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CONFERENCE ON RESEARCH IN ENGINEERING
2019

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2019
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CENTRE OF EXCELLENCE IN ENGINEERING AND TECHNOLOGY
(CREaTE)

DEVELOPMENT OF LANDSLIDE HAZARD ASSESSMENT MODEL FOR CUT-SLOPES ALONG TAMPARULI – SANDAKAN ROAD IN SABAH, MALAYSIA

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CONTENT

- Introduction
- Objective
- Methodology
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- Slope information collection
- Data analysis
- Hazard equation @ prediction model development
- Conclusion

INTRODUCTION

- Some definitions:
  - Landslide: The movement of a mass of rock, debris or earth flowing down a slope (Cruden,1991). Definition adopted by the International Geotechnical Societies UNESCO Working Party on the World Landslide Inventory (Fell et al, 2000)
  - Hazard: Probability or the likelihood of occurrence of a potentially damaging phenomenon within a specified time period and within a given area (Varnes, 1984 & OAS, 1991)

Methods For Landslide Hazard Assessment

Qualitative methods

- *Geomorphological mapping;*
- *Direct mapping method;*
- *Multi-class weighting method;*
- *Spatial multi-criteria analysis;*
- *Analytical hierarchy process;*
- *Fuzzy logic approach*

Quantitative methods

Statistical methods

Bivariate methods:

- *Weights of evidence;*
- *Certainty factors;*
- *Dempster-Shafer method;*
- *Fuzzy logic.*

Multivariate methods :

- *Discriminant analysis;*
- *Logistic regression analysis;*
- *Multiple regression analysis.*

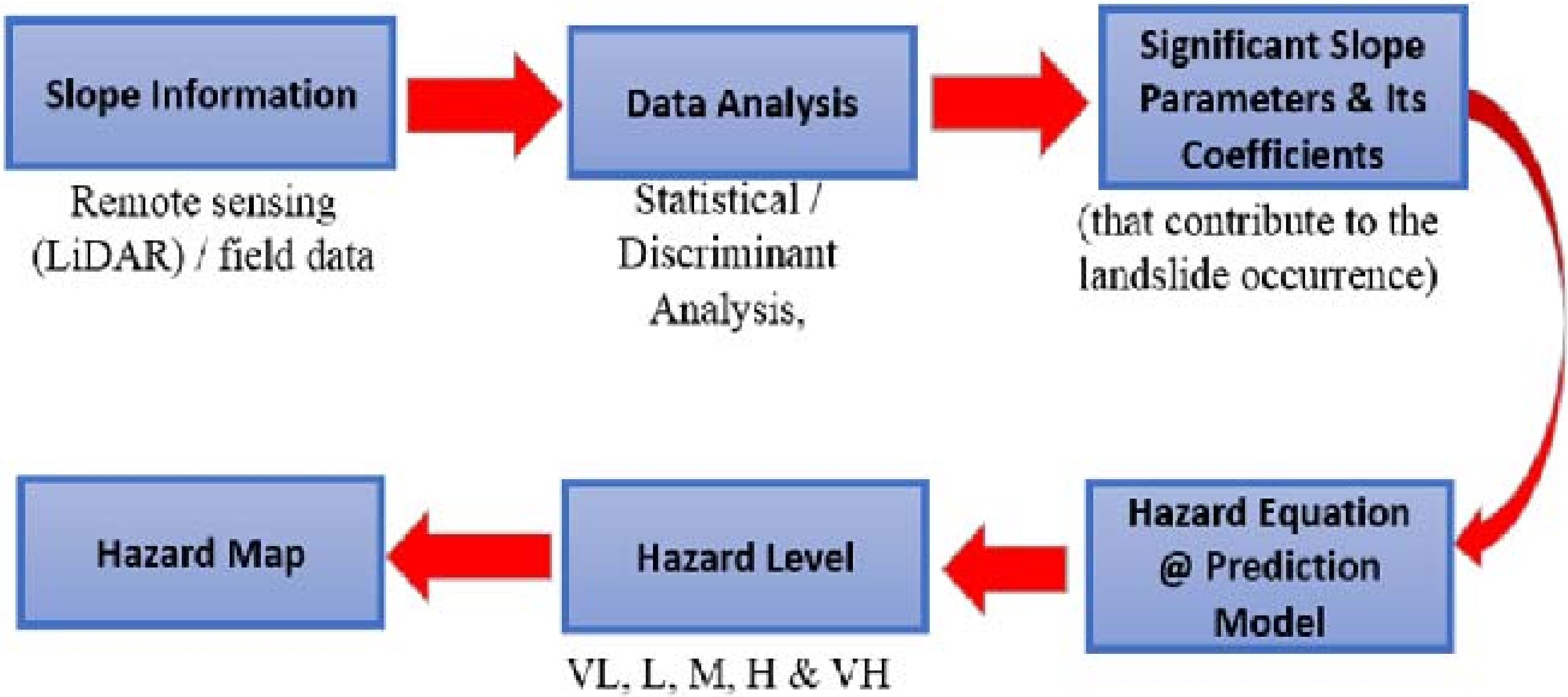
Deterministic methods

- *Static infinite slope modeling;*
- *Dynamic infinite slope modeling with rainfall trigger;*
- *Earthquake induced infinite slope modeling.*

OBJECTIVES

- To determine the most significant slope parameters contribute to landslide occurrences, develop landslide hazard assessment model to estimate and rank the landslide hazard and present it in form of hazard map for cut slopes along Tamparuli – Sandakan Road (FT22)

