3.2 Melaka

The basement of the study area is composed of Paleozoic sedimentary rocks covered by thick alluvial deposits except for the hilly area. The general geological map of study area is shown in Fig. III-6, and the geological formation and rock facies are summarized below.

Geological Age	Formation Name	Acronym of Map	Rock Facies
Holocene (to Pleistocene)	Quaternary Deposits	Qc	Coastal plain deposits, unconsolidated & semi-consolidated clay, silt & locally sand
		Qr, Qs	Qr ; Recent river deposits (Qs ; swamp deposits), unconsolidated soil, clay, silt & sand
Triassic	Granite*1	Gr	Medium to coarse-grained biotite granite
Permian	Kenny Hill Formation	Kh	Argillaceous-arenaceous facies (weakly to moderately metamorphosed shale, mudstone & sandstone)
Devonian to Silurian	Pilah Formation (Pilah Schist)	Pi	Pilah schist, intercalation of fine grained quartz-mica schist and graphite schist

Note: *1 The granite is widely distributed in the hilly area, east and north of the study area. Furthermore, the granite occurs along the west margin of the study area, which is located around the Petronas oil plant area but is restricted.

The above Quaternary deposits are classified into the coastal plain deposits and the river deposits. The coastal plain deposits are widely distributed from coastline to inland over a distance of more than 3 km. On the other hand, the river deposits spread out in the inland habitual flood inundation area along the major rivers such as Sungai Melaka, Sungai Malim and Sungai Leleh. In this case, the boundary between the distribution areas of both deposits is indefinite as a whole, owing to the complication by the effects of several phases of marine transgression and regression.

The coastal plain deposits consist of unconsolidated clay and silty/sandy clay, with thinner intercalated layers and lenses of sand, peat and rare gravel, which correspond to complex sediments of marine and nonmarine strata, i.e., present and former beach sand, lagoon mud and marine clay. The intermixing of marine and non-marine strata in the unconsolidated sediments underlying the coastal plain in the study area can be explained as the results of major fluctuation in sea level caused by glaciation and deglaciation in the Pleistocene. On the other hand, the recent river deposits consist of loose and soft unconsolidated clay, silt and locally very clayey or silty sand.

The Kenny Hill formation occurs in the Tanjong Minyak area and consists of monotonous sequence of interbedded shale, mudstone and sandstone. These rocks are almost invariably altered by the effects of regional or contact metamorphism, so that the shale and mudstone is phyllitic, commonly showing foliation and incipient cleavage.

The Pilar formation is located in the hilly area and the isolated hills dotted in the alluvial plain. This formation is mainly composed of quartz-mica schist and graphite schist. Most of the parent rocks of this formation are likely to be argillaceous rocks such as shale and mudstone. In addition, the mixed rock facies (argillaceous and arenaceous rocks as parent rocks) are widespread at the eastern area of the study site. The rock facies of both the Kenny Hill formation and the Pilar formation are initially hard, but frequently transformed to be soft by humid tropical conditions and weathering.

Furthermore, thick soils and weathered rocks frequently cover the surface ground in the study area. In this case, these soils have been termed as 'Melaka Series', which belong to a member of laterite (lateritic soil), and are characterized by a bright red colour due to oxidation of the contained iron to ferric state (hematite) under humid tropical surface conditions. They show usually about 1 m or more in thickness.

4. SEDIMENT RUN-OFF

The recent intensive land development tends to cause serious soil erosion within the area and bring sediment to the lower reaches. Due to the sedimentation, the flood mitigation capacity of the drainage facility is remarkably reduced, and at the same time, the environment in and around the drainage facility is seriously deteriorated.

The actual sediment runoff discharge has been gauged in Penang and Kuala Lumpur, although the gauging has not been made in the study area. The results of gauging on sediment runoff are as shown in the following table.

