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A geomorphological approach in predicting environmental impacts of proposed development in hilly terrain

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Abstract: Classification of slopes and the associated risk by means of slope angle alone is often not adequate to give appraisal on possible risk and environmental impacts. This is mainly because the geomorphic processes that take place differ with locations. This paper presents an example of geological studies with emphasis on geomorphology for an EIA report, which has been conducted recently at the proposed site of Ringlet National Secondary School, Cameron Highland, Pahang Darul Makmur. The study area is a sub-catchment within the larger catchment area of Sungai Bertam. The geology of the area consists of granitic and schist bedrock, which is locally unconformably overlain by alluvial/colluvial deposits notably in the valley floor. Natural slopes in the study area were divided into 9 geomorphic units based on the predominant geomorphic and pedogenic processes. Each geomorphic unit mapped has distinctive geomorphic processes and problems. In this way, prediction of the associated environmental impacts and planning for mitigation and abatement measure can be executed more effectively. Amongst the significant environmental impacts predicted due to the development activities in this area include landslide, erosion and associated problems, disaggregation, compaction and pollution, notably during the site clearing and construction phase. However, with well-planned mitigation measures, such as slope stabilisations, minimising slope cuttings, provision of vegetative covers and siltation traps, the impacts can be greatly reduced and minimised.

Abstrak: Pengkelasan cerun dan risiko yang berasosiasi dengannya yang dibuat berdasarkan kepada sudut cerun semata-mata lazimnya tidak memadai untuk meramalkan risiko dan impak alam sekitarnya. Ini disebabkan proses-proses geomorfologi yang bertindak pada cerun berbeza antara satu sama lain mengikut lokasi cerun. Kertas ini cuba menyajikan suatu contoh kajian geologi dengan penekanan kepada aspek geomorfologi untuk Penilaian Impak Alam Sekitar (EIA), yang telah dilakukan baru-baru ini di tapak cadangan Sekolah Menengah Kebangsaan Ringlet, Cameron Highland, Pahang Darul Makmur. Kawasan kajian terletak dalam sebuah cawangan kawasan tadahan Sungai Bertam. Geologinya terdiri daripada batuan dasar granit dan syis, yang ditindih secara tak selaras oleh endapan alluvium/koluvium, terutamanya di bahagian lantai lembah. Cerun-cerun semulajadi di kawasan kajian telah dikelaskan kepada 9 unit berdasarkan kepada proses-proses geomorfik dan pedogenik utama. Setiap unit geomorfologi yang dipetakan mempunyai proses dan masalah geologi yang tersendiri. Dengan itu potensi impak alam sekitar bagi setiap unit di dalam kawasan kajian dapat diramalkan dengan lebih terperinci, justeru memudahkan perancangan langkah-langkah tebatan dan mitigasi. Antara impak alam sekitar yang dikenalpasti akibat aktiviti pembangunan di kawasan ini termasuklah tanah runtuh, hakisan dan impak susulannya, disagregasi, pemadatan dan pencemaran, terutama semasa kerja-kerja pembersihan hutan dan pembinaan. Bagaimanapun, dengan langkah-langkah tebatan yang terancang rapi, seperti penstabilan cerun, pemotongan cerun yang minima, penanaman rumput, penggunaan perangkap kelodak, impak-impak yang boleh dikurangkan dengan berkesan.

INTRODUCTION

An Environmental Impact Assessment (EIA) prior to project approval is a mandatory requirement under Section 34A of the Environmental Quality Act, 1974, for prescribed activities listed in the Environmental Quality Order 1987 (DOE, 1995). Currently, geological aspects are included as a small part in descriptions of the existing environment (DMG, 2000). It is often divided into two categories of i) geology and ii) soil. Geomorphology (topography) forms part of the vital geological inputs to be considered in the EIA's.

Geological inputs in a number of EIA reports are often inadequate to give proper appraisal of the environmental impacts of a proposed project (DMG, 2000). This is probably due to insufficient detail in the geological studies conducted by the EIA consultants. Geological inputs required for the EIA Reports may also be different from one project to another due to variable geologic conditions. The lack of published practical examples of proper geological studies may also exacerbate this problem.

Recently, guidelines for the requirement of geological inputs in the preparation of EIA reports have been revised by the Department of Mineral and Geosciences Malaysia (DMG, 2000). The revised guidelines list detailed geological inputs based on the proposed activities, such as agriculture, forestry and housing. However, in some cases, additional inputs suggested in the guidelines are too detailed and impractical to be conducted in the preliminary stage of any proposed development project (prior to approval) as the incurred costs could be very high and beyond the allocated investment budget.