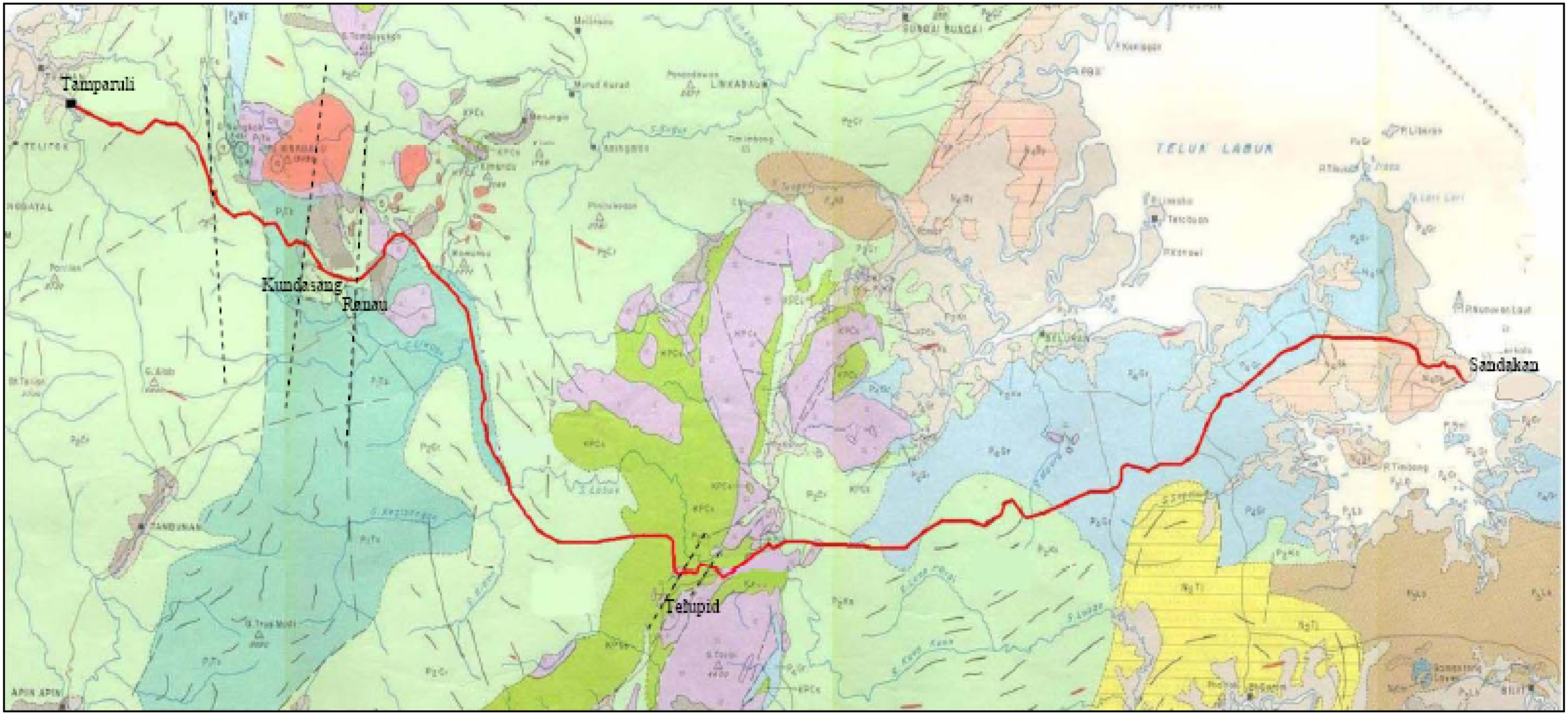
METHODOLOGY

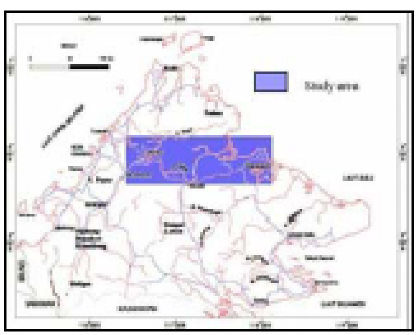


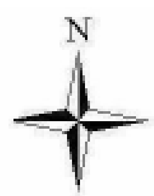
STUDY SITES

- **Federal Route 22, Tamparuli – Sandakan Road in Sabah**

Tamparuli – Sandakan Road







LEGEND

Crocker	Pinosuk Gravel
Trusmadi	Garinono
Ultrabasic	Sandakan

Fault

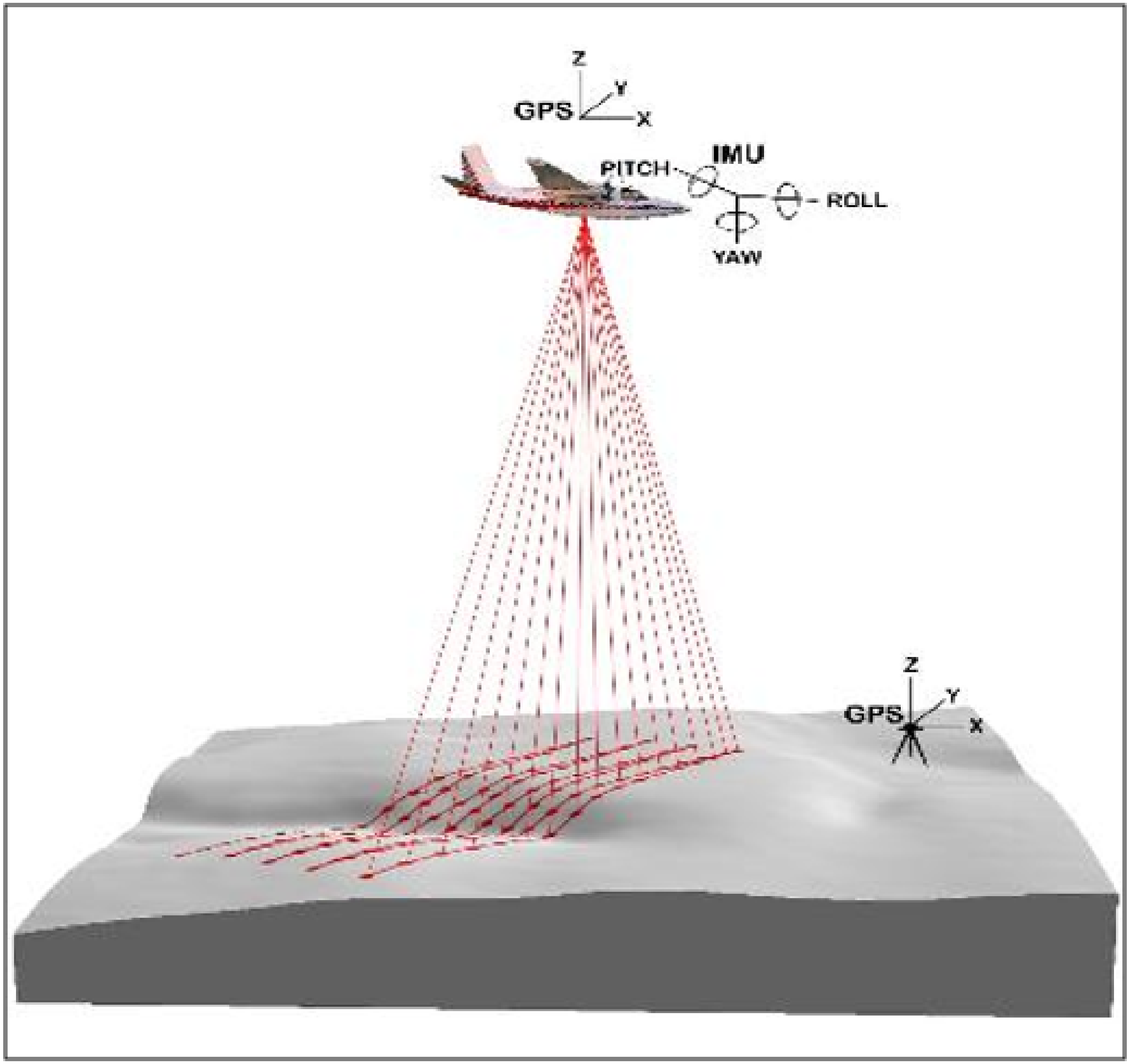
10 Km 0 50 Km

1 Cm

(Scale 1: 1,000,000)

