

SURVEY OF SLOPE FAILURES (SFS) ALONG THE BUNDU TUHAN KUNDASANG HIGHWAY, SABAH, MALAYSIA

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ABSTRACT. *This study focused on the slope failures survey (SFS) along the Bundu Tuhan - Kundasang highway, which is one of the most vulnerable areas to slope failures in west coast of Sabah. The area is underlain the Trusmi Formation (Palaeocene to Eocene age), the Crocker Formation (Late Eocene to Early Miocene age) and Quaternary Alluvium Deposits. These geologic units are dissected by numerous lineaments and structural styles produced by complex tectonic history of multi phase deformations. The tectonic complexity reduces the physical and mechanical properties of the rocks and soils; and produced intensive displacements in substrata, resulting in intensive high degree of weathering processes and instability. In this study, a total of 50 selected critical slopes were studied. This study classified the slope failures into three main groups: soil slope failures, rock slope failures and erosional failures. Failures in soil slopes (including embankments) total 34 (68 %) with 10 failures (20 %) of rock slopes and 6 failures (12 %) caused by erosion. Soil slope failures normally involved large volume of failed material compared to rock slopes, where most failures are small to large size. Of the 34 failures in soil slopes, 31 (91 %) are embankment failures making them 62 % of all types of failures. Engineering geological evaluation of the study area indicates that the slope failures took place when slope materials are no longer able to resist the force of gravity. These decrease the shear strength and increase the shear stress resulting slope failures, which is due to internal and external factors. Internal factors involve some factors change in either physical or chemical properties of the rock or soil such as topographic setting, climate, geologic setting and processes, groundwater condition and engineering characteristics. External factors involve increase of shear stress on slopes, which usually involves a form of disturbance that is induced by man includes removal of vegetation cover, vehicles loading and artificial changes or natural phenomenon. Development planning has to consider this disaster in order to mitigate their effect. A landslide risk management program should be implemented to prevent these losses. This engineering geological study will play a vital role in slope stability assessment to ensure the public safety.*

KEYWORDS: Slope failures survey (SFS), failure probability, physical and mechanical properties

INTRODUCTION

The Bundu Tuhan – Kundasang highway, connecting Kota Kinabalu city to the town of Ranau is the only road in Sabah connecting the west coast to the east coast (Figure 1). This highway crosses rugged mountainous terrain with an elevation exceeding 1000 m and covered with thick equatorial rainforest. While actual construction of the highway started in the late 1970s, it was open to traffic only in early 1980s. Since it's opening, the problem of slope stability has adversely affected use of the highway. Since early 1990s the Public Work

Department of Malaysia (JKR) has started a program of repair and rehabilitation of slope failures to improve the highway. This work is still going on today.

This paper deals with a slope failures survey (SFS) at 50 selected critical slopes along the highway with the aim of identifying the main types of failures, the main factors contributing to failures and the recommendation of mitigation measures. Generally, slope failures is influenced by a variety of control factors, such as geology and topography, and trigger factors, such as prolonged and/or heavy rains. Sometimes a combination of various factors is responsible for failures. Many researchers have conducted SFS triggered by rainfall (Ocakoglu et al., 2002; Petrucci & Polemio, 2003; Fiorillo & Wilson, 2004; Mikos et al., 2004; Wen & Aydin, 2005; Mikos et al., 2006; Sivrikaya et al., 2008). It is commonly recognized that the rainfall-induced slope failures are caused by excess pore pressures and seepage forces during periods of intense rainfall. It is the excess pore water pressure that decreases the effective stress in the rock and soil; and thus reduces the shear strength, consequently resulting in failures (Anderson & Sitar, 1995). In recent years, many studies have been published on debris flow and/or rainfall-induced slope failures (Chowdhury & Flentje, 2002; Delmonaco et al., 2003; Teoman et al., 2004; Benac et al., 2005; Dunning et al., 2006; Yilmaz & Yildirim, 2006; Wang et al., 2006; Ulusay et al., 2007; etc.).

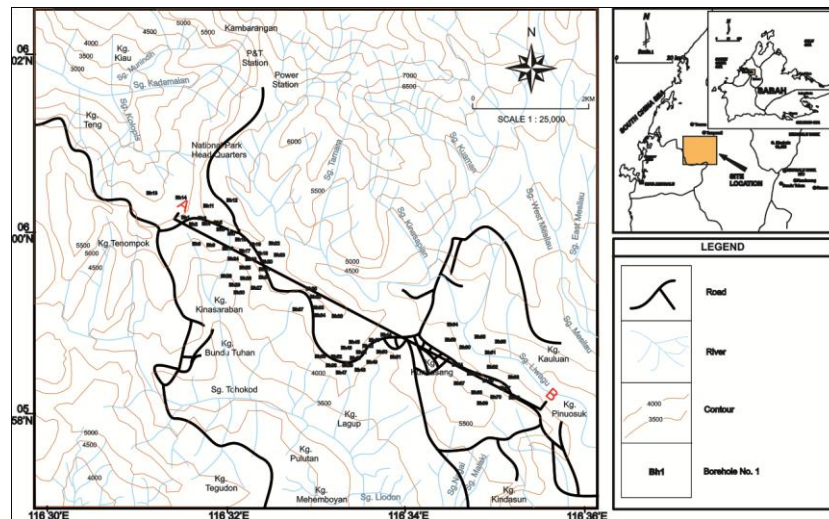


Figure 1. Location of study area with their boreholes location and cross-section A-B