This paper attempts to give an example of part of the geological aspect, i.e. geomorphology; that need to be considered in preparing the EIA report. The case study presented was, however, conducted before the guidelines by the DMG (2000) were published and made available to the public. It must be emphasized that this paper is by no means exhaustive, nor it is intended to stifle the existing guidelines published by the DOE (1995) and DMG (2000).

STUDY AREA AND OBJECTIVES

The study was carried out on the site of a proposed National Secondary School at Ringlet, Cameron Highlands, Pahang Darul Makmur. The main objectives were to predict significant residual (geology-related) environmental impacts and to propose appropriate abatement and mitigation measures.

The study area, measures about 44500 m^2 and is located in rugged hilly terrain to the north of Ringlet town (Figure 1). The site is located in a small sub-catchment within the larger Sungai Bertam catchment area, in which the popular reservoir "the Ringlet Lake" is located. The reservoir is a few hundred meters away to the east of the study area. All precipitation collected in the study area flows down into the Ringlet Lake and continuously flows into the Sungai Bertam.

The topographic height ranges between 1090 m and 1160 m above mean sea level. Rock outcrops are only exposed in slope cuts along the access road to the project site. However, the rock exposures are highly to completely weathered. The slope gradients are generally steep (40-60°), notably in the upper northern, northwestern, western and southern parts of the area. Most of the area is covered by dense tropical forest except in the abandoned vegetable fields on the northwestern and western hill slopes. The latter is now generally occupied by grass and shrubs. Adjacent to the south of the study area, earthworks for a Proposed Primary Schools are in progress.

GENERAL GEOLOGY

The general geology of the site is shown in Figure 2 and is discussed in Tajul Anuar Jamaluddin and Ahmad Nizam Hassan (*this volume*). The bedrock geology of the project site comprises metamorphic and igneous rocks. The metamorphic rocks consist predominantly of schists of probable Upper Palaeozoic age. The exposed schists are highly to completely weathered, light brownish grey to greyish brown in colour, fine to medium grained and very well foliated. In hand specimens, the schist is composed essentially of quartz and mica, with smooth and shiny foliation surfaces. In places, traces of original bedding are still visible, which is almost parallel to the foliation, suggesting that the schist was originally sedimentary rocks. Schist forms about two-thirds of the project site, notably in the central and eastern portions of the area.

The igneous rock consists of coarse, hypidiomorphic, coarse-grained biotite granite. The granite comprises essentially of quartz, feldspars and some black spots of biotite and/or tourmaline. An unconformable, discordant contact between the granite intrusion and schist is exposed

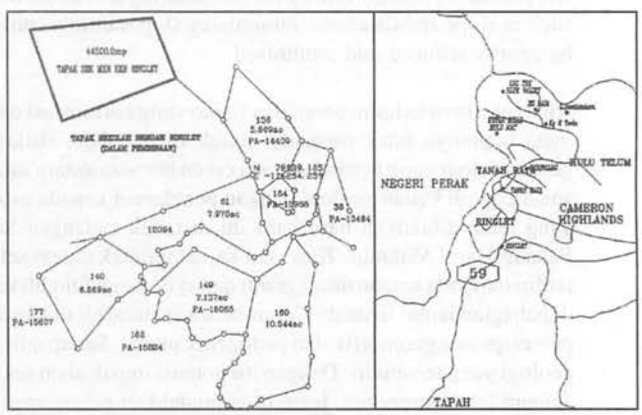

Figure 1. Map showing the location of the study area (Tapak Sek. Men. Keb. Ringlet).

