Slope Geomorphological Mapping and Landslide Prevention

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ABSTRACT: At present, sufficient technology is available to prevent landslide from occurring if the potential danger was spotted or identified with sufficient time available for mitigation measures to be implemented. However the probability of spotting a potential landslide and performing appropriate mitigation works are very low. Hence many landslides occur without warning and often result in loss of life and property. This has led many researchers to initiate research on landslide early warning systems. The development in information technology has contributed a major role in providing or integrating the state-of-the-art technology needed to manage analyses, predict and respond to potential landslide events in order to minimize losses. Hence a well guided and documented, area based geomorphological mapping, with proper documentation system for field data collection and database recording is required. This paper will address the itinerary required to conduct the area based geomorphological or field mapping such as proforma preparation, quality assurance and quality control together with some of the typical field findings.

KEYWORDS: Field Mapping, Landslide, Geomorphological Mapping, Proforma, Geological, Geotechinical.

1.0 INTRODUCTION

In order to establish an area based geomorphological map and to prepare proper documentation system for field data collection and database recording, it is important to list out the objective of the study carefully. Hence the objective of this paper is to identify various factors causing the landslides occurrences and to document the information systematically (geomorphology). Some of these factors are;

- Heavy prolonged rainfall with uncontrolled surface runoff
- Geomorphological factors
- Geological and geotechnical factors
- Hydrological factors
- Climatic factors
- Other factors such as vegetation cover and human activity

This paper also addresses the itinerary and methodologies required to conduct geomorphological mapping to extract out impediments which could lead to potential soil or rock slope failure.

2.0 GEOMORPHOLOGICAL MAPPING AND GIS DATABASE

The term geomorphology is explained as the science of the forms of Earth's surface and the processes creating and reshaping them (National Encyclopedia, 1992). This incorporates parts of many different factors such as geophysics, sedimentology, geochemistry, hydrology, climatology, and engineering. Geomorphology deals with the combination of these together with landscape configuration and development. Scientific attempts to understand and document the landscape since the late 19th century resulted in maps with emphasis on the geomorphology. To construct such a map the geomorphology first needs to be generalized into subparts of recordable data. A better method is to subdivide geomorphology into the descriptive parts: morphology, genesis, processes, lithology, chronology and hydrography.

Since the last decades before year 2000, geomorphological surveys approach and mapping have emerged from two different approaches. The first approach is the analytical, which base the map content on descriptive information on genesis, morphography, morphometry and chronology, while the second approach is the synthetic, where the geomorphological data are presented and combined with non-geomorphological parameters such as soils, vegetation and hydrology. Apart from these two comprehensive approaches, a third approach is the pragmatic approach, where only limited geomorphological information concerning a specific purpose is collected (Ten Cate, 1990). Early geomorphological investigations were published as verbal descriptions of landforms, including some profiles, photographs and drawings, and also thematic geomorphological maps were constructed (Klimaszewski, 1982 and Elvhage, 1983).

The descriptions of landscapes have changed over the years from simple illustrations with description to detail data collection with complex legend. With the development of Geographic Information Systems (GIS) which has huge data handling capacity, the description of landscape development has faded away. This has led to accurate development of field data collection method for GIS input and analysis. The geomorphological GIS developed in parallel with the mapping system are an attempt to connect the "traditional" geomorphological mapping with the modern GIS environment. The clear separation of descriptive and interpretative data in the new mapping system, GIS enables an easy transformation from the geomorphological map to an object based geomorphological geodatabase (Elvhage, 1983).

Rapid development of urban areas has made the local governments unable to establish adequate landslide or slope failure preventive measures. With geomorphological study in place, the Public Works Department would be able to identify the high risk areas and high light the relevant measures to be taken to prevent failures or loss of lives and properties. The measures taken can be considered as a program to manage failure prone areas and landslide mitigation using inspection records and spatial data (Keiko and Sadohara, 2006).

