CHAPTER 9 PREPARATION OF HAZARD MAP

9.1 Hazard Map using GIS

Generally, road on mountainous areas has difficulty in its construction due to higher cost and unstable terrain. Excavation for road construction often causes failures and landslides. Furthermore, erosion and landslides triggered by heavy rainfall cause also serious damage to the road and its damage extends to the environmental dilapidation. This vicious reaction makes mountainous road has not finally achieved their ultimate objectives.

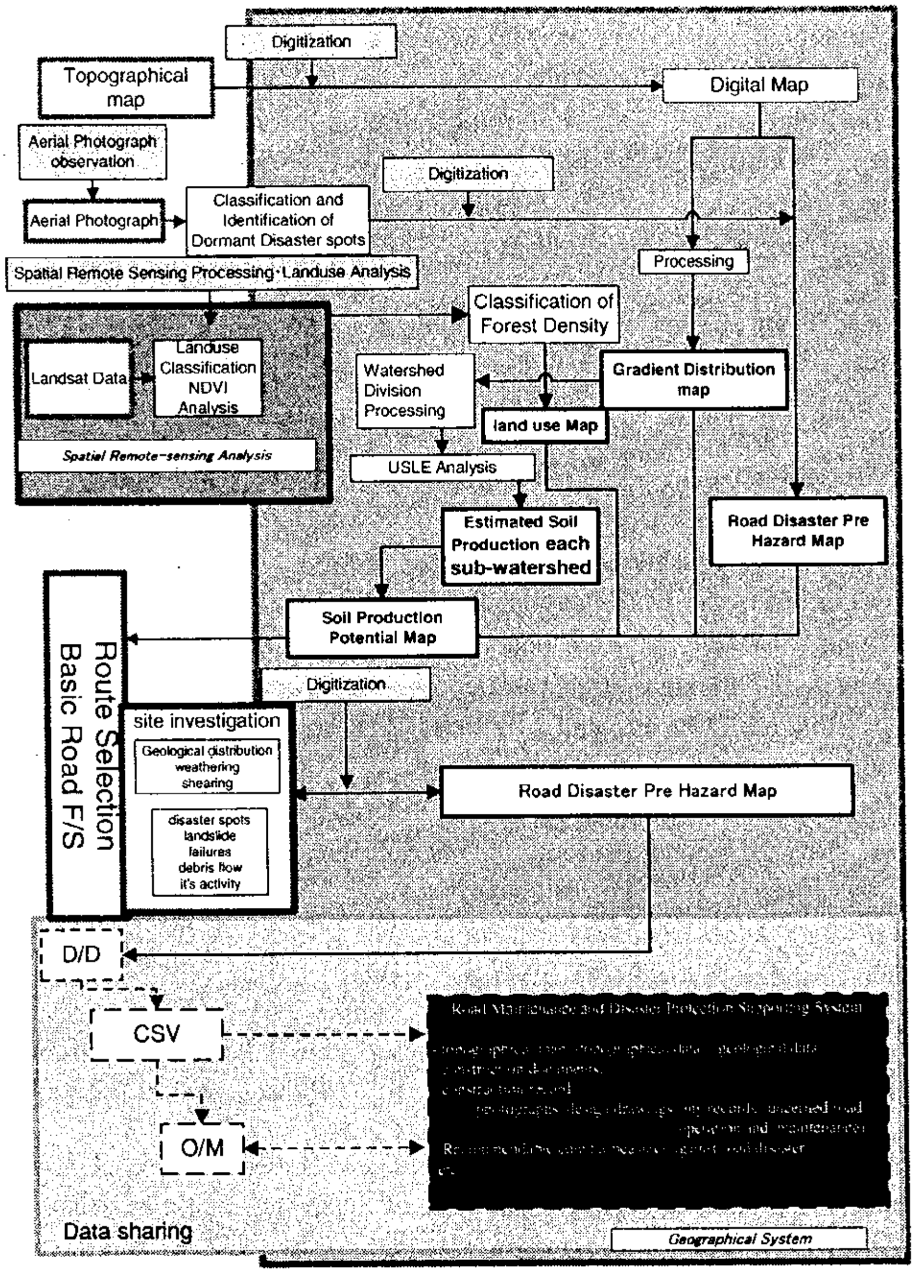


Figure 9.1 Procedure of Hazards Map

In corresponding to this situation, at the planning stage, it is important that the road alignment is designed to avoid dormant disaster spots including landslide, failures and also dangerous stream of debris flow. It is also important to carryout data collection during road planning and construction stage prior to the road maintenance and operation stage. From this point of view, the Study Team prepared hazards map using GIS and spatial remote sensing for alignment study in this Project. The methodology for the development of road disaster map and its application is presented in this chapter. The procedure of hazard map preparation is the following.

9.2 Preparing of Digital Map

The digital map of the Study area was made based on the aerial photograph referring to the topographical map (1:25,000). Contour lines have altitude data as property in the digital map since these data are inputted as vector data. The digital map is very useful to analyse the gradient distribution and soil production volume of each watershed from the results of the spatial remote sensing. These processes have been done using GIS by Arc/ Info in this Study.

9.3 Observation of the Aerial Photograph

Observation of the aerial photograph has been done using aerial photographs (S=1:50,000) taken in 1994. The purpose of the aerial photograph observation is the identification of the dormant disaster spots like landslides, failures and dangerous stream of debris flows that are to be avoided from road alignment. The avoidance of the dormant disaster spot leads the planning road to an economical alignment. Observation area is the watershed of Manamati khola and Mahesh kohla covered the probable alignment area.

