

Introduction

Landslides are a natural phenomenon involving movement of earth materials (soil/rock) on different scales, varying from small insignificant rockfalls to huge movements of materials producing catastrophic effects. Landslides, involving materials from the mountainous regions of the outer Himalayas, the Karakoram, and the Hindu Kush, occur frequently in the northern areas of Pakistan. This part of the country is bordered by China, India, and Afghanistan and therefore is of considerable strategic importance.

This study of landslide types or classification, causes, analysis, and remedial measures has been undertaken keeping in mind the significance of hazards caused by landslides.

Various important routes (highways) in northern Pakistan (Fig. 1) were selected for detailed slope stability studies. Detailed geological mapping was carried out on different scales, emphasising the role of lithology in slope stability. Landslide inventory maps were prepared to identify the stability conditions of slopes in different areas (Fig. 2). Slopes were initially broadly categorised as 'stable', 'unstable', and 'potentially unstable' on the basis of geological and geotechnical studies.

The critical areas termed 'unstable' or 'potentially unstable' were considered for qualitative and quantitative evaluation. On the basis of these evaluations, different relationships were established.

- i) Lithology and structure versus landslides
- ii) Earthquake activities and slope movements
- iii) Precipitation (during monsoon) and number of landslides
- iv) Types of landslide and their frequency in different climatic and lithological conditions
- v) Geometry of slopes (number of terraces and inclination versus stability)
- vi) Vegetation and its effects

Wherever suitable, relevant data have been presented in the form of tables, graphs, plots, and other illustrations. Appropriate landslide warning and monitoring systems have been carried out and recommended on the basis of quantitative evaluation. Different prevailing remedial measures to control landslides have also been critically studied for their effectiveness and, in the light of these studies, more suitable and justifiable methods have been suggested.

The significance and role of different government and non-government organisations have been highlighted at the end. Keeping in mind the varying conditions in different parts of the country, relevant findings and appropriate recommendations are presented.