2.1 Slope or Landslide Information

The slope or landslide information should comprise of information on slope management which consists of field survey slope information, past and present landslide information. The information collected is required to be updated periodically in order to integrate with landslide potential risk and prediction factors. Under the slope management scope of works it is critical to conduct continuous examination of slopes and information updating such as

- Slope inventory
- Past and present landslides
- Monitoring records of creeping land mass
- Real-time updating of precipitation data

The information present in GIS required to be extracted in a user friendly manner. As such the details of a particular slope are required to have the following information;

- Address of slope, by street name, land lot numbers, etc.
- Slope identification number and name, given as per GPS coordinates.

With the slope information system, on aerial maps indicating hazardous and high risk slopes for continuous observation, required to indicate:

- Areas of critical slopes
- Location of past and present landslide scars
- Areas showing signs of distress and movement

Hence the data input within the slope management database are required to be analyzed further to identify the hazards involved.

3.0 FIELD STUDY REQUIREMENT

The field study, requires the various factors which were involved in causing the landslides at to be identified. The field study will take into consideration of the factors which requires recording such as:

- Site investigation (from past development record)
- Rain fall intensity and duration
- Geomorphological factors
- Geological and geotechnical factor
- Hydrological factor
- Climatic factor
- Land use
- Vegetation cover
- Human activities

In order to conduct the field study effectively, field log sheets (Proforma) were created, which will record general information, information related to potential soil or rock slope risk features and factors related defects to soil slope, rock slope and structures.

3.1 Proforma Preparation

To conduct the field survey log, sheets were created, the sheet (Proforma) will detail out geomorphological condition of the site. Some of the important information required and will be logged in the proforma are as follows:

- Site location, slope condition, drainage system and the GPS location
- Slope features such as embankment, cut, natural slope etc.
- Slope geometry containing
  - Slope plan profile
  - Slope height and berm width
  - Distress location
  - Feature aspect
  - etc.
- Slope cover
- Pavement condition such as cracks, potholes, etc.
- Drainage system, drain sizes and condition
- Erosion condition
- Status of feature such as location of pass and present landslide scar, tension cracks, location of failure, etc.
- General comment and description of the site
- Sketch of the site
- Quality control check

Figure 1 shows legend for Geomorphological map used for the project.

3.2 Geological and Geotechnical Factors Requires Recording

Geological factors required to be studied and presented are as follows:

- Soil/rock type, rock profile, rock exposures percentage, presence of colluvium/scree, corestone boulders, percentage of surface crusting, adverse geological features and fault line.
- Discontinuities
- Material and weathered grade percentage
- Geological features such as joints, faults, uniformity, tension crack, bedding, raveling slope (heavily jointed with fragile material)
- Evidence of distress such as surficial loosening, overhanging blocks, tension cracks along crest of the slope
- Joint information, Dip/dip direction, spacing, persistence, termination, shape, aperture, roughness, infilled material and seepage
- Potential failure type, planar, topple, wedge fall, rock fall
- Length and angle of slope
- Distress location on slope
- Slope cover
- Tension crack – Length and width
- Soil type

3.3 Hydrological Factors

In order to perform the hazard analysis to identify the hydrological factors causing the landslide; studies will be made using the GIS platform to evaluate the catchment size and the direction of surface runoff. In order to have the sufficient data for analysis geomorphological mapping are required to be done to identify the areas of seepage, saturated ground and water pounding zones.

3.4 Other Factors

Other contributing factors are also required to be identified and noted such as :

- Vegetation cover and infiltration rate
- Human Activity
- The modifications of slopes by cut and fill activities associated with construction, interference with or without changes to natural drainage system, the removal of vegetation, and excavation.
- Natural causes, saturation of slope material due to rainfall or seepage, erosion, loose rock masses from vegetation growth within joints, etc.

Based on the above study and evaluation made, it is recommended to outline the slope proforma as detailed as possible to support accurate input for Geographical Information System (GIS). The field study under the project covers the aspect of survey for slope, structural and geological mapping. Hence four field proformas were required to complete the geomorphology survey namely:

- Slope Proforma
- Structural Proforma
- Geological Discontinuity Proforma
- Incident Proforma

The proformas will record details of distress, defects, inadequacy of construction or design, assess the potential risk and hazard and also identity mode of failures and record the failure conditions and locations using GPS. The proforma proposed for this study will include GPS location of the slope and also the previous failure and tension cracks. The team members are required to sketch out the survey details within the proforma using a given geomorphological map legend in order to standardize the legend marking within the sketch. Figure 3 shows an example of field geomorphological survey done for a soil slope, with a bunglow on top of slope showing signs of distress, with cracks on apron slopes and columns. Figure 2a, 2b and 2c shows the format and content of slope performa.

