VOLUME 3 – SECTOR III

SOIL AND GEOLOGY

THE STUDY ON INTEGRATED URBAN DRAINAGE IMPROVEMENT FOR MELAKA AND SUNGAI PETANI IN MALAYSIA

FINAL REPORT

VOLUME 3: SUPPORTING REPORT ON DRAINAGE STRUCTURE PLAN

SECTOR III: SOIL AND GEOLOGY

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SOIL AND GEOLOGY

1. TOPOGRAPHY

1.1 Sungai Petani

This study area is topographically classified into three groups; namely, (1) the low-lying flat plain, (2) the slightly sloping area, and (3) the hilly area.

The rivers in this study area originate in the hilly area, flow down westward through the slightly sloping area and the low-lying flat plain, and finally into the estuary of Sungai Merbok. Sungai Lalang, Sungai Petani and Sungai Pasir are the three large tributaries of Sungai Merbok, which are accompanied by a number of small tributaries with complicated drainage patterns in the study area. These rivers have frequently caused flood overflow, which progressively developed the thick alluvial deposits along the river and formed the low-lying flat plain. Furthermore, an extensive swamp spreads out in this low-lying flat plain, especially along Sungai Merbok, and a part of it is used as paddy field.

The slightly sloping area with the elevation of 20 m or less spreads westward and northwestward, where the existing major built-up areas such as the city proper of Sungai Petani (i.e., the urban area, industrial area and residential area) are located. The hilly areas lie along the eastern and southern borders of the study area with elevations of 20 to 100 m, forming the watershed boundary between the catchment area of Sungai Merbok and of Sungai Muda. A part of the hilly areas has been intensively excavated due to land development and the civil construction activities such as highway construction, etc.

1.2 Melaka

The topography of the study area is classified into three groups; namely, (1) broad alluvial plain area, (2) pedimental area, and (3) hilly area. Sungai Melaka, Sungai Malim and Sungai Leleh are the three major rivers with gentle gradients, and they flow into the Melaka Strait. Sungai Melaka originates in the mountainous area of the State of Negeri Sembilan and the river basin covers a total of approximately 60 km^2.

The alluvial plain area is composed of the coastal plain and the river flood plain, which had been formed by sedimentation of the above-mentioned rivers. The coastal plain is generally narrow, while the river flood plain spreads out from the coastline toward inland for more than

3 km. Furthermore, the river flood plain is dotted with several isolated hills (e.g., Bukit China, Bukit Piatu and Bukit Peringgit), which are probably the erosion remnants of a resistant bed in the sedimentary rock series.

The alluvial plain was formerly utilized as a paddy field and/or settlement area, but is now being intensively developed as residential and industrial area. A wide swamp was also previously seen along Sungai Melaka, about 3 to 8 km upstream from the river mouth. This swamp was probably formed due to the insufficient drainage capacity of Sungai Melaka. However, a greater part of this swamp is now also being developed as residential and industrial areas.

The pedimental area is relatively small and distributed at the foot of the hilly area; however, a part of this area has been transformed to a flat terrain due to intensive land development as residential and industrial areas. The major hilly area with an elevation of 70 to 110 m tends to lie around the northern and northeastern part of the study area, while the minor hilly area with an elevation of 20 to 30 m exists along the coastal line at Tangga Batu. It is also distributed along Cheng to Bertam, which is located on the right side of Sungai Cheng, generally ranging from 30 to 100 m in elevation. An intensive land development is also being made to several parts of these hilly areas, Ayer Keroh, Bukit Katil, Paya Rumput and Tanjong Minyak in particular, where the original hilly terrain is no longer seen.

2. SURFACE SOIL CONDITIONS AND GROUND INFILTRATION CAPACITY

The 'Generalized Soil Map, Peninsular Malaysia, MOA (1970)' was collected to overview the soil condition of the study area. The map shows that the soil type in both Sungai Petani and Melaka is represented by gley soil, saline gley soil and acid sulphate soil in the coastal plain area, and lateritic soil (laterite) in the hilly areas (refer to Fig. III-1 and III-2). The soil conditions on the coastal plain by the 'Reconnaissance Soil Map, Peninsular Malaysia, MOA (1968)' are classified into the Kranji, Chengai (Sungai Petani area) and Linau-sedu (Melaka area) types based upon flola facies. These soil types entirely belong to the acid sulphate soil group. The soil distributions described on the soil map are in general agreement with the information obtained from the field reconnaissance survey of study areas, excluding the distribution area of recent river deposits.

