FINAL REPORT
NORTHERN KENTUCKY
LANDSLIDE DOCUMENTATION INVESTIGATION
STATEWIDE CONSIDERATIONS

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Introduction

The greater Cincinnati area of northern Kentucky and southwestern Ohio has long been recognized as a region of unstable slopes. It is reported that landslides have been mentioned occurring as far back as 1850. As the metropolitan region has expanded onto the unstable slopes, landslides have become an increasingly significant problem that impacts the welfare of the citizens and the economic development of the community.

The susceptibility of this area to landslides is the result of a combination of factors. First, the region is a gently rolling upland dissected by deeply incised valleys of the Ohio River and its tributaries as well as those of ancient drainage systems. There is about 360 feet of relief between the Ohio River and the adjacent uplands and the slopes of these hillsides may become quite steep. Secondly, the region is underlain by a variety of surficial materials that contribute to slope instability. These include glacial tills on the uplands, lacustrine clays in the valleys and a clay- rich colluvium on the hillsides that has been derived from the weathering of the underlying shales, particularly those of the Ordovician Kope Formation. These factors, when accentuated by periods of heavy precipitation along with the ever- present demand for hillside development, have combined to create an environment that is highly susceptible to slope instability. As a result, landslides have a significant social and economic impact on the northern Kentucky – southwestern Ohio region and the costs of landslide prevention and remediation in this area reportedly are among the highest in the nation.

As a result of the considerable costs resulting from landslides experienced in this region, the northern Kentucky-southwestern Ohio area has been the subject of several studies defining the economic and social impact of their occurrence. Fleming and Taylor (1980) determined that the cost of landslide damage in Hamilton County, Ohio averaged about $5,170,000 per year between 1973 and 1978. Fleming and Taylor believed however that their estimates were lower than the actual costs incurred because many of the agency records were incomplete or unavailable and that indirect costs of damage, (for example legal fees and architectural fees), which were excluded from the estimates, could have equaled or exceeded the direct costs. A study by the Earth Surface Process Group (1987) indicated that the City of Cincinnati spent about $500,000 per year on emergency street repairs for damage due to landslides between 1983 and 1987. In addition, Pohana (1992) stated that Cincinnati's costs for landslide repair from 1988 to 1992 was $7.5 million and was projected to increase to $8.5 million from 1993 to 1997. An overview of landslide occurrence, cost estimates and mitigation considerations, along with a history of landslide investigations in the northern Kentucky-southwestern Ohio area, is presented by Baum and Johnson (1996).

To date however, it has been difficult to quantify the cost of landslide damage because of the variety and degree of applicability of accessible records available providing information on the extent of repair and

replacement costs or the costs associated with the implementation of procedures to prevent landslide damage. This study is part of a Landslide Loss Estimation Pilot Project directed by the Geologic Hazards Committee of the Association of American State Geologists and the USGS Volcano hazards and Landslides Hazards Program Office to determine, from selected local governments, what kind of information is currently available and if it is feasible to develop a program for more regularly kept records of landside losses.

METHODS AND SCOPE OF SURVEY

Being able to quantify the costs of landslide damage on an annual basis is an important way of demonstrating the real costs associated with landslides and for mobilizing greater efforts to reduce future damage. The objectives of this study have been to facilitate the quantification process by investigating methodologies currently used for the collection, tabulation, and the availability of landslide cost-of-damage data for Campbell, Kenton and Boone Counties of northern Kentucky and Hamilton, Clermont and Brown Counties of southwestern Ohio and to evaluate the applicability of this data for defining reliable estimates of landslide damage costs. It is particularly significant that this study has coordinated efforts in two states to meet these objectives. Since the geologic and topographic conditions that contribute to the development of landslides are very similar on "both sides of the river" in this area, this cooperative study provided a unique opportunity not only to an expand the scope of work, but also to document similarities and or differences in approaches to landslide remediation efforts and the availability of landslide cost-of-damage data in adjacent states.

DATA SOURCES IDENTIFIED

The work plan specified for this project (U. S. Geological Survey, Requisition No. 01HQ-R01917, 17 December 2001) described a number of individual tasks necessary to meet this objective. These tasks were to a certain extent sequential and were defined to be specific, identifiable components of the stated overall objective. It was anticipated that completion of these tasks would provide the opportunity to determine the thoroughness of current procedures for the documentation of landslide-damage costs and the feasibility of retrieving future landslide- damage data through regularly kept permit or other record systems. The individual tasks defined in the work plan are as follows:

A.– Identify the most landslide-prone jurisdictions in Boone, Campbell and Kenton Counties, Kentucky

B.– Contact private firms to evaluate records of repair or remediation of landslide damage

C.– Contact public- sector agencies to evaluate records

D.– Assess kinds, quality and accessibility of landslide loss records

E.– Analyze the data base to identify possible relationships among landslide occurrence and topographic conditions (slope), geologic conditions (bedrock lithology) and overburden materials (soils) using GIS procedures.