Landslides or Slope Failure

SLOPE INFORMATION COLLECTION

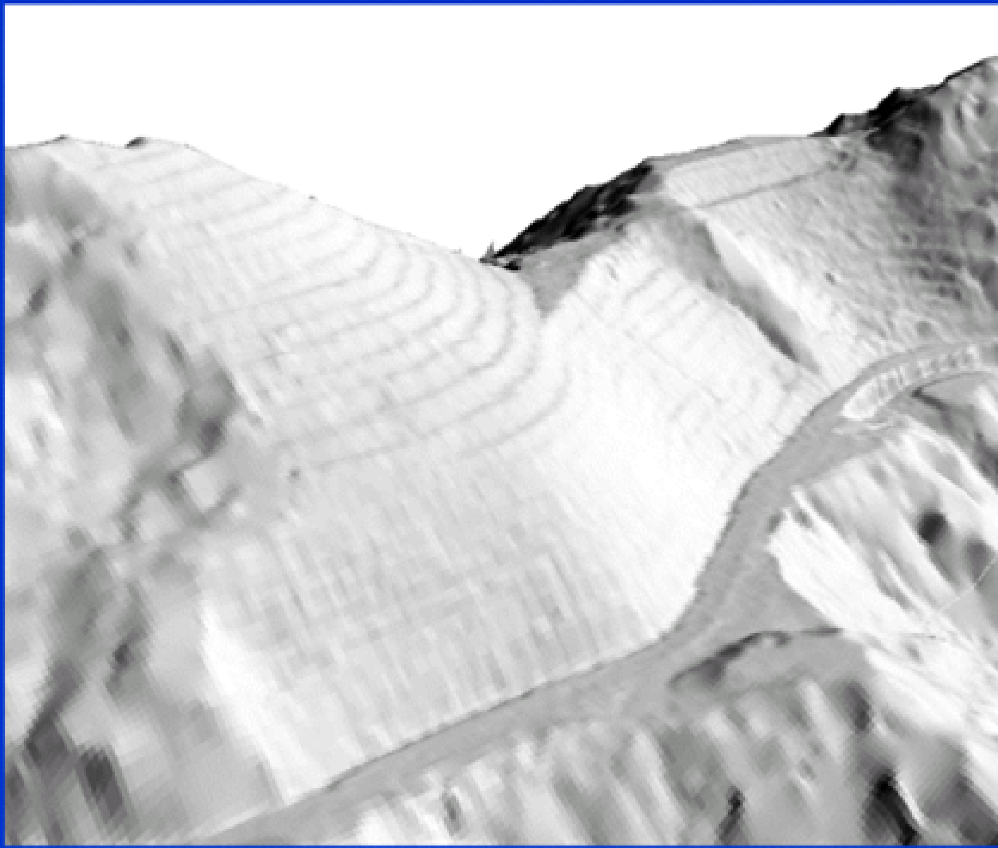


Light Detection And Ranging (LiDAR)

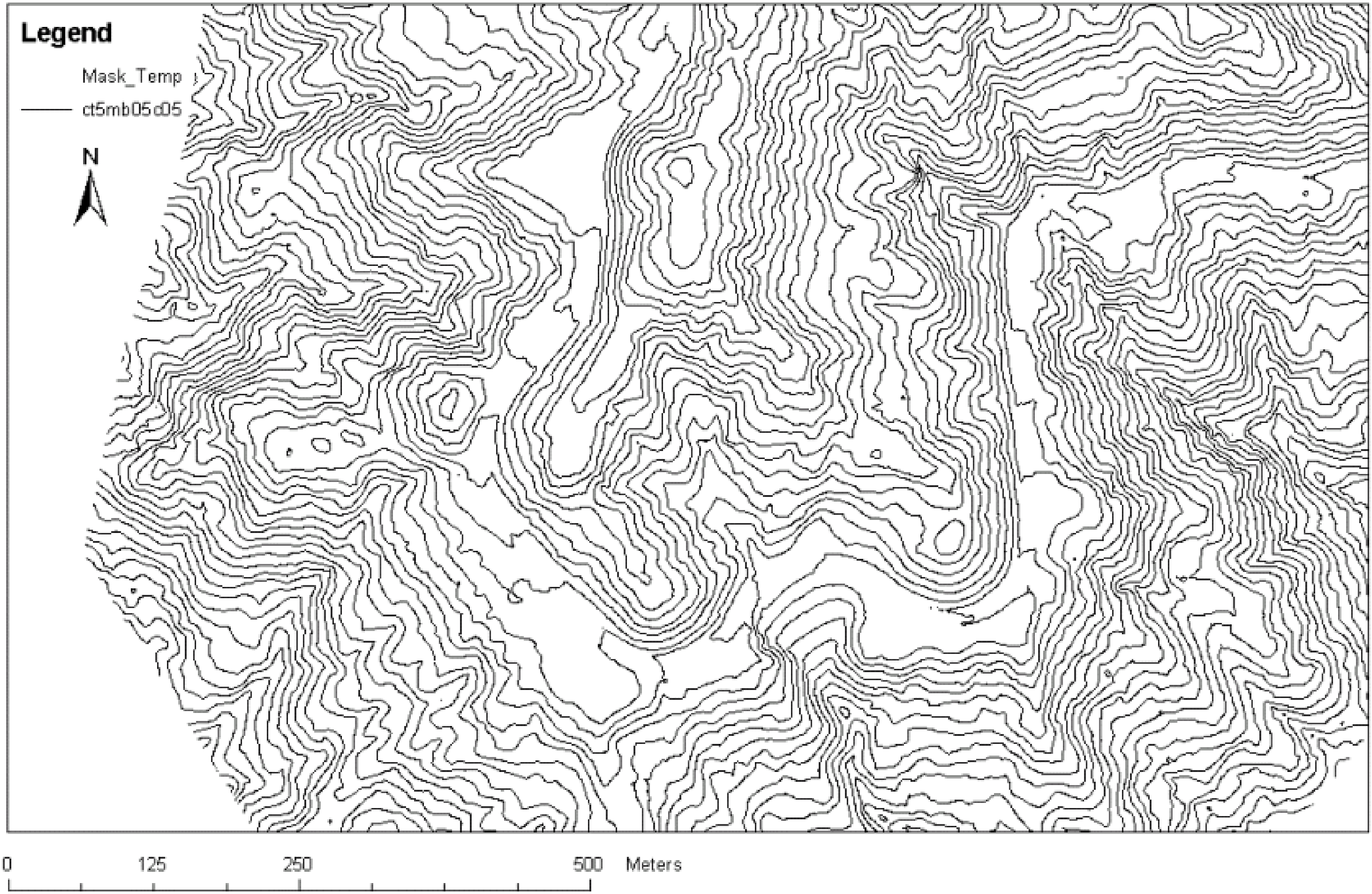
LiDAR:

- Cheaper than conventional land surveying
- Shorter period
- To develop Digital Terrain Model (DTM)
- The number, location and sizes of all slopes along the road was pre-identified

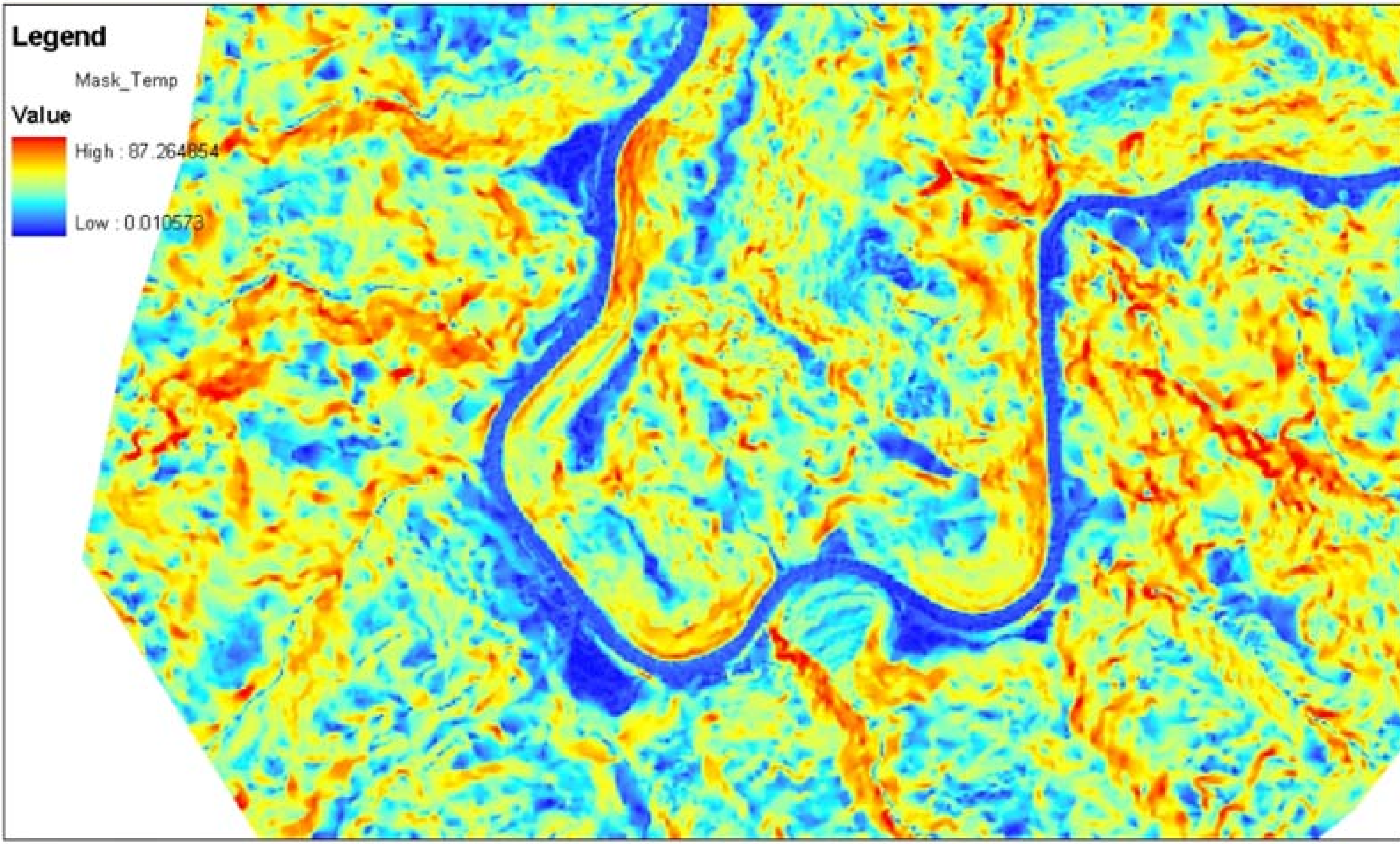
View Photographic records & High Resolution Digital Elevation Models