The geological investigation and soil test performed by PWD and DID in/around study areas were collected in this study. The collected data covers the results of a total of 33 boreholes at 8 sites, i.e., 7 boreholes in Sungai Petani and 26 boreholes in Melaka. The locations of investigation site are shown in Fig. III-3 and III-4. These collected data are summarized and shown in 'Vol. 6, Data Book'. In addition, these collected data were also incorporated to confirm the soil and geological conditions in the study areas.

2.1 Coastal Plain Areas

The soil conditions of coastal plain areas at Sungai Petani and Melaka consist of alluvial soils such as gley soil and acid sulphate soil. There is a strong resemblance between the surface soil conditions of coastal plain areas of both Sungai Petani and Melaka. These soils are basically characterized with clayey facies and are estimated to be about 1 m or less in thickness. Furthermore, these soils can be classified into low drainage soil (refer to the 'Guideline of Major Soil Series in Peninsular Malaysia, MOA'), and it is considered that permeable characteristics of soils are low as a whole.

The geological conditions of the shallow depth of coastal plain areas are mostly composed of typical coastal deposits made up of dominantly unconsolidated clay and silty/sandy clay with thinner intercalated layers and lenses of sand. Especially, at Melaka, the collected data as outlined the following description has resulted in the detailed geological conditions.

The geological conditions in urban area of Melaka consist of silty clay and clayey silt up to about 20 m or more in depth. The drilling data reveal an existence of poor ground (i.e., N-values by standard penetration test indicate only 5 to 6 or less) of up to about 10 m or more in depth. At the shallow depth within 5 m, they can be mostly classified into CH (inorganic clays of high plasticity, fat clays), MH (inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts) and OH (organic clays of medium to high plasticity). The feature described above suggests that the geological conditions around this area can be judged as impermeable layer. Furthermore, according to the drilling data, this area is also characterized with a shallow groundwater level such as GL.(-) 0.3 to 1.2 m as a whole.

In this area, the coastal plain deposits rarely intercalate the thin sand layer (based on the data of drilling holes BHR2, BH4 and BH5 at Jalan Bachang to Batu Berendam). However, the grain size component of sand layer contains about 42 to 48 % as fine grained silt/clay, which can be computed as low permeable layer (less than 1×10-5 cm/sec as coefficient of permeability) by Harzen's and Casagrande's formulas. Moreover, according to the results of drilling investigation, a part of the surface ground consists of thin gravel layer; however, there is a large possibility that this gravel material was transported from borrow site, and was compacted prior to the various civil works such as road construction, etc.

Around the coastal line, for example, the estuaries of Sungai Gelam, Sungai Klebang and Sungai Sri Melaka, the soils and geological conditions at the shallow depth are composed of sandy clay and show poor ground conditions. This signifies 3 or less as N-values by the standard penetration test, up to about 6 to 10 m in depth. The grain size component of silt and clay occupies about 80% or more. In this case, the geological conditions can be judged as impermeable layer. Furthermore, according to the drilling data, this area is also characterized with a shallow groundwater level such as GL.(-) 0.6 to 1.2 m as a whole.

At the inland area of the coastal plain, the drilling data of two sites, Kerubong Melaka (Cheng area) and Tanjung Minyak, were collected. These data revealed that geological conditions at the shallow depth consist of silty clay and clayey silt, which can be classified into MH, OH and CH, and also show poor ground conditions (less than 3 as N values by the standard penetration test) up to about 8 m in depth. These data show that geological conditions in this area have impermeable characteristics as a whole. Furthermore, according to the drilling data, this area is also characterized with a shallow groundwater level such as GL.(-) 1.0 to 1.4 m (Kerubong Melaka) and GL.(-) 2.1 to 2.2 m (Tanjung Minyak).

