Where studies of cost of landslide damages have been conducted, it is apparent that (1) costs to the public and private sectors of our economy due to landslide damage are much larger than anticipated; (2) taxpayers and public officials generally are unaware of the magnitude of the cost, owing perhaps to the lack of any centralization of data; and (3) incomplete records and unavailability of records result in lower reported costs than actually were incurred.

The U.S. Geological Survey has developed a method to estimate the cost of landslide damages in regional and local areas and has applied the method in three urban areas and one rural area. Costs are for different periods and are unadjusted for inflation; therefore, strict comparisons of data from different years should be avoided. Estimates of the average annual cost of landslide damage for the urban areas studied are $5,900,000 in the San Francisco Bay area; $4,000,000 in Allegheny County, Pa.; and $5,170,000 in Hamilton County, Ohio. Adjusting these figures for the population of each area, the annual cost of damages per capita are $1.30 in the nine-county San Francisco Bay region; $2.50 in Allegheny County, Pa.; and $5.80 in Hamilton County, Ohio. On the basis of data from other sources, the estimated annual damages on a per capita basis for the City of Los Angeles, Calif., are about $1.60. If the costs were available for the damages from landslides in Los Angeles in 1977–78 and 1979–80, the annual per capita costs probably would be much larger.

The landslide near the rural community of Manti, Utah, caused an expenditure of about $1,800,000 or about $1,000 per person during the period 1974–76. Because a recurrence for such a landslide cannot be established, it is not possible to develop a meaningful estimate of annual per capita damages.

Communities are urged to examine their costs of landslide damage and to evaluate the feasibility of several alternative programs that, for a modest investment, could significantly reduce these losses.

INTRODUCTION

Natural disasters may bring sudden and appalling destruction to an area, or they may slowly but inexorably take their toll in dollars and spirit. Damage from tornadoes and earthquakes is sudden and usually occurs with little or no warning. On the other hand, prolonged drought or ground subsidence may occur over a much longer period with equally damaging effects.

Landslides are disasters that encompass both extremes: sudden and catastrophic, and slow and insidious. About 200,000 people were killed in Kansu Province in China in 1920 when a major earthquake triggered massive landslides in extensive deposits of windblown silt. In 1970, a rapidly moving debris avalanche, also triggered by an earthquake, killed at least 18,000 people in Yungay and Ranrahirca, Peru. Nearly 3,000 people were killed in Italy in 1963 when a landslide into the Vaiont Reservoir caused the impounded water to overtop the dam and produce a devastating flood downstream. Other landslides have caused damage over a prolonged period. For example, a landslide in the Ventura oilfield, California, has been damaging oil wells for many years. Roads broken by slow landslide movement often have layers of road patching several feet thick, representing a significant maintenance expense over many years.

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 repair of damaged facilities and disaster relief after an event. Resources for research related to natural disasters are limited, and priorities for research should be based in part on the benefits and costs of such actions.

This report describes a method developed and used by the U.S. Geological Survey to obtain estimates of the cost of damage caused by landslides in four locations in the United States. Data have been collected in three urban areas and one rural area. The urban areas include the San Francisco Bay region, California (1968–69); Hamilton County including Cincinnati, Ohio (1973–78); and Allegheny County including Pittsburgh, Pa. (1970–76). The data for the San Francisco Bay region resulted from a reexamination of cost data compiled and published earlier by Taylor and Brabb (1972). The rural area studied is Manti, Utah, and vicinity, where a large landslide in a national forest about 6 km (4 mi) from town has been very costly in public funds. The studies were conducted independently at different times, and the reported cost figures have not been adjusted for inflation. Strict comparisons of cost of damage data from different years should be avoided.

As this report indicates, decisions must be made about what actually constitutes a damage cost and what does not. Some of the costs reported here might not seem legitimate to some economists. Other costs, which we decided not to include in these estimates because they were too poorly defined or might be duplicated in other data, could perhaps have been retained. In all of our attempts to compile cost-of-damage data, when definitive data were not available, we have used low estimates of costs and have discarded data that could be duplicated. Therefore, even though the damage costs are only estimates, the totals reported generally should be lower than the actual costs incurred. When assumptions are applied that produce speculative totals, the assumptions are specified.

Individual citizens and public agencies need to become more aware of the magnitude of annual damage due to landslides and the possibility of increased destruction. This report is intended to encourage governmental agencies to keep more complete records of the occurrence and cost of landslides. Such information can be used to facilitate comparison of preventive costs and restorative costs.

ACKNOWLEDGMENTS

We sincerely appreciate the cooperation of those supplying the costs-of-damage information and introducing us to the landslide problems in different areas. Special thanks go to James E. Hough in Cincinnati, William R. Adams, Jr., in Pittsburgh, and Charles R. Allred and Earl P. Olson of the U.S. Forest Service in Utah. An early form of the manuscript benefited greatly from a careful review by Earl E. Brabb and John T. McGill.

PREVIOUS STUDIES OF COSTS OF LANDSLIDE DAMAGE

NATIONAL COST OF LANDSLIDE DAMAGE

Studies by the U.S. Geological Survey of costs of landslide damage have not attempted to obtain a total annual cost for the United States. However, several estimates of the annual cost of damage have been published over the past 25 years that are probably as accurate as can be obtained using the present data base.

A study by the Highway Research Board in 1958, based on responses to a questionnaire, reported damages in the United States as "hundreds of millions" of dollars annually (Smith, 1958). Krohn and Slosson (1976) estimated landslide damage to private property in the United States by extrapolating cost of damage in Los Angeles to the rest of the country. The extrapolation was made by comparing the percentage of the population in the United States living on sites with similar landslide potential to Los Angeles and assuming that the sites were developed under inadequate or nonexistent grading codes. Krohn and Slosson concluded that the annual landslide damage to *private property* in the United States is about $400 million.

Schuster (1978) concluded, in a recent evaluation of landslide losses in the United States, that direct and indirect losses to *public and private property* exceed $1 billion annually. The total was obtained using previously published data combined with new data obtained through interviews and correspondence with agencies and organizations having cost information.

Jahns (1978) examined costs of damage from several types of natural disasters for the 50-year period of 1925–75. During that period, the combined losses from floods, hurricanes, tornadoes, and earthquakes were nearly $20 billion, unadjusted for inflation. In contrast, ground movements of two types, landslides and sub-

sidence, totaled at least $75 billion during the same period.

COSTS OF LANDSLIDE DAMAGE FOR SMALLER GEOGRAPHIC AREAS

The California Division of Mines and Geology has estimated that landslide damages for California will cost more than $330 million annually during the period 1970–2000 if loss-reduction practices in effect in 1970 are not improved (Alfors and others, 1973). In the San Francisco Bay region, where efforts have been made to identify costs of landslide damage, preliminary studies documented $25 million in damages for the nine Bay area counties for the rainy season 1968–69 (Taylor and Brabb, 1972). Within a single subdivision in this area, costs totaling over $760,000 between 1968 and 1971 were identified (Nilsen and Brabb, 1972).

Landslide-causing storms have plagued southern California for the past three decades, but cost-of-damage information is incomplete and not comprehensive. Damage estimates are generally only for private property and may include damages from erosion, sedimentation, and flooding, in addition to the landslide damage. Notable landslide events occurred in 1951–52, 1956, 1957–58, 1961–62, 1968–69, 1977–78, and 1979–80. Slosson and Krohn (1979) reported that the incidence of landsliding in earlier years was comparable to that in 1977–78 but that the cost of damages in 1977–78 was about seven times larger than for previous years. The differences in cost of damages were attributed to increased property values and construction costs, a larger number of structures exposed to damage as a result of development, and greater intensity of storms in 1978. Damages in 1977–78 were estimated at about $50 million. Damages from earlier storms were estimated at $7.5 million for 1951–52 (Jahns, 1969), $7.5 million for 1961–62 (Slosson, 1969), and $6 million for 1968–69 (Slosson, 1969). On the basis of studies in other areas by the U.S. Geological Survey, public costs of damage probably were at least equal to private costs. Therefore, the damage costs from Los Angeles, quoted above, should be doubled to produce a better estimate of total cost.

Tubbs (1974) conducted a study of landslides and associated damage that occurred during the early part of 1972 in part of west-central King County, Wash. He identified 80 landslides that caused estimated minimum damage of $250,000. The damage estimates were only for restoring the property as nearly as possible to its original condition and did not include decrease in property value, emergency repair, costs in time and energy to property owners, or any of the other indirect costs that might have been associated with the landsliding.