4.0 FIELD SURVEY AND PROBLEMS

The major difficulty in conducting field mapping is the lack of trained personnel to carry out the works. This could lead to:

- Inconsistency in the field recording and mapping works
- Missing out critical elements

In order to overcome these impediments, training were provided to the field team members. Along with training, quality control and quality assurance were implemented in order to ensure the information collected were usefull

4.1 Quality Assurance and Quality Control

In order to ensure quality of work, quality assurance and quality control were implemented and divided into three stages, namely,

Stage 1 –
Screening of proforma by the team leader, after completion of field survey the Proforma(s) need to be completed, checked and endorsed by the team leader to ensure no blank fields

Stage 2 –
Screening will be done by senior geotechnical engineers, senior structural engineers and senior geologist. Before the data were entered into the database by the team members, the quality of works were required to be varified by senior engineers.

Stage 3 –
Screening by the experts by conducting expert judgment. Each and every proforma will be studied by QA / QC team and field survey will also be conducted for critical sites. Additional field survey will also be conducted for very critical sites by senior project engineer.

5.0 FIELD FINDINGS

The field findings of a geomorphological survey will identify various problems which would require both short and long term solutions. As such the cases identified to prevent landslides are listed in Table 1.

6.0 CONCLUSION

Based on the field survey works, following are some of the finding

- Major failures are related to rock falls of which the places involved are mainly in ex quarry area, which developed without proper scaling and protection of loose rocks. The rocks falls are mainly due to discontinuity, daylighting effect and many other factors. Hence it is recommended that the rock slope areas need to be monitored carefully and perform stabilization works.
- The field survey has also identified numerous areas with landslide scars of both soil and rock slopes. Most of it have not been rectified and left unattended. These sites could become the potential slope failure site.
- Some of the slopes area have been stabilized using ground anchors, which left. It is highly recommended for the local authorities to take actions, as some of the slopes are very steep and high next to road and residential area.
- Another main factor causing slope failures are due to poorly maintained drainage system for slopes, the field survey have also identified the areas which requires improvement in the drainage system.
- The needs to conduct regular maintenance and repair works are also critical. There are areas with no drainage system to prevent surface runoff, water ponding and infiltration.

Hence based on the list of defects or matters related to geotechnical, geological and structural listed under Table 1 which could cause potential landslide or slope failures, the local authorities need to address the defects systematically. The field survey or geomorphological survey conducted were able to carefully identify the areas with problems or detects individually with reference to district, housing estate name, street name and GPS locations. This information will be useful for the local authorities to conduct rectification and maintenances works effectively.

