

## The Use of Aerial Photograph and Remote sensing system in the Study of Mass Movement Hazards in the Kulekhani Watershed Region in Central Nepal

— Indra Narayan Manandhar \*

"There is no such thing as a 100 % safe slope, whether natural or man-made."

— Taylor 1977.

### Introduction.

Slope instability is a universal problem. The problem becomes more severe in tectonically active mountain areas of the earth. Being a mountainous as well as tectonically active country Nepal has many examples of mass movement hazards.

Most of the watersheds of Nepal are naturally unstable due to the geologic, climatic, topographic, seismic and related conditions. Cultural factors such as the continuous destruction of forests, the construction of roads, dams and bridges, mining activities, the population growth and resultant pressure on agricultural lands have aggravated the situation and have lead to a man-induced acceleration of the already rapid natural erosion and landsliding processes. The scientific study on management of natural resources therefore is an urgent need in Nepal particularly in the context of environmental protection.

In most of the developing nations, a shorter time frame and comparatively cheaper methodology is required for collecting the land resources data and updating landuse maps. Remote sensing techniques provide an effective and useful means to achieve this goal. This study is mainly concerned with the mapping of geomorphological information particularly slope instability and mapping of geomorphic hazards and degrees of risks of the catchment using remote sensing techniques in the Kulekhani catchment in the central hills of Nepal.

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**Methodology.**

Several remote sensing methods, such as the interpretation of i) Aerial Photographs, scale 1:20,000, ii) Landsat Imagery, scale 1:250,000 and iii) Large Format Camera Photographs, scale 1:250,000 of the years 1972, 1977 and 1984 respectively were used for the purpose of producing landslide and erosion hazards map of the area.

The preliminary photo interpretation was carried out by using the above mentioned aerial photographs for the study area. The delineation of geomorphological units was carried out on the basis of lithology, geomorphic process, internal relief and slope forms. All the available mass movement and erosional hazard features were then located on each photograph and assembled into an uncontrolled mosaic to form a geomorphological hazards map. Landsat images as well as large format camera photographs were also interpreted for understanding of regional geologic structures and main geomorphological units with their inherent processes. With the help of preliminary map the study area was then checked by field visit. During that time changes of many mass movements and erosion hazard features were observed and more new features were added to the map on the basis of data obtained in the field. Re-interpretation of aerial photographs was done and then superimposed with topographic base map of the same scale. The final map was later reduced to the scale 1:50,000 by zoom transfer method.

**Application of Remote Sensing Techniques to Mapping of Mass Movement or Erosion Hazards.**

Remote sensing is the collection of information about an object or phenomenon using devices that are not in direct contact with the subject under investigation. The distance of separation varies from few millimeters to 800 km or more. (Shuster and Krizek, 1978). Various types of sensors are available for obtaining information in the different regions of the spectrum. Among their products aerial photographic infrared and radar images obtained from aircraft or satellites as a platform, are the most useful.

Remote sensing techniques can provide data that cannot be obtained in the field. Mass movement phenomena cannot be recognized in the field without the help of aerial photographs, specially when they are old, inactive and big enough that the limits cannot be seen. They, thus, are complementary and increase the accuracy of the survey. Of all remote sensing systems air photography is the most common sensor system and it provides most of the information required with relatively minimum cost. Other sensor systems may provide useful data that cannot be obtained from air photography alone.

A brief description of the use of different remote sensing techniques for the study of mass movement and erosion hazards mapping is given below:

### **Aerial Photographs.**

Landslides and erosional activities are more common in certain specific type of terrain and occur most frequently at certain vulnerable locations. The interpretation of aerial photographs by pattern-analysis technique is a valuable tool for delineating the vulnerable location.

The use of remote sensing techniques to recognize and identify landslides or erosion hazards mostly relates to the use of aerial photography which has proved to be an effective technique for recognizing and delineating mass movement features. No other technique can replace the over all three dimensional overview of the terrain. From aerial photographs the interrelation of topography, drainage, surface cover, geologic materials and human activities on the landscape can be viewed and evaluated. Stereopair satellite imagery such as large format camera photograph has comparable merits, though on a smaller scale.

The value of aerial photography in landslide investigations has been reported by many investigators in the past. The effectiveness of this technique was well demonstrated by Maruyasu and others in analysing a mountainous region where landslides and erosional features were common in Japan. The major advantages of using aerial photography in landslide investigations have been described by Harold T. Rib and Ta Liang in the book "Landslides Analysis and Control". (Shuster, 1978).

Although large-scale aerial photography is the most useful tool for the investigation of mass movement or erosional hazards, several reports indicate that other remote sensing systems such as landsat imagery, large format camera photographs, thermal infrared imagery also offer some unique information useful for landslide hazard studies. Landsat imagery and large format camera photographs were used in this study.

### **Landsat Imagery.**

At a smaller scale 1:250,000 landsat imagery, only extremely large individual hazardous features can be identified directly due to its limited spatial resolution of 80m and lack of stereoscopy. However, small scale landsat imagery can be used for the interpretation of lineaments, major drainage lines, main water divides, recent deposits, lake basins etc. (Fig.-1) The landslide or erosion susceptibility of an area can be determined indirectly from features identifiable at those scales. Regional physiography, geologic structure and major landform types as well as type and distribution of landuse and vegetation cover are evident on satellite imagery. Other features, reflected in the relief and tonal patterns in the Imagery provide due to the types of surface material present, the surface moisture conditions and the possible presence of buried valleys. Correlating these factors with local experience in a region makes it possible to rate susceptibility of various areas of sliding.

An additional advantage of landsat imagery is the frequent coverage available for landslide or erosional feature detection. Seasonal changes