Briggs and others (1975), reporting data collected by the Allegheny County Department of Planning and Development, placed average damages for Allegheny County including Pittsburgh, Pa., for the period 1970–74 at about $2 million annually.

Other published estimates of costs of landslide damage have generally been applied to single projects or landslide events. For example, Jones and others (1961) estimated that the filling of the reservoir behind Grand Coulee Dam in Washington cost at least $20 million in landslide damage and avoidance between 1934 and 1952. Merriam (1960), in describing the famous Portuguese Bend landslide in the Palos Verdes Hills, Calif., noted that property damage during the period 1956–59 was in excess of $10 million. About $5.3 million of the damage, recovered by property owners through litigation with the county of Los Angeles (Morton and Streitz, 1967), became a public rather than private cost.

The above damage studies, particularly those in the San Francisco Bay region (Taylor and others, 1975; Nilsen and others, 1976), revealed three facts: First, costs to the public and private sectors of our economy due to landslide damage are much higher than anticipated. Second, taxpayers and public officials generally are unaware of the magnitude of the cost, perhaps because of the lack of any centralization of data. Finally, incomplete records and unavailability of records resulted in lower reported costs than actually were incurred.

REDUCTION OF THE COSTS OF LANDSLIDE DAMAGE

Knowing the costs of damage from landslides in the United States is of little value unless the costs can be reduced through better and less expensive damage repair and through governmental programs designed to prevent landsliding

or to mitigate damage that does occur. A wide variety of engineering alternatives are available to correct landslide problems once they have occurred; however, the engineering solutions are usually very expensive and the costs of repair can exceed the intrinsic value of the property being repaired. Local governments, through planning and regulation, have several options to reduce the costs of landslide damage. Kockelman (1980) has prepared a comprehensive summary of the tools that can be used to avoid landslide hazards and reduce damage.

The technology is available to greatly reduce losses from landslides by avoiding or preventing them. Leighton (1976) estimated that, in California, a reduction in damaging failures of 95 to 99 percent is technically attainable through the use of three levels of investigation: regional, tract or community, and site, with progressively greater detail being obtained in the investigations of the smaller areas. However, 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. Requirements for technological solutions to landslide problems are subject to resistance or pressures from groups that dislike regulation or interference, that do not consider landslides amenable to loss-reduction measures, or that do not consider landslides a serious enough economic problem to justify the effort required to make a program work.

The City of Los Angeles provides an impressive example of an effective program to reduce landslide damages. Prior to 1952, controls on hillside grading and development in Los Angeles were very limited. In 1952, following severely damaging winter storms, a grading code was adopted that improved procedures for safe development of hillsides. The grading regulations were revised in 1962 to provide a more restrictive code and to specify responsibility for geologic and engineering participation in design, construction, and final inspection and certification of the adequacy of a grading project. The procedures and controls received a stern test with the winter storms of 1968–69. After the extensive flooding and landsliding, the Los Angeles Department of Building and Safety examined the damage to sites relative to when the site was developed and what grading regulations were in effect at the time of development. During the storms of 1968–69, for a comparable number of sites, the damage to sites developed before 1952 was nearly 50 times greater than that to those developed between 1963 and 1969 (Slosson, 1969).

The urban areas studied in this report have all undertaken some form of action designed to reduce landslide damages. Several local and county governments in the San Francisco Bay region have adopted planning devices and grading regulations. Allegheny County, Pa., established a Geotechnical Center in the Department of Works that maintains a technical data bank, recommends sources of assistance to individuals and organizations with problems, provides for public education about hazards, and conducts a data exchange with public agencies and consulting firms. Cincinnati, Ohio, has adopted a cut-and-fill ordinance similar to the grading regulations in Los Angeles.

Other communities with landslide problems generally have not adopted loss-reduction programs. They are apparently unaware of the magnitude of landslide losses or the potential for loss mitigation, partly because of a paucity of economic studies both locally and nationally. Major landslide disasters receive much attention, but the day-to-day accumulation of landslide events results in surprisingly large losses that receive little attention.

LANDSLIDES DEFINED

Landslides are downward and outward movements of slope-forming materials composed of natural rock, soils, artificial fills, or combinations thereof. Landslides can be classified in many different ways—by manner of movement, type of materials, or age. But, for the purpose of determining costs of damage caused by landslides, no differentiation was made here. Some agencies reporting landslide damage use the term "slipout" to describe an area in which a section of a road has moved downward or the underlying material has "slipped out" from under the road. Slipouts are included as landslides.

LANDSLIDE DAMAGE

Landslides commonly are considered to be only a local or a California problem. Neither is true.

Although single landslides may appear as isolated events both in time and place, the aggregate sum of individual landslides involves surprisingly large areas of land. In a nationwide study of the distribution of failed hill slopes and of materials susceptible to failure, Radbruch-Hall and others (1976) found significant problems in nearly every State. Colton and others (1976) mapped areas of previously failed slopes in Colorado and found that about 8 percent of the area of that State is underlain by landslide deposits. Similarly, in this report, we show that annual per capita[1] damages in some other parts of the country are probably larger than those in some of the more landslide-prone areas in California. Landslides, in contrast to some other natural disasters, may have longer lasting damage that may, in fact, render land unsuitable for an intended use. Landslides can damage most types of manmade structures and have been reported to have damaged buildings, roads, transportation and communication facilities, utility installations, pipelines, reservoirs, irrigation ditches, and canals, as well as lots, parks, cultivated fields, pasture, and timberland. Some landslides may involve no out-of-pocket expense for damage, but may require an expenditure of the property owner's time and effort, such as picking up debris or cleaning or realining an irrigation ditch. Other landslides may cause damage in the millions of dollars and perhaps loss of life. Loss of life from landslides in the United States averages about 25 persons annually (Krohn and Slosson, 1976). If deaths caused by collapse of trenches and other excavations are included, the annual total is between 100 and 150 persons.

Damages from landslides vary greatly from area to area and, as smaller and smaller parcels of land are examined, damage is found to vary from neighborhood to neighborhood, block to block, street to street, and lot to lot. This pattern is roughly analogous to that for earthquakes, which produce similar variations in damage. In both cases, damage differences are due to several natural and manmade conditions including method and materials of construction, type and condition of rock and soil, and steepness of slopes.

It is possible to separate some of the causal factors that contribute to differences in landslide potential, evaluate their significance, and produce useful maps that show where landslides have occurred in the past and that show areas having different relative potential for landsliding in the future. Newman and others (1978) found that a composite map which combined steepness of slope, geological materials, and locations of past landsliding was sufficient to separate areas according to potential for future landsliding. Such a map readily identifies those areas that require more investigation or protection through land-use strategies designed to insure that future use is compatible with the risk of landsliding. The characteristics of the different special-purpose maps for landslide studies have been discussed by Fleming and others (1979).

Landslides are also a secondary effect of other natural events and, as a result, the damage caused by landslides is often attributed to other natural disasters which trigger them. For example, it has been estimated that 65 percent of the damage of the Alaskan earthquake of 1964 was caused by ground failure (Youd, 1978). The damage and deaths in central Virginia in 1969 are commonly associated with Hurricane Camille, but most of the nearly 150 people killed at that time were caught in rapidly moving debris avalanches triggered by the high-intensity rainfall (Williams and Guy, 1973).

CATEGORIES OF DAMAGE COSTS

Costs of damage due to landslides have often been classified as being direct or indirect, without either term being defined. Probably no definitions, unless they are complex, will provide for a clearcut assignment of every cost into one or the other of these categories. For the purpose of this report, a direct cost is defined as follows: the cost of physical damage and (or) related restoration costs to structures and land within the boundaries of the responsible landslide. All other costs are indirect.

The greatest value of separating direct and indirect costs may be to help insure that all costs related to landslides are identified. The following

[1]Reducing the damage costs to a common figure is desirable so that crude comparisons of damage can be made for different areas. In this report, per capita costs of damage are obtained by dividing the total annual cost of damage by the population of the area studied. In doing this, we knowingly introduce some distortions in the data. For example, per capita costs include not only costs borne by the inhabitants of a given city or county, but also public costs shared by inhabitants of higher and larger government entities (State and Federal). Also, the costs within a study area are not evenly distributed. Private property owners with landslide problems carry the largest expense and the only truly distributed costs are public funds that are entirely generated within the study area.

lists, although incomplete, are intended to suggest the types of expenses in each category. Direct costs include destruction or damage to structures and other improvements, loss or damage to land, and (or) reestablishment of structures, other improvements, and land as nearly as possible to the same condition and degree of usefulness as prior to the landslide.