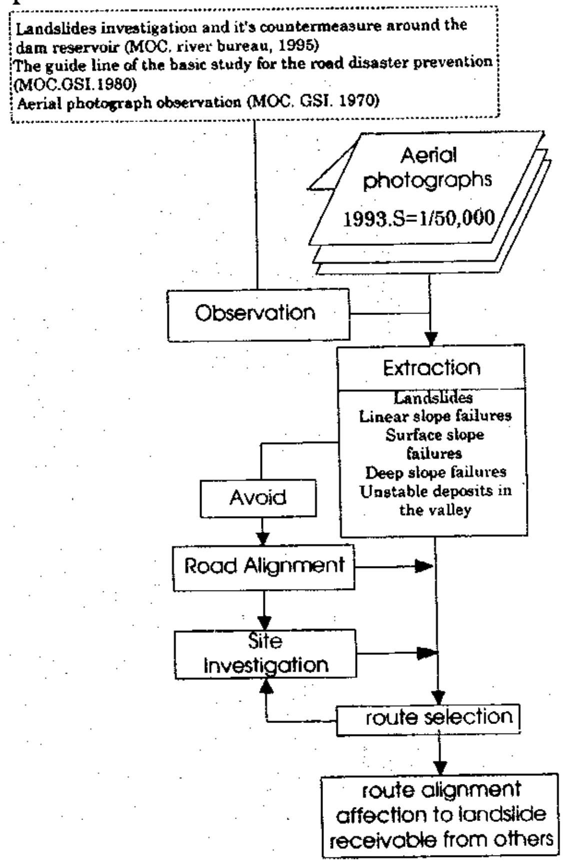


Figure 9.2 Observation of Aerial Photograph & Route Selection

The objective of aerial photograph observation is identification of dormant landslides, linear slope failures, surface slope failures, deep slope failures, unstable deposits and their location. Terrace, suitable for route to pass, will also be identified by this process.

Observation has been done in reference to "Landslides investigation and its countermeasure around the dam reservoir (River Bureau, Ministry of Construction, Japan: MOC 1995) ", "The guideline of the basic study for the road disaster prevention (Ground Survey Institute, Japan: GSI.1980)" and " Aerial photograph observation (GSI. 1970)".

9.4 Road Disaster Hazard Map

The result of the aerial photograph observation was converted into digital data and Road Disaster Pre-Hazard Map was prepared based on the data in digital format also. Road Disaster Hazard Map can be prepared only through the verification of pre-hazard map after the site investigation is performed to grasp the present information of study, as shown in figure 9.1. Identification of dormant landslides, failures, geological distribution and its weathering condition has been collected by site investigation. Road Disaster Hazard Map of the watershed of Manamati khola and Mahesh kohla is shown in Figure 9.3.

9.5 Land Use Map

Land use map has been prepared by spatial image analysis. This map has been also verified through the site investigation. Especially, an index is required to evaluate forests to be conserved during route selection from the viewpoints of environmental conservation. In this study, NDVI value has been applied as an index to evaluate the density of forest since NDVI can be judged to be useful in Nepal. This index is obtained through spectral analysis with infrared and near infrared of radio wave using Land-sat data. NDVI is also well known to be in relation to the proportion of total amount of vegetation in the world. The result of NDVI analysis in Siwalik that Nippon Koei has done in 1995 is shown in Figure 9.4. This figure indicates the proportional relation is between NDVI and vegetation. The formula of NDVI is given below.

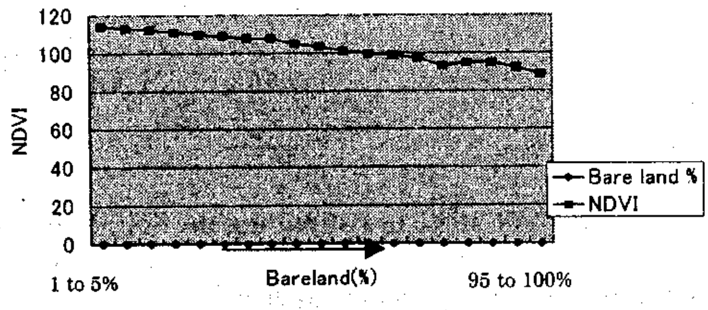


Figure 9.4 Result of NDVI Analysis in Siwalik

$$\text{NDVI} = \left[\left(\frac{TMband4 - TMband3}{TMband4 + TMband3}\right) + 1\right] \times 100$$

The Normalized Difference Vegetation Index (NDVI) can be commonly used in the vegetation analysis.

Vegetation index is a number that is generated by a combination of spectral bands of a remote sensor representing form of relationship to the amount of vegetation in a given image pixel. NDVI is concerned with visible red region (Band 3) and near-infrared region (Band 4) of the electromagnetic spectrum.

Land use map including forest density classified by NDVI value is shown in Figure 9.5.

9.6 Estimation of annual soil production volume of each sub-stream

Not only flood flow, but also debris flow will be carefully considered for alignment study of mountainous roads. For the alignment study and study on the river-crossing structure, annual soil production volume of the river or stream gives useful information and has been estimated by using GIS and spatial remote sensing in this study. The procedure of the estimation is shown in Figure 9.6.