MATERIALS AND METHODS

Several classifications can be used to describe SFS method. A very complete classification system for general use has been proposed by Terzaghi (1952), Varnes (1958 and 1978), Zaruba & Mencl (1969 and 1982), Crozier (1986), Hutchison (1988) and Dikau *et al.* (1996). For this study, the types of slope failures were classified according to the proposals of Ibrahim Komoo (1985). In this system, slope failures were classified into three main groups: soil slope failures, rock slope failures and special types of failures. Soil slope failures were divided into slides (T1), slumps (T2), flows (T3), creep (T4) and complex failures (T5) whereas rock slope failures were divided into circular (B1), plane (B2) and wedge failures (B3) together with rock falls (B4). Erosional failure is considered as a special type of failures (TB1). In this study, only failures with volumes exceeding 10 m^3 were considered, as failures of smaller volume did not generally affect road users. On this basis, the slope failures were

divided into three groups: small ($10 - 50 \text{ m}^3$), medium ($50 - 500 \text{ m}^3$) and large ($> 500 \text{ m}^3$). For each slope failures that was studied (Figure 2), the geometry of the slope, geological background characteristics, weathering characteristics, ground water condition, discontinuity characteristics, type of failures, physical and mechanical properties of the sliding materials and an interpretation of the factors causing the failure were recorded. Soil and rock samples from the study area were collected during field mapping for detailed laboratory analysis. The laboratory works such as classification tests (grain size, atterberg limit, shrinkage limit, specific gravity and water content), permeability test, consolidated isotropically undrained (CIU) test, rock uniaxial compressive strength and point load test were carried out in compliance and accordance to British Standard Code of Practice BS 5930-1981 (Site Investigation), British Standard Code of Practice BS 1377-1990 (Method of Test for Soils for Civil Engineering Purposes) and ISRM (1979a, 1979b & 1985). Besides of those, intensive literature review also has been done in order to obtain the useful reference and additional information of the study area.

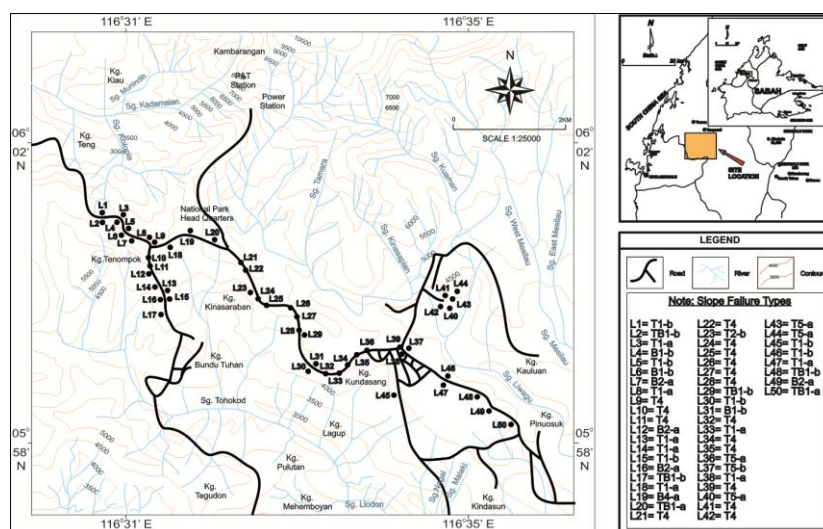


Figure 2. Location of slopes instability along highway

HYDROLOGIC AND HYDROGEOLOGIC SETTING

The highway and its surrounding area show a high drainage density with patterns (trellis, annular and parallel) (Figure 2). The structural control of the river tributaries of the area is evidenced by the physical characteristics of sedimentary rocks; highly fractured areas and less competent shale beds. The sedimentary rocks are more intensely dissected by fault zones than the ultrabasic rocks. Groundwater occurs and moves through interstices or secondary pore openings in the rock formations. Such openings can be the pore spaces between individual sedimentary grains, open joints and fractures in hard rocks or solution and cavernous opening in brecciated layers and cataclasites. The direction of groundwater movement is generally under the influence of gravity. The rock formations exhibit a high degree of weathering and covered by thick residual soil that extends to more than 65 feet in thickness. Evaluation of more than 60 boreholes drilled (Figure 1) and the cross-section constructed (Figure 3) from those boreholes in the study area indicated that the groundwater table in the study area is shallow and ranges from 6 feet to about 35 feet. It is also seen that the water table following the topography from highland toward the road and the valley side.

