Slope Stability Technology Transfer in the Forest Service

Presented at the 1994 ASAE International Meeting, June 19-22, Kansas City MO
Paper No. 942107

William J. Elliot	Thomas E. Koler	David Hall
Project Leader	Research Geologist	Comp. Prog. Anal.

USDA Forest Service, Intermountain Research Station, Moscow, Idaho

Introduction

Within the USDA Forest Service, there has been an award winning Technology Transfer Program between the Slope Stability Research Team, and the National Forest System who manage over 200 million acres of forest, grassland, and research lands (USDA, 1992). This paper describes this program and compares it to other technology transfer programs within natural resource management.

The relationship between research and application has always been vital in the development and adoption of new technology. Much research has gone into determining why some innovations were successfully adopted, and others, although as valid and useful, were not adopted (Lionberger and Gwin, 1982). With some innovations, the transfer of the technology is between highly qualified extension agents and individuals with relatively little technical knowledge, as is common in agriculture and third world development. With other innovations, the transfer of information is between researchers and highly trained users as is common in professional societies and within higher education and graduate education. Within natural resource management, all levels of technology transfer have been practiced, ranging from between extension technician and uneducated farmer to between government research scientist and agency policy makers who may be more technically qualified that the researcher.

Technology Transfer in Natural Resource Management

When considering the transfer of technical information in natural resources, there are several agencies who have traditionally been considered highly visible and effective: The Agricultural Extension Service, the Soil Conservation Service (SCS), and the teaching at Land Grant Universities.

The agricultural extension service was established in the 1860s to transfer technology from state research stations to farmers. Local agents work with university researchers to disseminate research results to thousands of individual farm managers. Generally, farmers can individually choose to adopt or reject any new innovations. The Food Security Act of 1985, however, limited federal aid to farmers who did not adopt management practices considered beneficial to the environment (Glaser, 1986). The Bill significantly increased the transfer of conservation-related technology.

The SCS has also had increased technology transfer activities associated the the 1985 Farm Bill The SCS has played a major role since the 1930s in obtaining technology from researchers, and transferring it to application on individual farms and local conservation districts. Generally, the decisions about exact applications and design procedures are made at state or national level, with area engineers working with local conservationists and technicians to apply the technology.

Technology transfer in engineering and geology professions beyond formal university education has a long tradition of relying on professional societies with their journals and meetings for dissemination of research results. If there are major new developments, universities, professional societies, and specialized consultants may offer high level courses to train practitioners. The decision to take such training and apply the new technology is generally made by the individual professional or his employer. The decision may be driven by changes in public policy which dictate the application of new technology in the professional's field.

Forest Service Culture

The Forest Service is a natural resource agency operating within the Department of Agriculture and has two branches, the National Forest Service (NFS) and Research. The agency is nearly 100 years old, being established as the Forest Reserve in 1897 and as the Forest Service in 1905. It has developed over this time from one that required land managers to use technology from horse back early in this century to today where specialists working for land managers use personal computers and data from satellites.

The NFS mandate from Congress is to manage the national forests for multiple-uses. Within the NFS, the U.S. is divided into ten regions. Each region will have a number of National Forests. National Forests are divided into Ranger Districts for onsite administration. Within each tier of management are specialists in areas such as forestry, soil science, hydrology, biology, geology, and engineering which includes geotechnical engineering on some forests. Regions and Forests usually have considerable scope for independent decision-making about the methods employed to achieve broad management goals set at Regional or National Level.

The Forest Service National Office in Washington D.C. provides the leadership in budget and management direction for various technical staff areas of national forests and research. The national engineering staff leadership has been vital for successful slope stability research and development; especially in this current age of ecosystem management of national forests.

The mandate for Research is to provide scientifically valid methods for the NFS to use in forest management practices. There are nine research stations within Forest Service Research, with over 70 research laboratories and research projects located throughout the forested areas of the United States.

National Forest Service Culture and Independence

Policy and management direction are provided from the national office to regional offices, but each forest has independence in accomplishing management objectives in a style suitable for the locality. This follows the legacy of Gifford Pinchot, the first chief of the agency, who espoused the need for managers "close to the ground", requiring a degree of autonomy to be successful forest managers. Consequently, the NFS culture supports this independence and confidence in its ground level managers, the district rangers. Complexity of forest management requires a wide spectrum of expertise to assist the district rangers in their decision-making. Therefore, the district rangers hire and maintain a staff of technicians and specialists to provide them with professional input for their management decisions. Not all ranger districts can afford large staffs; therefore, technicians and specialists are frequently shared between districts and are assigned to the forest headquarters or a zone office. This agency culture promotes a professionalism requiring journey-level technicians and specialists to have skills that include the ability to work independently with little supervision. Intraforest and regional mentoring is a key component in this corporate work ethnic, and this is especially true with the geotechnical engineers and engineering geologists who are slope stability experts.