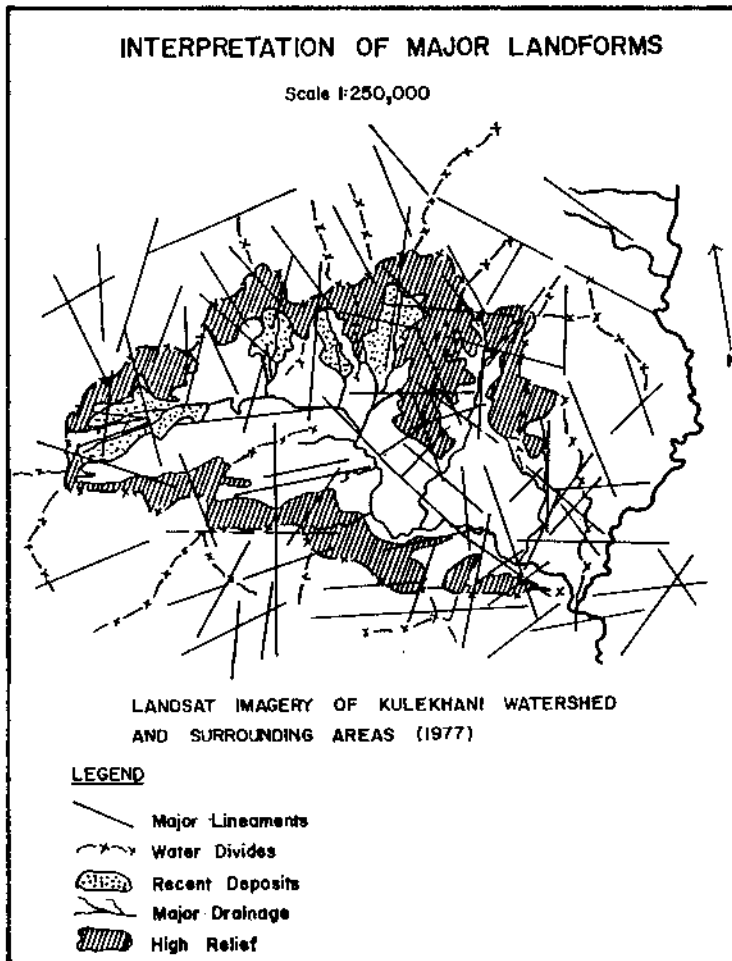
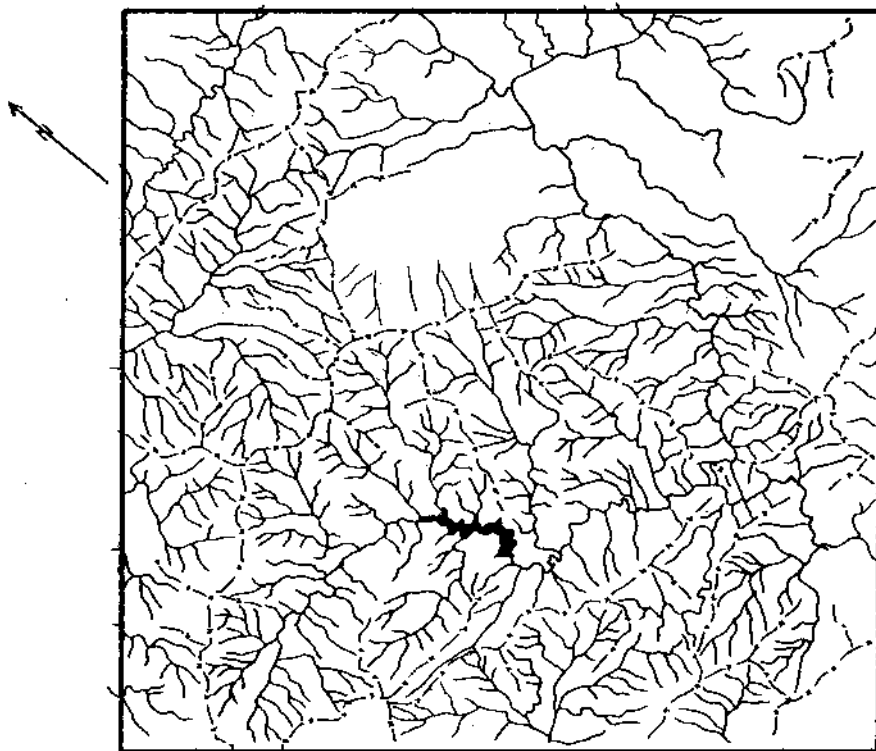





Fig 1

## Interpretation of Drainage Network

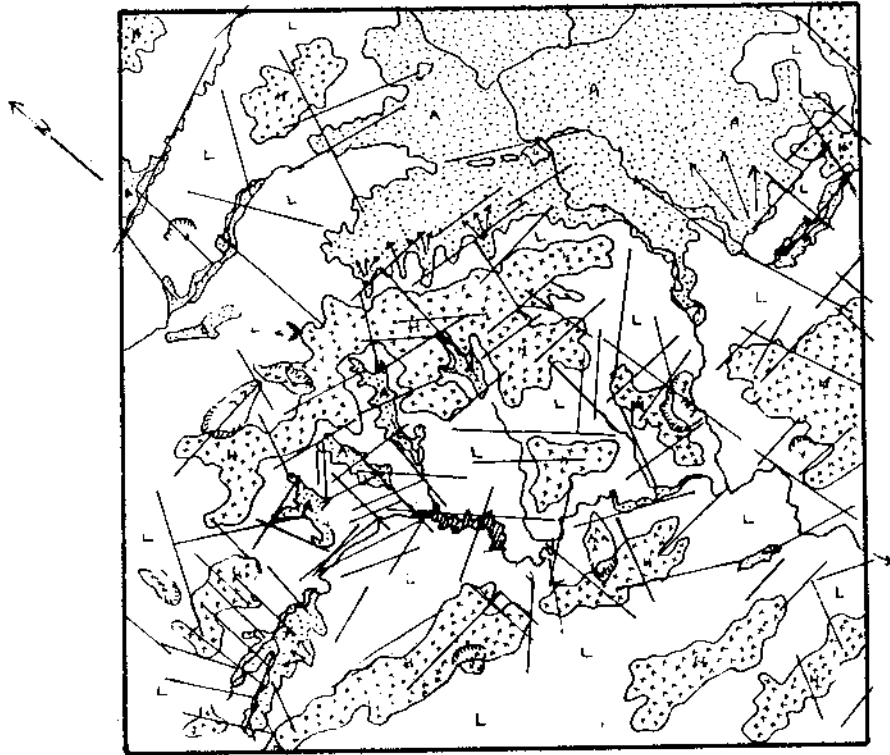


Large Format Camera Image of Kulekhani  
Watershed and Surrounding Areas (1984)  
Scale 1: 250,000

LEGEND

-  Water Divides
-  Major Drainage
-  Reservoir







Interpretation of Major Landforms



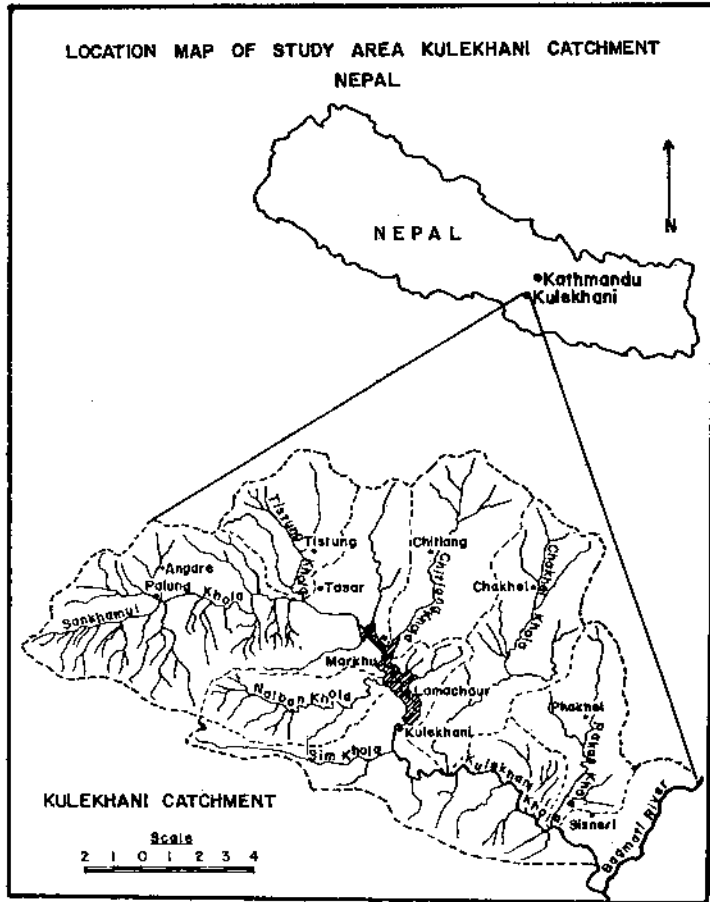
Large Format Camera Image of Kulekhani Watershed and Surrounding Areas (1984)