Catchment	Condition of Land Use	Area (km^2)	Rainfall (mm)	Sediment Run-off ($t/km^2/year$)	Data Source
Sg. Air Hitam, Penang	Tropical rainforest	4.75	2,580	74.49	Wan Ruslan, 1995
Sg. Air Hitam, Penang	Tropical rainforest in upper part, stable urban area in lower	8.87	2,580	376.59	Wan Ruslan, 1995
Sg. Relau, Penang	Disturbed forest and semi-urban	0.553	1,830	911.09	Wan Ruslan, 1995
Sg. Relau, Penang	Rapidly urbanising, quarrying, construction	11.523	1,830	911.09	Wan Ruslan, 1995
Sg. Jinjang (1), Kuala Lumpur	Newly urbanising	10.3	2,400	1,056	Balamurugan, 1991
Sg. Jinjang (2), Kuala Lumpur	Tin mining and urbanising	27.1	2,300	2,283	Balamurugan, 1991
Sg. Kelang (1), Kuala Lumpur	Newly urbanising	14.2	2,400	1,480	Balamurugan, 1991
Sg. Kelang (2), Kuala Lumpur	Newly urbanising and mature urban	29.0	2,300	1,372	Balamurugan, 1991
Sg. Keroh, Kuala Lumpur	Urban and industrial	35.9	2,200	1,759	Balamurugan, 1991
Sg. Batu, Kuala Lumpur	Forest and urban	145	2,400	1,265	Balamurugan, 1991
Mengkuang Heights, Kuala Lumpur	Bare, steep construction site	0.21	2,400	330,821	Mykura, 1989
Sg. Sering, Kuala Lumpur	27% bare construction site	6.50	2,400	42,076	Mykura, 1989
Sg. Gombak, Jln Pekeliling, Kuala Lumpur	Forest and urban	140	2,400	1,157	Douglas, 1978

* These data were taken from the 'Guidelines for Prevention and Control of Soil Erosion and Siltation in Malaysia, DOE, 1996')

The above table reveals that the natural reserve area yields 75 to 380 ton/km^2/year of annual sediment runoff as shown in case of Sg. Air Hitan in Penang. On the other hand, the annual sediment runoff from the land development area increases to more than 900 ton/km^2/year. Mengkuang Height and Sg. Sering in the above table in particular yields a remarkably large sediment runoff of 42,000 to 330,000 ton/km^2/year. The geological conditions of these two areas are dominated by deeply weathered rocks, particularly granite, where cutting slope causes numerous gully erosions, leading to a large amount of sediment runoff.

As stated above, the sediment runoff varies according to the actual land use in the river basin and the geological conditions (i.e., soil erodibility). Moreover, the sediment runoff volume also could be varied by rainfall intensity, slope length, slope gradient, and erosion control practice. Thus, the sediment runoff volume varies according to various factors, while the gauging record on the actual sediment runoff volume is limited. Under such conditions, the 'Urban Drainage Design Standards and Procedures for Peninsular Malaysia, DID, 1975' specifies 67 yard^3/acre as the standard sediment runoff volume from land development area for a period of 18 months. This standard volume corresponds to 8,440 ton/km^2/year and is larger than the aforesaid actual sediment runoff volume of 900 to 2,300 ton/km^2/year gauged in land development area. In due consideration of variable unknown factors of the study area, however, the standard value could be provisionally applied to the design of sediment control facilities in such cases as:

(a) If the intensive land development is made but any erosion control practice is not made to the area; and

(b) If the geological condition in the area is fare and not dominated by the deeply weathered rocks.

If the area still preserves its natural conditions without intensive land development, or if erosion control practice is made to the area, the actual sediment runoff volume could be less than 1,000 ton/km^2/year. On the contrary, if land development is introduced to the area dominated by deeply weathered rocks, the possible sediment runoff volume could be far larger than the above standard volume of 8,440 ton/km^2/year, and vary according to the particularities of the weathered rocks.