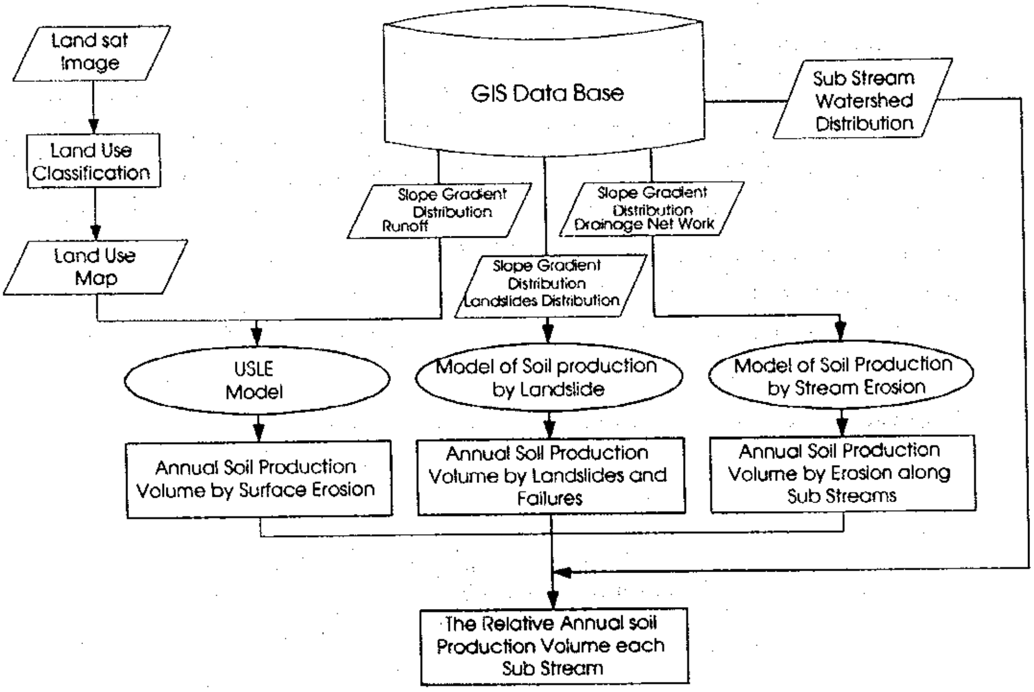


Figure 9.6 The Procedure of Estimating the Soil Production Volume

1) Estimation of annual soil production volume

Generally, soil production volume (E) in the sub- stream can be expressed by the formula below,

$$E = Es + Ef + Ese \quad \text{....eq.(8.1)}$$

Where, E : annual volume of soil production
Es : annual soil volume of surface erosion
Ef : annual soil volume of landslides and failures
Ese : annual soil volume of erosion along sub-stream way

2) Annual soil volume of surface erosion, Es

In case of a well-balanced natural environment system, the factors controlling the soil production are runoff, landform, soil condition, and vegetation in the sub-stream watershed. Although soil production volume is limited in this natural well-balanced condition, it could be accelerated by soil devastation due to immoderate cultivation development, deforestation, abnormal weather and vast disaster. Thus, unbalanced natural environmental conditions compel the soil erosion to fall in the vicious spiral conditions.

Through the observation of these phenomena, in 1978, Wischmeier and Smith proposed that annual soil surface production could be estimated as the products of all above-mentioned factors. This is known as USLE formula.

The formula of USLE was developed for the gentle cultivation area and is the most popular one all over the world. The formula is given below,

$$Es = FR(S/10)^{0.9}(L/72.6)^{0.35}(P/1.375)^{1.75}$$

Where,

Es : annual soil production volume of surface erosion
F : basic erosion depth
R : vegetation parameter
S : slope gradient
L : length of slope
P : runoff

In this study, the annual soil volume of surface erosion for each sub-stream watershed has been analysed by USLE formula, using the GIS inputted digital map and also the land use data acquired from land sat image.

3) Annual soil volume of landslides and failures, Ef

Annual soil volume of landslides and failures has been estimated by making assumptions of the soil erosion of landslides and failures from the hazard map.

Formula of Annual soil volume of landslides and failures is given below,

$$Ef = \sqrt{A} * \left(L_m / \cos(\theta) \right) * \sqrt{A} / L_d$$

Where,

Ef	:	annual soil volume of landslides and failures
A	:	area of landslides and failures
θ	:	slope gradient
Lm	:	annual landslide movement
Ld	:	failure depth

Following assumptions were made in the estimation:

- Annual surface erosion depth in the active failure reaches 10 cm/cm^2
- Annual surface erosion depth in the failure traces reaches 2 cm/cm^2
- Annual Land slide moving reaches 5 cm/year

4) Annual soil volume of erosion along sub-stream way, Ese

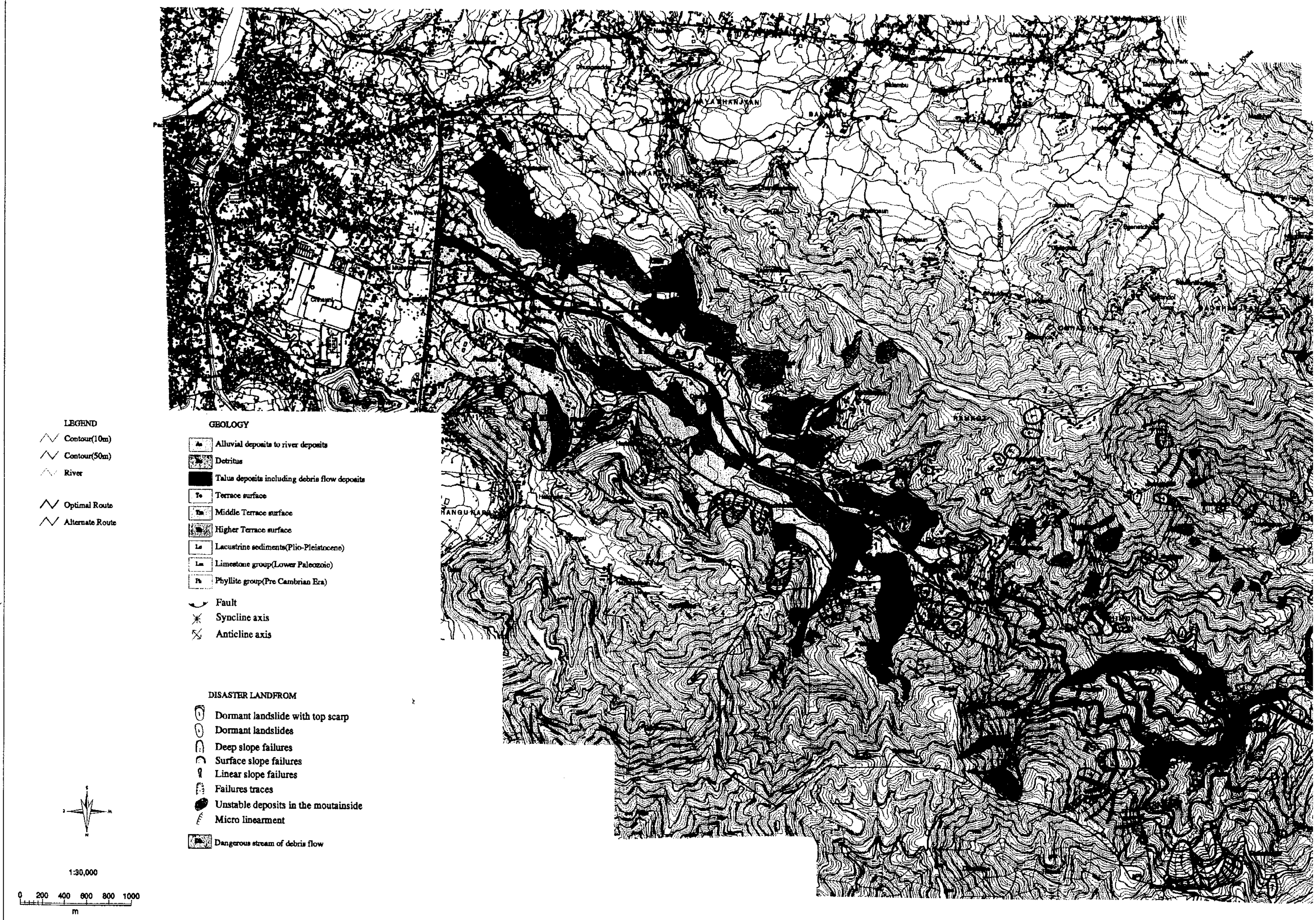
Annual soil volume of erosion along sub-stream way has been calculated based on the guideline for hydraulic formula of JCEA. Sub-stream length and its gradient can be calculated from the digital map using GIS. The slope gradient map is shown in Figure 9.7. Annual erosion depth along the sub-stream depend on the gradient is shown in Table 9.1.