Scale 1: 250,000

LEGEND

- |                                                                                     |                                             |                                                                                     |                  |
|-------------------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------------------------------------|------------------|
|  | High Relief<br>(Mainly Forested)            |  | Major Lineaments |
|  | Low Relief (Under<br>Cultivation & Erosion) |  | Major Landslides |
|  | Recent Alluvium<br>(Under Cultivation)      |  | Major Fans       |

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in vegetative cover and moisture levels can be evaluated and increase the accuracy of interpretation of terrain conditions. Also, all changes occurring in the erosion susceptibility zones, and draining of swamps that might induce new landslide and erosional activities can be detected. Past experience with landsat imagery suggests that band 5 images or infrared colour composites are the most suitable for landslide or erosion hazards investigations although moisture content variation normally show up well in band 7.

The most detailed information on morphological processes and their effects can be obtained if sequential imagery is available. More satisfactory is the use of several sequential coverages taken at known intervals and dates. The changes that have occurred between the recordings can then be mapped exactly and quantification is also possible (Verstappen, 1977).

#### **Large Format Camera Photographs.**

The large format camera photographs taken from satellites can have relatively more information due to its greater spatial resolution of 20m and stereoscopic capacity (Manandhar, 1987). It serves for identifying and recognizing features such as lineaments, detailed drainage, reservoir, high relief forested areas, cultivated and eroded areas of medium relief, low relief recent deposit areas, major landslides, alluvial fans and water divides (Fig 2a and b). The map production however, can only be a part of the process of future land capability mapping because the amount and detail of mappable mass movements depend on the scale, quality and the year of the photographs taken.

### **3. General characteristics of the Kulekhani Catchment area**

#### **Geographical Situation.**

The Kulekhani watershed region lies immediately southwest of the Kathmandu Valley within the outer Himalayan Mountains. It has a surface area of 212 square kilometers, 126 of which is the catchment area above the dam site of the Kulekhani hydro electric project. The area is part of Makawanpur District and contains seven panchayats (smallest administrative units) namely Kulekhani, Daman, Chitlang, Thachok, Palung, Sisneri and Phakhel. (Fig.-3).

#### **Physiography.**

The watershed is situated in the Mahabharat range and is surrounded by mountains and hills. The altitude varies from 1100m in the south-east corner to 2600m in the south-west. In general the Mahabharat range has rugged terrain with steep slopes. The general topographic features, tending west-northwest to east-southeast are related to the direction of geological bedding and major fault lines.

The Kulekhani region lies within two physiographic provinces, the Mahabharat Lekh to the south, which is part of the outer Himalaya and Midland to the north. There are many valleys and spurs in between these



two ranges. Several subdrainage basins of the tributary streams form a relatively flat part of the watershed where alluvial materials are deposited. The main valley basin becomes narrower towards the south-east corner.

#### **Drainage.**

The Kulekhani river originates in the Mahabharat mountain range about 5km. west of Palung and 30km south west of Kathmandu. It flows generally in an east-southeast direction and joins the Bagmati river about 20km south of Kathmandu. Sankha Mul, Tistung, Bishingkhel, Chitlang, Chakhel, Rakas, Naliban and Sim Khola are among many notable tributaries which join the main stream from different direction of the catchment. The drainage pattern is dendritic in the north but becomes structurally controlled in the south. The gradient of the trunk stream is 41m/km. The upper reaches of the Kulekhani khola, located in the west near Palung occupy a broad flood plain of coarse materials deposited during low frequency, high discharge floods. The channel here becomes braided and the floodplain gradually disappears at the damsite of the reservoir the antecedent river course flows through a deep gorge.

#### **Climate.**

Climatically the watershed ranges from the subtropics (1100-1800m) to the temperate zone (18-2600m). Two distinct seasons, exist, namely the summer monsoon rains and the dry winter. The relief patterns affect the climatic conditions, particularly temperature and precipitation that vary with elevation and north or south exposure of the slopes.

Two weather stations, Daman (2314m) and Markhu (1530m) are operated within the Kulekhani watershed. Data from these stations show an average annual precipitation of 1500mm, of which about 80% falls during the monsoon period (June-Sept). Most of the remainder falls in the so-called pre-monsoon (April/May) and postmonsoon (October/November) periods. Winter is distinctly dry. All precipitation falls as rain except for minor snowfalls in the higher elevations. Maximum 24 hour rainfall intensities exceeding 180mm have been recorded during the monsoon.

The temperature records of Daman show seasonal fluctuations in mean monthly temperature from 5.6°C. Relative humidity reaches a low of about 60% in winter and spring climbs up to 91% during the monsoon. These data show that the climate of lower Kulekhani is a sub-tropical monsoon climate becoming temperate at higher elevations in the surrounding mountains.

#### **Soil**

The dominant factors influencing the soil development in the study area are parent materials, relief (exposures and altitude), landuse and climate. Soils are generally shallow, brown in colour and range from gravelly sandy loam to loam in texture in the southern part of the study area. At lower altitude especially in the middle region, soils developed on phyllite, schist and marble are reddish brown to yellowish red in colour and range from loam to silty clay loam. The soils in the limestone

area of northern part are shallow and loamy in texture. The soils occupying the river terraces and narrow stream valleys are derived from rich alluvium materials are gravelly silt loam and sandy loam, generally shallow to medium depth.

#### Land cover and Land use.

Forests are the natural vegetation of the entire area, with sub-tropical broadleaf forests in the lowlands giving way to mixed forests in the uplands. However, in the lower and intermediate altitudes most natural vegetation has been replaced by cropland and pasture. Cutting, logging and burning activities are causing an upslope retreat of the forests, but the ridge lines still contain relatively good stands of timber.

The land use picture of Kulekhani watershed especially in productive land uses has changed significantly in the last three decades. For example, the forest area has decreased drastically and the agricultural and pasture land has increased.