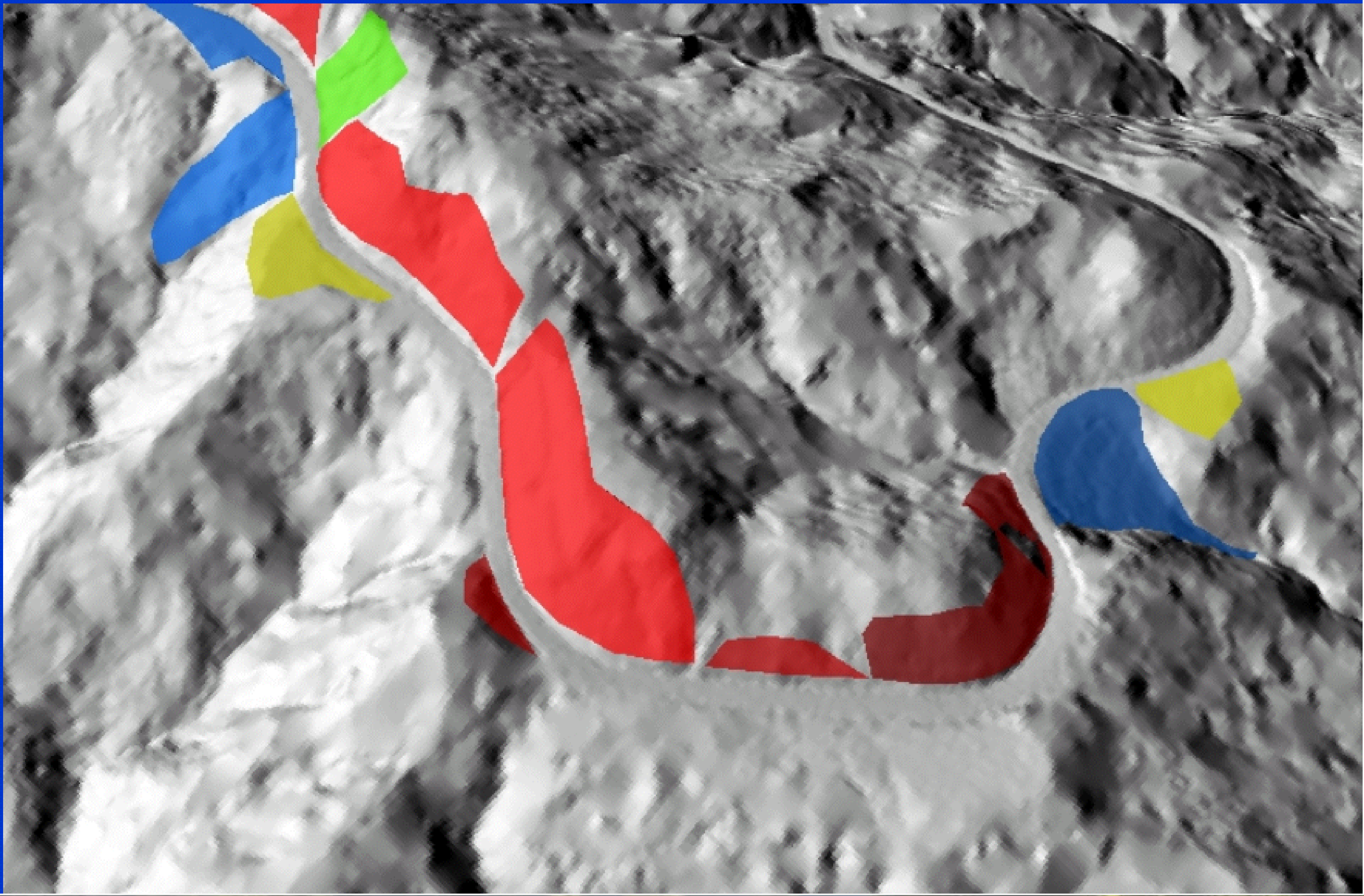
5m Contour Maps



Slope Model (Colour represents slope angle)



Visualising Digitised Features in 3D



Field data collection: proformas

SLOPE GENERAL INFORMATION (SGI)

FILL IN THE BOXES OR CIRCLE CORRECT ANSWER — SGI Rev/2016

STEP 1 GENERAL INFORMATION

1.1 INSPECTED BY

1.2 DATE | 1.3 TIME AM / PM | 1.4 WEATHER: SUNSHINE / CLOUDY / LIGHT RAIN / HEAVY RAIN

1.5 DISTRICT NAME & CODE | 1.6 STATE

1.7 SITE CATEGORY (CIRCLE ONE): A/B/C — Unaccessable / Moderate Accessable / Accessable

1.8 FEATURE TYPE (CIRCLE ONE): CUT/EMBANKMENT/NATURAL SLOPE/VALLEY/GRADE (FLAT)

1.9 BASED (LINEAR/AREA)

SLOPE GEOLOGY AND ROCK PROFORMA (SGRP)

FILL IN T HE BOXES OR CIRCLE CORRECT ANSWER — SGRP Rev/2016

STEP 3 GEOLOGY AND STRUCTURAL

3.1 ROCK TYPE
B) MAJOR
A) MINOR

3.2 WEATHERING GRADE (SCALE I TO VI)

3.3 GEOLOGICAL FEATURE

Jointed(Jt)	Faulted(Ft)	Unconformity (Uc)	Schistosity (Sc)	Instrusion Zone (It)	Sheared/crushed zone (Sp)	Foliation (Fo)
Bedding (Bd)	Folded (Fd)	Cleavage (Cl)	Overhang (Oh)	Tension crack (Tc)	Ravelling (heavily jointed & fragile material) (Rv)	Fissure (Fi)

3.4 ADVERSE GEOLOGICAL FEATURES/ EVIDENCE OF DISTRESS

1	No evidence of surficial loosening

3.5 EVIDENCE OF PAST FAILURE

1	No recorded or observed evidence of past instability

SLOPE PRIMARY PROFORMA (SPP)

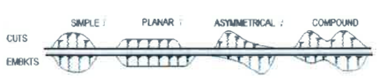
FILL IN BOXES OR CIRCLE CORRECT ANSWER — SPP Rev/2016

STEP 3 SLOPE GEOMETRY

3.1 IF THE SLOPE HAS FAILED RECORD THE ORIGINAL SLOPE GEOMETRY UNLESS NOT POSSIBLE (INDICATE GEOMETRY RECORDED) (Circle One): ORIGINAL GEOMETRY / FAILED GEOMETRY

3.2 LENGTH | 3.3 SLOPE HEIGHT | 3.4 INCLINE HEIGHT | 3.5 AREA | 3.6 ANGLE

3.7 SLOPE SHAPE

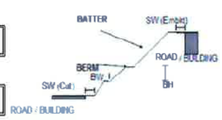


3.8 CROSS SECTION

3.9 SLOPE PLAN PROFILE

3.10 SHOULDER WIDTH (SW)

3.11 NUMBER BERMS



SLOPE STRUCTURE PROFORMA (SSP)