Indirect costs include the following: relocation of buildings and roadways, measures to prevent or mitigate additional landslide damage, secondary physical effects such as flooding and adverse effects on water quality in streams and irrigation facilities, measures to prevent secondary effects, decrease in agricultural or industrial production, decrease in market value of affected properties, tax loss due to decrease in appraised value, and measures to protect health and safety of the public. Indirect costs can also include time lost from work and the associated effects of decreased earnings: the loss of purchase power which is passed on through the economy, possible foreclosure of mortgages and other loans, depletion of savings accounts, and lack of funds for insurance or investment plans. Obviously, many of these costs are seldom if ever determined, and damage assessments tend to be conservatively low.

Perhaps the taxpayer and officials of involved agencies are more concerned with who pays the bill than with whether the cost is directly or indirectly attributable to a landslide. For that reason, costs compiled in this study are reported in two main categories: public and private. Public costs are dollars spent or lost by local, county, State, or Federal governmental agencies; these costs are ultimately paid by the taxpayer. Private costs are expenses to individuals and nonpublic groups, such as publicly owned utility companies, water districts, sanitation districts, communication companies, and businesses. Many of the private costs are probably passed on to clients and may be distributed to a large part of the public.

Public costs are mainly expenditures for repairing, restoring, or relocating roads. These include expenses readily attributed to specific large landslides and an educated guess for smaller landslides that are included in budgets for routine road maintenance. Lesser expenses resulting from damage to sewerlines, storm drains, street lighting, sidewalks, and other publicly owned facilities should also be included in cost compilations. In some instances, public agencies must obtain title to privately owned land in order to take measures to further protect property or to repair existing landslides. For example, in Daly City, Calif., title was obtained by the city for nine homes and the land damaged by landsliding in 1969. In addition to the procurement cost, continuing minor costs are incurred by the city for erosion control and weed abatement.

When possible, it may be more economical to obtain title to property and have it vacated than to attempt to maintain access and services that are continually disrupted by an active landslide. However, tax revenue is lost when land is transferred from private to public ownership. Revenue loss also results from the devaluation of private property because of landslide damage. Although these losses are substantial, to our knowledge no attempt has been made to estimate their value in tax revenue because assigning an amount would be too speculative to be of use. Additional public cost includes emergency expenses such as salaries to firemen, policemen, and others responsible for protecting public health and safety; but because records of these expenses are seldom available, the costs are not included in this report.

Private costs are mainly the loss of real estate value and possessions, and the cost of any repairs that are required because of landslide damage. Possessions can be replaced and improvements undertaken if an individual is financially able, but property may become unusable. In addition to the direct costs of repairs, real and personal property that has been damaged by a landslide is often depreciated in value. Reappraisal by the tax assessor's office, which indicates a decrease in the fair market value of property due to such damage, represents a loss to the property owner. Property adjacent to a landslide may also be depreciated, even though it has received no physical damage. Other private costs may include legal fees, consultant services, moving expenses, cleaning fees, and perhaps intangible social and psychological costs.

Loss in the private sector can affect the public sector, and vice versa. When a business is severely damaged, a loss occurs in the area's economy. This may be limited to a reduction in employee spending due to lost wages. If a plant is out of production for an extended period of time, it can

result in a shortage of products and a reduced demand for supplies, both of which affect employees of undamaged businesses. Decreased production can also cause a loss in tax revenue and a decrease in utility use. Loss of these revenues for fixed-cost services must then be spread among remaining users.

Some costs cannot be classified as public or private; and others, though recognized to exist, cannot be estimated at present. The first are classified as "miscellaneous," and the second as "undetermined."

Whenever feasible, it is advisable to assign costs of landslide damage as closely as possible to the segment of the economy in which the funds originate and minimize use of the category of miscellaneous costs. With adequate data, it should be possible to accurately place costs to the Federal government, State, county, township or city. However, this is not as simple as it seems. For example, total costs for repair of a city, county, State, or Federal highway are commonly the sum of support from two or more levels of government. If a detailed breakdown of costs is to be obtained, the sources and amounts of funds must be identified, as well as costs incurred by the agency that actually spends the money.

Miscellaneous costs are those that cannot be assigned to the public or private sector. Ideally, these would include only costs for which the amount of damage is known but responsibility is disputed, in addition to the litigation costs between the public and private parties. Litigation costs are common but difficult to determine because of reluctance to release information. Available data indicate that the expense of civil suits can quickly exceed the amount of the original damage. The amount of awards in civil suits and whether they will be borne by the public or private sector may not be known until years after the damage occurs.

Miscellaneous costs in the study by Taylor and Brabb (1972) of costs of landslide damage in the nine-county San Francisco Bay region in 1968–69 amounted to nearly 25 percent of the total. Included were costs to the Federal government, cities, and publicly owned utilities, as well as litigation costs and costs where responsibility was disputed. In the estimate of damages for the same region in 1972–73 (Taylor and others, 1975), no miscellaneous costs were reported. Costs to cities were grouped with public costs, and costs to publicly owned utilities were treated as private costs.

Undetermined costs include, for example, the loss caused by landslides occurring directly into a reservoir or in the tributaries of its watershed. Such landslides contribute to siltation, which will reduce the reservoir's holding capacity. Although the dollar value of the lost storage is available, data on how much is due to landslides are not. Damages from landsliding that occur in conjunction with an earthquake or tropical storm also may not be separately identified. An example of an undetermined cost in the San Francisco Bay region was a proposed $10 million road project necessitated by a continuing landslide problem. This item was not included in the San Francisco Bay region estimate of costs, because relocation of the road was only planned but not funded at the time of the study. Construction would include modernization and an increase in the number of traffic lanes, so the cost of the project would have to be discounted to a lower loss figure.

METHOD OF OBTAINING COST INFORMATION

The first step in obtaining cost information was to define the geographical limits of the area to be examined. For the study areas described in this report, the urban areas are bounded by county lines, and the rural area is partly within a national forest and partly within city limits. The next step was to obtain background information on the types of landslides, their abundance and distribution, and some of the notable landslide events in each area. The first personal contact was made with geologists and engineers in Federal and State geological agencies who either were working or had worked in the area. In addition to providing specific information on landslides, these contacts were helpful in providing the names of knowledgeable persons in outside agencies and organizations. Newsclippings maintained in scrapbooks, clipping services, and newspaper libraries were used to obtain partial data and a list of potential contacts. The preliminary contacts with geologists and engineers served two purposes: they identified individuals and organizations that might have information on costs of landslide damage and they informed others that a comprehensive study was underway.

The next step was to interview agency personnel who might have data on landslide costs. If the

appropriate individual within an agency was identified from the background study, initial contact was made with that person. Otherwise the head of the agency was contacted, because that official either had knowledge of, and access to, the information or could delegate the request to the appropriate individual and approve release of data. In most cases only one individual per agency was interviewed, and thus the information obtained may or may not be complete or even representative of the agency as a whole.

Knowing the name of the person within an agency or organization to whom a request should be directed facilitated the work. When going from one governmental unit to another, it is helpful to obtain from a person in the first unit the name of someone working in a similar capacity in another agency. This also facilitated the study in another way, for when the new contacts found that others in similar positions were contributing information, they were more apt to cooperate.

In the interest of impartiality, estimates of costs should be made by the agencies that contribute the data. If experience indicates that an estimate does not seem reasonable, an additional opinion can be sought from another official in the agency, but the estimate should be theirs.

Requested information may be provided by written or oral communication, or by copies of official records. When no records are maintained, the written communication is preferred from the standpoint of documentation; however, oral information is more common. When given orally, costs are apt to be in a range of amounts rather than specific figures. Attempts to arrive at a more precise cost may result in settling for the figure at the low end of the range or for the median amount. Either of these procedures probably results in a conservative cost estimate.

It should be recognized that the need for information on landslides is a new concept to most agencies, which usually do not maintain records useful for this purpose. As the need to be more aware of landslide problems becomes more widely accepted, we hope that losses and cost data will be more complete and accurate and can be obtained more easily.

