C. MASS WASTING

It is difficult to travel throughout the Nepalese Himalaya without being impressed by the massive landslides that scar the landscape from the Siwaliks up to the High Himalaya. Such landslides are often wrongly considered to be the result of the recent activities of man. Western experience is limited in the Himalaya, particularly in geomorphic studies. However, recent research has concluded that mass wasting is the dominant process in the evolution of natural slopes throughout much of the Nepalese Himalayas. Thouret (1981) has mapped mass wasting of slopes to determine "their speed of evolution". (See Figure 1) Slopes that are experiencing tremendous mass wasting processes, such as in the upper Ankhu Khola, are evolving very rapidly. Their instability is natural and man's effect on this erosion process is incidental at best.

One of the most spectacular geomorphic events to have occurred in historic time, was the glacial dam outburst flood on the Seti Khola in the Pokhara Valley. Around 600 years ago, a ten square kilometer lake behind Machhapuchare broke through its ice-moraine dam and surged down the Seti gorge, picking up colluvial debris as it went. In a relatively short period of time, over 5.5 cubic kilometers of glacio-fluvial material was deposited in the Pokhara Valley (see Photo II). Both Fort and Freytel (1982) and Yamanaka (1982) provide background information on this remarkable landform.

The largest documented landslide in Nepal occurred when a 15 cubic kilometer chunk of a Himalayan peak fell into the Langtang Valley some 30,000 years ago (Heuberger et al 1984). Many of the high alluvial terraces in Nepal can be explained by such catastrophic events higher up in the watershed. Certainly the major geomorphic events that have shaped the Himalayan landscape are natural, not the result of the misutilization of the land.

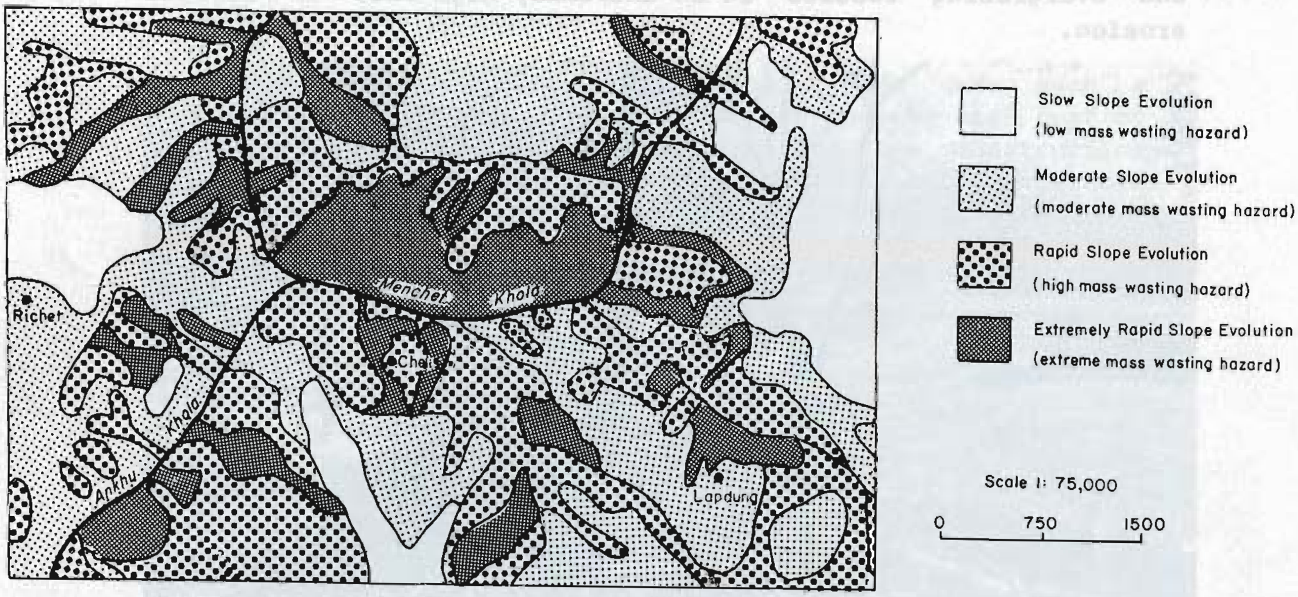
1. Factors Contributing To Mass Wasting

Research has been carried out on the causes of mass wasting processes with engineers stressing soil mechanics; geologists, rock type; hydrologists, prolonged precipitation; foresters, deforestation; and so on. Mass wasting processes are extremely complex, a result of a number of interdependent factors. It is not suprising that there is considerable confusion in the literature. Wagner (1983) in his study of mass movements along road alignments throughout the Middle Mountains of Nepal considered the following factors as significant.