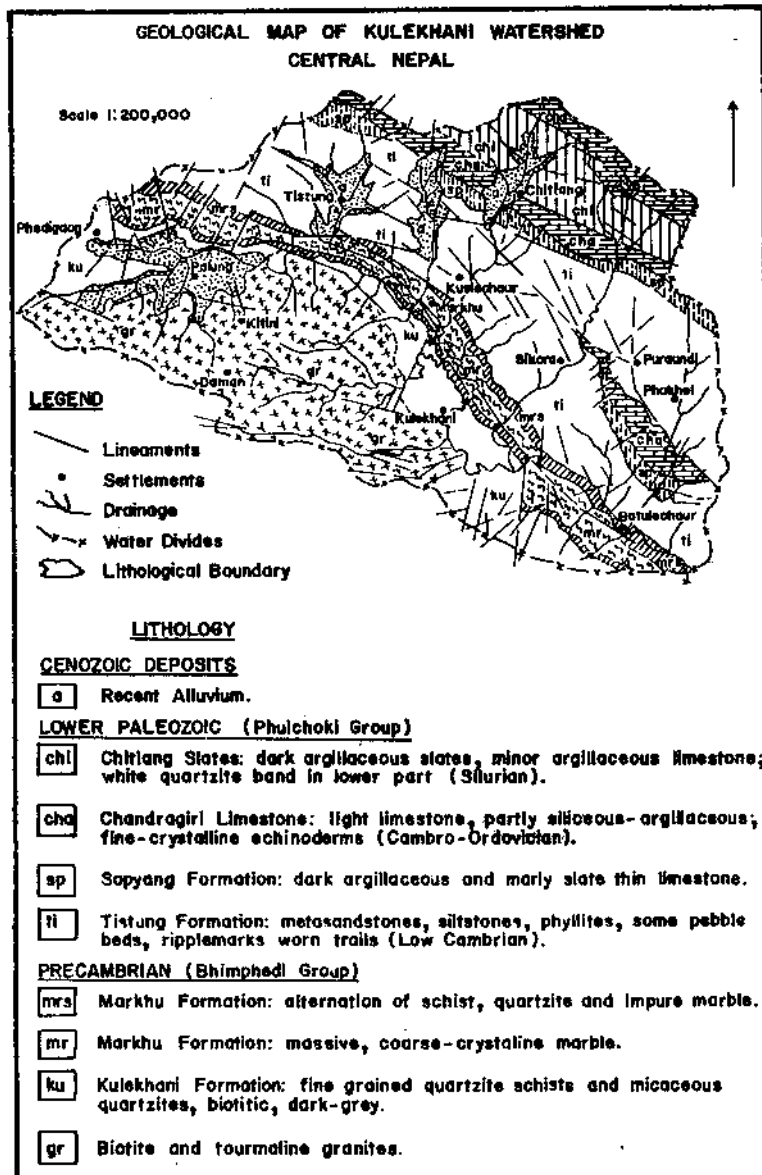
According to the calculation based on the report of Inger-Marie Bjonness (1982) the surface areas of the main land use type in the Kulekhani catchment are given in Table 1.

Table 1  
Land use pattern in Kulekhani Catchment Area \*

Type	Area in km <sup>2</sup>	Percentage in Total
1. Forests & Pasture lands	104	49.0
2. Agricultural Terraces	82	38.6
3. Barren lands	21	10.0
4. Reservoir & Water bodies	3	1.4
5. Settlements and others	2	1.0
Total	212	100.0

\*Source : APROSC Survey, 1979.

The table shows that forest constitutes the largest land use category. It covers nearly 50% of the total area. Most of the forests are located in the upper slopes of the catchment, but decrease very rapidly in size. Agricultural terraces rank second as a land use category which covers 38.6% of the total land surface. Denudation rates here range from moderate to high, depending on steepness of slope types of cultivation and quality of terrace construction/maintenance. Barren lands with 10.0% of the total are the third land use category and include most of the denuded areas where livestock grazing is practiced. These areas produce the highest level of denudation, especially along trails in areas of gullies and on slide scars. Barren lands are increasing at the expense of the forests. The remaining two land use categories cover only 2% of the total surface area. Water bodies (rivers, streams, reservoir), settlements and roads fall in these groups.



#### 4. Geological setting of the area.

##### Geology and Formation.

The Kulekhani watershed lies in the central Mahabharat Region of Nepal. It is structurally controlled by a syncline, having an ESE trending axis and controlling the alignment of principal mountain ridges and valleys. Rocks include ridge-forming granites, as well as quartzites and the softer phyllite schists. The southern rim of the syncline is a thrust nappe abutting against the Siwalik range to the south. Structural surfaces are often steeply dipping and provide abundant landslide surfaces. Tributaries, such as the Sim, Naliban, Rasar, and Sankha Mul kholas flow in ESE-trending structural valleys, but the trunk stream Kulekhani khola swings southward across the structure, crossing the Mahabharat Lekh in a steep gorge at the dam site. The mountains comprise of the steepest terrain of the region, most slopes exceeding 25°.

The Mahabharat Range is thrust steeply southward over the Siwalik belt along the Main Boundary Thrust (MBT). The large Mahabharat Synclinorium, composed of the major rock assemblages of the Kathmandu complex is the dominant structure of the range. According to the technical report (Stocklin and Bhattarai, 1977.) this complicated synclinal mega-structure can be divided into three major regions. a) Recent Alluvium, b) The Phulchauki Group of Paleozoic sediments and c) The Precambrian Bhimphedi Group consisting of relatively high-grade metasediments. In addition, the complex also contains granitic and migmatic rocks of Precambrian Bhimphedi Group. (Fig.-4).

A brief description of the main lithological units present in the study area is given below:

##### a) Recent Alluvium

The recent alluvial deposits occupy the river terraces and narrow valleys of the catchment. They consist of gravelly silt loam and sandy loam. Several levels of fluvial terraces are developed in the basin. There are four major alluvial deposits in the catchment, namely, Palung, Tistung, Bishingkhel and Chitlang. Besides, several small patches of recent alluvial deposits are located along the main stream. In the upper part of the alluvial fan terraces are sometimes mixed with gravelly and sandy footslope material.

##### b) Phulchauki Group

The name of this group is derived from the Phulchauki Hill south of Kathmandu which is well known among geologists because of its Palaeozoic fossils. The group consists mainly of limestone and subordinate zones of shales and sandstones. The total thickness is 3000-4000m (Stocklin and Bhattarai, 1977). The Phulchauki Group can be subdivided into four formations namely Sopyang, Chandragiri Limestone, Chitlang Slate and Tistung Formation.

##### c) Bhimphedi Group

The name was borrowed from Indian Geologists, who introduced it.

It was originally applied to the relatively high-grade metasediments that are widely developed around the town of Bhimpheedi which lies south of Kulekhani Dam. The metasediments of the Bhimpheedi Group show a steady decrease in metamorphic grade from a garnet-amphibole grade at the bottom to a sericite-chlorite grade on top. The original sediments were predominately shales and sandstones and included two important limestone zones. This group reaches a thickness of about 10,000m. Among many sub-units of this group three units such as Markhu, Kulekhani and Biotite and Tourmaline Granites occur in the study area.

### **Tectonics**

The area covers the axial part and the south flank of the Mahabharat synclinorium with Palung granite intrusions in the central sector. This is the standard reference for the stratigraphy of the Bhimpheedi Group, and the type localities of most of its constituent formations are found here.