Recent river deposits restrictedly occur around the major rivers such as Sungai Melaka, Sungai Malim and Sungai Leleh and consist of loose and soft unconsolidated clay, silt and locally very clayey or silty sand. In addition, the river deposits of Sungai Melaka are characterized with rich sandy materials at the upstream area from Kerubong.

The results of drilling investigation reveal that the geological conditions around the surface ground at Kerubong Melaka consist of sand and gravel layers ranging from 1 to 2 m in thickness. There is a large possibility that these sand and gravel materials were transported from the borrow site, and were compacted prior to the various civil works and construction.

These accumulated data and results of field reconnaissance survey indicate that the soil and geological conditions of shallow depth at the coastal plain areas are mainly composed of impermeable layer, silty clay and clayey silt etc., and are characterized by the presence of shallow groundwater level. From these facts, it is concluded that the application of infiltration measures at the coastal plain areas in the study areas of Sungai Petani and Melaka is difficult because the infiltration capacity is generally low and the groundwater table is situated on the shallow subsurface.

According to the collected data such as borehole profile, the surface ground in the urban area of Sungai Petani is covered by medium dense silty sand layer, which shows reddish brown due to ferric oxidation. This area is also characterized by the presence of shallow groundwater level such as about GL.(-) 1.2 m, and it is highly impossible to apply infiltration measures in this area.

At the previous swamp area in the coastal plains of Sungai Petani and Melaka, the soil and geological conditions show loose clay facies including organic materials, and the groundwater conditions are located at shallow depth. In this case, if these areas were filled with soil material such as lateritic soils for urban development, it also hardly seems possible that infiltration measures apply in this area.

2.2 Hilly Areas

The soil conditions of the hilly area of the study sites are mostly made up of lateritic soils. The standard profile for distribution of lateritic soils can be divided into 5 zones, and in general, the second layer of standard profile, which is named as ferruginous crust zone, is equivalent to lateritic soil layer in a narrow sense. The thickness of this layer is extremely variable: within 1 m at Sungai Petani and 1 to 2 m (rarely 2 m or more) at Melaka.

Lateritic soils of the study areas, Sungai Petani and Melaka, are generally clayey in texture including the topsoil layer due to the basement rocks rich in argillaceous sedimentary rocks and metamorphic rocks (shale and schist etc.) as parent materials, which give rise to clayey fine materials by weathering. Furthermore, these lateritic soils mostly show granular structure, which has somewhat friable tendency, so that soil facies are not compacted in spite of a high content of gravel. It is considered that these parent materials are easily weathered, and oxidation phenomena in soils proceed rapidly, therefore, the soils have a granular structure. In general, these lateritic soils have a high void ratio and large macro-pores. Therefore, lateritic soils generally show high permeability as a whole. In some places at Melaka, large ferruginous boulders and large laterised angular fragments are scattered in the lateritic soils.

On the other hand, underlying variegated layer (plinthite layer) and pallid layer, which correspond to a transitional zone between lateritic soils and unweathered rocks, indicate a different permeable characteristic in comparison with the lateritic soils. The pallid layer corresponds to a saprolite, which refers to materials to be in a stage of transition from rock to soil, in other words it signifies strongly weathered rocks. In the study areas, the parent material is mostly composed of argillaceous rocks such as shale and schist. Therefore, the saprolite is accompanied with a distinct variegated layer consisting of a clay to silty clay with clear white or gray matrix and red segregation of iron which forms soft material called plinthite. The variegated zone (plinthite layer) and pallid zone (saprolite) have low permeability due to the massive structure and clay to silty facies. At the field, it also easily tends to cause ponding of water at the surface ground after conditions of either prolonged or high intensity rainfall when the saprolite is situated near the surface ground.

Furthermore, geological conditions of the study areas are mainly represented by argillaceous rocks, which are composed of shale (Sungai Petani area) and schist (Melaka area, parent rock is shale). These basement rocks are frequently soft in spite of the remaining original bedding, and show low permeable characteristics.