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APPENDIX

APPENDIX I

REFERENCE ON LATERITIC SOILS (LATERITE)

(1) General

Lateritic soils (laterite) are most famous superficial soils in humid tropical countries, however, due to their highly variable nature, the term lateritic soils (laterite) have been used to rather loosely in those countries. The original term laterite was applied to the soft material which hardens on exposure. This term was also used to describe earthy iron and aluminium rich materials that do not harden, and often such soils were referred to simply as lateritic soils. In recent years, it is generally agreed by most workers that lateritic soils (laterite) are a highly weathered material rich in secondary oxides of iron, aluminium or both. It is nearly devoid of bases and primary silicates, but it may contain large amounts of quartz and kaolinite.

In Peninsular Malaysia, the term lateritic soils (laterite) is mainly used to describe soils which have indurated ferruginous layers or hardened ironstone, concretions and gravels, in this case, iron-coated (laterised) parent materials which are formed in-situ are also included in the definition of laterite. Furthermore, in recent years, detailed soil surveys including geomorphological studies have led to a better understanding of the nature and properties of these soils. The soil classification and soil profile of lateritic soils (laterite) in Peninsular Malaysia, which are based on the results of the recent surveys, are summarized as follows. Furthermore, some physical properties of those soils on the basis of collected data in the study area are also summarized as bellow.

(2) Classification of Lateritic Soils in Peninsular Malaysia

In Peninsular Malaysia, lateritic soils are classified into the following 7 series on the basis of soil characteristics: Changloon, Chuping, Gajah Mati, Melaka, Pedu, Pokok Sena and Terap series. In the study areas, among of these soil series, Gajah Mati series is distributed in Sungai Petani and Melaka series is distributed in Melaka, respectively. The soil types of these two soil series are basically characterized by the gravel clayey facies and frequently porous structure, and can be classified into well-drained soil.

Furthermore, in Peninsular Malaysia, the existence of two main groups as for lateritic soils has been identified by soil scientists. (Refer to 'Lateritic soils in Peninsular Malaysia, S. Paramananthan & M. Tharmarajan, 1983' and 'Reworked petroplinthic soils and their landscapes in Peninsular Malaysia, Lim Jit Sai, 1992'). These are as follows.

- Soils with iron-coated or iron-indurated parent material (in-situ type)
- Soils with petroplinthite gravel (reworked type)

The main distinction between these two groups of lateritic soils is that the soils with iron-coated parent materials are considered to be essentially in-situ type, while those with petroplinthite gravels are considered to be reworked type, and petroplinthite gravels are considered to lie unconformably over an eroded plinthite layer.

< Soils with iron-coated or iron-indurated parent material (in-situ type) >

These are materials which have been indurated by iron. They are essentially in-situ type, and bedding and structure of parent material is retained. Such materials are common over iron-rich rocks such as shale, schist, basalt, andesite and amphiborite. On sedimentary and metamorphic rocks, these materials tend to be platy while on igneous rocks they frequently present fine gravel. It is considered that these materials were formed by iron being released during weathering and coating the rock fragments.

< Soils with petroplinthite gravel (reworked type) >

The plinthite is used to describe the variegated material which commonly occurs the pallid zone (saprolitic zone). Plinthite is defined as an iron-rich, humus-poor mixture of clay with quartz and other diluents. It commonly occurs as dark red or red mottles, which form a reticulate pattern with light gray to white matrix. The mottles in the plinthite have sharp boundaries. Plinthite is probably formed in a horizon that saturated with water at some season followed by a dry period. In this case, this wetting and drying is essential for iron to segregate.

When plinthite is exposed it hardens irreversibly to petroplinthite. Petroplinthite occur in-situ as vesicular or nodular particles. The nodular petroplinthite is common in Peninsular Malaysia and occur as gravel or ironstone of various shapes and size. Moreover, the nodular petroplinthic gravels are believed to have been formed by the reworking of the soft plinthite into the nodular shape before hardening take place. The size and roundness of these nodular gravels depend on the degree of reworking and instance of transportation. Furthermore, recementation of petroplinthite occurs in some places to form large boulders.