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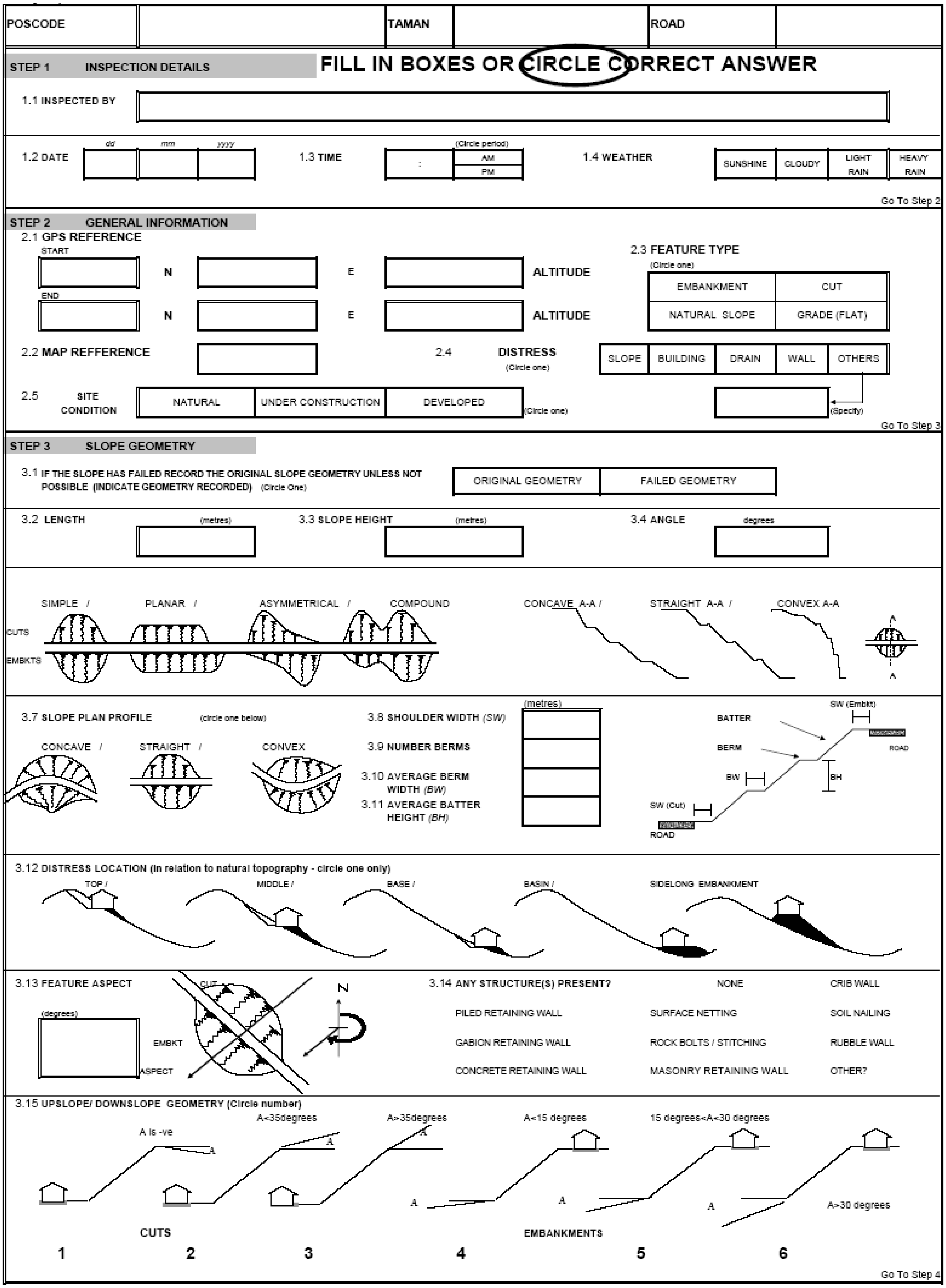
Table 1: Cases identified to prevent landslides

a) Geotechnical related matters :	b) Geological related matters
i. Areas of blocked drains	i. Areas of potential rock fall
ii. Areas of broken drains	ii. Areas of daylighting rock and soil slope
iii. Areas of undersized drains or no drainage system	iii. Areas of rock overhang
iv. Areas of surface runoff	iv. Areas of inadequate buffer zone (<6m) near rock slope
v. Areas of over grown bushes	v. Areas with rock surface runoff over joint
vi. Areas of steep slopes condition at developed area	vi. Areas with weak interface between soil and rock
vii. Areas of steep slope condition with inadequate design (assumed)	vii. Areas with seepage on rock slope
viii. Areas of steep slope condition due to ignorance of resident's cutting	viii. Areas with deep tree rooting in cracks or joints in rock
ix. Areas of heavy seepage	
x. Areas of saturated ground	
xi. Areas of inadequate buffer zone (< 6m) for old development (assumed older than 1995)	c) Structure related matters
xii. Areas of inadequate buffer zone (< 6m) for new development	i. Areas of structural defects on walls
	ii. Areas of weep holes requires services
xiii. Areas with valley and stream facing development	iii. Areas of seepage from wall
	iv. Areas of cracks on wall
xiv. Areas of potential debris flow	v. Areas of cracks on buildings
xv. Areas of serious erosion	vi. Areas with structural defects (on buildings)
xvi. Areas of tension crack on pavement and gunite surface	
xvii. Areas of soil creep on slope	
xviii. Areas of ground anchors	