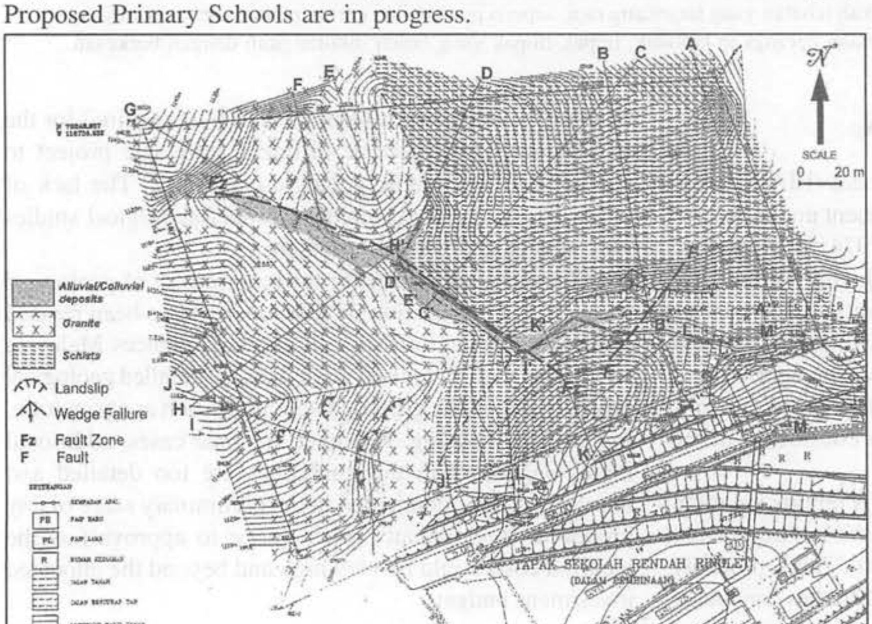

Figure 2. General geological map of the project site. Cross sections along A-A' to M-M' are shown in Figure 4.

in the cut slope on the north side of the access track to the site. Both the lithologies, however, are highly weathered. Unconsolidated colluvial deposits are locally encountered at the foot slope along the river to the NW part of the area. The deposit is characteristically a mixture of boulder, pebbles, sands and mud derived from the upper slopes.

GEOMORPHOLOGY

Drainage

On a regional scale, the study area is located in a sub-dendritic drainage system within the Sg. Bertam catchment area. The site of the proposed school is situated in a V-shaped valley, where the upper branches of the streams coalesce into a small river flowing southeast-easterly into the nearby Ringlet Lake.

The NW-trending stream is structurally-controlled, in that it is developed along the strike of a fault zone. The downstream part of the river has been slightly modified and the water flow diverted by a man-made earth ditch. The water is still clean and clear, suggesting minimal disturbance from its original condition.

Slope Geomorphology

In order to visualize the likely impacts caused by the proposed development on a hilly terrain such as the study area, the contemporary geomorphic and pedogenic processes in the terrain have to be fully understood. Classification of slopes by means of slope angle alone, however, is insufficient to assess the possible risk and environmental impacts. This is mainly because the geomorphic processes that take place, for example on a 10° slope located on a hill top will not be the same as the one located at a foot hill, and vice versa. In the former, the predominant geomorphic processes would be erosion and mass wasting, while in the latter it would be predominantly depositional.

For the reasons described above, existing natural slopes in the study area were analysed and classified according to a hypothetical model of Dalrymple *et al.* (1968). According to this model (Figure 3), a natural slope can be differentiated into 9 units based mainly on the form and predominant geomorphic and pedogenic processes.

It is noted that this model was originated from observations of slopes and soils in the North Island of New Zealand with humid temperate climate. Whereas in a humid tropical country such as Malaysia, weathering predominates due to intense and prolong rainfalls throughout the year. Therefore, the dominant geomorphic processes are expected to be slightly different from those proposed in the model. For example, according to the model, the dominant geomorphic processes in Unit 2 (seepage slope) would be mechanical and chemical eluviation by subsurface water movement. However, in humid tropical country, the likely dominant processes (once the slopes are devegetated) would be sheet and rill erosions as the volume and velocity of the surface runoff are normally high, as well as the regoliths are generally thick to allow for substantial soil erosions. A similar condition is applicable to Units 1 and 3, the dominant geomorphic processes are likely to be of sheet erosions and rill/gully erosions, respectively. Despite of the limitations of this model, as discussed by Young (1972), its should be applied with precautions by taking into accounts the properties (e.g. surface features, composition and profile) of regoliths and the relevant processes that take places which vary with climates and geographic positions.