- Structure and incline of slope
- Number and density of natural fracture planes
- Type of rock or mineral and state of weathering
- Presence of water

Figure I

Geomorphic Nature of Upper Ankhu Khola (after Thouret 1981)



AERIAL PHOTOGRAPH OF UPPER ANKHU KHOLA

The interpretation of the above features requires a trained eye.

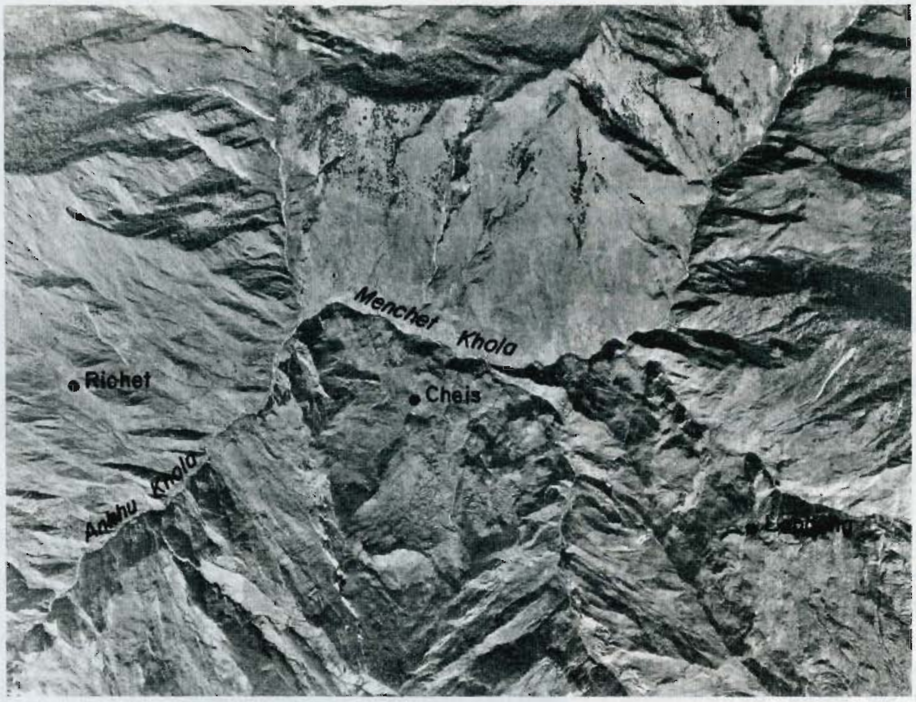


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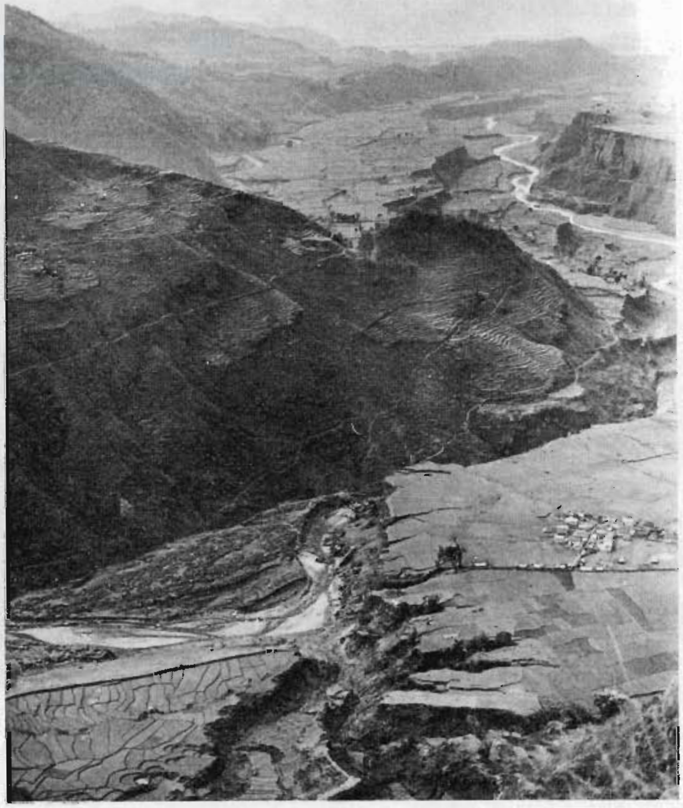
Photo I. - North of Nepalgunj, Banke District, dissected alluvial upland. High intensity rainfall combined with repeated burning and overgrazing results in an extremely high rate of surface erosion.