The stratigraphic position of the Markhu Calcareous Formations and the transitional nature of the contacts are well displayed in the Kulekhani Valley. In the Chitlang area a lower unit is known as Tistung Formation, and a higher unit is named Chitlang Slates. They are separated by the thick Chandragiri Limestone. A transitional zone between the Tistung and Chandragiri Formations can be distinguished and is known as the Sopyang Formation. The discovery of Late Ordovician fossils in the upper part of the Chandragiri Limestone dates the Chitlang Formation as Silurian and correlates it with the fossiliferous Silurian beds of Phulchauki. The Tistung Sopyang interval is considered transitional between the late Precambrian and the earliest Paleozoic.

Structurally, the area is dominated by the large Chandragiri syncline. Its south west flank goes round the large bulge of the Palung Granite at Palung, and is enforced upon the synclinal fold by the granite intrusion. A small, faulted subsidiary syncline with a core of Chandragiri Limestone appears in the Rakas Khola (Stream) area, indicating a major longitudinal fault that doubles the Tistung succession in this part of the Chandragiri south flank.

### **Lineaments**

Lineaments are frequently observed in the phyllites, schists and impure quartzites of the study area (Fig.- 2b). They often appear as fine crenulations on schistosity planes. Lineaments are usually related to the bedrock geology. The processes of interpreting aerial photographs, satellite imagery and large format camera photographs has resulted in the identification and recording of many of these lineaments. An attempt has been made to measure and analyze the lineaments statistically and to relate them to the various stress directions (Manandhar 1987).

## **5 Geomorphological Setting of the area.**

### **Geomorphological Units.**

The Kulekhani catchment has been divided into four major land scapes which can be further sub-divided into several units. In the coding system

used the first capital letter is designated to genesis, using (F) for landforms of fluvial origin, (P) for structural/denudational origin (mainly in Phyllites), (L) for structural origin (mainly in Limestone) and (G) for forms of denudational origin in Precambrian Granites. Since it was difficult in some place to make a clear-cut distinction between purely structural landforms and denudational ones, two terms have been combined and the unit is named as "Structural/Denudational". A brief description of each landscape and its sub-units is given below. (Fig.-5)

a) Forms of Fluvial Origin. (F)

The valley bottoms and surroundings of the main stream of the Kulekhani Khola and its tributaries constitute the fluvial landscapes. These include the terraces of above mentioned streams and alluvial fans. The upper parts of this unit are wider than the lower parts. The slope gradient is 0-12%. This landscape covers approximately 27 square kilometers or nearly 13% of the total area of the basin. The Sankha Mul khola occupies a broad flood plain of coarse materials with braided channels. This landscape is sub-divided into three units.

i) Flood Plain. (F.1)

This unit occupies the middle zone of the Fluvial forms. Most of them are narrow and elongated. The relief is almost flat, locally with a slightly irregular topography. This unit is of wide-spread occurrence in the Shankha Mul and Tistung valleys. The absence of grasses and bushes indicates high frequency of flooding during the summer monsoon. Lateral cutting and shifting of channel are the main problem of this area.

ii) Fluvial Terraces. (F.2)

The fluvial terraces are developed along the upper parts of flood plain areas of the Kulekhani Khola. This unit is generally characterized in the terrain by nearly flat to gently sloping surfaces separated by scarps. The fluvial terraces are composed of alluvial materials carried down by the main tributaries of the Kulekhani Khola. The lower terrace parts are sometime affected by flooding during heavy rainfall. Thus the distinction between floodplain and the lowest terraces is not always fully clear.

iii) Alluvial Fans. (F.3)

Alluvial fans are found mostly in the headward region of the main stream, Palung Valley. They have resulted from fluvial deposition by streams running down from the north facing slopes of the granitic mountains in the south. Two major fans are notable which are in contact with each and even partly overlap. Besides, there are several smaller fans bordering the central and lower parts of the catchment. The materials of this unit consist of gravels, fine sands, clays silts etc., which are derived from the south situated ridges. This unit is characterized by gentle, straight, and generally undissected slopes.

b) Forms of Structural/Denudational Origin, mainly in Phyllites. (P)

This major landscape occupies nearly 49% of the total catchment area. Almost the entire middle part of the W-E stretching catchment is covered

by these landforms. It is divided into several parts due to the existence of fluvial landscapes in the lower valley bottoms. Complex landforms with many folded and faulted structures are characteristic. The lithology is diversified and consists of phyllites, schists, metasandstones, quartzites, marbles etc. Phyllites and sandstones are dominant, however. The area has been divided on the strength of relief amplitude and slope form into three units each of which has several sub-groups.

i) High Hills. (P.1)

This unit comprises the crest regions in the North/West, East and South/East. The elevation varies between 1900m to 2500m above sea level and covers 12 sq. kms. The slopes are generally steep (more than 30 degrees). Most of the area is covered by thick forest. There the area is less susceptible to mass movements and other erosional processes than the steep relief does suggest. Some mass movement features can be traced, however, in tectonically active areas, especially in the lower parts of the catchment.

ii) Medium Hills. (P.2)

The middle region of the structural/denudational landscapes, formed mainly in phyllites have been classified as medium hills. The elevation of this unit ranges from approximately 1200m to 2200m above sea level. It is the most extensive unit of the catchment, and covers an area of 74.5 sq. kms. Steep to moderate/gentle slopes are characteristic. Due to deep weathering of the rocks and poor vegetation cover it is badly affected by landslides and gully erosion. Many types of landslides occur in this unit, which on the basis of relief and slope angle has been further subdivided into two parts: Steeply Sloping (P. 2.1) and Moderate/Gently Sloping. (P. 2.2)

The steeply sloping unit is mostly located along the lower region of both sides of the major stream. This is the most unstable part of the catchment and is susceptible to many types of mass movement. This unit is highly dissected. The moderate/gently sloping sub-unit is located relatively higher region. Most of it is used for farmland. Gullies, slumps and landslides occur in many irrigated as well as non-irrigated areas. They are particularly numerous in areas with non-irrigated terraces. In some places active badlands have developed.

iii) Low Hills. (P.3)

This unit comprises the lowest parts of the area covered by landforms of structural/denudational origin (in Phyllites). The lower part of this sub-unit is in contact with the fluvial landscapes. The elevation ranges from 1300m to slightly above 2000m in the western part of the catchment. The average slope of this unit is 15-20 degrees. It covers approximately 8.5% of the total land area of the catchment. Many erosional and mass movement features are concentrated in this sub-unit. The intensity of erosional processes and mass movement features vary with the vegetation cover and agricultural practices. This unit is further sub-divided into three sub-units: i) Steeply/Moderately Sloping areas (P.3.1), ii) Moderately/Gently Sloping areas (P.3.2) and iii) Foot slopes, mainly colluvial. (P.3.3)

The steeply/moderately sloping areas are concentrated in the central and lower parts of the catchment with the exception of an area in the headwaters in the west. The moderately/gently sloping sub-unit is widespread all over the phyllitic zone. Most of them are dominated by denudational processes. Foot slopes are of common occurrence where phyllites interrupt. They are the result of accumulation of debris transported laterally from adjacent steep slopes. The materials are generally boulders and gravels. Only one large foot slope occurs in the upper part of the Palung valley in the west. This unit is moderately dissected and its relief amplitude is approximately 100m. It is characterized by relatively short and gentle slopes.