The weathered materials are weak and caused slope failures due to high pore pressure subjected by both shallow and deep groundwater.

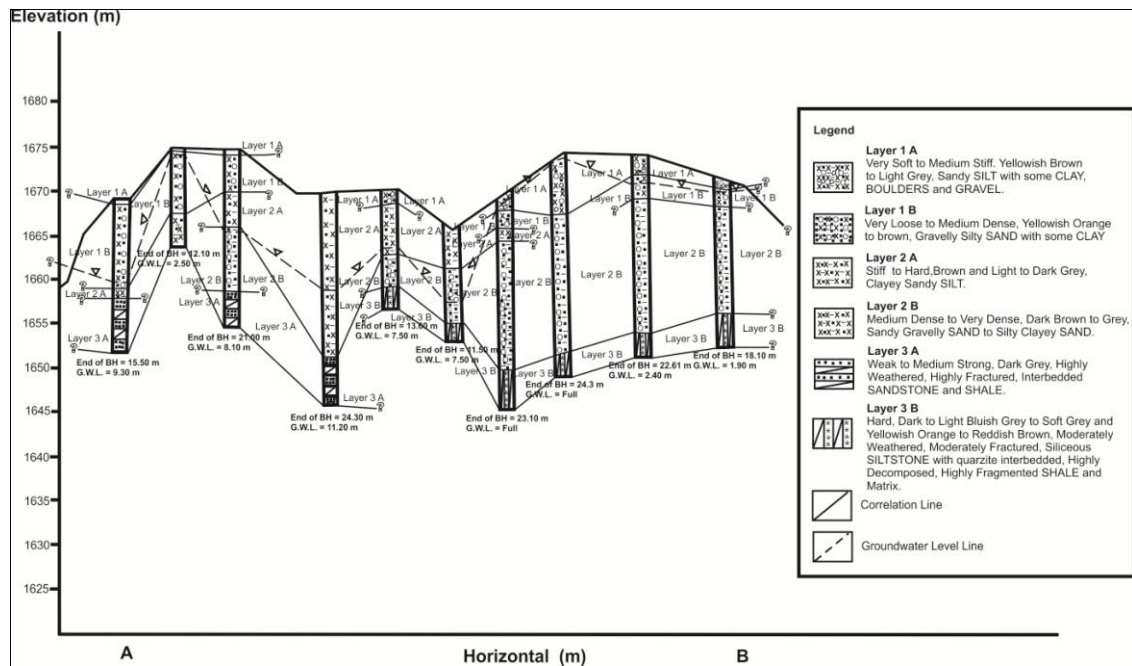


Figure 3. Cross – sectional A-B of groundwater table (From Figure 1)

GEOLOGY BACKGROUND

The local geology of the study area is made up of sedimentary rock of the Trusmadi Formation (Palaeocene to Eocene age), the Crocker Formation (Late Eocene to Early Miocene age) and the Quaternary Alluvium Deposits (Table 1 and Figure 4).

Table 1. Local Stratigraphic Column and their Water Bearing and Engineering Properties

Age	Rock Formation	Unit	General Character	Water-Bearing Properties	Engineering Properties
Quaternary	Alluvium	-	Unconsolidated gravel, sand and silt with minor amounts of clay deposited along the rivers or streams and their tributaries. Includes natural levee and flood plain deposit.	Gravelly and sandy, portions are highly permeable and yield large quantities of water. Important to groundwater development.	Generally poorly consolidated. Hence not suitable for heavy structures and subsidence under heavy load.
Late Eocene to Early Miocene	Crocker Formation	Shale	This unit is composed of two types of shale red and grey. It is a sequence of alteration of shale with siltstone of very fine.	It has no significant to groundwater development due to its impermeable characteristic.	Very dangerous site for heavy structures and the main causes of mass movement.
		Interbedded Shale-Sandstone	It is a sequence of interlayering of permeable sandstone with impermeable shale. The permeability of this unit is quite variable. Groundwater in this unit tends to be under semi-confined to confined system.	Little importance to groundwater provides some water but not enough for groundwater development.	Dangerous site for heavy structures and high potential for mass movement.
		Sandstone	Light grey to cream colour, medium to coarse -grained and some time pebbly. It is highly folded, faulted, jointed, fractured occasionally cavernous, surficially oxidized and exhibits spheroidal weathering.	Importance to groundwater.	Good site for heavy structures with careful investigation. Stable from mass movement and provide some modification like closing of continuous structure.
Paleocene to Eocene	Trusmadi Formation	Trusmadi Slate and Trusmadi Phyllite	Comprise of dark colour argillaceous rock either in thick bedded or interbedded with thin sandstone beds reported along with isolated exposures of volcanic rock is a common feature of this formation.	Fractured sandstone has significant to groundwater.	Dangerous site for heavy structure. Improvement should be conducted before any project.