FILL IN BOXES OR CIRCLE CORRECT ANSWER — SSP Rev/2016

STEP 3 STRUCTURE INFORMATION

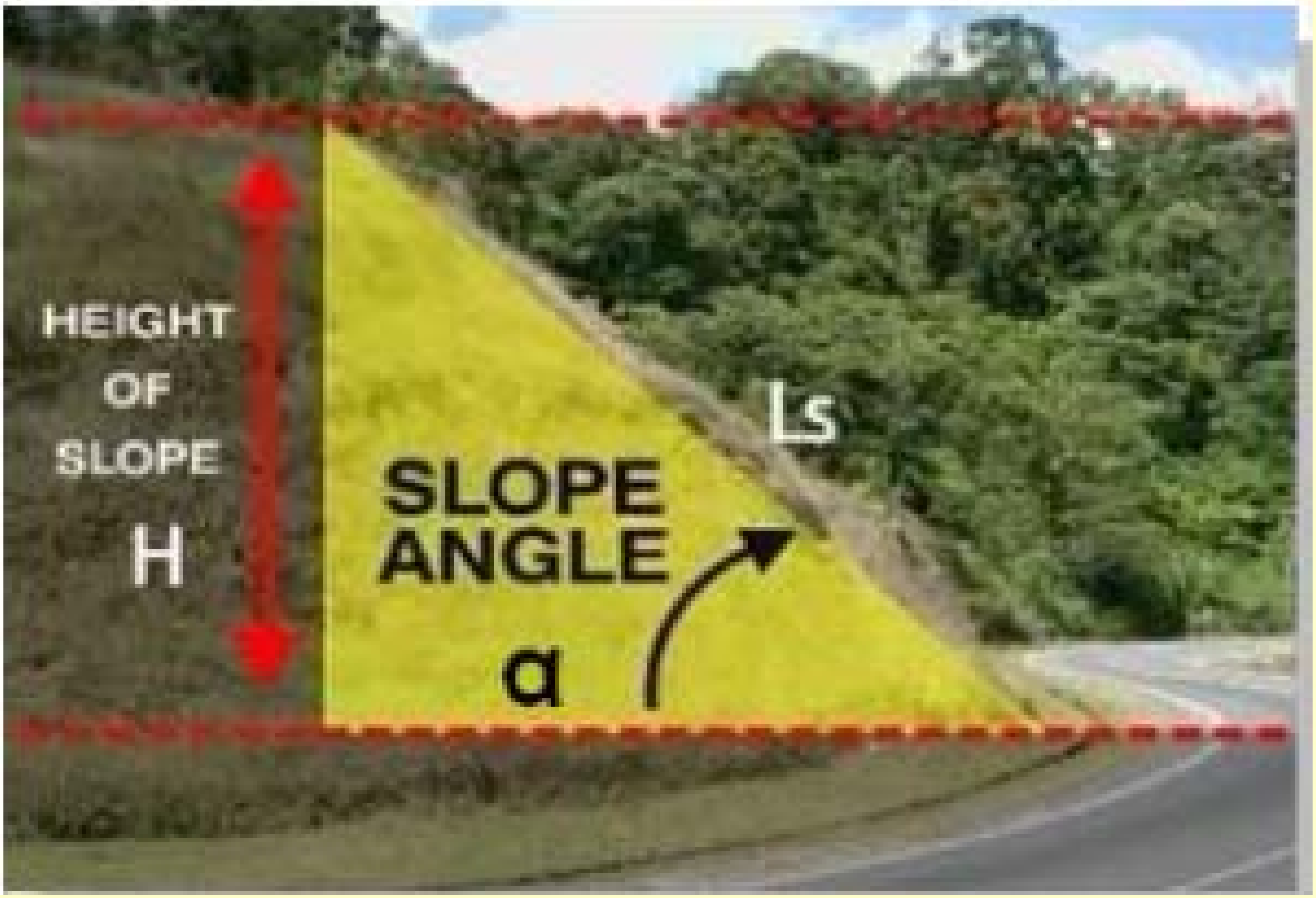
3.1 ROCK TYPE — SLOPE COMPONENTS IS APPLICABLE FOR THIS SLOPE: NO / YES

TYPE			
CONCRETE RETAINING WALL	NO	YES	GO TO STEP 4
GABION RETAINING WALL	NO	YES	GO TO STEP 5
MASONRY RETAINING WALL	NO	YES	GO TO STEP 6
CRIB WALL	NO	YES	GO TO STEP 7
REINFORCED EARTH RETAINING WALL/MSE WALL	NO	YES	GO TO STEP 8
PILE RETAINING WALL	NO	YES	GO TO STEP 9
RC COLUMN BORED PILE RETAINING WALL	NO	YES	GO TO STEP 10
BUTTRESS	NO	YES	GO TO STEP 11
NETTING	NO	YES	GO TO STEP 12
WEEP HOLE	NO	YES	GO TO STEP 13
HORIZONTAL DRAIN	NO	YES	GO TO STEP 14
SOIL NAIL	NO	YES	GO TO STEP 15
GROUND ANCHOR	NO	YES	GO TO STEP 16
ARTIFICIAL COVER	NO	YES	GO TO STEP 17

CERUN YANG SELAMAT MENYELAMATKAN NYAWA

Field data collection:

• 29 slope parameters .....

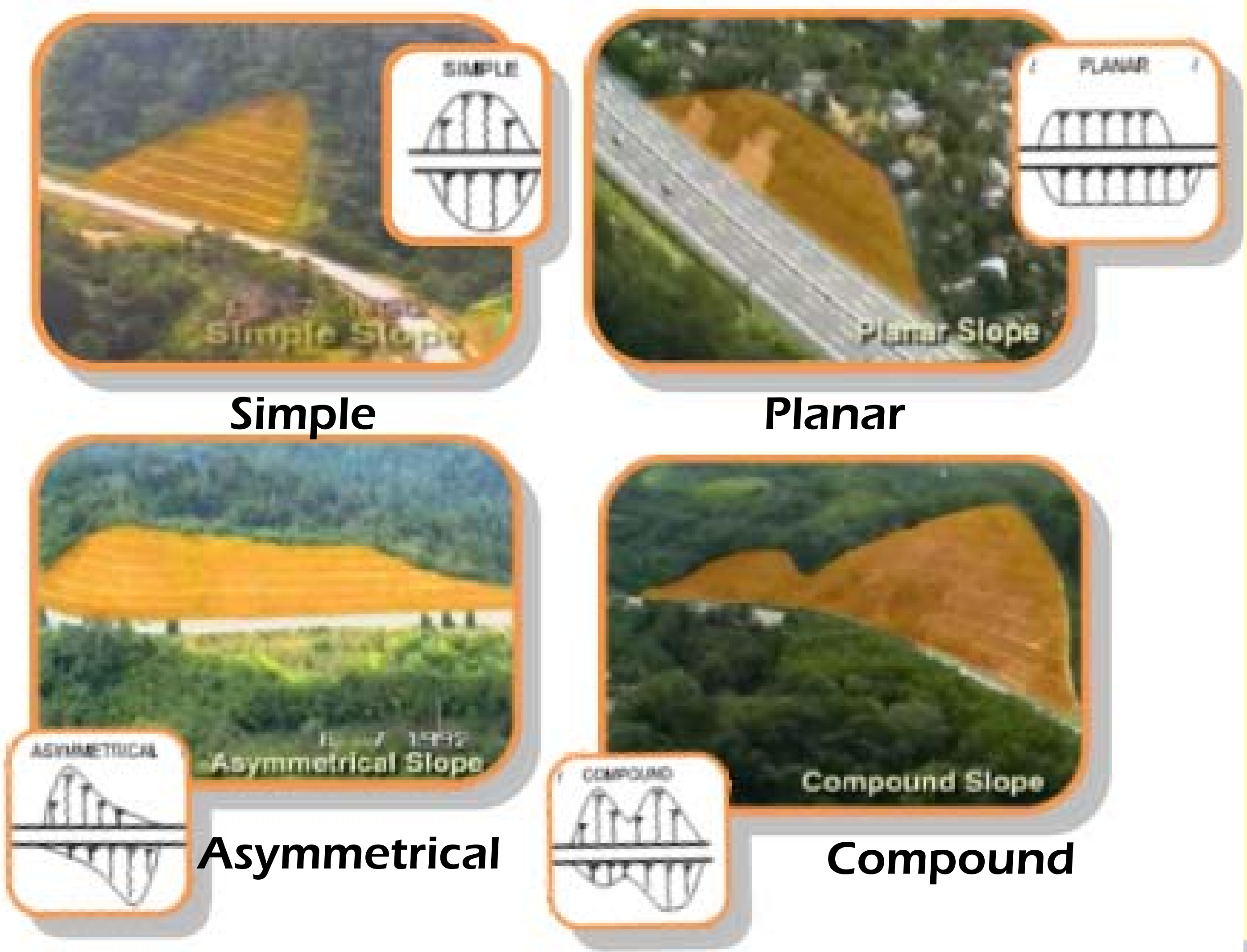


Slope Angle & Height

• 29 slope parameters …..