Slope Stability Research Program in the Forest Service

The role of slope stability research is to provide the NFS with methods to measure, classify, evaluate and analyze unstable and potentially unstable slopes in forest uplands. To this end several methods have been developed over the last fifteen years by the Intermountain Research Station. During the development of these methods, the researchers used the knowledge base of the engineers and scientists working in the NFS. This synergistic approach provided two valuable results: NFS ownership in the developed methodology, and, a large empirical database. This close working relationship between Research and the NFS has fostered many viable products and tools that are not only used within the agency but also by specialists in other federal and state agencies, timber industry, and geotechnical engineering consulting firms.

Historical Work

Slope stability work was carried out by foresters and forest engineers up to the early 1960s at which time the agency recognized the importance of hiring civil engineers in this work. Many of the engineers became geotechnical engineers through on-the-job-training and graduate course work. Also during the 1960s, and to the present time, much slope stability work was completed by soil scientists. The hiring of engineering geologists and the establishment of geotechnical engineering staff areas on most forests were the result of environmental policy legislation enacted in the late 1960s and early 1970s. These laws include the National Environmental Policy Act of 1969, the Federal Water Pollution Control Act Amendments of 1972, the Endangered Species Act of 1974, and the National Forest Management Act of 1976. Slope stability work for timber sale planning in the 1970s and 1980s was usually completed by foresters and soil scientists assigned to ranger districts. Engineering geologists, assigned to the geotechnical staff area in forest headquarters, were usually requested to work on complex slope stability problems for these proposed timber sales. Slope stability work associated with transportation planning, road construction and reconstruction, rock and aggregate resources (pits and quarries), fish ladders and dams was completed by the geotechnical staff. Today, these geotechnical positions have been eliminated or greatly reduced as a result of the timber program reduction. For most forests, the slope stability work has returned to the domain of foresters, soil scientists, and now hydrologists and fish biologists.

Slope stability research, carried out by the Intermountain Research Station, was initiated in the 1970s in response to requests from forest engineers in the NFS by Burroughs and Prellwitz (Koler, 1992). Prellwitz developed a three-level slope stability method that is scalar dependent: a) Level I for area planning has a scale of 1:24,000; b) Level II for project planning has a scale of 1:3,600; and, c) Level III for design work has a scale of 1:120 (Koler and Neal, 1989). In the mid-1980's Hammond joined the research project and worked primarily in Level I, soil mechanics, and computer simulation research. All three researchers built their mutual research in slope stability on their contacts with technicians and professionals in the NFS and the Bureau of Land Management (BLM) under several memorandums of understanding and cooperative agreements. Most of the field sites were in Northern California, Oregon, Washington, Idaho, and Montana.

Model Development

Prellwitz's early work was developing 2-dimensional models using the limit equilibrium infinite slope and method of slices equations, and stability charts for use in each slope stability level. During this time the Hewlett-Packard 41 CV programmable calculator became widely available. Prellwitz coded the the infinite slope equation for Level I, and the method of slices for Levels II and III for the calculator. These programs were popular with the NFS specialists and were used on many forests by geotechnical engineers and engineering geologists (Koler and Neal, 1989). The NFS specialists provided evaluations of these programs allowing corrections and improving the code for each level. By the mid-1980s, three-level models were being used by many geotechnical specialists in forests in the Intermountain, Rocky Mountain, Pacific Northwest and Southwest areas, by the Federal Highway Administration, and private consultants (Koler and Neal, 1989; Koler, 1993; Cloyd, in press).

In the mid-1980s Hammond and Prellwitz developed a computer program for the limit equilibrium analyses in Levels I and II to be used with personal computers. From this work the computer program for Level I Stability Analysis (LISA) was developed, documented and validated in the late 1980s (Hammond et al., 1988). Version 2.0 and a user guide for LISA is currently available to the public upon request to the Intermountain Research Station (Hammond et al., 1992). LISA provides a stochastic approach to slope stability analysis and therefore is ideal for large area analysis where physical properties and conditions have non-uniform frequency distributions.