Furthermore, taking the collected data and the results of field reconnaissance survey into consideration, lateritic soils of the study areas, Sungai Petani and Melaka, are characterized by abundantly containing petroplinthite gravels, therefore, it can be judged that they correspond to the lateritic soils of 'reworked type'.

(3) Standard Profile of Lateritic Soil

The standard profile (stratification) of lateritic soils can be divided into five zones and they are summarized as below.

Layer	Zone	Description
1st layer	Soil cover zone	Red friable free draining clay. Often removed by erosion. (Surface soil zone)
2nd layer	Ferruginous crust zone	Mixture of petroplinthite gravel, stones and boulders. Matrix is composed of above soil materials. (Lateritic soil zone)
3rd layer	Variegated zone	Soft impervious, massive mottled layer which harden on exposure. (Plinthite zone)
4th layer	Pallid zone	Soft impervious, light gray, massive silty clay. Weathered rock fragments may be present. (Saprolite zone)
5th layer	Unweathered rock zone	Unweathered rock zone. (Fresh rock zone)

The soil cover zone consists of red or reddish brown, friable iron-rich clay which is free-draining. This soil cover zone is of varying thickness with ranging from 0.1 m to 3 m. In some places this soil cover zone is eroded exposing the ferruginous crust zone below.

The ferruginous crust zone in Peninsular Malaysia is frequently made up of nodular petroplinthite embedded in a matrix similar to the surface soil cover, and this zone is commonly equivalent to lateritic soils in a narrow sense. In general, the thickness of this layer is extremely variable, within 1 m in thickness at Sungai Petani and 1 to 2 m (rarely 2 m or more) in thickness at Melaka*.

* In Peninsular Malaysia, by convention among research workers as for lateritic soils, unless the petroplinthite and/or iron-coated layers exceed 25 cm in thickness, the soil is not considered to be a lateritic or petroplinthic soil.

The variegated zone consists of highly variegated and massive impervious layer of plinthite. The plinthite has many reddish and whitish streaks forming a honeycomb structure.

The pallid zone is composed of a pale coloured massive weathered rock and is corresponds to saprolite in the study areas. In general, this zone is well developed over iron-poor argillaceous rocks such as shale which is distributed in study areas. The colours of this layer are characterized by light gray to white with few fine reddish spots which harden on exposure. Basically, this layer is impervious because of indicating massive structure and high silt contents.

Furthermore, the unweathered rock zone corresponds to fresh rock zone.

(4) Physical Properties of Lateritic Soils

Lateritic soils are characterized by a highly weathered material rich in secondary oxides of iron, aluminum or both iron and aluminum. The chemical components of typical lateritic soils in the study area, Sungai Petani, are tabulated as below*. In this case, the sampling points are located in descending order of same profile, from sample 1 to sample 5. These data reveal that samples of ferruginous crust zone (i.e. lateritic soil layer) contain 60 to 72 % sesqioxidide (Fe_2O_3+Al_2O_3).

* These data are taken from the report on 'General geology of Sungai Petani, Kedah Area, with a study of slope stability at the North-south Highway, Gurun-Sungai Petani, Geology Department in University Malaysia, 1991-1992'.

Components	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	Ferruginous crust zone	**Ferruginous crust zone**	**Ferruginous crust zone**	**Variegated zone**	**Variegated zone**
Fe_20_3	40.5	32.4	22.2	18.1	15.5
$A1_20_3$	31.5	35.7	37.5	38.5	39.5
$Si0_2$	23.3	32.2	38.5	38.5	43.3
K_20	1.7	2.1	4.0	42.9	4.3
$Ti0_2$	0.8	0.9	1.4	3.4	1.0
Na_20	0.2	0.2	0.2	0.4	0.5
Ca0	0.1	0.1	0.1	0.1	0.1
P_20_5	-	-	-	-	-
Mn0	-	-	-	-	-
Mg0	-	-	0.1	-	0.1
Total	98.1	103.7	104.8	104.0	104.3
Sesquioxide ($A1_20_3$+Fe_20_3)	72.0	68.2	59.7	56.5	55.0

*Ferruginous crust zones (sample 1 to 3) correspond to laterite layer, and variegated zones correspond to plinthite layer, respectively.