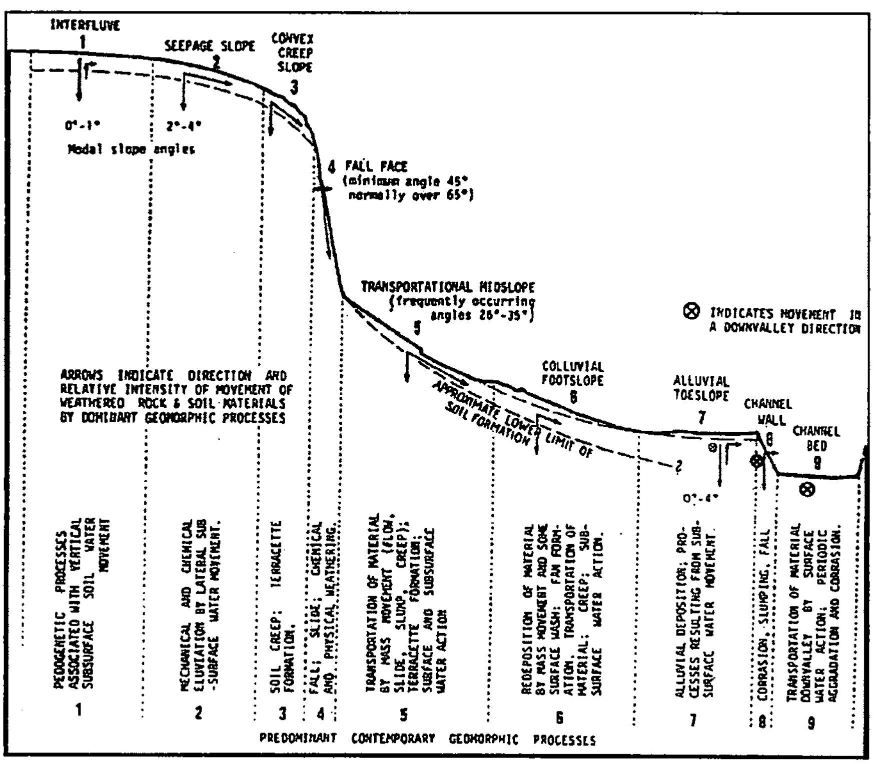

Figure 3. Classification of slope units and the associated predominant geomorphic processes (after Dalrymple *et al.*, 1968).

Table 1. Summary of geomorphic analysis of the slopes (based on 1343m of slope cross-sections).

Unit	Frequency	Slope Angle	Group	Dominant processes (modified from Dalrymple *et al.*, 1968)
1	4	<2°	1	pedogenic processes and sheet (occurring outside project site)
2	8	2-6°		mechanical & chemical eluviation, erosions (sheet & rill)
3	5	12-42°		soil creep, erosions (rill and gully)
4	3	45-60°	2	accelerated mass movement (earth falls)
5	15	20-54°		mass movement (landslides, landslips, slump)
6	9	6-22°		redeposition
7	9	3-20°		alluvial deposition
8	-		-	-
9	6	<2°	3	transportation of material by surface water

A total of 13 slope cross sections were constructed from a total length of 1343 m traverse lines. The line positions are shown in Figure 2 and the corresponding cross-sections (slope profiles) with the assigned geomorphic units are shown in Figure 4.

Results of this analysis indicate that slopes in the project site can be broadly grouped into 3 main groups, namely Group 1: Hill top section (Units 1, 2 and 3); Group 2: Mid slope section (Units 4, 5, and 6); and Group 3: Toe slope section (Units 7 and 9). Group 1 is dominated by Unit 2 (seepage slope), Group 2 by Unit 5 (transportational midslope) and Group 3 is predominantly represented by alluvial/colluvial toe slope and channel bed (Units 7 and 9). These are summarised in Table 1.

The hilltops are generally convex-shaped with very gentle slopes (2° to 6°) on the top. The peripheral mid-slopes are generally moderately steep to steep (20° to 60°). The foothills are gentler with slope angles between 5° to 20°.

Under present site conditions the mass wasting processes (e.g. erosion, soil creep) take place at a very slow rate. Minor and shallow landslips were encountered locally, notably in the mid slope section. However, accelerated mass wasting is expected to take place if these slopes are cleared and modified.

ENVIRONMENTAL IMPACT ASSESSMENTS – GEOLOGICAL ASPECTS

Slope and Risk Classification

Two important elements are considered in the slope classification of the study area, i.e. slope angle and the slope form or the position where the slope is located on the hill morphology. The slope (landform) classification is shown in Figure 5 and their general characteristics are summarised in Tables 2 and 3.

According to the "broad-brush" method of risk classification suggested by the Ministry of Housing and Local Government of Malaysia (1996), the study area can be broadly grouped into two risk groups; i.e. low risk and high risk. Areas with slope angles <25° are considered to be of low risk and slopes with angle >25° are considered to be of high risk (Table 2).

Landform Units	Map Area (m^2)	Percentage	* Risk Classification	Comments
1	—	—	—	Located outside boundary
2	300	0.6	Low Risk	
3	5930	13.0	High Risk	<25° slopes (low risk) present
4	750	1.6	High Risk	
5	26830	59.0	High Risk	<25° slopes (low risk) present
6	9200	20.0	Low Risk	
7	1950	4.0	Low Risk	
8	—	—	—	
9	1150	2.0	Low Risk	
Total	45730	100.2		

Table 2. Slope classification in the project area. *Ministry of Housing and Local Government of Malaysia (1996) outlined that for the purpose of hill development, natural slope with angle less than 25° is interpreted as low risk slope, and natural slope with angle of more than 25° is interpreted as high-risk slope.