Figure 1: Legend for Geomorphological Map, used for the project



POSCODE		TAMAN		ROAD	

STEP 1 INSPECTION DETAILS **FILL IN BOXES OR CIRCLE CORRECT ANSWER**

1.1 INSPECTED BY

1.2 DATE dd mm yyyy

1.3 TIME : (Circle period) AM PM

1.4 WEATHER: SUNSHINE / CLOUDY / LIGHT RAIN / HEAVY RAIN

Go To Step 2

STEP 2 GENERAL INFORMATION

2.1 GPS REFERENCE
START N E ALTITUDE
END N E ALTITUDE

2.3 FEATURE TYPE (Circle one)

EMBANKMENT	CUT
NATURAL SLOPE	GRADE (FLAT)

2.2 MAP REFFERENCE

2.4 DISTRESS (Circle one): SLOPE / BUILDING / DRAIN / WALL / OTHERS (Specify)

2.5 SITE CONDITION: NATURAL / UNDER CONSTRUCTION / DEVELOPED (Circle one)

Go To Step 3

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 (metres)

3.3 SLOPE HEIGHT (metres)

3.4 ANGLE degrees

SIMPLE / PLANAR / ASYMMETRICAL / COMPOUND

CUTS

EMBKTS

CONCAVE A-A / STRAIGHT A-A / CONVEX A-A

A

A

3.7 SLOPE PLAN PROFILE (circle one below)

CONCAVE / STRAIGHT / CONVEX

3.8 SHOULDER WIDTH *(SW)* (metres)

3.9 NUMBER BERMS

3.10 AVERAGE BERM WIDTH *(BW)*

3.11 AVERAGE BATTER HEIGHT *(BH)*

SW (Embkt)

BATTER

BERM

ROAD

BW

BH

SW (Cut)

ROAD

3.12 DISTRESS LOCATION (in relation to natural topography - circle one only)

TOP / MIDDLE / BASE / BASIN / SIDELONG EMBANKMENT

3.13 FEATURE ASPECT (degrees)

CUT

EMBKT

ASPECT

N

3.14 ANY STRUCTURE(S) PRESENT?

	NONE	CRIB WALL
PILED RETAINING WALL	SURFACE NETTING	SOIL NAILING
GABION RETAINING WALL	ROCK BOLTS / STITCHING	RUBBLE WALL
CONCRETE RETAINING WALL	MASONRY RETAINING WALL	OTHER?

3.15 UPSLOPE/ DOWNSLOPE GEOMETRY (Circle number)

A is -ve

A<35degrees

A>35degrees

A<15 degrees

15 degrees<A<30 degrees

A>30 degrees

CUTS

EMBANKMENTS

1 2 3 4 5 6

Go To Step 4

Figure 2a: Shows the format and content of slope proforma page 1 of 3

STEP 4	SLOPE COVER

4.1 MAIN VEGETATION COVER TYPE — GRASS / SHRUB / FERN / JUNGLE / PLANTATION / AGRICULTURE / GUNITE/OTHER ---> Please Specify [ ]

4.2 VEGETATION COVER CONDITION — | GOOD(100%) | AVERAGE (80-<100%) | POOR (<80%) |

4.3 LOGGING IN VICINITY? NO / YES

4.4 HAMMOCKY SURFACE NO / YES

4.5 ARTIFICIAL COVER PRESENT NO / YES-->

4.6 TYPE (circle)	4.7 % OF SLOPE SURFACE	4.8 CONDITION (Circle appropriate case)	
GUNITE	%	POOR	Extensive cracking with minor spalling of gunite or stone pitching, severe deformation of reno mattresses or riprap
STONEPITCHING		AVERAGE	Minor cracking, no spalling of gunite or stone pitching, minor distress or deformation of reno mattresses or riprap
RENO MATTRESS		GOOD	Intact, no cracking or spalling of gunite and stone pitching, no distress to reno mattresses or riprap

Go To Step 5

STEP 5	PAVEMENT CONDITION

CONSIDER ONLY THE PAVEMENT IMMEDIATELY ADJACENT TO THE FEATURE EXTENDING TO THE ROAD CENTRELINE.