**c) Forms of Structural origin mainly in Limestone. (L)**

Structural landscapes mainly in limestones, occupy an extensive area in the Chandragiri Hills in the central and north-eastern ridges of the catchment. One similar, isolated landscape is also found in the phyllitic zone on the eastern side of the catchment. The altitude varies between approximately 1500m to nearly 2500m. It is characterized by moderate/gentle slopes with gentle foot slopes in the lower part of the hills. The area covered by this landscape is nearly 17% of the total surface area of the catchment. These landforms are mostly covered by thick forest. Due to this forest cover and the permeability of the rock, the drainage density is relatively low. The susceptibility for landslides and other mass movements is also relatively low. However, some old landslides and gullies can be traced in this region. One large debris flow occurs in the upper part of Chitlang Valley. On the basis of slope steepness and relief amplitude this landscape can be further sub-divided into three units:

**i) Steep Topslope Zone. (L 1)**

The steep topslope zone occupies almost all crest zones of the limestone area. The elevation of this unit varies from 2100m to nearly 2500m. From the slope-hazard point of view this unit is relatively stable. Some gully erosion has started where the forest has been cleared. Nearly 50% of the structural landforms is occupied by this unit.

**ii) Moderate Midslope Zone. (L.2)**

The moderate midslope zone is concentrated between the fluvial landscape and the top slope zone of the limestone area. The altitude of this unit varies between 1700m to 2100m and it is covered by 8% of the total surface area of the catchment. Processes of gully erosion and inactive mass movement can be observed in some parts of this unit.

**iii) Gentle Footslope, mainly colluvial. (L.3)**

The Foot slope unit occurs in the lower parts of the limestone landscape. It is characterized by gentle slopes with a gradient of 12-15 degrees. The altitude ranges from 1900m to 2100m. The foot slopes are formed by colluvial processes transporting materials from the upper parts of the limestone area. The soils are generally stony and boulders occur at some places.



**d) Forms of Denudational origin in Precambrian Granites. (G)**

The denudational landscape, mainly in granites, is found in the south-western parts of the study area. The granites are mainly biotite and tourmaline granites. The landforms are mostly massive, rounded and dome-like hills, the tops of which are softly rounded whereas their sides are steeper. The weathering processes of pressure-release and exfoliation tend to maintain the dome-like appearance. Large boulders, rounded by weathering and fine debris accumulate in the drainage courses and depressions.

The upper part of the slopes is mostly covered by thick forest. In the lower part however, the forest has been cleared and these parts are highly dissected by a dendritic drainage pattern. The altitude of these landforms ranges from 1600m to 2600m. The area covered is 44 sq. kms or 21% of the total area of the catchment. It can be subdivided into three units on the basis of relief and geomorphological processes.

**High Hills. (G 1)**

South-western granitic region of the catchment can be classified as High Hills. The slopes are steep, with an average gradient of 25-35 degrees. The elevation varies from 2300m to 2600m which makes it the highest region of the study area. Thick forests cover the entire this unit. Not many mass movement features therefore occur in this area. It is a rather stable part of the study area. The surface area covered by this unit is 10 sq. kms of 5% of the total area of the catchment.

**Midium Hills. (G 2)**

This unit occupies a rather extensive part of the forms of denudational origin in granites. It covers 32 sq. kms or 15% of the total area and the terrain is generally characterized by gentle to steep slopes. The altitude varies from 1600m to 2300m. The lower part of this unit can be further subdivided into two groups: i) The gently sloping unit (G 2.1) and ii) Steeply sloping unit. (G 2.2)

**Low Hills. (G 3)**

This third, unit of the landforms of denudational origin is lowest of the three. Its altitude ranges from 1600m to 1800m. The unit is found in two localities and covers only 2 sq. kms of the catchment. It is characterized by moderate/gently slopes.

**6. Types and distribution of Hazard Features in the Kulekhani Watershed.**

**Geomorphic Processes.**

Kulekhani Catchment in the central middle hills of Nepal was selected for the study of mass movement and erosion hazards. This catchment is densely populated and comprise many textbook example of landslides and erosion hazards. Therefore this area is most suitable for the study of mass movement processes. These processes are dominant factors in the retreat of the slopes in the catchment.

The main aim of this study is an interpretation of geomorphic processes with various terrain units and the production of a 1:50,000 scale of mass movement hazard map. Landforms result from the interaction/combination of geologic, climatic and man-related factors. Most landforms have visible evidence of the processes that have fashioned them. The chief geologic forces in the study area include lithology, large and small-scale tectonism and metamorphism. The most important climate related factors are weathering, mass wasting, erosion and deposition of which mass wasting and erosion were emphasized in this study. The most important human activities in the study area affecting the geomorphic processes include cropping methods and patterns, grazing, construction of roads and dams, removal of natural vegetation etc.

A map made of geomorphic features and slope instability, if properly interpreted, helps to reveal both natural and man-made past and present processes. It also give guidelines regarding likely events. This map thus can be used as a basis for the analysis and mapping of the geomorphic hazards which the population has to face.

The following types of erosional and mass movement features have been recognized in the study area on the basis of above mentioned geomorphic processes.

#### **Erosional features and their characteristics.**

Several types of erosional processes occur in Kulekhani Catchment. Among them rill, gully lateral, headward and badland erosion are notable. The prominent factors in producing erosional features are topography, geologic setting (including tectonic movements), climate, soil type and vegetation cover. Clays and sands are especially subject to the formation of rills, gullies and badlands in the catchment.

A brief description of two of the visible erosional features shown in the map is given below :

##### **a) Gullies.**

A gully is a steep-sided ravin measuring several tens of meters in width and depth. It may develop along a high-gradient stream eroding relatively weak materials. Gully sides are steeply inclined or vertical and are prone to mass wasting. Gullying is common on weak bedrock, alluvial terraces, alluvial fans, slides and flow deposits. It is a wide spread phenomenon in this catchment especially in the areas covered by structural/denudational landform (mainly in Phyllites). They threaten adjacent agricultural etc. Lands since gullies may rapidly grow laterally and headward.