Table 9.1 Erosion depth/year along each sub-stream from its gradient

Sub stream profile gradient	Erosion depth (cm)
0 to 3	Below 1
3 to 10	1
10 to 15	3
15 to 30	12
Over 30	15

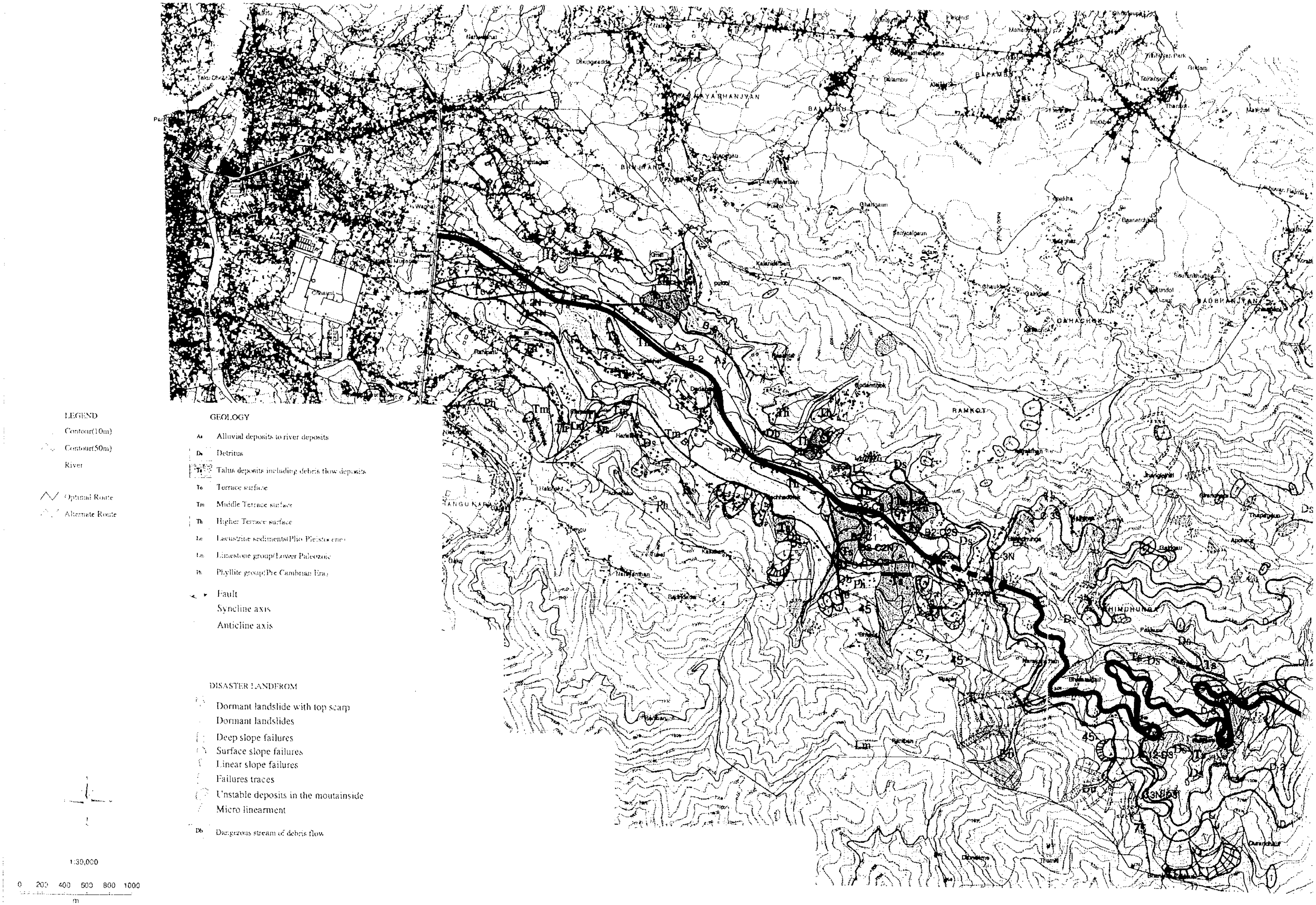
The soil production potential map of the result through these analyses is shown in Figure 9.8.