SOURCES OF COST INFORMATION

Table 1 lists the public agencies and private sources in the San Francisco Bay region that contributed information and indicates the level of government at which each public agency operates. Sources of information for the other examples in this report are listed in the discussion of damage costs for the particular area. Although these lists reflect our sources for these particular examples and we recognize that sources will vary from region to region, nevertheless, we hope that

TABLE 1.—*Public and private sources of data relating to the costs of landslides in the San Francisco Bay region*

	Governmental level			
	Local	County	State	Federal
Public Sources:				
Advanced Planning	----	X	-----	-------
Agricultural Commission	----	X	-----	-------
Assessor's Office	----	X	-----	-------
Building Inspector	X	------	-----	-------
Chamber of Commerce	X	X	-----	-------
City Manager	X	------	-----	-------
Civil Defense	----	X	-----	-------
Community Developers	X	------	-----	-------
Corps of Engineers	----	------	-----	X
Department of Sanitation	----	X	-----	-------
Department of Survey and Mapping.	X	X	-----	-------
Department of Transportation.	----	------	X	-------
Design Office	----	X	-----	-------
Disaster Office	----	X	-----	-------
Division of Mines and Geology.	----	------	X--	-------
Educational institutions	X	------	X	-------
Emergency Services	----	X	X	-------
Engineers	X	X	-----	-------
Farm Advisor	----	X	-----	-------
Fire Department	X	------	-----	-------
Fish and Game Department	----	------	X	-------
Flood Control District	----	X	-----	-------
Forest Service	----	------	-----	X
Irrigation District	----	X	-----	-------
Land Development	----	X	-----	-------
National Guard	----	------	X	-------
National Weather Service	----	------	-----	X
Parks and Recreation	X	X	X	-------
Planning Commission	X	X	-----	-------
Public Information Office.	----	------	X	-------
Public Works Department	X	X	-----	-------
Roads Department	X	X	-----	-------
Seismic Safety	----	X	-----	-------
Small Business Administration.	----	------	-----	X
Soil Conservation Service.	----	------	-----	X
State Senator's Office	----	------	X	-------
Storm Damage Coordinator	----	X	-----	-------
U.S. Geological Survey	----	------	-----	X
Utility departments (gas, electric, water).	X	------	-----	-------
Private Sources:				
Communication companies	----	------	-----	-------
Consulting engineers and geologists.	----	------	-----	-------
Gas and electric companies.	----	------	-----	-------
Homeowners	----	------	-----	-------
Insurance companies	----	------	-----	-------
Land developers	----	------	-----	-------
Private businesses	----	------	-----	-------
Real estate agents	----	------	-----	-------
Sanitation districts	----	------	-----	-------
Water companies	----	------	-----	-------

STATE OF CALIFORNIA
DEPARTMENT OF FINANCE

APPLICATION FOR STATE AID
UNDER THE EMERGENCY FLOOD RELIEF LAW
Sections 54150-54164 of Government Code

LIST OF STORM AND FLOOD DAMAGE

Local Agency Contra Costa County

(a) Item No.	(b) Description and Location of Facility	(c) Description of Damage & Repairs	Total Estimated Cost	Approximate Expenditure To Date
6	FAS 794, San Pablo Dam Road, 2.2 miles north of Wildcat Canyon Road, at "Sta. 235" Road 0961	Major slip-out encroaching into shoulder, progressing toward traveled way. Stabilize and/or reconstruct slope, install subdrainage, move road, if necessary.	$200,000	-0-
7	FAS 794, San Pablo Dam Road, 2.1 miles north of Wildcat Canyon Road, at "Sta. 226" Road 0961	Major slip-out breaking across AC berm at edge of pavement. Install subdrainage, replace cross culvert, cut back hillside and grade for road relocation.	$350,000	-0-
8	FAS 794 Camino Pablo, Orinda, opposite Ardilla Road Road 0961 W.O. 6265	Slip-out and creek erosion resulting in roadway settlement. Stabilize roadbank, install subdrainage, construct culvert for creek if necessary.	$ 82,400	$ 3,500
9	FAS 794, Moraga Way, Orinda, at northerly intersection with Ivy Drive Road 0961 W.O. 6469	Slip-out of shoulder due to creek erosion. Install culvert in creek, reconstruct roadbank over it.	$ 14,000	$ 1,000
10	FAS 1019 Camino Tassajara, Danville, at M.P. 5.15 Road 4721 W.O. 6474	Slip-out of shoulder and damaged traveled way due to creek erosion. Fill eroded bank with riprap, reconstruct roadbank, repair pavement.	$ 16,200	$ 500
11	FAS 1019, Camino Tassajara, Danville, at M.P. 8.25 Road 4721 W.O. 6426	Slide blocking part of one lane. Remove slide, flatten cut slope.	$ 3,140	$ 500

(a) Care should be exercised in designating items since covering agreement will correspond if State aid is granted. Cost must be segregated accordingly in local agency accounting records.
(b) If application covers damage to roads, streets and bridges, include FAS or County route designations.
(c) If application covers damage to roads, streets and bridges, include net length.

FIGURE 1.—Extract from an application for State disaster relief from Contra Costa County, Calif., listing landslide location, description of damage, and total estimated cost of repairs. What the "total" cost includes is not stated, and experience indicates that it may not represent the complete cost of damage including such items as emergency services and engineering costs.

Form Approved
OMB No. 063-R1424

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
DAMAGE SURVEY REPORT
FEDERAL DISASTER ASSISTANCE ADMINISTRATION
(See instructions on reverse of last copy)

3. DECLARATION NO.: FDAA 5/16/73
4. INSPECTION DATE: 5/1/73
5. WORK ACCOMPLISHED BY: ☒ CONTRACT ☐ FORCE ACCOUNT

1. TO ▶ REGION 9 FEDERAL DISASTER ASSISTANCE ADMINISTRATION (FDAA)

2. APPLICANT *(State Agency, County, City, etc.)*: County of Hawaii — PA NO.: P-1927

7. WORK CATEGORY *("X" Applicable Box)*: ☐ EMERGENCY ☒ PERMANENT ☐A ☐B ☒C ☐D ☐E ☐F ☐G ☐H ☐I — ITEM NO.: 22

6. PERCENTAGE OF WORK COMPLETED TO DATE: 90 %

8. DAMAGED FACILITIES *(Location, identification and description)*

Mamalahoa Highway at Kolekole Gulch, Honokaa side of Kolekole Park. 28' roadway with 16' A.C. pavement and C.R.M. wall at down hill side.

9. DESCRIPTION OF DAMAGE

C.R.M. wall badly ruptured but still intact. Earth cracks and pavement cracks 110' long parallel to the road at downhill side of road.

10. SCOPE OF PROPOSED WORK

Relocate road closer to uphill side by cutting back at a 1:2 slope and surfacing the widened area. Patch all cracks and C.R.M. wall. Provide striping and delineators.

11. ESTIMATED COST OF PROPOSED WORK

QUANTITY (a)	UNIT (b)	MATERIAL AND/OR DESCRIPTION (c)	UNIT PRICE (d)	COST *(dollars)* (e)
696	c.y.	Unclassified Excavation	20.00	13,920.00
95	c.y.	Subbase	15.00	1,425.00
32	c.y.	Base Course	25.00	800.00
33	Tons	2" A.C. for widening	40.00	1,320.00
84	Tons	1-1/2" A.C. for Resurfacing	32.00	2,688.00
16	Each	RM-1 Delineators	75.00	1,200.00
1	Each	R-7-1 "No Parking At Any Time" sign	75.00	75.00
L/S		Striping	900.00	900.00
L/S		Repairing Existing C.R.M. Wall	1,000.00	1,000.00
		Construction Sub Total		23,328.00
		Surveying		150.00
		Engineering		250.00
		Drafting and Construction Engineering		650.00

12. EXISTING INSURANCE *(Type)*: Not Covered — AMOUNT $ — TOTAL ▶ 24,378.00

13. RECOMMENDATION BY FEDERAL INSPECTOR *(Signature, Agency, date)* — Eligible ☐ YES ☐ NO — ATTACHMENTS

14. CONCURRENCE IN REPORT BY STATE INSPECTOR *(Signature, Agency, date)* — ☐ YES ☐ NO — ATTACHMENTS

15. CONCURRENCE IN REPORT BY LOCAL REPRESENTATIVE *(Signature, Agency, date)* — ☐ YES ☐ NO — ATTACHMENTS

16. FEDERAL REVIEW *(Signature, Agency, date)* — FDAA REVIEW *(Initials and date)*

HUD - 484 (9-74) REPLACES OEP FORM 164 WHICH IS OBSOLETE — COPY 1 – FINANCIAL MANAGEMENT — SHEET____ OF____ SHEETS

FIGURE 2.—Application for Federal disaster relief from the County of Hawaii, Hawaii. In addition to providing location and description, this document itemizes estimated costs of construction and engineering that are included in the total.