Photo II - The Pokhara Terraces, looking Southwest towards Gachok, Kaski District. These terraces are the result of a glacial dam outburst flood that occurred just 600 years ago.



By rating the above factors, predictions were made regarding the inherent stability of slopes. Besides site inspection, Wagner mapped a small area north-east of Tansen using the same parameters.

When constructing roads, canals, and dams such a detailed methodology is appropriate because the high cost of the survey can be easily absorbed into the construction budget. However, for the majority of Nepals' mountainous regions, such a survey is prohibitively expensive and one must weigh results against their possible utility. The exhaustive work in the Kakani area, by Kienholz et al (1981) was very useful for demonstrating the geomorphic character of the Himalayan Middle Mountains. The mapping on 1:10,000 scale topographic maps revealed tremendous density and diversity of mass movements (see Figure 2) and it was hoped would shed some light on the role of the forest in preventing mass movements. Unfortunately, the forested areas were on a different rock formation, and the lack of slides in the forested areas could not be correlated with improved forest cover as had been anticipated.

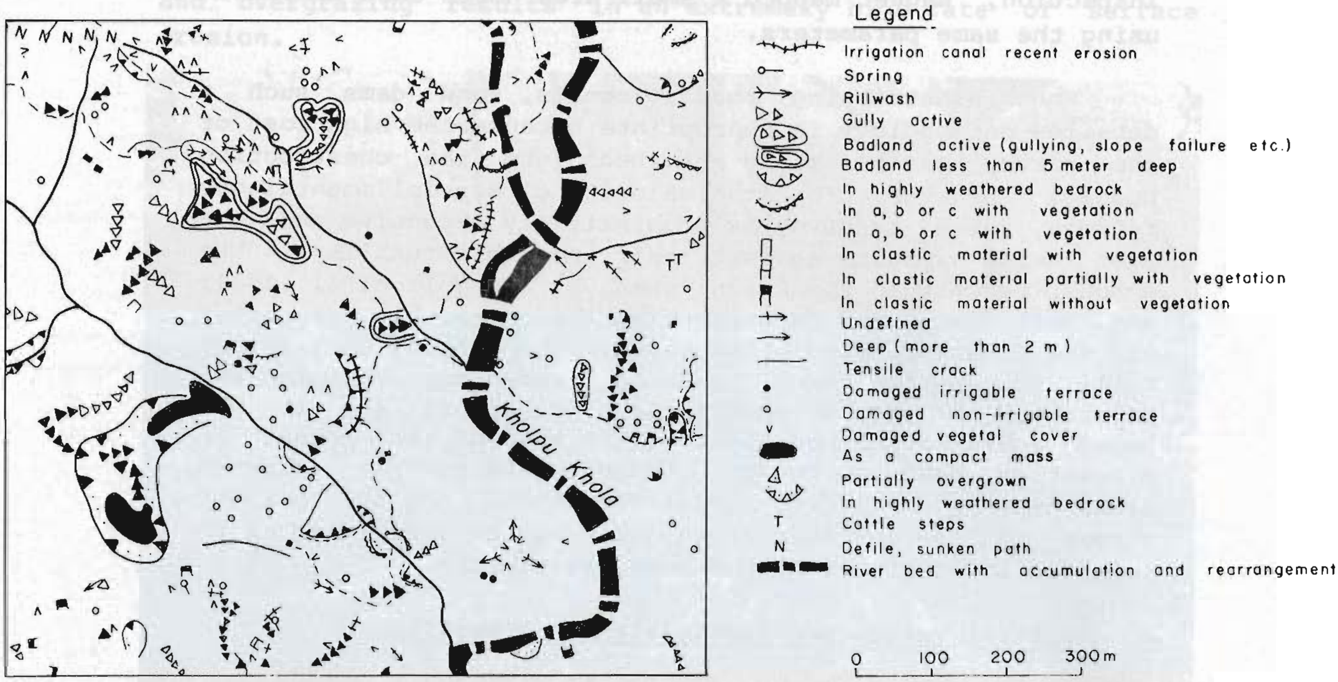
a. Natural Versus Man-Accelerated Mass Wasting