The features of surficial ground conditions at hilly areas described above indicate that soil and geological conditions are unfavorable for application of infiltration measures, excluding lateritic soils. However, in the case of lateritic soils, the thickness in the ground will become a problem.

In the projected residential and industry development sites in the hilly areas, the original ground conditions have been excavated on a large scale for land leveling and it is inferred that the remaining development sites will be excavated prior to construction. As a result, lateritic soils have almost been removed from the ground, and/or compacted leading to low permeable characteristics. Field evidences show that the variegated zone (plinthite layer) and the pallid zone (saprolite), which are characterized by low permeable characteristics, can be found easily on the ground surface in the development areas.

At the remaining area of thin lateritic soils or at the exposed areas of the variegated zone (plinthite layer) and/or pallid zone (saprolite) on the land development areas, wet ground conditions can be easily observed. That is, the ground view under conditions of heavy rainfall, and hexagonal patterns (in other words, mud cracks) is finally formed on the ground when the ground dries up. From these facts it may be inferred that evaporation on the ground is predominant in comparison with infiltration in the ground. Due to the soil and geological conditions in the land development area of the study sites of Sungai Petani and Melaka, it is concluded that the application of infiltration facilities is difficult because the infiltration capacity in the actual ground conditions shows highly low permeable characteristics.

3. GEOLOGICAL CONDITION OF THE STUDY AREAS

3.1 Sungai Petani

The major basement of the study area consists of Paleozoic sedimentary rocks, and thick alluvial deposits overlie these basement rocks at the flat plain area. The general geological map of the study area is shown in Fig. III-5 and the geological formation and rock facies of this area are summarized below.

Geological Age	Formation Name	Acronym of Map	Rock Facies
Holocene (to Pleistocene)	Quaternary Deposits	**Qf, Qs**	Coastal plain deposits (Qf ; Estuarine flood deposits, Qs ; Swamp deposits), Unconsolidated clay, silt & locally sand
		Qr	Recent river deposits, unconsolidated soil, clay, silt & sand
Cretaceous to Jurassic	Granite*[1]	**Gr**	Medium-grained biotite granite
Carboniferous to Ordovician	Sungai Petani Formation*[2]	**Sp**	Argillaceous facies (shale, mudstone & phyllitic shale) and arenaceous facies (sandstone & orthoquartzite)
Cambrian	Jerai formation*[1]	**Je**	Metamorphosed argillaceous facies (schist) and metamorphosed arenaceous facies (quartzite)

Note: *1 These formations are distributed at the Jerai mountain area, which is located on about 14 km northwest of Sungai Petani city, and are not exposed in the study area.

Note: *2 This formation is named as Mahang formation on the geological map 'Bedung area' (GSDM) of eastern area of Sungai Petani. In this case, 'Sungai Petani formation' is homologous with 'Mahang formation'.

The Quaternary deposits are classified into coastal plain deposits (the estuarine flood deposits) and river deposits. The coastal plain deposits are mainly seen in the swamp area along Sungai Merbok, and are characterized by extremely poor ground conditions, still very silty or clayey. The recent river deposits, which consist of loose and soft unconsolidated clay, silt and sand, are distributed along the major rivers such as Sungai Lalang, Sungai Petani and Sungai Pasir.

The Sungai Petani formation constitutes the basement rock in the study area and is classified into two rock units. The first rock unit includes a greatly predominant argillaceous facies, which are commonly ferruginous and subject to lateritization and sometimes change to phyllitic shale derived from shale and mudstone. The second rock unit is made up of arenaceous facies consisting of sandstone and orthoquartzite, which make the more prominent topographic features such as Bukit Sungai Pasir and Bukit Berapit. These facies are interbedded conformably with one another. The rocks of this formation are initially hard, but frequently transformed to be soft under humid tropical surface conditions.

Furthermore, the surface ground in the study area is almost all covered by thick soils and weathered rocks. These soils have been termed as 'Gajah Mati Series', which belong to a member of laterite (lateritic soil) and are characterized by a bright red colour due to the oxidation of the contained iron to a ferric state (hematite) under humid tropical surface conditions. They commonly have about 0.5 m to 1.0 m in thickness.