The computer program for Level II for Slope and Road Analysis (SARA) is currently in the final stages of testing and validating. SARA provides a deterministic approach to slope stability evaluation for roads constructed using full bench, self-balance, and through-fill road prism designs. Critical cutslope height, angle, ditchline geometry, road width, and cutslope angle and height are included in this road prism evaluation. Soil physical properties, subsurface soil and rock unit geometry, soil fill compaction values, and ground water geometry are used in SARA to evaluate the road prism stability.

In the early 1990s cooperative research work was completed between the Intermountain Research Station and Sharma at the University of Idaho to develop a personal computer model for Level III. The result from this work is a U.S. Forest Service version of XSTABL which is currently available to the general public at a nominal cost from Sharma (Sharma, 1990).

Much field work has been completed for the testing of LISA, SARA, and XSTABL, over the last decade; and additional testing will continue as newer versions are developed.

As management objectives shift from road systems and facilities to watershed restoration, there is a greater emphasis in evaluating slope stability for road closures and reducing slope movement in watersheds where timber harvesting has been prevalent. Although SARA was initially developed for transportation planning, it can also be used in road closure work where roads are to be temporarily or permanently decommissioned. Slope stability technology may need to be applied by managers with different backgrounds in ecosystem management than was the case in the past with an emphasis on production.

Over the past seven years the engineering staff in the Washington Office (WO) have provided funding and other resources to initiate, develop, and implement a national slope stability guide and training program. The methods for evaluating unstable slopes, developed by the engineering research work unit at the Intermountain Research Station and used nationally by forest geotechnical staffs, was identified by WO engineering staff as the preferred methodology to be used on U.S. Forest Service lands. They also recognized that most geotechnical specialist positions would be eliminated in the 1990s as the national timber program would be reduced; and consequently, there was a high probability of geotechnical slope stability skills becoming lost. Therefore, a concentrated effort was initiated and recently completed to produce a national slope stability guide and training developed and implemented by a joint effort from the Washington Office, Regional Offices, and the Intermountain Research Station.

Preparation of Guide

The preparation of the national slope stability guide was initiated by an multi-regional editorial committee in December, 1990, under the coordination of Prellwitz and the Washington Engineering Staff. As the guide evolved during 1991 through 1992 it grew to a text of over 1,500 pages covering geotechnical engineering, engineering geology, and geomorphology tools used in the three-level slope stability method. Over twenty authors from the research station and national forests in California, Oregon, Washington, Idaho, Utah, and Colorado contributed to this guide. The first peer review was completed by agency geotechnical specialists and individuals from the geotechnical consulting community. A second peer review was completed by a panel from the U.S. Geological Survey, Universities, and the Washington Office. The guide will be available to the public at the end of 1994.

Need for Technical Transfer

There is a need for technical transfer of slope stability analysis methods to non-engineering staff areas as forest geotechnical staff are reduced. This is especially important as forests temporarily close or decommission roads. Successful road closure will require an understanding of surface and subsurface conditions to diminish the probability of slope failures from occurring. Also, as watershed restoration progresses under ecosystem management, a clear understanding of geological processes will increase the knowledge of how the watersheds sediment budgets change in response to weather, fire, and management conditions.

Field Monitoring

Ongoing cooperative work between the Intermountain Research Station and several forests is occurring with the monitoring of field data. Some of this field monitoring has been continuous since the mid-1980s. Observations include piezometric ground water levels within and adjacent to landslides, movement in landslide headwalls, and rainfall. Personnel fro NFS and Research cooperatively identified the monitoring sites. The costs invloved in equipment, and the time for monitoring, have frequently been shared between NFS and Research.

Courses for Technology Transfer

Many forests have "checker board" boundaries with other federal and state agencies, timber industry, Native American tribes and nations, and private ownership. It is important that this technology transfer includes these constituencies. Over the last decade the technology transfer between Intermountain Research Station and NFS and others has included several slope stability workshops.

With the completion of the Slope Stability Guide aimed at natural resource personnel with limited formal geotech training, a new training programming was required. Therefore, the Intermountain Research Station with the engineering staff from the Washington Office have implemented a training program for professionals from these constituencies and consultants who may complete the slope stability work for them or the U.S. Forest Service. This training program is offered at universities through continuing education programs. The first session was held in May, 1994, at Western Washington University, in Bellingham, Washington, and had students with professional backgrounds in hydrology, soil science, geomorphology, geology, engineering geology, civil engineering and geotechnical engineering. The next scheduled session will be at Portland State University in Portland, Oregon, in September, 1994. Tentative sessions will most likely be held at other universities and colleges in the Pacific Northwest, although there has been some planning to offer these sessions to other areas in the U.S.