The results of Atterberg limits test as for typical lateritic soils at Sungai Petani are also tabulated as below. In this case, the fine components of lateritic soils show low to medium plasticity and values of specific gravity indicate to be in harmony with sesquioxide (Fe_2O_3+Al_2O_3) contents.

Components	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	Ferruginous crust zone	**Ferruginous crust zone**	**Ferruginous crust zone**	**Variegated zone**	**Variegated zone**
Liquid limit (%)	27.5	43.7	60.0	43.0	48.1
Plastic limit (%)	13.4	24.1	33.2	22.6	25.5
Plasticity index	14.1	19.6	26.8	20.4	22.6
Specific gravity	2.86	2.70	2.70	2.50	2.43

* Plasticity index = Liquid limit (%) – Plastic limit (%)

Lateritic soils contain whole grain size from gravel to silt/clay and occasionally even larger material, and are commonly characterized by content of abundant gravel (about 65 to 75 %). Furthermore, the soil classification of fine-grained components is classified as CL (inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays). Collected data as for components of grain size of lateritic soils are shown as bellow.

Depth (cm)	**Clay (%)**	**Silt (%)**	**Fine sand (%)**	**Coarse sand (%)**	**Gravel (%)**
0 – 10 (Top soil, A horizon)	34.7	3.9	10.1	16.3	35.0
10 – 20 (Transition zone to B horizon)	26.4	1.4	3.2	5.0	64.0
20 – 70 (Ferruginous crust zone, B horizon)	19.6	0.8	2.7	2.9	74.0
70 or more (Ferruginous crust zone, B horizon)	19.3	2.1	1.5	2.1	75.0

* Collected location of sampling data : Kg. Seberang, Gajah, Tangkak, Muar

APPENDIX 2

REFERENCE ON THE PREDICTION OF SEDIMENT RUNOFF

In many countries, including Peninsular Malaysia, the prediction of sediment runoff (soil loss) is widely performed by the use of Universal Soil Loss Equation (USLE), which was published by Wischmeier and Smith. This equation is shown as follows.

$$\mathbf{A = R \times K \times L \times S \times C \times P}$$

where, A : Computed soil loss per area

R : A rainfall erosivity factor converted to erosion index units (EI-units) for the period of consideration

K : A soil erodibility factor depending on soil types, and the EI is a measure of the erosive force of a specific rain event

L : Slope length factor; the ratio of soil loss from the field slope length to that from 22.1 m length, on the same soil type and gradient (dimensionless factor)

S : Slope gradient factor; the ratio of soil loss from the field gradient to that from 9 % slope, on the same soil type and slope length (dimensionless factor)

C : Cropping management factor; the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated (dimensionless factor, C=1 in the bare surface)

P : Conservation practice factor; the ratio of soil loss with contouring, strip-cropping or terracing to that with straight row farming, up-and-down slope (dimensionless factor, P=1 in the bare surface)

On applying the USLE equation, the decision of some factor such as an erodibility factor should be paid attention, because in principle, this equation is for farmland and its direct application in planning for storage capacity of sediment basin is somewhat impractical. In addition, it cannot be definitely quantified with respect to the sediment runoff from large gullies and/or from slope surfaces during construction.

In this case, if the land development is planned at the area consisting of thick lateritic soils and/or deeply weathered rocks such as granites and any erosion control measures is not performed at the sites, there is a large possibility that the possible sediment runoff volume is far larger than the values getting by the above USLE formula.