HAZARD MAP



LEGEND
Contour(10m)
Contour(50m)
River
Optimal Route
Alternate Route
GEOLOGY
Alluvial deposits to river deposits
Detritus
Talus deposits including debris flow deposits
Terrace surface
Middle Terrace surface
Higher Terrace surface
Lacustrine sediments(Plio-Pleistocene)
Limestone group(Lower Paleozoic)
Phyllite group(Pre Cambrian Era)
Fault
Syncline axis
Anticline axis
DISASTER LANDFROM
Dormant landslide with top scarp
Dormant landslides
Deep slope failures
Surface slope failures
Linear slope failures
Failures traces
Unstable deposits in the moutainside
Micro linearment
Dangerous stream of debris flow
1:30,000
0 200 400 600 800 1000
m

HAZARD MAP



RAMKOT
KHIMPHUNG
DADBHANJYAN
DAHACHOK
BHIMPHEDI
LEGEND
Contour(10m)
Contour(50m)
River
Optimal Route
Alternate Route
GEOLOGY
As Alluvial deposits to river deposits
Ds Detritus
Ts Talus deposits including debris flow deposits
Tc Terrace surface
Tm Middle Terrace surface
Th Higher Terrace surface
Lc Lacustrine sediments(Plio Pleistocene)
Lm Limestone group(Lower Paleozoic
Ph Phyllite group(Pre Cambrian Era)
Fault
Syncline axis
Anticline axis
DISASTER LANDFROM
Dormant landslide with top scarp
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Deep slope failures
Surface slope failures
Linear slope failures
Failures traces
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Micro linearment
Db Dangerous stream of debris flow
1:30,000
0 200 400 600 800 1000
m