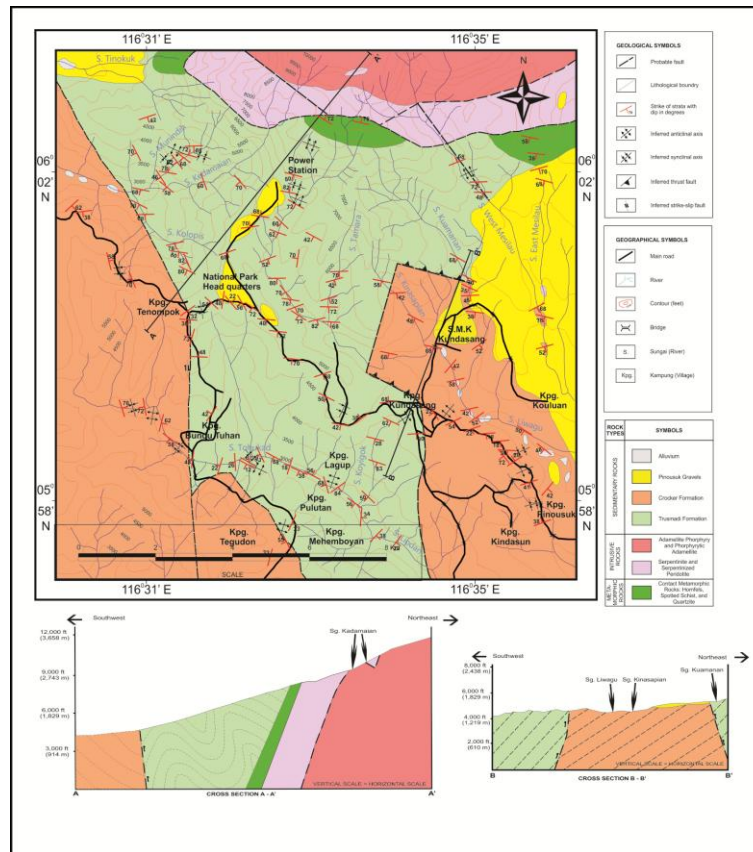


Figure 4. Engineering geological map

Jacobson (1970) divided the Trusmi Formation rock sequence into four main lithological units; argillaceous rocks, interbedded sequences (turbidites), cataclases and massive sandstones. Trusmi Formation is characterized by the presence of dark colour argillaceous rocks, siltstone and thin-bedded turbidite in well-stratified sequence. Some of the Trusmi Formation rocks have been metamorphosed to low grade of the greenish-schist facies; the sediment has become slate, phyllite and metarenite. Cataclastic rocks are widespread and occur as black phyllonite enclosing arenitic and lutitic boudins with diameter up to a meter or demarcating thin to thicker fault zones or as flaser zones with hardly any finer grain matrix or as zones of closely spaced fractures (Tjia, 1974). Quartz and calcite veins are quite widespread within the crack deformed on sandstone beds. The shale is dark grey when fresh but changes light grey to brownish when weathered. The Trusmi formation generally shows two major structural orientations NW-SE and NE-SW (Tongkul, 2007).

The Crocker Formation forms the main exposure in the area where outcrops can be found along road-cuts, paths and excavations. Major exposures are moderately to highly weathered materials. The Crocker Formation can be divided into four main lithological units; namely thick bedded sandstone, thinly bedded sandstone and siltstone, red and dark shale and slumped deposits. The sandstone of the Crocker Formation is normally fine to very fine-grained and highly fractured while the shale layers are sheared. The shale unit is generally composed of red and grey types of shale. The grey variety is occasionally calcareous. The sandstone composition is dominated by quartz with subordinate amounts of feldspars and chloritized, illitized or silicified lithic fragments. Calcareous fractions are rare. These are poorly sorted and well compacted with the pores filled by fine grained detritus or squeezed lithoclasts resulting in very low to nil primary porosity. Thin shale or siltstone bed between 3

to 40 cm thicknesses occurred between the thick sandstone beds. The argillaceous beds are frequently site of shearing while the sandstone beds site of fracturing or jointing.

The alluvium is restricted to the low land. It mainly represent unconsolidated alluvial sediment on river terraces composed of unsorted to well-sorted, sand, silt and clay of varying proportions which were derived from upstream bed rocks. They occur in irregular lenses varying in the form and thickness. The alluvium may also consist of very thin layer of organic matter. The alluvium sediment is soft, compressible and may be prone to settlement.