According to this classification, low risk areas of the project site are predominantly represented by morphological Units 2, 6, 7 and 9 (Figure 5), which occupy approximately 39.6% of the study area. The high risk areas are mainly represented by geomorphic Units 3, 4 and 5, which occupy 13%, 1.6% and 59% of the study area, respectively. However, it is to be noted that some sections of Units 3 and 5 can be categorised as low risk because the slope angles are gentler than 25°. This is not always true because their geomorphic position exposes them to significant impacts of mass wasting processes, either directly taking place on the slope itself or by the consequent impacts from processes occurring above and/or below them.

The high-risk areas are commonly situated in the upper part of the midslope sections. Special care must therefore be taken when dealing with earthworks in these areas. The likely impacts associated with the development activities on the slopes are discussed in the following sections. Table 3 summarises the potential impacts on each geomorphic units and the recommended mitigation measures.

Potential Impacts

The development of hilly terrain will inevitably involve extensive deforestation or removal of trees. These, in combination with earthworks during development, will inevitably cause direct impacts on the soil and geology of

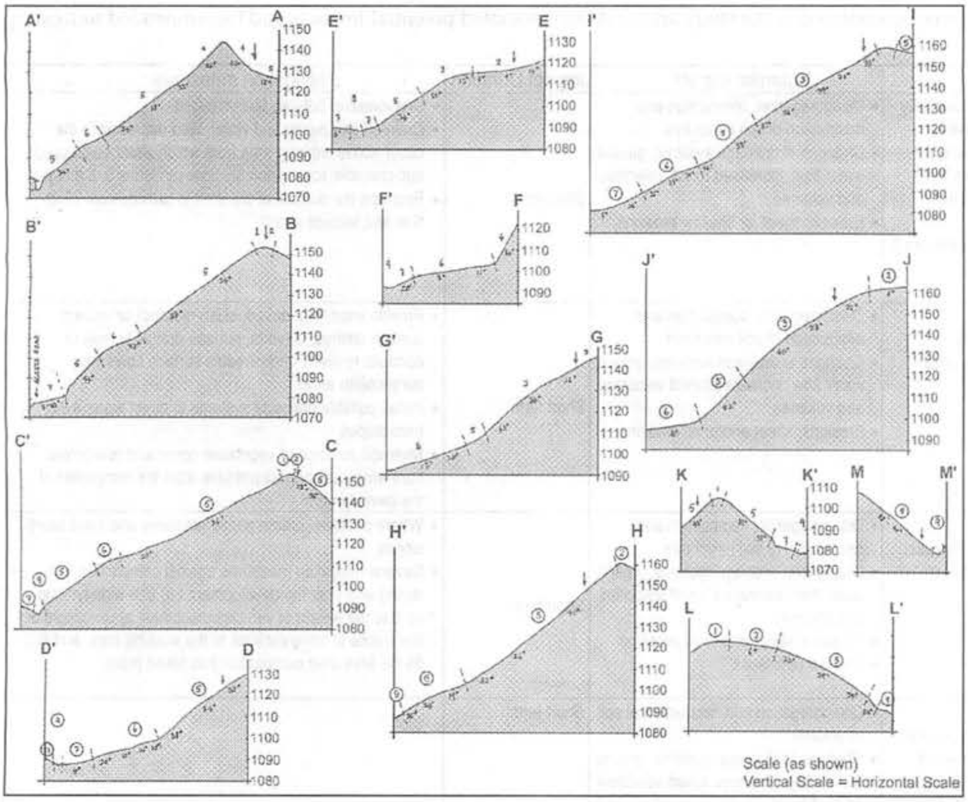

Figure 4. Cross sections showing the profile and classification of the geomorphic units.

the project site and adjacent areas. The most likely environmental impacts (with relation to the geology) due to proposed development, which are of prime concern, are: erosion, disaggregation, landslides, compaction and pollution. These are discussed in the following sections.

Erosion and associated impacts

Almost all development is likely to lead to some soil erosion, unless suitable mitigation procedures are adopted. In a new development such as this project, two major controlling factors of erosions are the removal of vegetation and the steep slopes. Deforestation will result in a drastic increase in runoff volume and velocity. Increased runoff over the hilly terrain will certainly cause substantial soil erosion. Excessive erosion can cause toe undermining and destabilization of slopes, leading to large downslope mass-movements (landslides, debris/mud flow).

When soil erosion by water occurs, damage will often not be restricted to the terrestrial environment. The removed soil can affect nearby watercourses, such as causing an increase in siltation and sedimentation, and consequently causing flash flood at downstream and surrounding low-lying areas. In this case, the existing quarters which are situated at the foothill area to the east will be at risk of flash flood and mudflow. The Ringlet Lake which is situated to the east of the main road will also be substantially affected by sedimentation and siltation, so as the the main river of Sungai Bertam. Although this is an unavoidable impact particularly during the construction phase, it can be reduced by adapting appropriate mitigation measures.