5.1 PAVEMENT CONDITION

POOR	severely potholed, broken and/or uneven surface
AVERAGE	minor potholing and breakup of surface, slightly unever
GOOD	no potholes or patching, unbroken even surface

5.2 RUTTING PRESENT?	YES	NO
5.3 POTHOLES PRESENT?	YES	NO
5.4 ROAD DEPRESSION	YES	NO

5.5 DEPRESSION DEPTH (m) [ ]

5.6 CRACKING PRESENT

		Total CRACKING EXTENT (metres length)	MAXIMUM CRACK APERTURE (mm)	CRACKS SEALED?
Alligator, longitudinal, transverse or block cracking?	NO / YES --->	metres	(mm)	YES / NO
Arcuate Cracking?	NO / YES --->	metres	(mm)	YES / NO

Go To Step 6

STEP 6	GEOLOGY

6.1 GEOLOGY / ROCK TYPE [ ]

6.2 COLLUVIUM / SCREE YES / NO

6.3 ROCK EXPOSURES YES / NO

6.4 EXPOSED PERCENTAGE (of total slope area) [%]

6.5 CORESTONE BOULDERS YES / NO

6.6 % SURFACE CRUSTING [%]

6.7 ADVERSE GEOLOGICAL FEATURES? YES / NO

6.7.1 FAULT LINE YES / NO (If YES, indicate in the sketch)

6.8 ROCK CONDITION PROFILE (Circle One)

1	Majority of slope Grade III or less (Rock)
2	Slope consists partly of Materials of Grade III or less and partly of materials greater or equal to Grade IV
3	Slope consists predominantly of grade IV to Grade VI
4	Slope consists of predominantly Grade IV to VI but with corestone boulders
5	Slope consists predominantly of Colluvium / loosely compacted /uncompacted soil

Go To Step 7

STEP 7	DRAINAGE

	DRAIN TYPE	PRESENCE?		SHAPE			AVERAGE WIDTH (m)	AVERAGE DEPTH (m)	CONDITION (Circle only 1of the following)				BLOCKAGE (Circle only 1of the following)		
7.1	CUT-OFF	NO	YES	V	U	Trapezoid			GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.2	BERM DRAINS	NO	YES	V	U	Trapezoid			GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.3	CASCADE DRAINS	NO	YES	V	U	Trapezoid			GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.4	ROADSIDE DRAINS	NO	YES	V	U	Trapezoid			GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.5	SUMPS	NO	YES						GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.6	CULVERT INLET	NO	YES						GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.7	CULVERT OUTLET	NO	YES						GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.8	CULVERT PASSAGEWAY			PIPE	BOX	OTHER	WIDTH (m)	HEIGHT (m)	GOOD	FAIR	POOR	BAD	CLEAR	PART BLOCKED	BLOCKED
7.9	CULVERT WINGWALLS	NO	YES						GOOD	FAIR	POOR	BAD			

		PRESENCE?		Total Number	Number Flowing	HORIZONTAL SPACING (m)
7.10	HORIZONTAL DRAINS	NO	YES			

	SURFACE WATER	PRESENT?	MAIN LOCATION
7.11	Evidence of seepage?	NO / YES --->	TOP / MID-SLOPE / BASE
7.12	Saturated Ground?	NO / YES --->	TOP / MID-SLOPE / BASE
7.13	Ponding?	NO / YES --->	TOP / MID-SLOPE / BASE
7.14	Surface Runoff/ Flow	NO / YES --->	TOP / MID-SLOPE / BASE

Go To Step 8

STEP 8	EROSION

		EROSION DETAILS PRESENT?	SEVERITY
8.1	SHEET	NO / YES ------->	FAIR / POOR / BAD
8.2	RILL	NO / YES ------->	FAIR / POOR / BAD
8.3	GULLY	NO / YES ------->	FAIR / POOR / BAD
8.4	MASS MOVEMENT	NO / YES ------->	FAIR / POOR / BAD
8.5	FRETTING	NO / YES ------->	FAIR / POOR / BAD