Slope Plan Profile

• 29 slope parameters …..



Simple

Planar

Asymmetrical

Compound

Slope Shape

• 29 slope parameters .....

Structure Type

DATA ANALYSIS

- Detail inventories of slope parameters for 1,341 cut slopes
- Separated into two groups; 1,090 failed slopes and 251 not yet failed slopes

- Discriminant analysis
- Using available software; Statistical Package For Social Sciences (SPSS)
- Out of 29 slope parameters analysed, 12 significant parameter

Significant parameters & its coefficients:

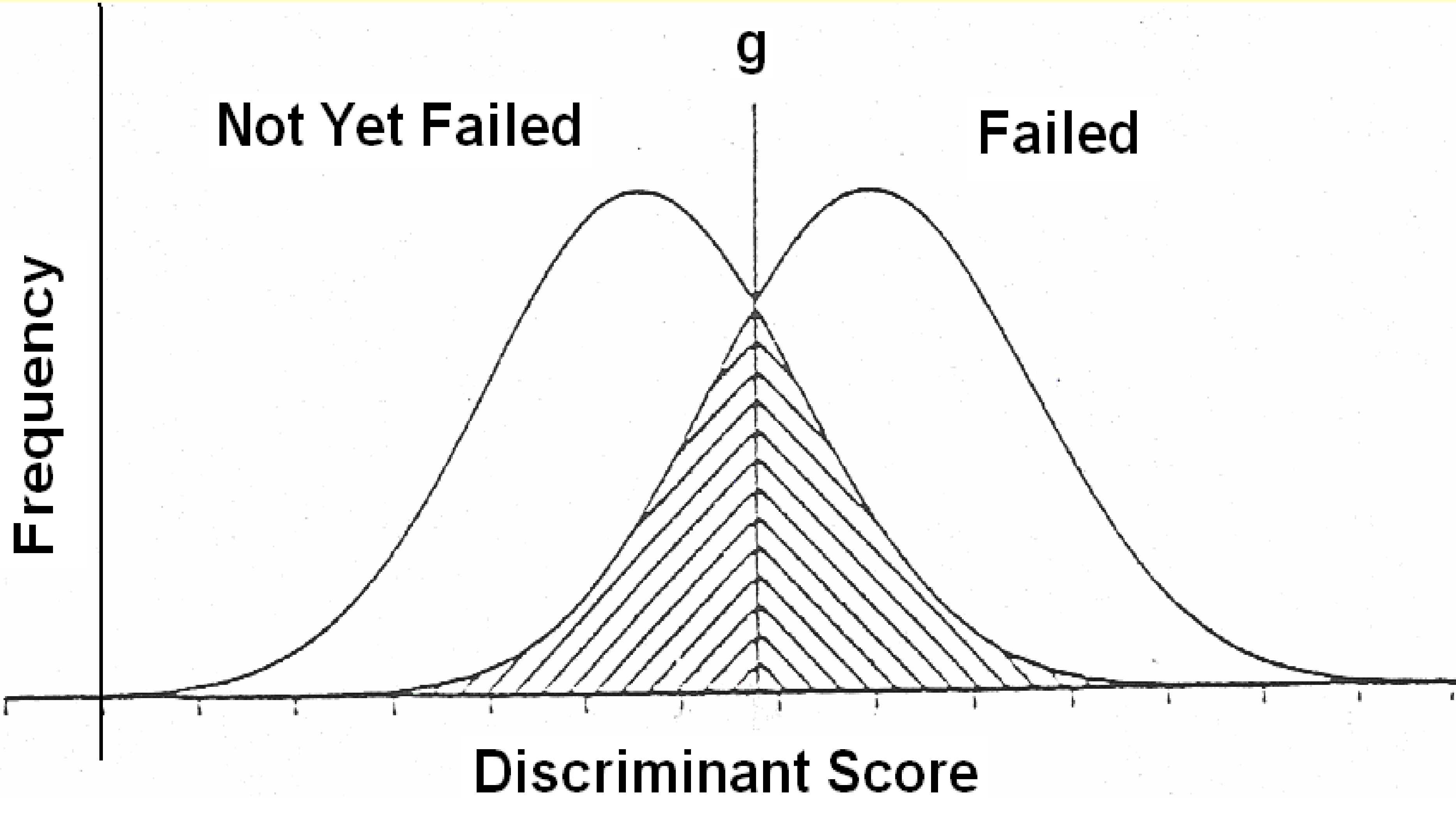
Slope Parameter	Discriminant Function Coefficients
Slope height	0.027
Slope angle	0.02
Slope shape	0.163
Slope plan profile	0.354
Cutting topography relationship	0.278
Presence of structure	0.202

Main cover type	– 0.172
Slope cover	0.472
Percentage rock exposure	0.017
Presence of corestone boulders	– 1.266
Rock condition profile	0.249
Ground saturation	0.281
Constant	– 4.293

HAZARD EQUATION @ PREDICTION MODEL DEVELOPMENT

- D = 0.027(height) + 0.02(angle) + 0.163(shape) + 0.354(plan profile) + 0.278(cutting topography) + 0.202(structure) - 0.172(main cover type) + 0.472(cover) + 0.017(% rock exposure) – 1.266 (corestone boulders) + 0.249(rock condition profile) + 0.281(ground saturation) – 4.293

Separating 2 groups of slopes:



Group	Group mean
Not Yet Failed	1.128
Failed	-0.276
Average mean	0.426

- **Not Yet Failed D < 0.426, otherwise Failed.**

Accuracy of the model:

Number of assessed slopes	1,341
Numbers of actual landslide or failed slope	1,090
Number of failed slopes correctly classified	873
Number of not yet failed slopes	251
Number of not yet failed slopes correctly classified	170
Overall correctly classified	1,043
% of overall correctly classified	77.8