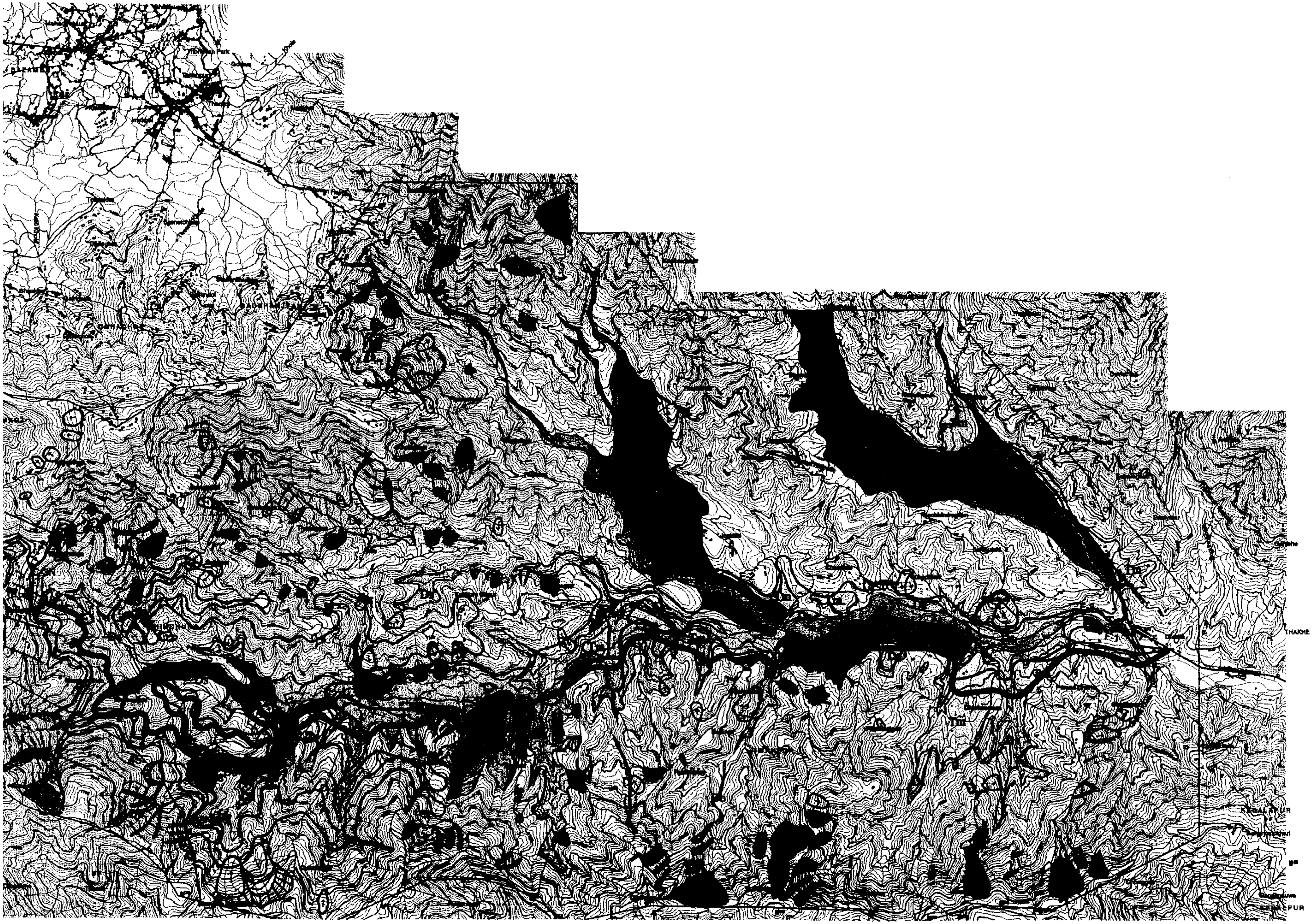


Figure 9.3 Hazard Map

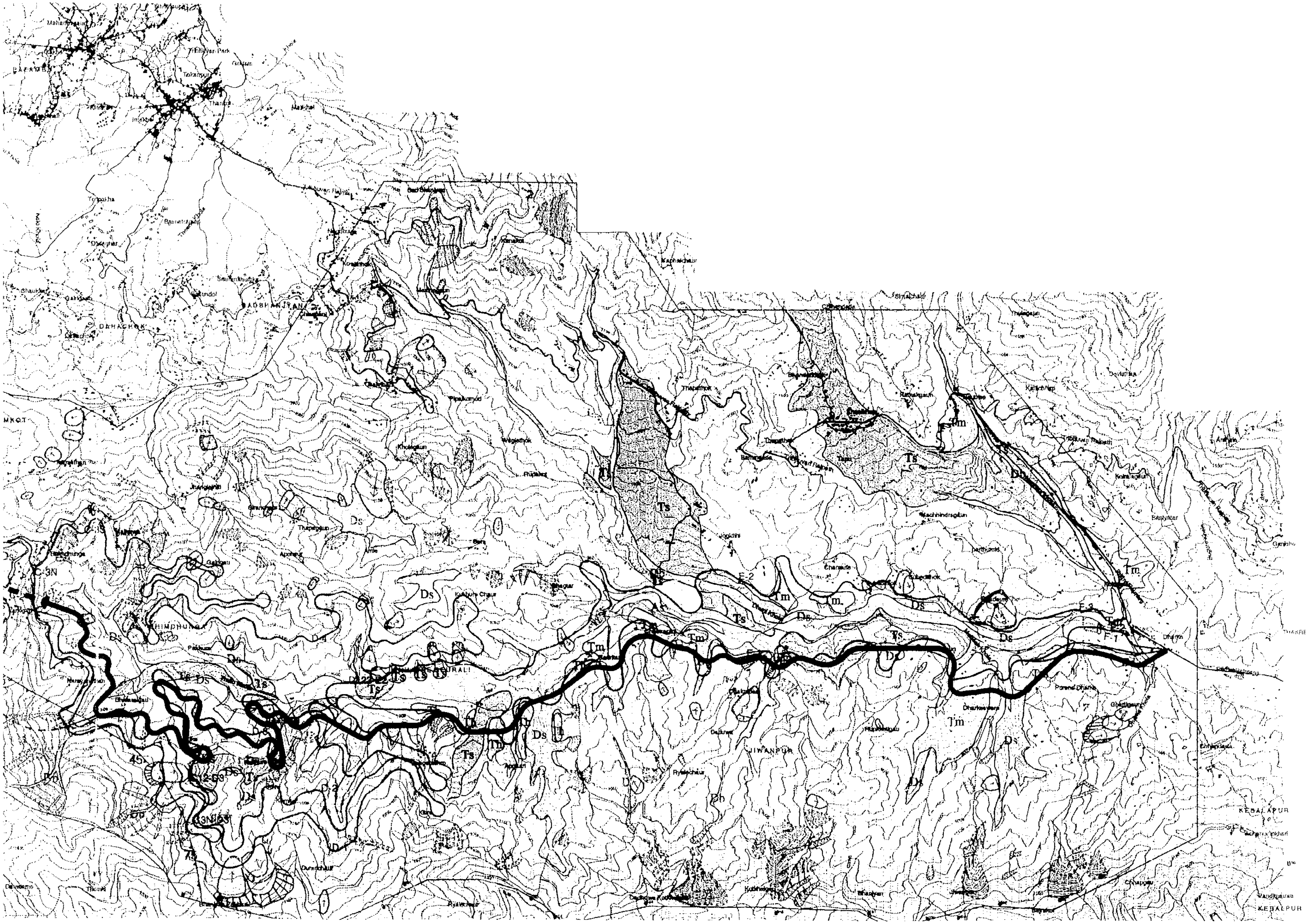