Laban (1979) after reconnaissance overflights, concluded that at least 75% of all landslides in Nepal were natural. By necessity the methodology was simplistic; if a landslide occurred in a forest it was considered natural: whereas, in cleared or cultivated areas it was considered as man caused. Brunsden et al (1981) working in the Middle Mountains of Eastern Nepal, stated that landsliding should be considered as a normal process rather than an exceptional one for the study area. Phyllites, shales and schists showed no significant differences in degree or type of mass wasting, while the deeply weathered gneisses seemed considerably less subject to landsliding but much more prone to piping and gully formation. Erosion processes, although different were nevertheless intense.

Many Himalayan landscapes appear to have a period of relative stability of slopes when mass wasting is not a dominant process, followed by a spell of instability during which a large number of landslides occur almost simultaneously on an otherwise undisturbed slope. (See Photo III.) Villagers often tell stories about extreme precipitation events, occasionally concurrent with earthquakes, that trigger large scale slope failures. In one area south-west of Banepa the villagers acknowledged that the landslides still visible had all occurred during two heavy rainfall events, one in 1934 and the other in 1971. In spite of heavy, more recent rains, no major sliding had occurred since the 1971 monsoon. Such processes tend to be similar throughout much of the Middle Mountains of Nepal.

Figure 2

Geomorphic Damage; Kakani Area (after Kienholz et al 1981)



Phyllitic landscape similar to the Kakani area. Note the wide variety of erosion processes and their significance to landscape formation. Gullys, slumps, slides and debris torrents are common.

Starkel (1972) in his study of an extremely intense precipitation event in Darjeeling (500 mm in 24 hr) found that many new landslides had been initiated and old slides reactivated resulting in ten times more than the average yearly rates of erosion. During such catastrophic rainfall events, there was not a direct relationship between the amount of mass wasting on forested versus nonforested slopes. Starkel considered that catastrophic events should be considered the most significant for normal slope evolution.

Information such as presented above suggests that in many cases mass wasting is unavoidable, a result of discrete levels of increasing instability of slopes over time.

b. Effect Of Vegetation On Mass Wasting

Brunsden et al (1981) found that during a particularly heavy storm in 1974 on phyllite in Eastern Nepal, mass wasting was common on steep forested land but not common in cultivated areas. In these areas it appears that slopes were originally gentle and the Tamur River downcutting has resulted in areas of local high relief. These areas, although forested, are subject to ongoing mass wasting slowly cutting back into the more stable gently sloping cultivated terrain.

Winiger (1983) considered that many of the cultivated slopes are indeed unstable even in their natural state; but, that the local farmers have a remarkable stabilizing input by the maintenance of terrace systems. Providing agricultural activity remains economical, the landscape remains in a stable state. Sastry and Narayana (1984) found that bunding agricultural land in a Dun Valley in India reduced soil loss and runoff considerably compared with adjacent forested land. However, if agricultural productivity declines and the farmer has less interest in terrace maintenance, slope degradation can occur at a greatly accelerated rate.

There is disagreement over the role of vegetation in reducing landslides. Singh et al (1983) postulated that deep rooted tree are required to stop landsliding and that grasses and shrubs have little effect on holding soil in place. Better rainfall infiltration, enhanced by well vegetated soil surface, can actually result in higher rates of mass wasting by increasing slope pore pressure. Singh acknowledged that sediment production was a result of mass wasting and inexplicably assumed that mass wasting was largely a man accelerated process. On the other hand, Wagner (1983), in his work on landslides, did not find it necessary to include vegetation as a factor in assessing on-site risk of mass failure. Between these two extremes one finds many other opinions that probably reflect conditions in the watershed that the researcher was

Photo III Near Lele, Lalitpur District. After a prolonged rainfall in Sept. 1981, this slope failed en masse in spite of thick shrub cover. Such catastrophic events are common on certain landforms within the Nepal Himalayas but are difficult to predict.