Apart from that, fieldwork observation indicates that too many cut and filled slopes was designed does not take into account input or geological interest. For example most of the slopes were designed too steep, lack of monitoring on proper drainage system or slope physical state and also we can found most of the slope cutting surface activities is parallel following to the strike direction of the sandstone bedding orientation. The trend of strike and dip of the sandstone bedding orientation along the highway can be observed in different patterns such low angle dip (030-100/10-20); medium angle dip (220-280/30-50) and high angle dip (320-345/60-70). The slope surface orientation was observed is ranging from 210-330 (dip-direction) and 35-80 (dip) values (Figure 5). Hence, the main factors of slope failures occurrences along the highway are sourced from the relationship between the factors of dip-direction slope cutting surfaces with the strike direction of the sandstone bedding orientation. That is why there were some SFS found in the variable potential of falls, slides and topples mode types as well as the combination of more than one mode of aforementioned in the form of the slope failures complex due to this design negligence described to the above aided by the discontinuities nature complex very often encountered at study area.

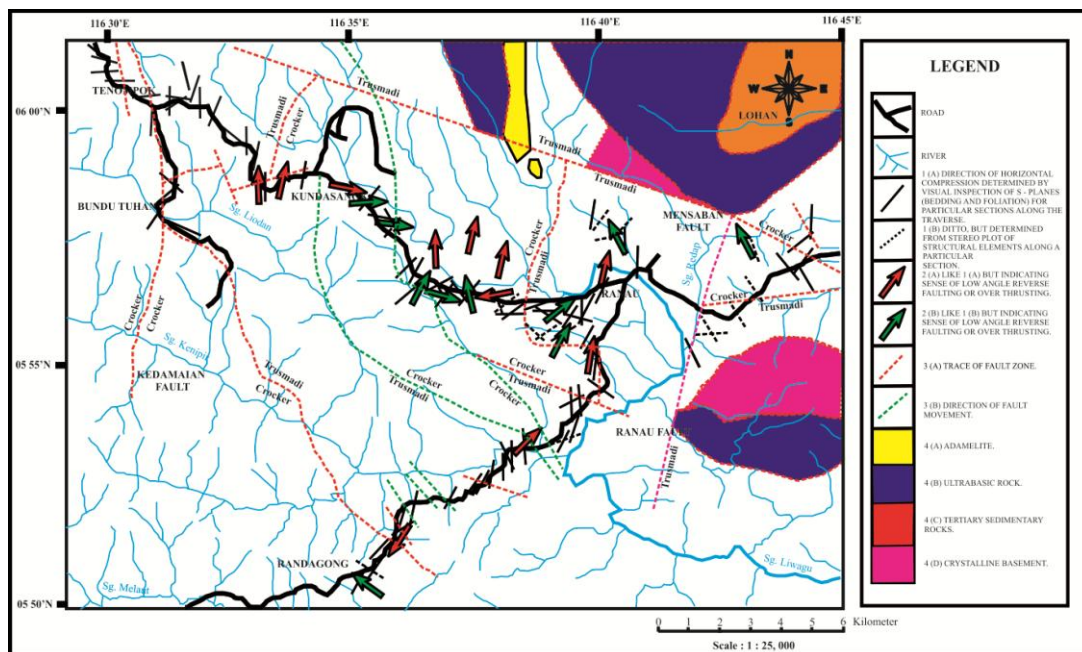


Figure 5. Structural geology map (Modified after Tjia, 1974)

RESULT AND DISCUSSION

In this study, a total of 50 selected critical slopes were studied. The types of slope failures and their frequency according to volume are shown in Table 2. Failures in soil slopes

(including embankments) total 34 (68 %) with 10 failures (20 %) of rock slopes and 6 failures (12 %) caused by erosion. Soil slope failures normally involved large volume of failed material compared to rock slopes, where most failures are small to large size. Of the 34 failures in soil slopes, 31 (91 %) are embankment failures making them 62 % of all types of failures.

Table 2. Frequency of slope failures and volume of failed materials

Type of failures	Frequency according to volume (m ³)			Frequency	(%)
	10 – 50	50 – 500	> 500		
Soil slope failures					
T1	5	4	4	13	26
T2	-	-	1	1	2
T3	-	-	-	0	0
T4	1	13	2	16	32
T5	-	0	5	5	10
Rock slope failures					
B1	-	3	1	4	8
B2	-	2	2	4	8
B3	-	-	-	0	0
B4	-	-	1	1	2
Special type of failures					
TB1	1	3	2	6	12
Total	7	24	19	50	100

Table 3 shows the results of a detailed analysis of rock slope failures. Although rock slope failures contributed only 20 % (10 failures) of the total failures, they involved large volume of rock weathered (Figure 6). The main factor contributing to rock slope failures was the orientation and intensity of discontinuity planes. That is why rock slope failures occurred most frequently along the highway on sedimentary rocks, which were highly breccias and fractured. About 90 % of the rock slope failures occur in sedimentary rocks of Trusmadi Formation and Crocker Formation while the remaining 10 % occurrences in metasedimentary rocks of Trusmadi Formation. Generally the failed material underwent only moderate to complete weathering (grade III, IV and V). Other factors contributing to slope failures were the presence of groundwater, climatological setting, joints filling material, high degree of rock fracturing due to shearing in shear, steep of slope angle, high intensive of faulting and folding activities, locating at the fault zones area and design negligence.