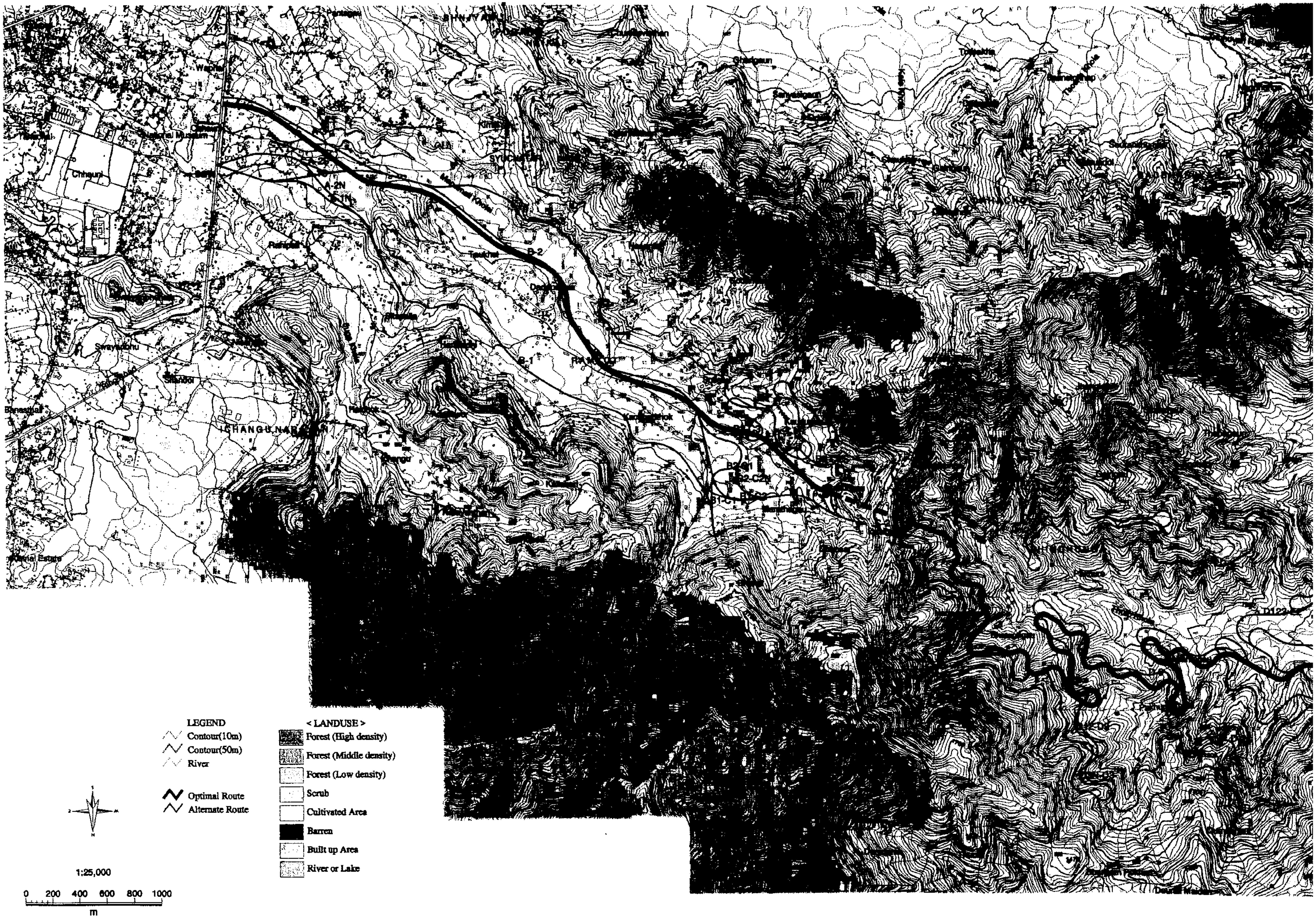
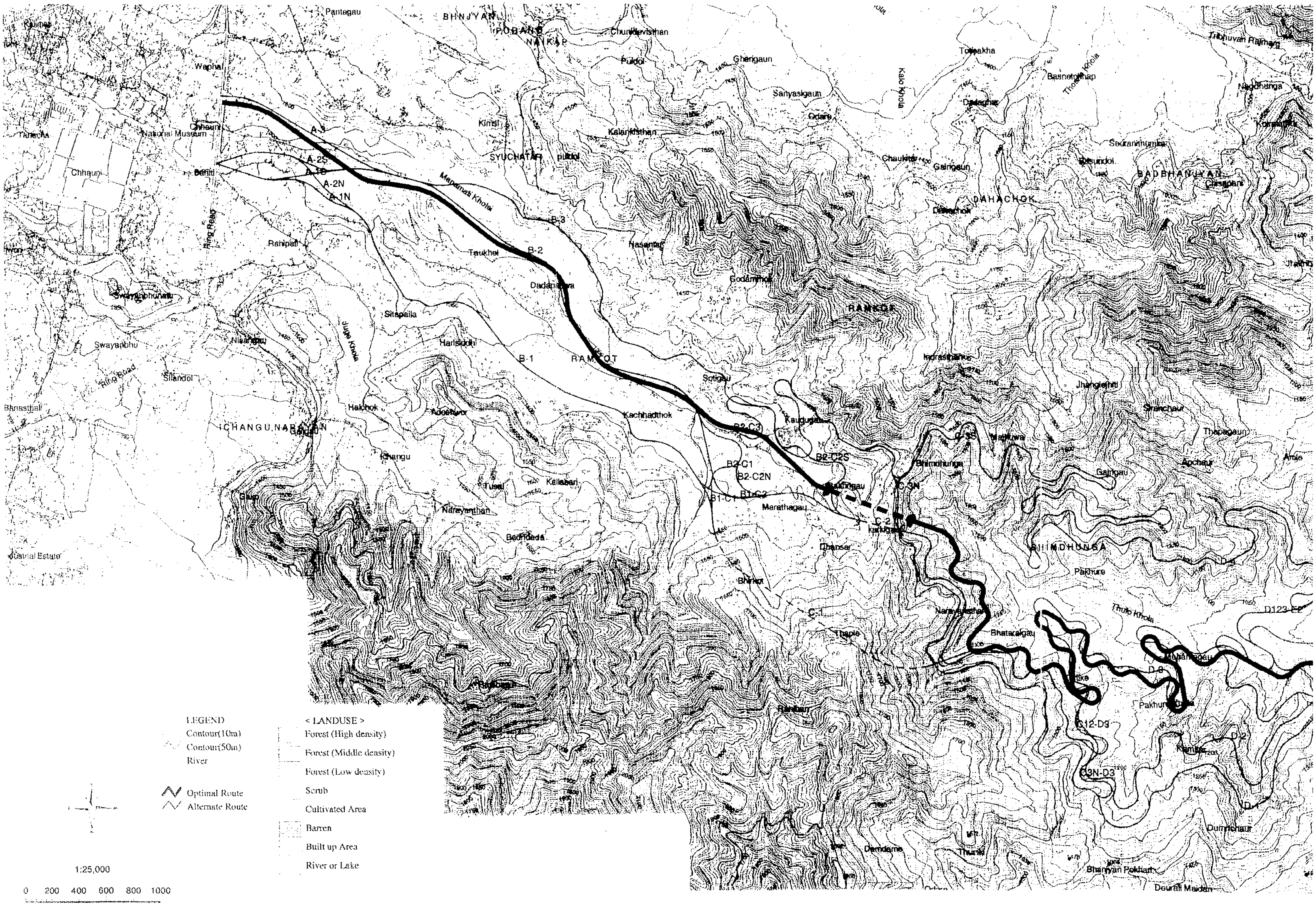