8.6

GULLY DIMENSIONS	WIDTH (m)	Depth (m)	Length (m)
LARGEST GULLY			

Go To Step 9

Figure 2b: Shows the format and content of slope proforma page 2 of 3

STEP 9 **INSTRUMENTATION**

	PRESENCE?	
9.1 PIEZOMETER	NO / YES	
9.2 INCLINOMETER	NO / YES	SPECIFY TYPE
9.3 RAINGAUGE	NO / YES	
9.4 OTHER / UNIDENTIFIED	NO / YES ______	

Go To Step 10

STEP 10 **STATUS OF FEATURE** (IF MORE THAN ONE FAILURE RECORD DETAILS FOR LARGETS FAILURE ONLY) 10.1 Number of failures present

10.2 SEVERITY CODE

(Circle appropriate number)

CUTS and NATURAL SLOPES		EMBANKMENTS	
1	Slope is stable, no evidence of failure	1	Slope is stable, no evidence of failure
2	Minor shallow failure affecting less than one berm (<5m in length)	2	Cracks on embankment crest, road unaffected, no subsidence, no other evidence of failure
3	Localised surficial loosening, localised evidence of fallen material (rock) at base of slope	3	Shallow failure on embankment surface, no cracks or depression on road
4	General evidence of fallen blocks and/or boulders at base of slope	4	Arcuate cracks on road and/or depression less than 10cm - otherwise no mass movement evident
5	Failure affecting more than one berm but not the whole slope	5	Slope Failure with arcuate cracks on road and/or depression less than 10cm
6	Failure extending height of slope	6	Slope Failure with extensive arcuate cracks on road and/or depression greater than 10cm
	*arcuate means 'in the shape of an arc'	7	Failure of slope and road - diversion required.

10.3 COORDINATE

Start	N		END	N	
	E			E	

10.4 FAILURE DETAILS

	W, MAXIMUM WIDTH (m)	D, MAXIMUM DEPTH (m)	L, MAXIMUM LENGTH (m)	AREA AFFECTED (%)	FAILURE TYPE						LOCATION OF FAILURE
PRIMARY FAILURE					Toppling	Rotational / slump	Translational / wedge	Creep	Debris / Mud Flow	Subsidence	TOP
											MIDDLE
											BASE
											WHOLE SLOPE

10.5 TENSION CRACK?

	Presence of Tension Crack?		MAXIMUM CRACK WIDTH (m)	L, MAXIMUM CRACK LENGTH (m)	Water Filled ?	
PRIMARY FAILURE	NO	YES			NO	YES

10.6 PRIMARY CAUSE?

	APPARENT CAUSE OF FAILURE (APPLY YOUR ENGINEERING JUDGEMENT)					
PRIMARY FAILURE	Overly steep	Poor/Weak Material	Erosion	High Groundwater	Geological Discontinuity	Other
				Describe		

10.7 SLOPE MATERIAL

	DESCRIPTION OF MATERIAL TYPE
PRIMARY FAILURE	

Go To Step 12

STEP 11 SERVICES/ FACILITIES/ BUILDING

			SERVICES LOCATION		SERVICE TYPE: CABLES				SERVICE TYPE: PIPELINES			Other (describe)
11.1 **ANY SERVICES ?** ANY pipes, cables, and pylons known to be in the vicinity of the slope	NO	YES-->	Crest	Toe	High Voltage	Low Voltage	Telephone	Fibre Optic	Water	Sewerage	Gas	

			BUIDLING LOCATION			BUILDING TYPE				
11.2 **ANY BUILDINGS ?**	NO	YES-->	Crest	Middle	Toe	Terrace	Apartment/ condominium	Bunglow	Commercial	Other -->

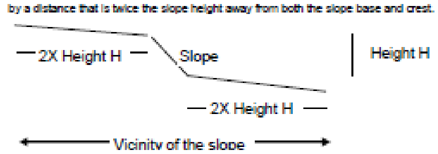
11.2 FACILITY TYPE (Circle only one number)