FIGURE 3.—View of a landslide scarp adjacent to a home in Oakland, Calif., illustrating some of the problems of assigning dollar values to landslide damage. The landslide occurred during the winter of 1968-69 and destroyed several houses. Although access to this house was impaired and resale value reduced, the house remained habitable.

these lists will serve as a starting place to identify organizations that otherwise might be overlooked.

Names of agencies fulfilling the same function may vary from place to place. For example, what is known as "Design Office" in one county may be called "Public Works" in another. In addition, several offices may be included under any one heading and so, for example, a Road Division may be divided into grading, materials, design engineering, construction engineering, maintenance, accounting, and perhaps other units. Each may have cost figures but may not be aware of information in other offices.

Probably the most extensive and accessible records, when they exist, are agency applications for State or Federal disaster relief. Such applications include location, type of damage, and estimated restoration costs. Even these records vary in completeness (figs. 1, 2), however, and do not include administrative staff time. Almost equally useful are records in any agency where a separate file is kept of information relating to landslides. If the agency has one person responsible for maintaining such data and being aware of all work on landslides, relatively complete information can be obtained.

Although an agency may maintain files of work orders or job tickets for damage repair, they may not be indexed by type of occurrence. This necessitates an examination of all work orders for the time period in question in order to locate data pertaining to landslides. The same process may be necessary with contracts or requisitions when an agency has used outside contractors or suppliers in conjunction with repair of damage.

Agencies that do not categorize road work by type of damage may provide a radio log that gives an indication of the type of occurrence, its location, and date. By knowing the location and date, further search of job files may reveal cost figures filed under those headings. Commonly, cost estimates must be based on the memory or field notes of employees, and it may be helpful to them to mention specific landslides in the area to prompt recall.

In some agencies the only pertinent data may be a total figure from the yearly report or budget in which a specific amount is allotted for landslide problems. It may or may not include costs of emergency services, restoration, maintenance, inspection, fees for outside services, and related staff time.

PROBLEMS ENCOUNTERED

The major problems encountered in obtaining cost information are lack of, or incomplete, records; difficulty experienced by sources in retrieving information; unwillingness of sources to attempt to locate data; confidentiality of data; and data that do not separate damage from other costs. For various reasons some sources simply refuse to release information, leading to the conclusion that documented costs are minimum figures.

Numerous additional problems are encountered. Different periods of data recording (fiscal year, calendar year, seasonal year) are used by various contributing agencies. Litigation, whether threatened or in progress, results in a natural reluctance to release information.

Difficult decisions may be required pertaining to what part of a total cost is attributable to landsliding (fig. 3). In the studies reported here, when interpretation of cost data was necessary or duplications of costs could exist, a low or conservative estimate was used. For example, the SBA (Small Business Administration) loans for landslide losses indicated private damages in Cincinnati and Delhi Township, Ohio, during 1973 of $1.2 million. This figure was larger than the reported costs provided by the consulting firms. The data from the consultants for those areas during 1973 were dropped because some duplication of costs was probably involved.

Establishing a yearly cost for a landslide event is a problem if its movement is a chronic, continuing, or yearly process, or if the landslide occurs 1 year but no funds are available for repair until a later year. The first instance might require taking one-tenth of the amount spent over a 10-year period, while the other might necessitate taking one-tenth of the amount spent in 1 year to repair damage during the preceding 10 years.

Probably the greatest shortcoming in record-keeping is that few agencies maintain a centralized record of the total amount of money or time expended on any specific landslide problem, or on landslides in general.

The net effect of problems associated with the data gathering is that reported costs of landslide damages tend to be less than those actually incurred. Investigations following preliminary published reports of landslide damage in the San Francisco Bay region (for example, Taylor and Brabb, 1972) show that, as further studies are made, additional costs can be identified. Assumptions must be made in order to compare costs from county to county and from year to year. Until more complete data are available, however, these costs provide a conservative estimate of the total cost of landslide damage.

REEXAMINATION OF COSTS OF LANDSLIDE DAMAGE IN THE SAN FRANCISCO BAY REGION (1968-69)

The winter storms of 1968-69 in the nine-county San Francisco Bay region produced an unusually large amount of landslide damage. In an attempt to determine direct and indirect costs of landslides to public and private interests, the U.S. Geological Survey undertook one of the first detailed studies of the cost of landsliding in so large a geographical area in the United States (Taylor and Brabb, 1972). Although the investigation followed the methodology described earlier, practically no guidelines existed at that time. Nevertheless, the study identified landslide-damage costs totaling about $25 million. In a followup study of damages that occurred in the same area during the winter of 1972-73, Taylor and others (1975) identified nearly $10 million in landslide damages. The second study revealed new sources of information and improved familiarity with record-keeping practices; as a result, previously undetected costs in sources that had been examined were uncovered. The improved perspective on types of costs and locations of in-

TABLE 2.—*Estimated costs of landslide damages in the nine-county San Francisco Bay region (1968-69)*

Source	Initial survey (Taylor and Brabb, 1972)	Reexamination	
Public:			
State	$ 4,996,000	$ 7,000,000	
County	5,177,000	6,000,000	
City	----------	4,200,000	
Tax loss	12,000	----------	
Private:			
Property depreciation	7,106,000	7,100,000	
Utilities	213,000	200,000	
Property damage	1,983,000	[1]2,000,000	[2]($25,800,000)
Miscellaneous	5,907,000	5,900,000	
Total	$25,394,000	$32,400,000	($56,200,000)

[1]Assumes SBA loans duplicated or did not exceed cost of damage as determined from other sources. The estimate is conservative.

[2]Assumes costs of damage to private property were equal to 1.5 times public costs. Ratio was determined from SBA data on loans provided during the winter of 1972-73. The estimate probably exceeds actual costs of damages.

formation led us to reexamine the sources and data for 1968-69. The data are summarized in table 2, which shows the results of the initial analysis and the reevaluation.

In the initial survey (Taylor and Brabb, 1972), State expenses were reported to be about $5 million for damage to highways. However, subsequent information indicates that amount should be about 40 percent greater (Robert M. Schroll, California Department of Transportation, oral commun., 1976). This is an 8 percent increase in the reported total of $25 million due to landslide damage for that single winter. Data as originally furnished did not include staff time and complete engineering costs. For similar reasons county expenditures previously reported, which were mainly for county roads, should be about 15 percent higher (Edward H. Meyer, Alameda County Public Works Department, oral commun., 1976) or an additional 3 percent of the total. A report covering the same area for the winter of 1972-73 (Taylor and others, 1975) indicated that the costs to cities (about $1,195,000) were about 0.7 as great as those of the county (about $1,653,000). With a few exceptions, which would not materially change the results, city costs were not included in the report covering 1968-69.[2] Revised county costs for the period of 1968-69 are $6,000,000, and if city costs are 0.7 as great it would add about $4,200,000 or 17 percent to the total initially reported for the 1968-69 period.

Information not previously available suggests that costs initially assigned to the private sector could have been greatly understated. In Marin County, the SBA gave assistance to those suffering storm damage during the winters of 1968-69 and 1972-73. Data have been made available for only the 1972-73 period but will serve as a basis for better estimates of private costs. The SBA interviewed 1,967 prospective applicants for loans to cover expenses due to flooding and landslide damage. Ninety percent of permanent damage was due to landsliding (Herbert Wimmer, Marin County Building Inspector, written commun., 1976), and SBA data herein quoted are reduced to this amount. Approval was given for 690 home loans amounting to about $2,300,000 and 65 business loans for about $900,000; this is an average of $3,000 per home loan, with business loans averaging $14,000 (Robert Belloni, SBA, oral commun., 1976).

Of the 952 persons interviewed but not applying, SBA estimated that 85 percent or 809 had damage that would have been covered had they been willing to go through the required procedure, or if the request exceeded $6,000, to secure the loan application with real property. If these prospective applicants had only about one-third the average home damage ($1,000), it would be an additional $800,000.