F.– Evaluate any correlations developed to determine if landslide prone areas could be defined for future landslide-loss prevention efforts.

G.– Design and develop a computerized database for capture of historic and future landslide data to include: types of landslides, causative factors, types of damage and resultant costs for remediation and stabilization

H.– Analyze the quality, quantity and accessibility of landslide data

FINDINGS FROM SURVEY

A.– Identification of landslide-prone areas---

One of the major factors that determine the overall costs to a region or municipality for landslide prevention and/or mitigation is the amount of area that is susceptible to slope instability. The contribution of bedrock lithology, soil type and topography in forming unstable slopes in Cincinnati has been described in a previous study (Sowers and Dalrymple, 1980). From this investigation, Sowers and Dalrymple developed a Landslide Susceptibility Map that identified and ranked areas of potential landslide susceptibility for the City of Cincinnati. Generally, it was found that the Kope and Fairview Formations, the Pate and Eden soil types and slopes greater than 20% most closely correlated with landslide occurrence. From the results of this study, four landslide susceptibility categories were established, based on the extent to which these parameters were present in an area. Given that geologic, topographic and overburden conditions in northern Kentucky are very similar to those in Cincinnati, it is to be expected that landslide susceptible areas in Boone, Campbell and Kenton Counties will exist where there are similar relationships.

B Contact private firms---

The geotechnical engineering firms considered as having significant experience in landslide investigations and design of landslide remediation projects were contacted for this task. This involved personal interviews with both engineering geologists and geotechnical engineers. These firms were most cooperative and provided opportunities to review data on landslide occurrence, causative factors and remediation efforts and to discuss company policy on the availability of landslide-cost data and the limitations to its accessibility.

C.– Contact public-sector agencies---

A broad spectrum of public–sector agencies were contacted for this study with the result that discussions were held with individuals having a broad range of both experience in and involvement with landslide remediation efforts. Those agencies that seemed to have the most applicable records on landslide costs included:

- Northern Kentucky regional Planning Commission
- Kentucky Transportation Center
- Kentucky Transportation Cabinet
- City Engineer, Covington, Kentucky
- City Engineer, Newport, Kentucky
- Similar agencies in Ohio, including geologists and geotechnical engineers with the City of Cincinnati and Hamilton County responsible for landslide mitigation efforts.

D Assess kinds, quality and accessibility of landslide loss records---

As would be expected where a broad spectrum of firms and agencies are involved in landslide remediation activities, there is a wide range in the kinds, quality and availability

of landslide- cost data. The results of this study suggest some general observations regarding the development of a landslide- cost database.

Landslide- cost data is much more readily available from public- sector agencies than from private firms. This is of course to be expected considering the confidentiality that must be respected in private practice. In addition however, it was noted that the firm doing the landslide site investigation and remediation design in private practice may not necessarily be the firm involved in the construction phase of the project, thus may not have access to the total remediation cost. Landslide- cost records maintained by most private firms however reportedly are well documented and may be cross referenced by type of event as well as location in a computer database maintained by the firm.

In the public sector, the Kentucky Transportation Cabinet maintains a comprehensive database of landslide- remediation costs on state and federal highways. Landslide-remediation efforts are maintained as project files although it did not appear that the database included a category for just landslide events. The costs for landslide-remediation projects are included as part of the database. Annual maintenance costs do not appear to be considered in this database but are considered as an additional expense and part of the overall budget for maintenance expenses.

The Kentucky Transportation Center has recently published a report on Rockfall Mitigation Measures (Hopkins et. al., 1966) for the Kentucky Transportation Cabinet that is designed to establish a highway rock cut slope policy for Kentucky and to devise a statewide system of dealing with rock slope instability. Currently, as part of a project to develop a comprehensive Geotechnical Database, the Kentucky Transportation Center has compiled a listing of 1300 landslides and 2100 rocks slopes susceptible to failure. The objective of these studies is to reduce the estimated $10 million dollars a year the state spends to repair landslides (Hopkins, 2002).

E.– Initially, GIS vector data including soils, slope and general geology were collected from the Boone and Northern Kentucky Area Planning Commissions, Kentucky Office of Geographic Information and the Kentucky Geological Survey, respectively.

The soil data was classified with respect to their relative stability by using the U. S. Department of Agriculture Soil Survey for Boone, Campbell and Kenton Counties, Kentucky (USDA, 1989). Each soil was rated on a scale of 1 to 4 according to its stability, the higher the number, the more susceptible the soil to down slope movement. The same process was carried out for rating the slope and bedrock lithology. Slopes between 0 - 10% were rated at 1, between 10 – 20% slopes were rated as 3, and slopes greater than 20% were rated as 5. The bedrock lithologies were evaluated with the Bull Fork formation rated as 1, the Fairview rated as 3 and the Kope Formation as 5. Although the ratings were arbitrarily assigned, they represent relative relationships among the parameters.