In addition to the training discussed above, future courses are being developed in soil/rock mechanics for non-engineers, engineering geology for geologists and civil engineers, use of stereonets for slope stability designs, road closure designs, and applied geomorphology for non-geologists.

Cooperative Research Developments

One of the major benefits of the technology transfer program has been the development of ongoing cooperative research projects. The field monitoring and model testing activities developed cooperative linkages which can now serve as a basis for developing new research projects. Currently these projects include a major study developing a dynamic groundwater slope stability model. Additional piezometers will be installed this summer on two active landslides to measure spatially the fluctuation of the ground water table in the landslides. The temperature and the vapor pressure deficit measurements will also be initiated at several of these sites this summer for use in a research project that will include the evaluation of the relationship between actual evapotranspiration and slope stability. A two-dimensional slope stability model that includes rainfall, dynamic ground water movement, and actual evapotranspiration is currently being developed by the Intermountain Research Station and will be used in the future for analyses of Levels II and III.

Other future cooperative research will assist in developing models to predict stream sedimentation risks due to landslides in environmentally sensitive watersheds.

Summary and Conclusions

The relationships developed between the Slope Stability Research Team and the National Forest System have led to the development of a suite of slope stability models, with wide-spread application by practitioners within the Forest Service as well as by State Agencies and the private sector. Cooperation between researchers, practitioners, and staff within the Forest Service Washington Office was essential at all stages of technology development and transfer. Key elements in the development and transfer of this technology were the cooperative monitoring programs, the cooperative development of the models, and the cooperative planning of technical courses. The success of the program was recognized with the 1993 Forest Service Chief's Award for excellence in Technology Transfer.

References

Cloyd, C. In Press. Dedication to Rod Prellwitz. *In* Hall, D.E., M.T. Long, and M.D. Remboldt, (eds.) Slope Stability Reference Guide for National Forests in the United States. p iii.

Glaser, L.K. 1986. Provisions of the Food Security Act of 1985. USDA-ERS, Agr. Info. Bul. 498. GPO. Washington, D.C.

Hammond, C.J., S.M. Miller and R.W. Prellwitz. 1988. Estimating probability of landslides by Monte Carlo simulation. *In* 24th Symposium on Engineering Geology and Soils Engineering: University of Idaho and Washington State University, Coeur d' Alene, ID. pp 319-331.

Hammond, C.J. D. Hall, S. Miller, P. Swetik. 1992. Level I Stability Analysis (LISA) Documentation for version 2.0. Gen. Tech. Rep. INT-285. Ogden, UT: USDA Forest Service, Intermountain Research Station. 190 pp.

Koler, T.E., and K.G. Neal. 1989. Chestershire and Backdrop timber sales: Case histories of the practice of engineering geology in the Olympic National Forest. Engineering Geology in Washington II: 933-944.

Koler, T.E. 1992. Literature Search of Effects of Timber Harvest to Deep-Seated Landslides: CMER Steering Committee of the Timber Fish Wildlife Agreement, State of Washington, TFW-SH5-91-001, 52 pp.

Koler, T.E. 1993. The three-level slope stability analysis used in forest management. *In* Miller, E.G. (ed.). Association of Engineering Geologists 36th Annual Meeting Program Abstracts. p 59.

Lionberger, H.F., and P.H. Gwin. 1982. *Communications Strategies: A Guide for Agricultural Change Agents*. Danville Illinois: Interstate Printers & Publishers.

Sharma, S. 1990. XSTABL: An integrated slope stability analysis program for personal computers - reference manual. Moscow, ID: Interactive Software Designs. 98 pp.

USDA Forest Service. 1993. *Land Areas of the National Forest System*. Publication No. FS-383.

This paper was published as:

Elliot, W.J.; Koler, T.E.; Hall, D.E. 1994. *Slope stability technology transfer in the Forest Service.* ASAE Paper No. 94-2107. June 19--22, 1994, Kansas City, MO. St. Joseph, MI: American Society of Agricultural Engineers. 6 p.
Keywords:
1994d

Moscow Forestry Sciences Laboratory
Rocky Mountain Research Station
USDA Forest Service
1221 South Main Street
Moscow, ID 83843

http://forest.moscowfsl.wsu.edu/engr/