Results of a detailed analysis of soil slope failures are presented in Table 4. Considering cut slopes, all the major lithologies are involved showing that this type of failure is not mostly controlled by lithology. The failure volume scale involved generally small to large in size possibly endangering road users. In term of weathering grades, the materials that underwent failure were in the ranges from grade IV to VI (Figures 7 to 9). Weathering is the main factor causing failure with the depth of weathering influencing the volume of material that fails. It appears that grade IV and grade V materials actually failed with the overlying grade VI material sliding or slumping down together with this material during failure. The presence of ground water, slope angle, removal of vegetation cover, lack of proper drainage system, artificial changing, climatological setting, geological characteristics and material characteristics are additional factors contributing to the failures. Failures of embankments always involve large volume scale and often resulted in the partial or entire destruction of the highway. It appeared the improper construction is the main factor leading to failure. In many cases, the slope angle, removal of vegetation cover, overburden or vibration from vehicles, climatological setting, geological characteristics and material characteristics contributed to failure. As many of the embankments were across in valleys, insufficient the embankment

slopes caused the failure. It was also observed that the failure plane surface occurred on the interface between in-situ highly weathered rock and residual soil, debris and embankment material.

Table 3. Analysis results of rock slope failures

Type of failures	Location (km)	Slope	Geological formations	Lithology	Weathering grade	Discontinuity plane orientation and intensity		Volume (2)	Main factors causing failures (3)
						Orientation (Strike / dip)	Discontinuity Intensity (1)		
B1 – b	East KM 84.40	L4	Crocker Formation	Sediment	IV to V	345/76	Very High	Medium	D, SA, W, GWL, M, CR, G & AC
	East KM 84.90	L6	Crocker Formation	Sediment	IV to V	010/62	Very High	Medium	
	East KM 92.50	L31	Trusmadi Formation	Sediment	IV to V	110/50	Very High	Large	
B2 – a	East KM 85.50	L7	Crocker Formation	Sediment	III to IV	350/58	High	Medium	D, SA, W, GWL, M, BF, G & AC
	South KM 87.45	L12	Trusmadi Formation	Sediment	IV to V	190/73	Very High	Medium	
	South KM 87.90	L16	Trusmadi Formation	Meta Sediment	III to IV	185/43	Very High	Large	
	East KM 95.70	L49	Crocker Formation	Meta Sediment	III to IV	085/18	Very High	Large	
B4 – a	East KM 87.30	L19	Trusmadi Formation	Meta Sediment	III to IV	310/54	High	Large	D, SA, W, GWL, M, BF, G & AC

- Note**
 (1) Discontinuity intensity: low (< 0.5/m), medium (0.5 – 1.0/m), high (1.0 – 5.0/m) and very high (> 5.0/m)
 (2) Volume: small (10 – 50 m³), Medium (50 – 500 m³) and Large (> 500 m³)
 (3) Discontinuity (D), Slope angle (SA), Weathering (W), Groundwater level (GWL), Material characteristics (M), Crushed rock (CR), Blocks and fragments (BF), Fall and blocks (FB), Geological characteristics (G) and artificial changing (AC)