Disaggregation

Disaggregation is simply the mixing-up of soils when soils are disturbed during development, especially where the development involves removal of soil and rock from one location to another, slope cutting and excavations. Two major effects may be anticipated: physical disaggregation which involves physical disruption of soil and rock structures, and chemical disaggregation which may involve the redistribution of elements within soil profile. The latter may be of little significance because the granite is relatively homogenous and lack of hazardous minerals. In both cases, infertile subsurface material may be brought to the surface, causing problems for the re-establishment of vegetation after development is completed.

Landslides

The creation of cut slopes in the project site will inevitably expose the area to the risks of landslides or slope failures. Two common types of slope failures in this terrain are residual soil slides and block, planar and/or wedge failures along relict discontinuities. Slope stability aspects and the predicted environmental impacts are discussed in detail by Tajul Anuar Jamaluddin & Ahmad Nizam Hassan (*this volume*) and will not be repeated herein.

Compaction

Compaction is an almost inevitable result of any development, especially during the construction phase. Soil will be compacted by vehicular movements, as will the storage of soil heaps, bricks and other construction materials.

Table 3. Summary of geomorphic units encountered in the study area and the associated potential impacts and recommended mitigating measures.

Group	Unit	Description	Potential Impact	Impact Duration	Mitigation measures
1	1	• Unconsolidated, yellowish brown silty - clayey SAND with some gravels, derived from completely weathered GRANITE, and reddish brown fine sandy – clayey SILT derived from weathered schists. • Hill top section, slope angle between 0 - 2° • Dense vegetation cover	• Disaggregation, compaction and destruction of soil structures • Changes in drainage systems, ground water flow, increased runoff velocities and volumes • Erosion; sheet or shallow erosions	Short term	• Unavoidable, but can be minimised • Drain off sag ponds and water-filled depressions that occur above working area from which water could seep into unstable zones; notably zones in Units 3, 5 and 6 • Reshape the surface of the area to provide controlled flow and surface runoff
	2	• Geology same as above • Seepage slope; convex upper shoulder slope; modal slope angle between 2-6° • Dense vegetation cover	• Disaggregation, compaction and destruction of soil structures • Changes in drainage systems, ground water flow, increased runoff velocities and volumes • Erosions; sheet and/or rill erosions	Short term	• Provide lined (e.g. paved, slush-grouted) or unlined surface ditches, culverts, surface drains, flumes or conduits to divert undesireable surface flows into nonproblem areas • Install suitable drainage systems to direct water away from slopes • Minimise removal of vegetative cover and revegetate bare areas as soon as possible after the completion of the development
	3	• -Geology same as above • Convex creep slope; lower shoulder slope; slope angle varies between 10 - 20° • Dense vegetation cover	• Disaggregation, compaction and destruction of soil structures • Changes in drainage systems, ground water flow, increased runoff velocities and volumes • Erosions; sheet and/or rill erosions • Shallow landslides	Short term	• Where possible, create gentle gradients and avoid steep slopes • Several mitigation measures against compaction both during and after the development : a) use wide tyres to spread the weight of vehicles/machines, a) use single or few tracks to bring vehicles to the working area, and c) till the area after compaction has taken place
2	4	• Geology same as above • Poorly exposed weathered core-stone boulders may occasionally present. • Upper midslope section; slope angle on average varies between 45-47°; however in places up to 60° • Dense vegetation cover.	• Disaggregation and destruction of soil structures • Changes in drainage systems, ground water flow, increased runoff velocities and volumes • Erosions; sheet, rill and/or gully erosions • Shallow to deep landslides, earthfalls and topples • Debris and/or mud flow	Short term	• Reduce the slope angle, apply bench terraces • If cut slopes to be created, avoid slopes with daylighting discontinuities (joints, faults, relict joints) • Apply proper drainage control, e.g. lined ditches/drains, sub-surface drains, etc. • Place additional supporting structures (e.g. soil nails, anchors, shotcrete, etc.) on potentially unstable slopes. • Reduce the load (weight, shearing stress) on slope by removing some of the rock or soil high on the slope.
	5	• Geology same as above • Poorly exposed weathered core-stone boulders may occasionally present. • Midslope section; slope angle on average varies between 20° - 30°; however in places up to 54° • Dense vegetation cover.	• Disaggregation, compaction and destruction of soil structures • Changes in drainage systems, ground water flow, increased runoff velocities and volumes • Erosions; sheet, rill and/or gully erosions • Shallow to deep landslides • Debris and/or mud flow	Short term	
	6	• Geology same as above, plus reworked clayey-silty SAND, and sandy-clayey SILT derived from *in-situ* GRANITE and SCHIST residual soils and/or from downslope movement. • Colluvial footslope, slope angle varies between 5 - 22° • Dense vegetation cover, with occasional intermittent streams and seepage	• Disaggregation, compaction and destruction of soil structures • Changes in drainage systems, ground water flow, increased runoff velocities and volumes • Erosions; sheet and/or rill erosions • Landslides • Debris and/or mud flow	Short term	• Apply and establish vegetative covers on all slope cuts, preferably fast growing plants with sturdy root systems.
3	7	• Loose, gravelly - coarse sand, derived from washed granitic soils, of 15 to 30cm thick; underlain by completely weathered Granite. • Alluvial toeslope, slope angle varies between 0 - 4°, and locally reaching up to 20° • Dense vegetation	• Disruption of drainage pattern and runoff flow regime • Siltation; deposition of debris and/or mud derived from downslope mass movements. • Risk of floods, water ponding	Short term	• Construction of siltation trap and use of culverts for streams • Provide buffer strip along streams • Grass seeding and terracing • Install suitable drainage systems to direct water away from slopes
	9	• River/stream beds; mainly of gravelly sand and boulders • River channel between 0.5 to 1.5 m wide and less than 0.5m deep.	• Increase in stream-sediment loads and consequently siltation. • Risk of river-bank erosions due to sudden increase of channel flow due to increased runoff from the upslope area. • Degradation of water quality • Flood risk down stream • Pollution of water courses, e.g. from corrosion of construction materials, oil from vehicles and plant nutrients from amenity area.	Short term	• Install siltation traps to trap sedimentation and prevent damage to the freshwater ecosystem • Provide buffer strip along streams • Prevent pollution at source.