Accuracy of other researchers works:

Country	Accuracy (%)	References
Italy	72.7 and 80.7	Carrara et al (1995)
Italy	72.0	Guzzetti et al (1999)
Bolivia	78 to 89	Péloquin & Gwyn (2000)

Computation of hazard equation:

Transformations from the individual discriminant score (D) to probabilities (P) have been derived through curve fitting:

Value of D	Calculation of probability, P
$D < -2$	$P = 0.05$
$-2 < D < 0.5$	$P = 0.0037D^3 + 0.0891D^2 + 0.3195D + 0.3531$
$0.5 < D < 4$	$P = 0.0105D^3 – 0.1275D^2 + 0.5152D + 0.2952$
$D > 4$	$P = 1$

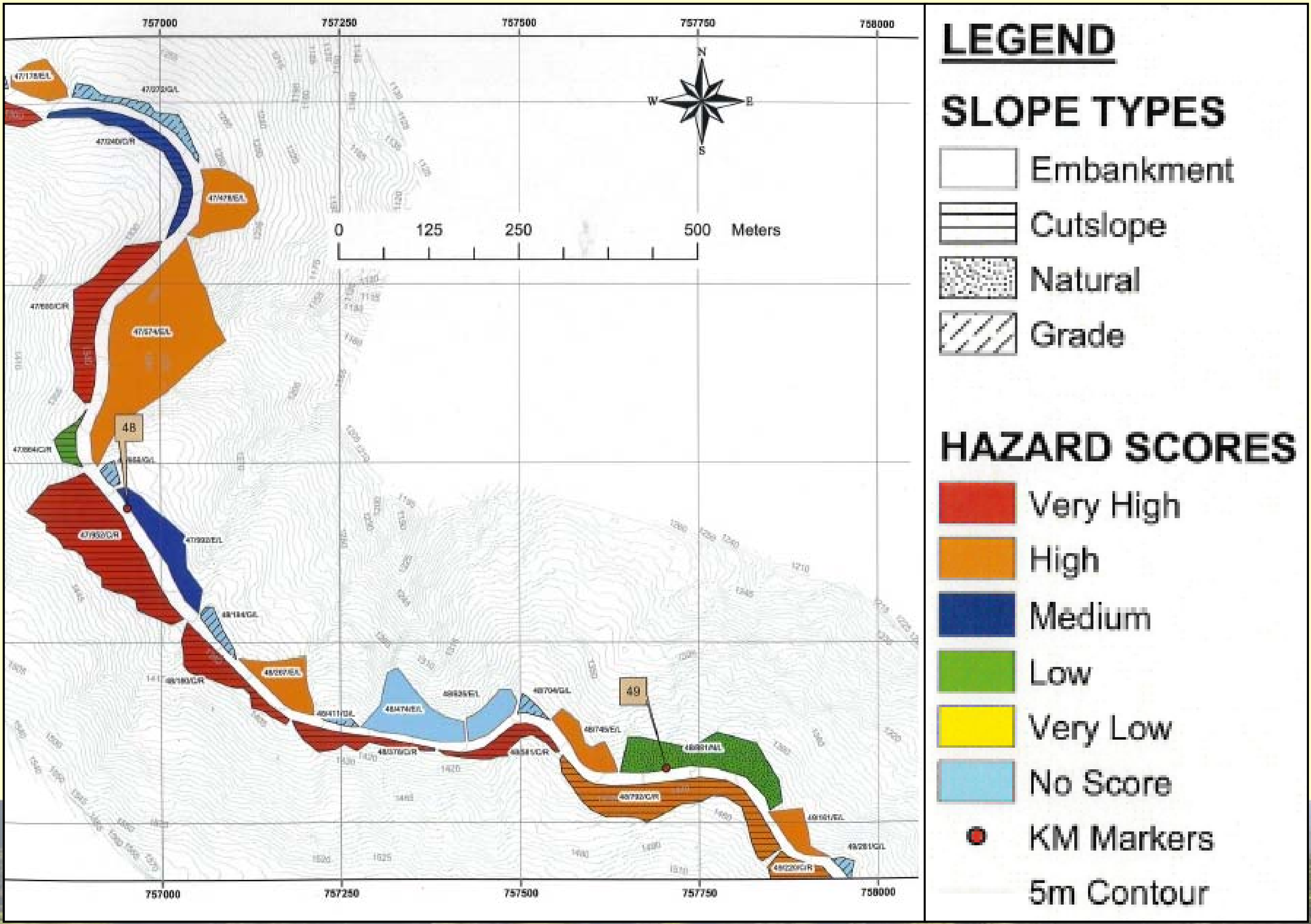
Transformation of Hazard Probability Into Qualitative Hazard Category:

Probability Score	Hazard Category
0.0 – 0.2	Very Low
0.2 – 0.4	Low
0.4 – 0.6	Medium
0.6 – 0.8	High
0.8 – 1.0	Very High

Transformation of Hazard Probability Into Qualitative Hazard Category:

Probability Score	Hazard Category
0.0 – 0.2	Very Low
0.2 – 0.4	Low
0.4 – 0.6	Medium
0.6 – 0.8	High
0.8 – 1.0	Very High

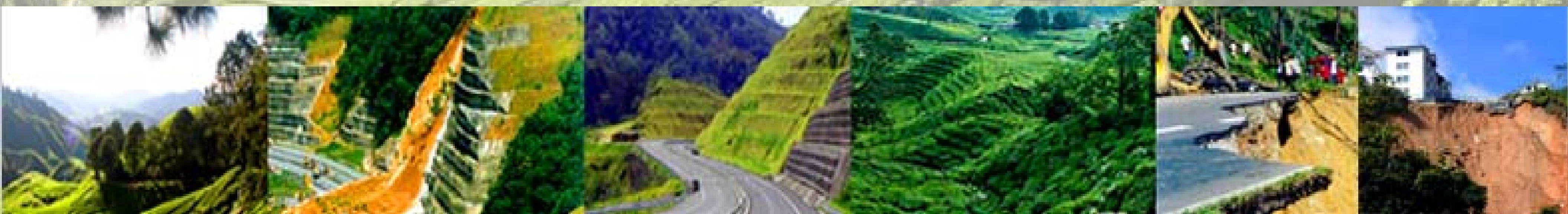
Typical Hazard Map



CONCLUSION

- 12 significant parameters influencing the landslides occurrence along the Tamparuli – Sandakan road was identified
- An accuracy produced was at par with other previous researcher's works
- Based on principle by Varnes (1984), it can be extended to other slopes with similar geomorphic, geologic, and topographic conditions

TERIMA KASIH



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