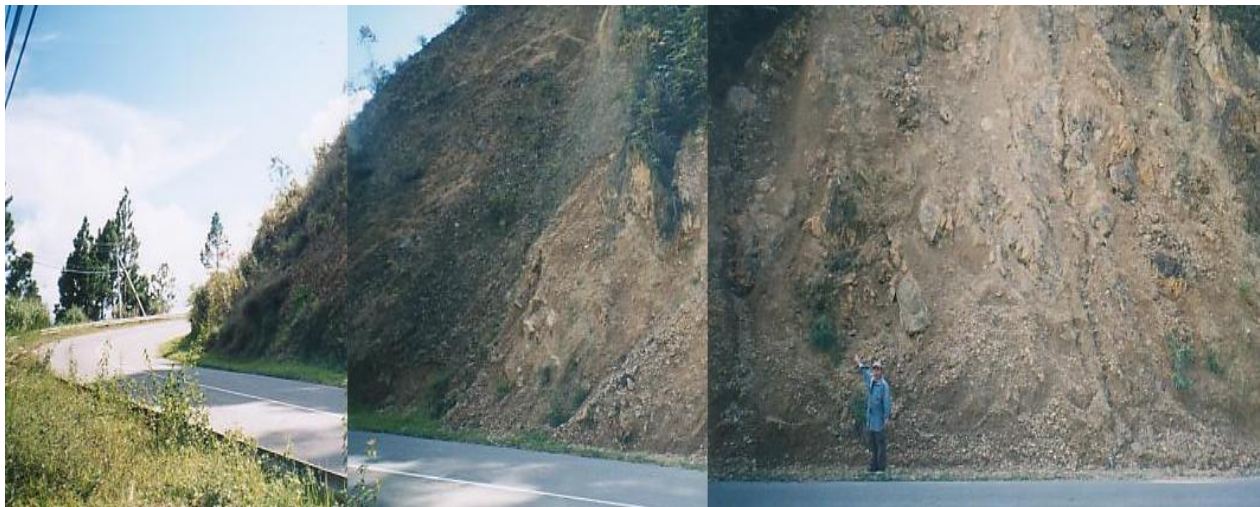


Figure 6. Fall and blocks (B4 – a) at East KM 87.30 (L19) shows the form of discontinuities provides intersecting sheets to form yield stepped surfaces or boundary vertical joints

Table 4. Analysis results of soil slope failures

Type of failures	Location (km)	Slope	Geological formations	Lithology	Weathering grade	Volume (1)	Main factors causing failures (2)
T1 – a	East KM 84.40	L3	Crocker Formation	Sediment	IV to VI	Small	SA, W, V, GWL, M, C, G, OBV, DS, EC and AC
	East KM 86.10	L8	Crocker Formation	Sediment	IV to VI	Large	
	South KM 87.80	L13	Trusmadi Formation	Sediment	IV to VI	Small	
	South KM 87.80	L14	Trusmadi Formation	Sediment	IV to VI	Large	
	East KM 86.80	L18	Trusmadi Formation	Meta	IV to VI	Large	
T1 – b	East KM 93.10	L33	Trusmadi Formation	Sediment	IV to VI	Small	SA, W, V, GWL, M, C, G, OBV, DS, EC and AC
	East KM 95.30	L47	Crocker Formation	Sediment	IV to VI	Small	
	East KM 84.00	L1	Crocker Formation	Sediment	IV to VI	Small	
	East KM 87.45	L5	Crocker Formation	Sediment	IV to VI	Small	
	South KM 87.90	L15	Trusmadi Formation	Meta	IV to VI	Medium	
T2 – b	East KM 92.50	L30	Trusmadi Formation	Sediment	IV to VI	Small	SA, W, V, GWL, M, C, G, OBV, DS, EC and AC
	South KM 94.70	L45	Crocker Formation	Sediment	IV to VI	Medium	
	East KM 95.30	L46	Crocker Formation	Sediment	IV to VI	Medium	
	East KM 90.30	L23	Trusmadi Formation	Sediment	IV to VI	Large	
	East KM 86.10	L9	Trusmadi Formation	Sediment	IV to VI	Medium	
T4	South KM 86.60	L10	Trusmadi Formation	Sediment	IV to VI	Medium	SA, W, V, GWL, M, C, G, OBV, DS, EC and AC
	South KM 86.60	L11	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 88.50	L21	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 88.50	L22	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 90.30	L24	Trusmadi Formation	Sediment	IV to VI	Medium	
	South KM 90.30	L25	Trusmadi Formation	Sediment	IV to VI	Large	
	East KM 91.00	L26	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 91.00	L27	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 91.50	L28	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 93.10	L32	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 93.30	L34	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 93.30	L35	Trusmadi Formation	Sediment	IV to VI	Medium	
	East KM 94.50	L39	Trusmadi Formation	Sediment	IV to VI	Small	
	North KM 95.80	L41	Crocker Formation	Sediment	IV to VI	Medium	
	North KM 95.80	L42	Crocker Formation	Sediment	IV to VI	Large	
T5 – a	East KM 94.10	L36	Crocker Formation	Sediment	IV to VI	Large	SA, W, GWL, M, C, G, DS, and AC
	North KM 95.80	L40	Crocker Formation	Sediment	IV to VI	Large	
	North KM 95.80	L43	Crocker Formation	Sediment	IV to VI	Large	
T5 – b	East KM 94.50	L37	Trusmadi Formation	Sediment	IV to VI	Large	SA, W, GWL, M, C, G, DS, and AC
	North KM 95.80	L44	Crocker Formation	Sediment	IV to VI	Large	

- Note**
 (1) Volume: small (10 – 50 m³), Medium (50 – 500 m³) and Large (> 500 m³)
 (2) Slope angle (SA), Weathering (W), Vegetation (V), Groundwater level (GWL), Material characteristics (M), Climatological setting (C), Geological characteristics (G), Over burden or vibration (OBV), Drainage system (DS), Embankment construction (EC) and Artificial changing (AC)



Figure 7. Shallow slide (T1 – a) at South KM 87.80 (L13 & L14) shows the failure movement are starting to move into several discrete blocks through the development of transverse cracks



Figure 8. Embankment failure in the form of a deep slide (T1 – b) at East KM 84.00 (L1)



Figure 9. Creep (T4) at North KM 95.80 (L41) often display complex cracks pattern. All of the cracks are capable of becoming residual weakness after this type of failure had ceased to move

Erosional failures are mainly small to large scale and are caused by high volumes of running water and the condition of the materials due to weathering process (Figures 10, 11 and Table 5). Erosional failures occur most frequently on clayey loamy of residual soil materials of the slope, mainly because of the thick and well developed grade IV to V layers of the weathering profile. These clayey loamy materials have high clay fractions and are generally cohesion. When erosion of IV to V occurs, the overlying grade VI is also transported away.