These three items—home loans, business loans, and potential loans—amount to $4,000,000 which, to avoid duplication, replaces the $1,094,000 already reported as private expense. The costs, which are for only one county (Marin) of the nine counties in the San Francisco Bay region, increase the estimate of cost of damages for 1972-73 of Taylor and others (1975) by 30 percent. If costs of damage to private property as revealed by SBA loans in the other eight counties were in the same proportion to those initially compiled in Marin County, the estimate of costs of private damages is $8,700,000 larger than reported (Taylor and others, 1975) and the total cost of damages for 1972-73 is about $18,400,000. This revised value has been based on some assumptions that may not be conservative and may overestimate the cost of damages for 1972-73.

SBA data on loans to repair costs of landslide damage for the winter of 1968-69 were not

[2]That city costs are substantial and nearly as large as county costs was not learned until the costs of damage were compiled for the winter of 1972-73 (Taylor and others, 1975). During the initial survey, city costs were thought to be relatively insignificant and to not justify the time required to document them.

available, and assumptions are necessary to revise the estimate of costs to the private sector. In table 2, two values are provided: The lower value assumes that SBA loans were equal to or less than the estimate of private costs obtained from other sources, in which case the SBA value would be discarded because of possible duplications. The higher estimate was obtained by comparing ratios of public to private costs for 1968–69 and 1972–73. Costs for damage to private property in Marin County in 1972–73 were about 1.5 times as large as the reported public costs of about $2,000,000 (Taylor and others, 1975). In 1968–69, the estimated public costs (as revised) for the nine-county region were approximately $17,200,000. Assuming that the 1.5 ratio of private property damage to public costs in Marin County in 1972–73 is approximately valid for the entire nine-county region for the winter of 1968–69, the revised costs of damage to private property in 1968–69 are about $25,800,000.

These increases in cost estimates for State highways, county roads, city expenses, and damage to private property indicate that the total of $25,394,000 initially recorded for 1968–69 was understated and should be increased at least by an additional $7,000,000 and perhaps by as much as $30,800,000. The total cost of damages for the nine-county San Francisco Bay region for the winter of 1968–69 is probably between $33,200,000 and $56,200,000.

The upper value ($56,200,000) is probably unrealistically large. Although the total amount of rainfall and number of landslides were about the same in 1972–73 as in 1968–69, the cost of damage was only about half as much in 1972–73 and more than 30 percent of it was in Marin County. In 1968–69, only about 4 percent of the cost of damage was in Marin County. The extrapolation of cost-of-damage data from Marin County in 1972–73 to all nine counties of the Bay region in 1968–69 is speculative but serves to place an upper limit on the costs. The lower value of $33,200,000 is a conservative estimate. The procedure discards information that could be duplicated and uses a low value if interpretation or apportionment of costs is necessary.

The incidence of landsliding in the San Francisco Bay region is related to patterns, intensity, and total amount of rainfall. In some years, numerous landslides occur and in others, practically none. To obtain an annual per capita estimate of costs of damage for the San Francisco Bay region, it is necessary to determine the recurrence of landslide-causing storms and to apportion the costs over years of little or no landslide activity. During the past 30 years in southern California, damaging landslides have been triggered about every 4 years. Nilsen and others (1976) estimated that mean annual rainfall similar to that in 1968–69 and 1972–73 has occurred in about 4 out of every 10 years in the Bay region during about the past century. The total estimated costs of damages for 1968–69 and 1972–73 are assumed to represent a 10-year period of landslide damage (probably a conservative estimate). Taking the mean of the estimated costs of damage for 1968–69 and 1972–73, adding them, and dividing by ten produces an estimate of the average annual costs of about $5,900,000. Dividing this by the 4,600,000 population of the nine Bay region counties gives an estimate of annual per capita costs of damage of about $1.30. This estimate ignores litigation and repair costs accrued in years other than the years when the landslides occurred and costs of damage were compiled.

COSTS OF LANDSLIDE DAMAGE IN ALLEGHENY COUNTY, PENNSYLVANIA (1970–76)

Costs of landslide damage have been documented for several areas in the Western United States, but few studies have been completed of losses in the East. William R. Adams, Jr., of the Allegheny County Geotechnical Center, conducted a preliminary study of the costs of landslide losses in Allegheny County. His study revealed that large losses occur annually and that a more complete accounting of landslide damages could be obtained through interviews with some of the affected agencies and individuals. The assistance of Mr. Adams in providing data and information on organizations is gratefully acknowledged.

Allegheny County is a highly urbanized county in western Pennsylvania, and Pittsburgh is its principal city. The county has 1.6 million inhabitants within its 1886-km² (728-mi²) area. Landslides have been a continuing problem for many years (fig. 4). The areas susceptible to landsliding in Allegheny County have been mapped by Pomeroy and Davies (1975).

FIGURE 4.—Rockfall in Pittsburgh, Pa., that closed Parkway East on April 27, 1978. Photo courtesy of William R. Adams, Jr.

This is a summary of the estimated costs of landslide damage in Allegheny County for the 7-year period of 1970–76. All costs are in terms of dollars expended during a given year, and no adjustments have been made for inflation. Information reported here was obtained from interviews conducted in Allegheny County during the week of August 8–12, 1977, from Mr. Adams, and with followup correspondence. Only a small percentage of all the potential sources of information was contacted. Undoubtedly a more comprehensive survey would reveal additional losses. Public sources that were contacted included Federal, State, county, and city agencies such as road departments, planning departments, environmental departments, and assessors; utility companies; sewage disposal agencies; and schools. In most organizations, only one individual was contacted. A listing of organizations that were contacted or that contributed information is in table 3.

The principal problem in obtaining data on costs of damage from landslides in Allegheny County is the very large number of sources that might have information. Only the most obvious sources could be contacted in the time available. There are 129 municipalities in Allegheny County. Some of these have offices that maintain records of costs for repair of landslide damage; others contract such work through private consulting companies and may have an incomplete account of costs. At least 200 utility companies exist in the county (table 4); added to these are several railroads, various river transportation authorities, and numerous commercial concerns. Other organizations that might have infor-

TABLE 3.—*Sources of information contacted on costs of landslide damage in Allegheny County, Pa.*

Source	Source
City of Pittsburgh:	Non-county agency:
City Parks	Allegheny County Sanitary Authority.
Department of Lands and Buildings.	Commonwealth of Pennsylvania:
Department of Public Works	Bureau of Topographic and Geologic Survey.
District Permit Engineer	Department of Environmental Resources.
Personal property Tax Office	Department of Transportation (PennDOT).
Pittsburgh Public School System	National Guard
Planning Department	Property Tax Assistance Bureau.
Police Department	Solid Waste Management
Statistical Information	State Forestry
Water Department	Water Quality
Allegheny County and Regional Offices:	Federal government:
Allegheny County Geotechnical Center.	Corps of Engineers
Allegheny County League of Municipalities.	Soil Conservation Service
County Parks	Private:
Intermediate Unit (schools)	Consulting engineering and geology firms.
Police Disaster Office	Utility companies
Public Works Planning and Development.	
Regional Parks	

TABLE 4.—*Types and number of utility companies in Allegheny County, Pa.*

[W. J. Adams, Jr., written commun., 1978]

Type	Number
Telephone companies	8
Gas companies	11
Electrical companies	3
Heating transmission companies	1
Petroleum transmission companies	11
Cable television companies	15
Oil companies	30
Water companies	58
Sewerage companies	63
Total	200

mation but were not contacted are the Allegheny County Assessor's Office, Southwest Pennsylvania Regional Planning Commission, Pennsylvania Department of Mine Subsidence, and various other county and city of Pittsburgh offices. Additional Federal and private costs might have been obtained, particularly for 1972, from the SBA and the Federal Disaster Assistance Administration.

The willingness or ability to provide data varied from organization to organization. Some sources could give a fairly complete account of expenditures for landslide damage, whereas others could give only a yearly estimate. Some consultants were reluctant to release information out of concern for the confidentiality of their clients.

Most of the costs data in this report are for the calendar years 1970–76. However, because some agencies use different recording periods—fiscal year or seasonal year—some costs may not have occurred in the calendar year to which they are ascribed. This discrepancy probably does not materially affect the total cost estimates.