PHOTO IV. - Large landslide north of Taplejung, measuring over one km wide, three km long and over 20 meters deep. In the past fifty years over one hundred million tons of soil material has washed into the Tamur River from this slide. The progressive destruction of the hillside is difficult to blame on man's activities, as the land is generally well managed.

studying. There is a great diversity of landscapes in the Nepalese Himalaya, and for each hillslope one must consider somewhat different contributing factors. Landslides occur on all types of slopes; vegetated, unvegetated, treed, barren, terraced and nonterraced throughout the hills. The majority are initiated on slopes between 32 and 45 degrees. Small, shallow slides tend to occur more frequently on unvegetated slopes while much larger, deeper slides tend to occur independent of vegetation cover. The existence of forest may increase the period of time between slides, but in the long run may not prevent them if the terrain is inherently unstable. Over a sufficiently long period of time the net contribution of sediment might be similar. In Nepal, the largest, deepest landslides such as at Jharlang and north of Taplejung often occur in forested or otherwise well managed land. (See Photo IV). If a slope is inherently unstable, as must be the case on many Himalayan landscapes, mass wasting is such a complex process that one must start with the premise that the effect of vegetation on slope stability is not clear and that other factors are probably more important.

c. Effect Of Man's Engineering Activities On Mass Wasting

i. Roads

Disturbance of slopes by man's activities, particularly slope cutting and changing drainage patterns introduces serious mass wasting onto otherwise "stable" slopes. Road construction in particular is responsible for the initiation of many landslides. (See Photo V.) Deep side hill cuts and side-cast material result in initiation of cycles of instability. Proper location of roadways, by avoiding potential slide areas, appropriate drainage works, avoiding or at least minimizing cuts when unstable slopes are encountered and prohibiting side casting of cut bank material can all greatly reduce the destabilizing effect of road construction.

Although there is no doubt that proper road engineering can solve many of these problems, methods are very expensive. One of the best engineered roads in Nepal, the Dharan - Dhankuta road cost over $1 million U.S. per km to construct and annual maintenance costs are astronomically high, certainly beyond the budget of the Nepalese government. In spite of the care made in the assessment of the alignment and during construction, this road has been closed during part of the last two monsoons by serious landslide activity. In the 1984 monsoon over 5 million dollars of damage was done by slope failure.

Considering the present stage of economic development in Nepal, single lane roads with pullouts, suited to farm tractors with trailers and open only in the dry season might be more appropriate. Such a road design for feeder roads in the hills could result in a great reduction of engineering and maintenance costs and greatly reduce the number of landslides produced by road construction.

ii. Irrigation

Irrigation of hillslopes is also a source of accelerated mass wasting. Generally, bunded rice terraces represent a stable land use in which one can often measure net additions to the soil surface by sediment laden irrigation water. However, in certain cases the extra weighting of slopes and increased pore pressure, caused by irrigation water within slopes can cause slopes to fail, especially when coinciding with earth tremors. The introduction of new water sources onto slopes rarely occurs because all easily irrigable areas have been irrigated. Those areas that were likely to fail have often already done so. Obviously, newly planned irrigation on presently unirrigated sloping land must take into account the increased likelihood of major slope failures. Smaller slumps and terrace riser failures frequently occur in rice terraces but are quickly repaired by the farmer. (See Photo VI.) Without constant attention, terrace, and eventually slope degradation proceeds rapidly.

iii. Dam Construction

Large dam construction projects can have a significant effect on the stability of a watershed. The flooding of a valley by a reservoir may result in watering the base of unstable slopes. Increase in pore pressure within the slope followed by rapid drawdown may be enough to set such a slope into a phase of active sliding even after a long period of relative stability. Below the dam, the sediment load has been interrupted and without a source of sediment to protect the river bed, a cycle of river cutting and land degradation may begin. With the increase in river cutting, adjacent slopes could be destabilized, initiating a cycle of mass wasting shortly after completion of the dam.

In spite of the increased number of slides introduced by man's engineering activities, they have as yet constituted only a small increase to the already enormous magnitide of mass wasting processes. However, they are extremely important for road construction and maintenance and irrigation water distribution. Consequently, mass wasting strongly affects the cost of economic development in Nepal.

PHOTO V. - Feeder road construction northeast of Dharan Severe erosion has been initiated by the poor layout, design and construction technique of this road. This alignment has since been abandoned as too costly to construct and maintain.

PHOTO VI. - Irrigated rice terraces in Accham. Irrigated lands are generally worth at least twice the value of nonirrigated lands. Small slope failures such as seen in this photo are quickly reclaimed as long as soils remain productive.