Table 5. Analysis results of erosional failures

Type of failures	Location (km)	Slope	Geological formations	Lithology	Weathering grade	Volume (1)	Main factors causing failures (2)
TB1 – a	East KM 88.10 East KM 96.10	L20 L50	Trusmadi Formation Crocker Formation	Sediment Sediment	V to VI V to VI	Large Large	SA, W, V, GWL, M, C, G, DS, and AC
TB1 – b	East KM 84.00 South KM 88.10 East KM 91.50 East KM 95.30	L2 L17 L29 L48	Crocker Formation Trusmadi Formation Trusmadi Formation Crocker Formation	Sediment Sediment Sediment Sediment	V to VI V to VI V to VI V to VI	Medium Medium Small Medium	SA, W, V, GWL, M, C, G, DS, and AC

- Note**
(1) Volume: small (10 – 50 m³), Medium (50 – 500 m³) and Large (> 500 m³)
(2) Slope angle (SA), Weathering (W), Vegetation (V), Groundwater level (GWL), Material characteristics (M), Climatological setting (C), Geological characteristics (G), Over burden or vibration (OBV), Drainage system (DS), Embankment construction (EC) and Artificial changing (AC)

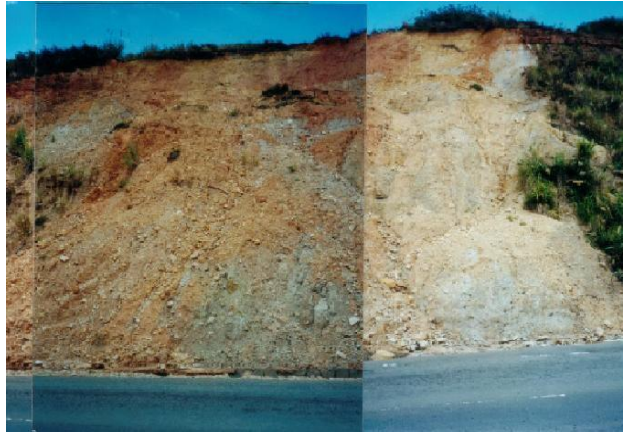


Figure 10. Erosional failure (gully erosion) (TB1 – b) often associated with human made tip and spoil heaps, although it occurred in rock debris of geological origin (Location: L50 at East KM 96.10)



Figure 11. Erosional failure (sheet erosion) (TB1 – a) tend to flow follow shallow depressions and then to spread out into a flat, bulbous fan or even a thin sheet when they reach low ground (Location: L2 at East KM 84.00)

RECOMMENDATION

To correct or prevent the slope failures in the study area, the following recommendations are proposed:

1. Installation of piezometric and clinometers to monitor seasonal build-ups of pore water pressure and creep movement respectively.
2. Surface drainage, which include:
 - a) Sealing off of the cracks;
 - b) A good vegetation cover;
 - c) A good drainage pipe system and gutter system; and
 - d) Shotcrete or other means of reducing erosive action of rainwater runoff.
3. Subsurface drainage, i.e. horizontal drainage method.

In light of available information, the following conclusion may be drawn from the present study:

1. A total of 50 selected critical slope failures were studied. Failures in soil slopes (including embankments) total 35 (70 %) with 10 failures (18 %) of rock slopes and 6 failures (12 %) caused by erosion. Soil slope failures normally involved large volume of failed material compared to rock slopes, where most failures are small to large size. Of the 35 failures in soil slopes, 31 (89 %) are embankment failures making them 62 % of all types of failures.
2. Geologic evaluation of the study area indicates that the slope failures took place when slope materials are no longer able to resist the force of gravity. These decrease the shear strength and increase the shear stress resulting slope failures, which is due to internal and external factors. Internal factors involve some factors change in either physical or chemical properties of the rock or soil such as topographic setting, climate, geologic setting and processes, groundwater condition and engineering characteristics. External factors involve increase of shear stress on slope, which usually involves a form of disturbance that is induced by man includes removal of vegetation cover, vehicles loading or vibration and artificial changes or natural phenomenon such as tremors.

ACKNOWLEDGEMENTS

A lot of thanks to the Universiti Malaysia Sabah (UMS) on ease of use in laboratory and fieldwork equipments. The highest appreciation is also given to the Ministry of Education (MOE) on fundamental research grant award (B-0201-01-ER/U0038) to finance all costs of research.

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