##### **b) Badlands.**

Badlands have developed mostly in the steeply sloping areas with a high channel density. Active badlands are mostly devoid of vegetation. They are common on erosional and mass movement scarps and alluvial terraces. Badland erosion is usually rather localized but it can transform productive land rapidly into barren, steep and useless wastes. Most of

the badlands in the study area are concentrated in the lower parts of the granitic landforms. Badlands also developed near Markhu area after the excavation of clay and sand for the Kulekhani dam construction. (Fig.-6)

#### Mass movements features and their characteristics.

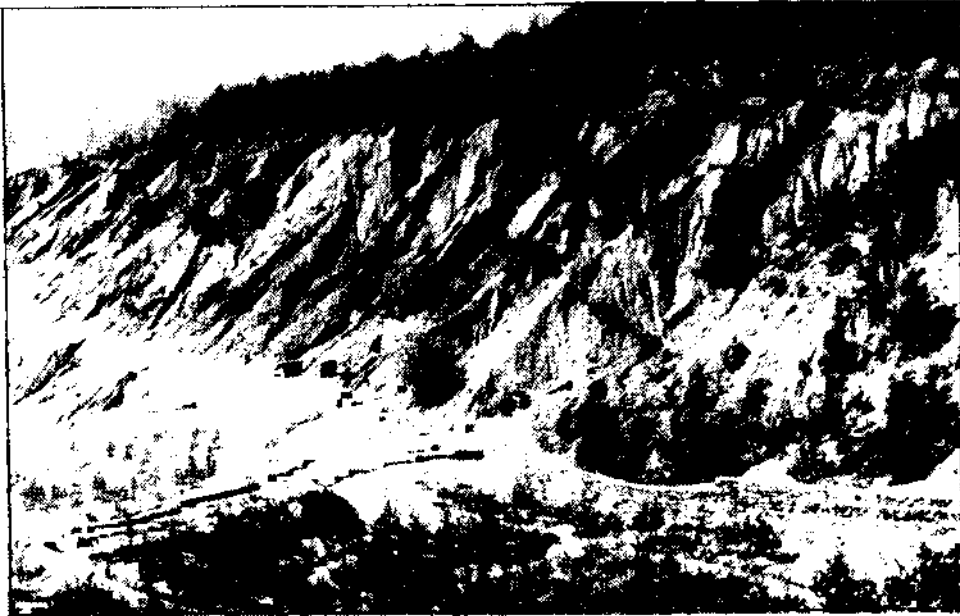
Most of the central part of the Kulekhani Catchment is affected by severe mass movements. The limestone area in the north-east and the granitic zone in the south-west of the catchment have a comparatively low density/frequency of mass movement features. Mass movement features are best developed in the weaker parts of structural/denudational areas mainly in Phyllites. The density and frequency of mass movements vary with factors such as lithology, structure, relief, slope steepness, vegetation cover. The most spectacular and wide spread slope movements processes of the Kulekhani Catchment occur in the area below the dam site and the headwaters of the main stream near Phodigaon Village. The lithology of these two places is weak clay, composed of fine-grained quartz and mica alternating of macaceous quartzite and quartzitic schist. The high clay content results in water retention and increase of pore water pressure which lead to mass movements. Due to the high relief and slope characteristics these two areas can be considered sites of active slope movements.

A variety of mass movements in fact occurs in the study area. A brief description of these movement types and their characteristics is given below:

##### a) Slides.

Both rotational slide (slump) and translational slides are occurring in the study area. Slumps are deep seated slides of weak material along a curved plane. The headward margin of each slump unit is usually marked by a steep scarp. Slumping often occur along scarps in unconsolidated deposits, especially in terraces and mixed colluvium. It is favored by stream, undercutting, and is also common in weak materials with a resistant caprock. They are easily identified on aerial photographs of the scale 1:20,000 due to their typical morphology. Rotational slides or slumps are distributed all over the structural/denudational landforms, mainly in Phyllites, especially upstream parts in the west as well as in the central region of the catchment. One large slump is developing dramatically near Markhu village following temporary road cut at the stage of Kulekhani dam construction. (Fig.-7)

Translational slides generally occur in steep to gentle bedding planes. They lack the backward tilting characteristics of rotational slides. The movements are usually rapid and structurally controlled by zones or planes of weakness like faults, joints etc. The sliding mass is greatly deformed into many smaller units. Smaller, shallow (planar) slides occurring in great numbers over a large hillslopes of the phyllite zone of the study area. (Fig.- 8) They generally occur in areas of rather resistant rocks. Good examples of block and debris slides are located



Development of badlands after the excavation of clay and sand for Kulekhani Dam construction.



Active slump developed after road construction.



Block slide on the bedding plane along the lower part of the Kulekhani Valley.

all over in the lower region of the Kulekhani dam site. Large inactive translational slides are outlined in the map by dashed line symbols.

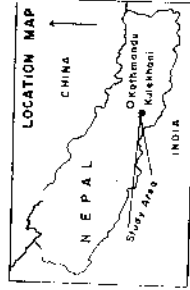
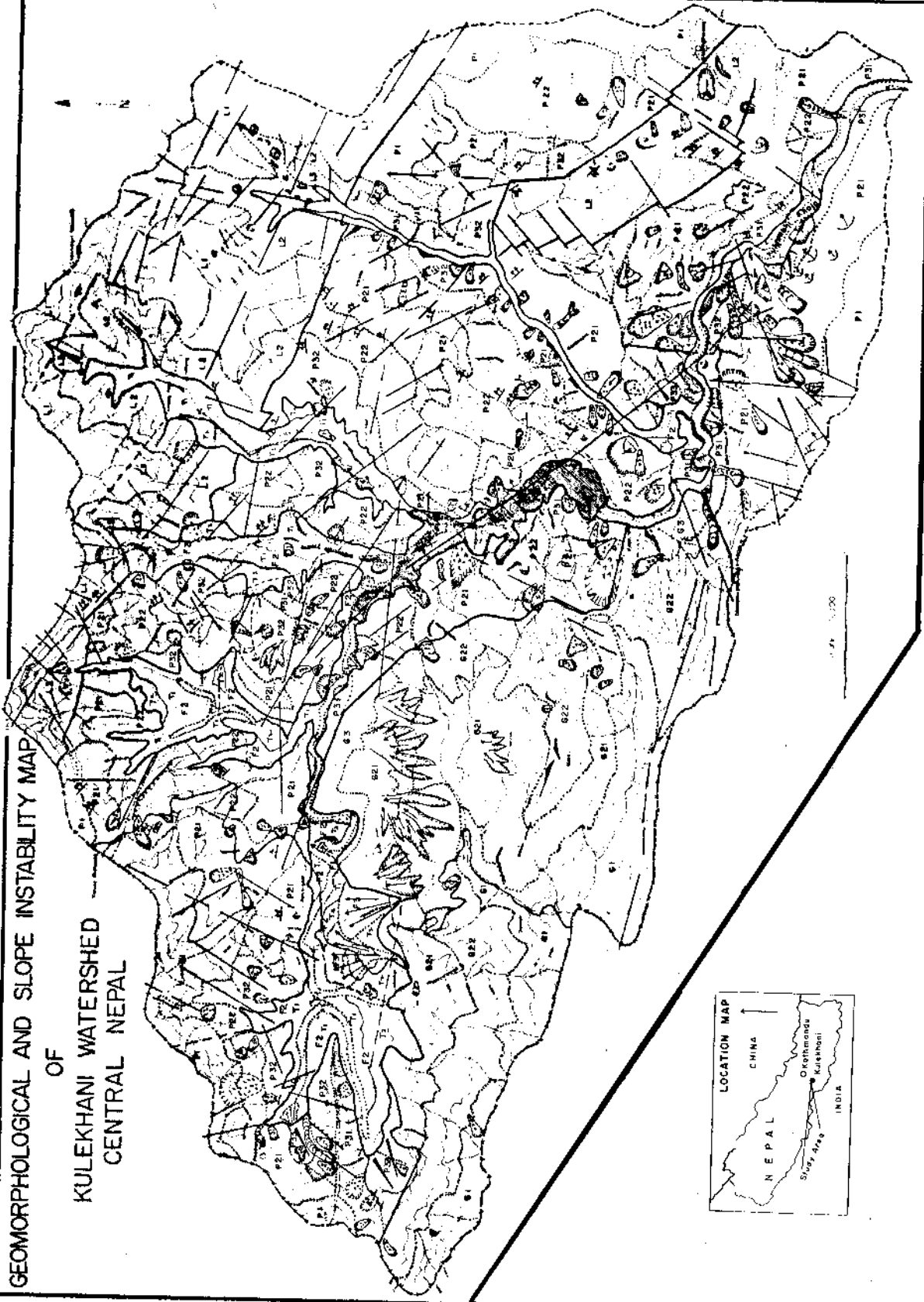
**b) Falls.**