After the parameters were rated, the data was converted into raster data sets of 10-meter resolution. The ratings from each layer was added together and given a total score. The range of possible total scores was from 3 to 15. A score of 3 – 6 was considered to represent a low potential for landslide susceptibility, a score of 7 – 9 slight susceptibility, a score of 10 – 12 moderate susceptibility and slopes having scores of 13 - 15 were considered to be highly susceptible to landsliding. The results are presented on the map of Landslide Susceptibility in Northern Kentucky (Dougherty, 2002).

F.– The map of Landslide Susceptibility in Northern Kentucky delineates those areas in which the major factors that contribute to slope instability in this area are present.

As such, it provides a basis for defining regions that are landslide-prone and may require additional efforts to minimize losses from landslide occurrence in the future. It must be considered however that the layers used in the preparation of this map were not given any differential weight and all factors were considered as if they had equitable affects on slope instability. As such, the map produced should be considered as an initial study that illustrates that landslide-prone areas may be identified, but also that additional correlations with landslide frequency of occurrence must be considered to determine if there is a more applicable weighting scale for the contributing parameters.

G.– Design and develop a computerized database for capture of landslide information---

The Kentucky Transportation Research Center is now near completion of a two-year project to develop a Comprehensive Geotechnical Database that includes very thorough documentation of the details of landslide events and the costs associated with landslide and rockfall remediation. Development of a computerized database for capture of landslide information equivalent to those currently available or in process thus was considered to be unnecessary at this time but should be implemented for a future comprehensive landslide cost-of- damage study.

LIMITS AND OPPORTUNITIES

Landslides and the cost of landslide remediation have a large economic impact in northern Kentucky. As such, a large number of private firms and public-sector agencies are involved in landslide remediation and there is a broad spectrum of data available on the costs of this remediation. The completeness of the data, the type of data collected and the availability of the data documented however depends on the needs and responsibilities of the collecting agency, thus varies greatly from source to source. There is at this time no central location or authority responsible for the documentation of landslide events or the costs of landslide remediation.

This study, being conducted in conjunction with a similar study in Southwestern Ohio, provided a unique opportunity to analyze the quality, quantity and accessibility of landslide data in two distinct urbanization environments. Hamilton County and the City of Cincinnati are highly urbanized, the hillsides are under great pressure for development and these political entities have the financial ability to support technical staff necessary to implement programs to minimize the losses from potential landslides. As a result, these political entities have developed comprehensive programs for documentation of landslide events and, to the extent available, have records of landslide remediation costs for public works facilities. Boone, Campbell and Kenton Counties in northern Kentucky however are not as urbanized yet and do not have the financial resources or the need to support similar activities. Landslide remediation generally is the responsibility of the county or city engineer and there is no existing regional effort to develop a database for the costs of landslide remediation. This is probably a very typical situation and future activities to develop a statewide database to document the costs of landslides to the economy will have to consider the structure of the various political entities involved and their ability to participate in the program.

It appeared however, that the Kentucky Transportation Cabinet, because of their experience in landslide remediation and the fact that their responsibilities cross political entities, has established a landslide database for the documentation of landslide remediation efforts that is most representative of those available. The forthcoming Comprehensive Geotechnical Database being developed by the Kentucky Transportation Center for the Cabinet will expand the applicability of this effort. Although the existing procedures for documentation of landslide related costs do not seem to be organized for an evaluation of

the total cost to the economy, records for costs associated with annual maintenance and for specific remediation projects are documented and should be available for evaluation.

The cost to the economy from landslides remediated in the private sector however will be much more difficult to define. Because of the limitations noted previously, it is most likely that the data available for evaluation will be an "educated guess," based on an estimate of the number of landslide remediation projects on record and an average cost for a remediation project.

The results of this study suggest that it appears as if there is a sufficient quantity of data available on the costs of landslide remediation so that it would be possible to determine a reasonable estimation of the overall economic impact of landslides to the northern Kentucky area. The results also indicate however, that the type, quality and availability of this information does vary considerably and that it would consist primarily of direct costs, mainly from public-works activities, thus there would be the potential for basing the report on an incomplete or not thoroughly representative database.

ADDITIONAL INFORMATION

A presentation of specific recommendations for further investigation based on the conclusions of this investigation would help build a case for additional federal funding of landslide-cost estimation projects. For example, a plan could be presented to create a landslide-cost/information database for the tri-county northern Kentucky area that is populated by querying databases already established, or to be established through the Kentucky Transportation Cabinet.

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