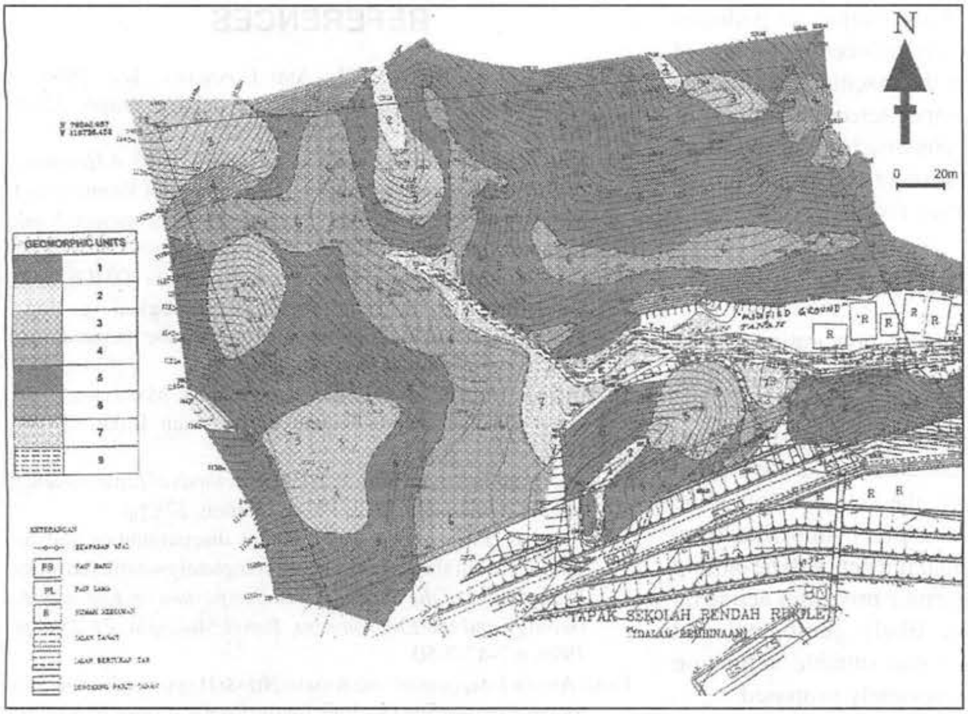

Figure 5. Map showing the zonation of the existing slopes/ landforms based on the geomorphic units.

Such compaction of soil can cause difficulty in root penetration and reduced infiltration of water. The latter will lead to increased runoff and the associated risk of erosion. Compaction may also cause waterlogging, which results from water being unable to move easily through the compacted soil.