	Above Crest	Below Toe
GROUP 1 Presence of any residential building, commercial office, store, shop, hotel, factory school, power station, ambulance station, market, hospital, clinic, welfare centre, bus shelter, dangerous goods storage area (e.g. petrol station)	1	1
GROUP 2 Built up area (e.g. indoor carpark, building, mosque, church, temple, manned substation, sewerage treatment plant, railway, flyover, subway, reservoir, construction site	2	2
GROUP 3 Densely used open space and public waiting area (e.g. playground, open carpark, picnic area)	3	3
GROUP 4 Lightly used open-air recreation area, non-dangerous goods storage area, intensive agricultural area, golf course	4	4
GROUP 5 No facilities present or it is a remote area (e.g. Jungle, Plantation, forest, low intensity agriculture).	5	5

11.3 PROXIMITY TO FACILITIES

	Above Crest	Below Toe
The SHORTEST distance (in meter) from the crest / toe to the facilities/buildings		

For both services and facilities then assume that the area to be considered is the area defined by a distance that is twice the slope height away from both the slope base and crest.



11.4 ENGINEERING JUDGEMENT IN YOUR OPINION:-

How likely is it that remedial or preventive measures will be needed for	LOW	MEDIUM	HIGH
The Consequence of a failure at this location will be.........	LOW	MEDIUM	HIGH

Go To Step 12

Figure 2c: Shows the format and content of slope proforma page 3 of

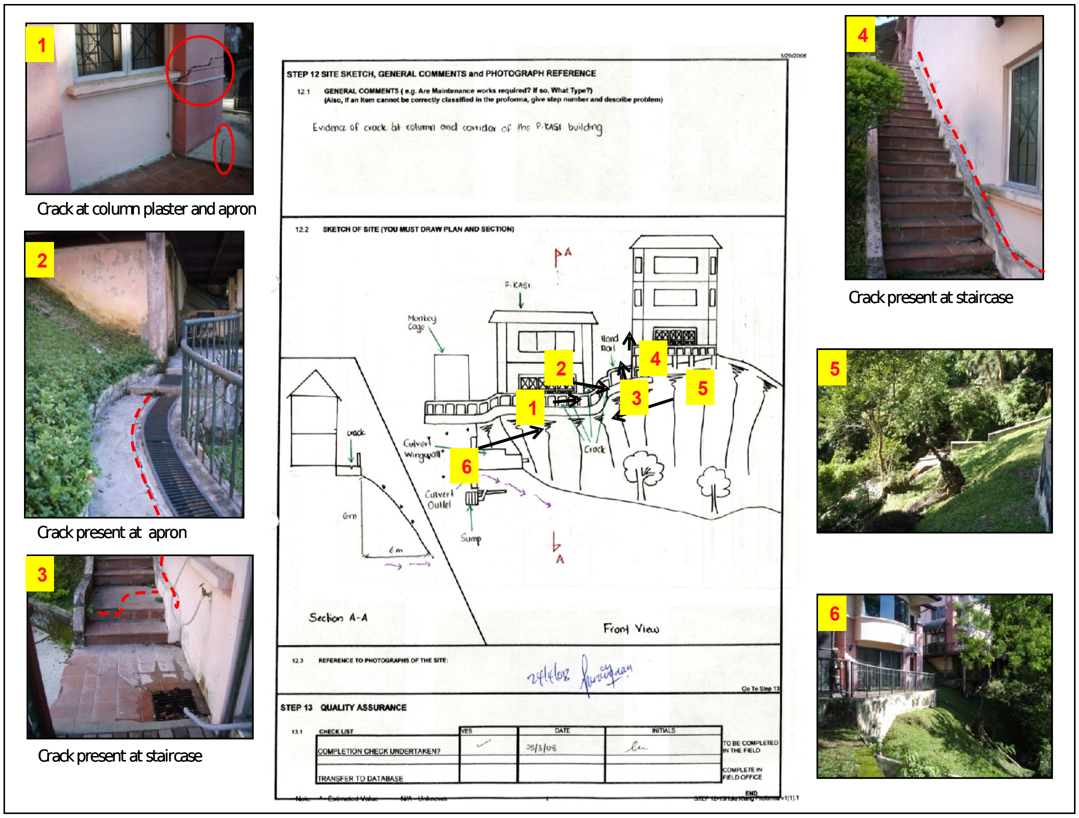


Figure 3: shows an example of field geomorphological survey done for a soil slope, with a bungalow on top of slope showing signs of distress, with cracks on apron slopes and columns.