Two categories of costs are reported: public and private. Most of the public landslide costs is the direct expense of repairing and restoring roads. This includes expenses readily attributed to specific large landslides and an educated guess for smaller slides, as these costs are included within budgets for routine road maintenance and repair. Public costs also include damage to municipally owned utilities and sidewalks and to other publicly owned facilities. Some public costs could not be classified as Federal, State, or county and were grouped as "municipal and other public funds." Items under this heading include expenses jointly funded by several levels of government, expenses of schools and parks, and those for several landslides believed to have resulted in local expenses but for which documentation was incomplete. Private costs are expenses to individuals and nonpublic groups.

Table 5 shows amounts attributed to both the public and private sectors for the years 1970–76. Damage repairs, including construction and maintenance costs, by the Department of Transportation are generally the highest single yearly expense. Several sources indicated that costs of preliminary design and engineering work and inspection, which are not routinely included in quoted construction costs, are almost 15 percent of the construction cost. This amount has been added to repair costs for each yearly total. Extensive Federal funds were expended in 1972 to repair landslide damage caused by Hurricane Agnes.

Private costs for the 7-year period range from 15 to 45 percent of the yearly total. The 15-percent figure is for 1972, when additional public monies were spent owing to Hurricane Agnes. The yearly average of private costs is 31 percent of the total. Information regarding private expenses was provided almost exclusively by seven private consulting engineering and geology firms. More extensive participation by other such firms would have resulted in a more complete account of costs and a higher yearly total. Note that the estimated costs of damages provided by consultants is the same amount for each of the years 1970–72. This is a result of all seven consulting firms estimating that the costs of landslide damages were the same or in the same range for those years.

TABLE 5.—*Costs of damage due to landslides in Allegheny County, Pa. (1970-76)*

Source	1970	1971	1972	1973	1974	1975	1976	7-year total	Yearly average	Annual per capita cost
Public:										
Federal	$3,000	$3,000	$903,000	$3,000	$3,000	$3,000	$3,000	$921,000	$132,000	$0.08
State	no data	319,000	1,801,000	703,000	290,000	1,768,000	952,000	5,833,000	833,000	.52
County	no data	10,000	122,000	10,000	20,000	2,000	2,000	166,000	24,000	.01
Municipal and other public funds	878,000	393,000	600,000	466,000	705,000	793,000	450,000	4,285,000	612,000	.38
Subtotal	881,000	725,000	3,426,000	1,182,000	1,018,000	2,566,000	1,407,000	11,205,000	1,601,000	.99
Private	582,000	582,000	582,000	621,000	590,000	574,000	554,000	4,085,000	584,000	.36
Total	$1,463,000	$1,307,000	$4,008,000	$1,803,000	$1,608,000	$3,140,000	$1,961,000	$15,290,000	$ 2,185,000 [1]($4,000,000)	$1.35 ($2.50)
Percent of total that is private	40	45	15	34	37	18	28	27	27	

[1]Because only a few of the more obvious sources of costs-of-damage information were contacted, the authors think that the annual cost exceeds $4 million.

This study, limited in both time and in the number of sources contacted, indicates that an average of nearly $2.2 million per year is spent in Allegheny County owing to landslide damage. Studies of the San Francisco Bay region (Taylor and Brabb, 1972; Taylor and others, 1975; and this report) have shown that preliminary documentation of economic loss due to landslide damage may be less than half the actual total. This is likely true for Allegheny County, and landslide damage probably costs the public and private sectors there an average of at least $4 million per year.

If the $2.2 million figure is divided by Allegheny County's 1975 population of 1,605,016, the annual per capita cost of landslide damage is $1.35. Using the more realistic $4 million figure would raise this to $2.50 per capita per year.

COSTS OF LANDSLIDE DAMAGE IN HAMILTON COUNTY, OHIO (1973-78)

Hamilton County, Ohio, and nearby counties in Ohio and Kentucky have experienced severe landslide problems in both public and private land. Landslides occur most commonly in colluvium developed on shales of the Kope Formation and in glacial deposits, principally till and lake clays. The types and physical setting of the landslides in the Hamilton County area have been described by Fleming (1975). Figure 5 shows a typical landslide problem involving several homes in the northern part of Cincinnati. The landslide, which is developing very slowly in glacial-lake clays, has produced obvious cracks in the house, sidewalk, and driveway. The small scarps and bumps in the lawn could be easily overlooked as landslide features by an unsuspecting observer.

FIGURE 5.—Cracks in a slowly developing landslide in glacial materials damaging this house and several others in a subdivision in Hamilton County, Ohio. Landslide problems in 1973 in this same subdivision did not affect homes but necessitated expensive repairs.

Local officials and the general public are working to reduce landslide damages. The City of Cincinnati enacted an excavation and fill ordinance in 1974, and the City Planning Department is regulating development through the use of zoning districts for hillside areas. The City of Cincinnati has also sponsored a project to identify and map slopes susceptible to landsliding. The Hamilton County Departments of Planning and Engineering have active programs to reduce landslide losses. Landslide events receive extensive coverage in the news media, and the public is being informed of the signs that a slope failure

TABLE 6.—*Sources of information on costs of landslide damage in Hamilton County, Ohio*

Source	Source
Cities, villages, and townships	Federal Government:
City of Cincinnati:	SBA
Structures, Permits, and Highways, sections of Engineering Division.	Federal Housing Administration
Highway Maintenance	Cincinnati Metro Housing Authority
Planning Department	U.S. Department of Agriculture
Building, License, and Permit Office.	Soil Conservation Service
Metro Sewage Disposal	Internal Revenue Service
Water Works	U.S. Geological Survey
City Park Board	Private:
City Public Utilities	Engineering Society of Cincinnati
City Public Library	Cincinnati Institute
Regional Computer Center	Salvation Army
Hamilton County:	Cincinnati Gas and Electric
Engineering Division	Cincinnati Bell
Auditor's Office	N & W Railroad
Real Estate Tax Office	Conrail
Planning Department	Chesapeake and Ohio Railroad
Building Department	"Cincinnati Enquirer"
Ohio:	Private consulting firms
Department of Transportation	
Bureau of Employment	

may be occurring and of potential remedial techniques.

Contact was made with 39 of the 50 municipalities within Hamilton County. Calls to the telephone numbers of 11 cities and townships were unanswered, but it is likely that data supplied by the Hamilton County Engineer's office include damages incurred by most of these municipalities. Other agencies that might have cost data were also contacted. Table 6 lists the organizations contacted.

The local interest in landslide problems facilitated the collection of costs-of-damage information. Virtually everyone contacted gave freely of time and costs data. Although 38 cities, 12 townships, and a large unincorporated area compose the 1072-km^2 (414-mi^2)area, we believe that the survey of costs of damage is reasonably complete.

Although the data are considered complete, an event that would have greatly increased damage figures was intentionally not included. A major landslide in Cincinnati in 1974 resulted in damage to a highway under construction and to several private structures. Some public and private funds have been expended for study, emergency services, and temporary repairs; and some of these costs may be included in our compilation. In 1979, estimates for permanent repair of the landslide went upward from about $22 million and litigation is in process. Many interests are involved, including public agencies, private landowners, consultants, and attorneys; and it is likely that the landslide will be one of the most costly to date in the history of the United States. Because the landslide has not been repaired and the legal issues have not been resolved, the only costs associated with it included in this tabulation are relatively insignificant.

The costs of landslide damage in Hamilton County, Ohio, for the years 1973–78 are summarized in table 7. Total damage costs for the 6-year period are $30,990,000. The annual average cost of damage is $5,165,000 unadjusted for inflation. Dividing this figure by the population of Hamilton County (883,800 in 1977) produces an average annual cost per capita of about $5.80.

PRELIMINARY ESTIMATE OF COSTS OF LANDSLIDE DAMAGE IN THE MANTI, UTAH, AREA (1974–76)

BACKGROUND

The city of Manti, with a population of about 1,800, is situated near the geographic center of Utah. It is located on an alluvial fan at the mouth of Manti Canyon, which is about 14.5 km (9 mi) long from east to west and as much as 5 km (3 mi) wide (fig. 6). Most of the canyon slopes, particularly on the south side of Manti Creek, are characterized by hummocky topography and scars of past landslides. One of these old landslides, located within the Manti-La Sal National Forest and about 6.5 km (4 mi) from the city of Manti, was reactivated in the spring of 1974 (fig. 6).