Figure 9.3 Hazard Map

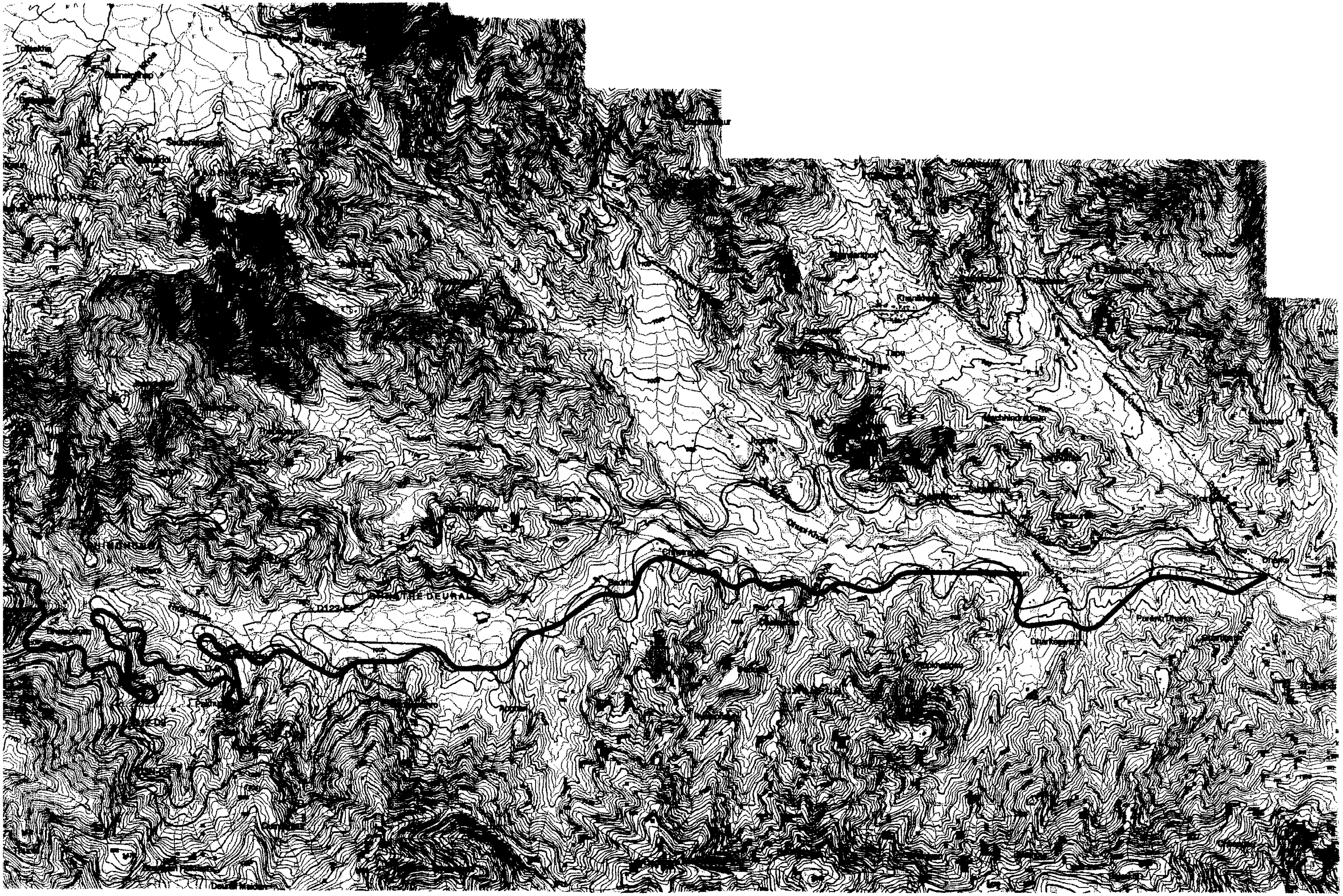
LANDUSE MAP


Chhauni
A-2N
B-2
B-1
LEGEND
Contour(10m)
Contour(50m)
River
Optimal Route
Alternate Route
< LANDUSE >
Forest (High density)
Forest (Middle density)
Forest (Low density)
Scrub
Cultivated Area
Barren
Built up Area
River or Lake
1:25,000
0 200 400 600 800 1000
m

LANDUSE MAP



Pantagau
Chundevisthan
Pulchok
Gherigaun
Sanyasigaun
Kalo Khola
Tribhuvan Rajmarg
Nagdhunga
Basnetothap
Thosne Khola
Waphal
Chhauni
National Museum
Chhauni
A-3
A-2S
A-1S
A-2N
A-1N
Kirtipur
SYUCHATAR
Kalankisthan
Chaukitar
Dahachok
DAHACHOK
Manamati Khola
B-3
B-2
B-1
Ring Road
Ranipati
Taukhel
Dadagaun
Swayambhunath
Swayambhu
Sitapaila
Jugje Khola
Harisiddhi
RAMKOT
Silandol
Halchok
ICHANGU NARAYAN
Kachhadthok
Sotigau
B2-C3
B2-C1
B2-C2N
B2-C2S
B1-C1
B1-C2
Marathagau
Bhimdhunga
C-3N
C-3S
C-2
Changu
Kailabari
Narayanthan
Dhansar
BHIMDHUNGA
Pakhure
Jhanglejhul
Sranchaur
Thapagaun
Apchaur
Gangau
Thulo Khola
D123-E2
Bhataraigau
C-1
Thaple
Ramban
D-3
C12-D3
C3N-D3
D-2
D-1
Dumrichaur
Bhanjyan Pokhari
Deurali Maidan
Thumki
Damdame
LEGEND
Contour(10m)
Contour(50m)
River
Optimal Route
Alternate Route
< LANDUSE >
Forest (High density)
Forest (Middle density)
Forest (Low density)
Scrub
Cultivated Area
Barren
Built up Area
River or Lake
1:25,000
0 200 400 600 800 1000
m



The Landuse was estimated using Landsat TM 14th March,1998

Figure 9.5 Landuse Map