A fall is the detachment of a mass of any size from a steep slope or cliff along a surface on which no shear displacement takes place. Falls are common along the steep sides of the valley especially in the lower regions of the catchments. Falls are not very easily identified with some exception of large one on aerial photo graphs due the restriction of the scale.

**c) Flows.**

Flows usually occur in loose materials and weak bedrock especially in clay-rich shales and in phyllites which become saturated by spring discharges and/or heavy rainfall. They move as a viscous semi-liquid, lacking internal cohesion. Flows are found mainly below rotational slides. Active flows are very temporary features, but their movement may start afresh when renew favorable conditions occur. Stable flow deposits are highly prone to erosion, especially gullyng. The flows found in the catchment range in size from a few meters to tens of meters in width up to several meters deep and elongated up to several hundred meters. The number of flows in the catchment, is comparatively low but the size of the flows of the catchment, on average, is larger than that of any other type of mass movements.

# GEOMORPHOLOGICAL AND SLOPE INSTABILITY MAP OF KULEKHANI WATERSHED CENTRAL NEPAL



## TOPOGRAPHICAL DETAILS

- Contour line with height indication
- Highway
- Improved road
- Railway
- Bridge
- Mountain peak with elevation
- Lake
- Reservoir
- Stepped boundary
- Settlement
- Circular line with height indication
- Highway
- Improved road
- Railway
- Bridge
- Mountain peak with elevation
- Lake
- Reservoir
- Stepped boundary

## GEOMORPHOLOGICAL AND GEOLOGICAL DETAILS

- Geomorphological boundary - major
- Geomorphological boundary - minor
- Fault line
- Alluvial fan
- Foot slope
- Scree slope
- Alluvial fan
- Point bar
- Stepped slope with sand bar

## GEOMORPHOLOGICAL UNITS

- Form of Fluvial Origin
  - Flood plain
  - Fluvial Terraces T, T, T, from newer to old
  - Alluvial Fan
  - Infilled Valley
- Form of Structural/Denudational origin mainly in Phyllites
  - High Hills-Steep Slopes mainly Denudational
  - Moderate Hills



**d) Creep.**

Creep is a very slow type of mass-movement on hill slopes. It depends not only on climatic conditions and angle of slope but also on type of soil, parent material, etc. In the study area this movement usually occurs in combination with other types of movement such as slides, flows etc. It is however infrequent and is restricted to few areas only. Due to the difficulty in identifying creep on aerial photographs the occurrences are mapped on the basis of field check.

**e) Complex mass movements.**

Where two or more types of movements occur in one unit is considered as a complex mass movements. These occur at many places in the Kulekhani Catchment. Almost all combinations of movement types are found in this study area. Many flows for example are the result of slumping in the upper parts of the failure. The combination of movements adversely affects in the identification. Many complex failures were observed and mapped during the field work.

**7. Conclusion.**

The main purpose of the study was to devise a system, adopted to the condition prevailing in Nepal, for mapping of land degradational features and their characteristics as affecting potential and existing mass movement hazards. Both natural and anthropogenic factors are responsible for generating environmental problem in the study area. The density of hazard features varies with landuse, vegetation cover, lithology and anthropogenic activities. The densely forested area of the catchment is comparatively stable zone. Lithological factors such as Phyllitic zones with clay quartzites, schists and metasandstones are most susceptible for the various types of mass movements. Limestone and Granitic areas to the contrary are relatively less affected by such problems. But gullies and badlands erosional processes here started badly in the deforested parts of the catchment.

At the end, conclusion can be derived from this study that several remote sensing devices as discussed earlier may be valuable tools for the proper planning of environmental protection of certain area. Because without a knowledge of potential and existing environmental problems one cannot plan for the future development of that area.

Among all the remote sensing devices which were used for the study of mass movement hazards, aerial photographs of the scale 1:20,000 and larger proved to be the best tools for studying. All these techniques however, useful for the efficient mapping of such hazard features may not be sufficient for accurate map. All the interpreted informations from aerial photographs has to be checked and conformed in the field.



**BIBLIOGRAPHY**

- Schuster, Robert L. and Krizek, Raymond J. (1978)  
"Landslides Analysis and Control, Special Report 176"  
National Academy of Sciences, Washington D.C.
- Sharma, C.K. (1976)  
"Landslides and Soil Erosion In Nepal"  
Published by Mrs. Sangeeta Sharma, Nepal.
- Sissakian, Varoujan Kh. (1986)  
"The study of Mass Movement from Aerial Photographs"  
Proceedings of the 7th International Symposium on Remote Sensing for  
Resources Development and Environmental Management, ITC  
The Netherlands. Part-2.
- Stocklin, J. and Bhattarai, K. (1977)  
"Geology of Kathmandu Area and Central Mahabharat Range, Nepal  
Himalaya".  
HMG/UNDP Mineral Exploration Project, Kathmandu.
- Verstappen, H.Th. (1977)  
"Remote Sensing in Geomorphology"  
Elsevier, Amsterdam.
- Ginneken, P. Van & Joshi, S.P. (1982)  
"Development Plan for the Kulekhani Watershed"  
Kathmandu : UNDP/FAO/Department of Soil and Water Conservation,  
HMG, Nepal.
- Laban, Peter (1979)  
"Landslide Occurrence in Nepal"  
Kathmandu : Department of Soil and Water Conservation, HMG, Nepal.
- Manandhar, Indra N. (1987)  
"The use of Aerial Photographs and other Remote Sensing Systems in  
the study of Mass Movement Hazards in Mountainous Regions, Specifi-  
cally the Kulekhani and Phewa Tal Watersheds, in Nepal",  
Unpublished M.Sc. Thesis ITC, The Netherlands.
- Sauchyn, D.J. & Trench, N. R. (1978)  
"Landsat Applied to Landslide Mapping"  
Photogrammetric Engineering and Remote Sensing, Vol.44, No.6 USA.