Reactivation of the landslide was triggered by a rock slide from the south rim of the canyon. The rock slide, mixed with abundant water from snowmelt, mobilized into a debris flow. Part of this debris flow came to rest on, and thus loaded, the upper portion of the old landslide. Cracks propagated downslope in the landslide mass, and a waterline supplying water and providing hydroelectric power for Manti was broken. During the first year, movement was confined to the upper two-thirds of the landslide. Movement rates locally exceeded 6 m (20 ft) per day, and a total of more than 60 m (200 ft) of downslope displacement occurred. In mid-1975, cracks formed in the lower part of the landslide; by August 1975 the active landslide, comprising perhaps 15 million m^3 (20 million yd^3) of debris, was about 3.2 km (2 mi) long and as much as 0.8 km (0.5 mi) wide. Dif-

TABLE 7.—*Costs of landslide damage in Hamilton County, Ohio (1973-78)*

Source	1973	1974	1975	1976	1977	1978	6-year total	Yearly average	Annual per capita cost
Public:									
Cincinnati and other cities and townships	$1,410,000	$560,000	$3,460,000	$1,000,000	$320,000	$400,000	$7,150,000	$1,192,000	$1.35
Hamilton County	200,000	350,000	150,000	540,000	160,000	2,000,000	3,400,000	567,000	.64
State	no data	no data	120,000	60,000	no data	580,000	760,000	126,000	.14
Federal	40,000	2,310,000	2,400,000	1,640,000	1,760,000	120,000	8,270,000	1,378,000	1.56
Miscellaneous public	no data	70,000	50,000	no data	no data	no data	120,000	20,000	.02
Subtotal	1,650,000	3,290,000	6,180,000	3,240,000	2,240,000	3,100,000	19,700,000	3,280,000	3.71
Private:									
Consultants, utilities, and SBA disaster loans	1,650,000	30,000	2,980,000	1,480,000	1,370,000	3,470,000	10,980,000	1,830,000	2.07
Total	$3,300,000	$3,620,000	$9,160,000	$4,720,000	$3,610,000	$6,570,000	$30,680,000	$5,110,000	$5.80
Percent of total that is private	50	9	33	31	38	53	36	36	

ferent parts of the landslide moved at different rates. The lower part moved at about the same rate that the now nearly stationary upper part had moved a year earlier. Federal, State, and local officials were concerned that the landslide would block Manti Creek and that subsequent large "breakout" flows of the creek would inundate a large part of the city of Manti with floods or debris flows.

The concern over the potential blockage of Manti Creek precipitated a significant expenditure of money for analysis and preparation for a disaster that fortunately has not occurred. Various local, State, and Federal agencies worked on contingency plans and examined alternatives for remedial or preventive treatment of the unstable areas. The risk to the city of Manti was concluded to be small compared with the costs of any of several possible remedial plans, especially considering that the success of the plans could not be assured.

Since the initial movement during 1974 and rapid movement of the lower part of the landslide in 1975, the rate of movement has decreased. This supports the decision not to attempt to stabilize the moving ground or the channel of Manti Creek. However, a large fractured mass of rock remains in the canyon rim above the landslide, and a renewed cycle of movement could start if the events of 1974 were to be repeated. The landslide will likely continue to be a troublesome problem for many years to come.

COSTS OF LANDSLIDE DAMAGE

Although the landslide is 6.5 km (4 mi) from the nearest permanent dwelling, it has proven to be a

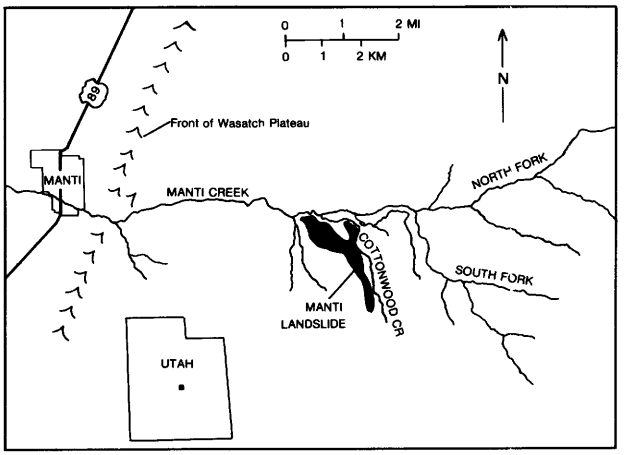

FIGURE 6.—Map showing the Manti landslide, Manti Canyon, Utah. (Modified from Fleming and others, 1977.)

costly problem for the Manti area. The broken waterline caused loss of revenue from the hydroelectric system and has necessitated development of an emergency water supply and replacement of the waterline. In addition, large amounts of debris introduced into the creek by the landslide resulted in the deposition of sediments in the irrigation systems and agricultural fields downstream. Documented costs attributable to the landslide were nearly $1.8 million by August 1976. Approximately one-third of this cost was related to physical damage or cleanup work resulting from the earth movement. The greater portion, some $1.1 million, was spent for investigation of the landslide and preparation for the potential disaster that did not occur.

Additional funds have been expended since August 1976, but they are small in comparison

TABLE 8.—*Sources of information on costs of landslide damage in Manti, Utah*

Source	Source
City of Manti:	Federal Government:
Mayor's office	National Weather Service
County of San Pete:	Soil Conservation Service
Civil Defense	U.S. Army Corps of Engineers
Public Works Department	U.S. Forest Service
State of Utah:	U.S. Geological Survey
Office of Emergency Services	Office of Senator Moss
Utah Geological and Mineral Survey.	
Utah National Guard	

TABLE 9.—*Expenditures by governmental agencies on the landslide in Manti Canyon (June 1974-August 1976)*

Federal Government	$ 769,000
State of Utah	76,000
County of San Pete	61,000
City of Manti	883,000
Total	$1,789,000

with funds spent earlier. This preliminary accounting of expenditures documents costs through August 1976; it does not, however, include some known losses that could not be evaluated and for which a cost could not be assigned. For example, on the landslide, a large number of trees were killed, a small reservoir was destroyed, and a few animals, mostly deer, were killed. Also, damage from siltation to cropland and the irrigation system was an undetermined cost.

Costs of the Manti landslide were obtained by interviewing individuals in the different organizations known to have expended funds (table 8). In general, only one individual was interviewed in each governmental unit, and the information may not be complete.

The costs attributable to the Manti landslide are summarized in table 9. The amounts listed are actual expenditures, except that the figure for the State of Utah includes an estimated value of $59,000 for service provided by the Utah National Guard. As part of their training, they donated manpower, equipment, and emergency water treatment units to the city of Manti. Including this amount seems appropriate because the services were essential and would have been required of another source if the Utah National Guard had been unable to cooperate.

The costs to the city of Manti include $67,000 directly attributable to landslide damage. The additional $816,000 includes funds for replacement of the waterline and valves, the drilling of a water well for an auxiliary water supply, and preventive maintenance on drainage channels. A 30.5-cm (12-in.) waterline was installed to replace the original line of 20.3 cm (8 in.) and 25.4 cm (10 in.), thus doubling the capability for water delivery. The installation of a new well and pump and a booster pump in the city of Manti provides a standby water system not previously available. Some part of the cost should perhaps be assigned to upgrading the water-supply facilities and not be treated as landslide damage. However, the total amount has been included because the expenditure was precipitated by the landslide. If this results in an overstatement of costs attributable to the landslide, it is offset somewhat by undetermined costs associated with the loss of timber and siltation damage to cropland and the irrigation system.

The cost to the city and, therefore, to the 1,800 residents of Manti was about $883,000 or nearly $500 per person. The total cost of the landslide, excluding the items that could not be defined, was about $1,800,000 or $1,000 per person in Manti. The costs were accrued over a 3-year period, making the average cost $333 per person per year. Obviously, this was an unusual event for Manti, and some estimate of recurrence should be applied to obtain a meaningful cost. Unfortunately, we do not know whether the landslide was a 50-, 100-, 500- or even a 1,000-year event. The range of per capita cost of landslide damage in Manti, Utah, is probably between $1 and $20 per year.

SUMMARY

In those communities for which estimates of costs of damage have been compiled, the costs are much larger than generally believed by the public and by government officials. Schuster's estimate (1978), placing the national cost of landslide damage at in excess of $1 billion per year, is reasonable.

In areas where landslide control programs have been implemented, however, they have proven effective in reducing damages. Communities that have landslide problems are encouraged to assess the costs of damage to public and private property and weigh those costs against the costs of a landslide reduction program. The prevention of a

single major landslide in a community may more than compensate for the effort and cost of implementing a control program.

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