Pollution

Most development poses some pollution to the local geological material (soils, rocks, water) during the construction phase (such as oil from vehicles and construction waste). During the dry season, the bare surfaces may also cause air pollution from fugitive dust particles due to vehicular movements. This may become acute during windy seasons. Drilling of hard rocks for blasting works and the blasting works themselves, can also release a substantial amount of particulate matter into the air. Noise pollution will also be inevitable during the construction phase.

RECOMMENDED MITIGATION MEASURES

Mitigation measures aim to avoid or minimise the impacts of development (Morris and Therivel, 1995). The following general mitigation measures are recommended to mitigate impacts during the construction and operational stages of the developments. More specific mitigation measures related to the impacts predicted for each geomorphic group/unit are summarised in Table 3.

It is not possible to cover all the details of mitigation measures because the actual form, type and extent of impacts are yet to occur in the field. However the following general guidelines are of use:

(a) Remove as little vegetation as possible during development, and revegetate bare areas as soon as possible after completion of the development.

(b) Where possible, create gentle gradients and avoid steep slopes. Create landscape according to the existing contours (contoured landscape), with appropriate siting of structures, roads and buildings. Avoid excessive cutting of natural slopes, excessive earthworks and excavation. Abandoned holes or excavations must be back filled and compacted to their original level.

(c) Install suitable drainage systems to direct water away from slopes. Divert run-off originating from upgrade with ditches or proper drainage system to prevent water from flowing over work areas and adjacent low grounds.

(d) The use of sediment or siltation traps and uncleared buffer strips along rivers can minimise siltation and sedimentation of rivers and the nearby lake.

(e) Landslides can be minimised or prevented by various established methods (*see* Tajul Anuar Jamaluddin and Ahmad Nizam Hassan, *this volume*). It is a good practice for geologists, engineers and planners to work together to tackle problems related to slope instability.

(f) Except for intended foundation purposes, compaction both during and after development can be mitigated by using wide tyres to spread the weight of vehicles/ tractors. Use of a single or few tracks to bring vehicles to the working area, will also help. The area should be tilled after compaction has taken place.

(g) Prevent pollution at source. For example, air pollution by fugitive dusts can be greatly reduced by the use of water sprinklers, noise from the machine and tractors can also be reduced with proper selection and use of mufflers. Pollution from construction or building materials such as steel and cement can be minimised with proper and secure storage rooms.

CONCLUSION

Geological inputs required for the preparation of EIA report may vary from one location to another, depending on the nature of the proposed project and geology of the project site. The case study presented herein illustrated examples of a geological study conducted at a site located in a hilly terrain. In this example, the key elements to be considered are geomorphological aspects (slope/landform classification), as the environmental impacts will be closely related to the predominant geomorphic processes acting on the slopes. By identifying the likely geological and geomorphic processes, then only can suitable mitigation and abatement measures be appropriately proposed.

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REFERENCES

DALRYMPLE, J.B., BLONG, R.J., AND CONACHER, K.J. 1968. A hypothetical nine-unit land surface model. *Geomorph., 12*:60-76.

DEPARTMENT OF ENVIRONMENT MALAYSIA (DOE), 1995. *A Handbook of EIA Guidelines*. 2nd edition. Department of Environment, Ministry of Science Technology and the Environment, Kuala Lumpur Malaysia.

DEPARTMENT OF MINERAL AND GEOSCIENCES MALAYSIA (DMG), 2000. Guidelines for the requirement of geological (geology, geotechnical and hydrogeology) inputs for the preparation of EIA report. (Seminar Note).

MINISTRY OF HOUSING AND LOCAL GOVERNMENT MALAYSIA, 1996. Garis Panduan Pembangunan di Kawasan Bukit. (Draft), 13pp.

MORRIS, P. AND THERIVEL, R. (eds.), 1995. *Methods of Environmental Impact Assessment*. UCL Press. London, 378 pp.

TAJUL ANUAR JAMALUDDIN, 1999. Relict discontinuities and the stability of cut slopes in Highly to completely weathered rocks. *Proceedings of the Second Asian Symposium on Engineering Geology and the Environment, Bangi Malaysia, 23-25 Sept. 1999*. p.7-47-7-50.

TAJUL ANUAR JAMALUDDIN AND AHMAD NIZAM HASSAN, (*this volume*). Slopes Engineering Geology for the Preparation of EIA – Case Study from the site of the Proposed National Secondary School At Ringlet, Cameron Highland, Pahang Darul Makmur. *Proc. Ann. Geol. Conf. 2001, Geol. Soc. Mal.*

YOUNG, A., 1972. *Slopes. Geomorphology*. Oliver & Boyd, Edinburgh. 288p.