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CREAM
Construction Research Institute of Malaysia

GUIDELINES FOR CONSTRUCTION ON PEAT AND ORGANIC SOILS IN MALAYSIA

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FOREWORD

Peat occurs over about 25,000 square km in Malaysia corresponding to about 8% of the country's land area. Malaysia despite being a relatively small country area has, on a country basis, the 9th largest peat area in the world. About 69 % of Malaysia's peat area is in Sarawak. Significant parts of major towns like Sibu and Kuching are founded over peat.

Construction on peat is always more problematic than on soft clay with greater difficulties in access, earthworks and settlements. Over the last 25 years the industry has made appreciable advances in methods of construction over peat.

This document **"GUIDELINES FOR CONSTRUCTION ON PEAT AND ORGANIC SOILS IN MALAYSIA"** commissioned by Construction Research Institute of Malaysia (CREAM) a research institute fully funded by CIDB Malaysia and supported by the Ministry of Works Malaysia was prepared by a committee of practising engineers, geologists, and academics. The guidelines constitute an embodiment of design and construction experience developed from practice in Malaysia over the last 30 years.

This document contains maps that show the locations of peat, classification systems, information on methods of testing, methodology for obtaining parameters, design and construction. Case histories reflective of good practice are included. This document is however not a code or a set of specifications. Engineering judgement must be applied to determine whether the methods and techniques contained in the document are applicable.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	
ha	Hectare
km	Kilometre
m	Metre
S_u	Undrained shear strength (total stress)
S_{uv}	Vane shear strength
Φ’	Effective fiction angle
σ_{vo}’	Initial in-situ effective vertical stress
C_c	Coefficient of primary consolidation
C_α	Coefficient of secondary consolidation
C	Correction factor for the calculation of organic content
c_v	Coefficient of Consolidation
e_o	Initial void ratio
e	Void ratio’
$\Delta\sigma_v$	Increment in vertical stress
t	Time
t_p	Time corresponding to end of primary consolidation
k	Coefficient of permeability
M	Critical state strength parameter
H	Thickness of soft clay
γd, ρd	Dry density
γb, ρ	Bulk density
f_s	Sleeve friction
G_s	Specific gravity
q_t	Tip resistance
R_f	Cone penetration test friction ratio
τ_h	Horizontal shear stress
τ_v	Vertical shear stress
ϕ’	Effective friction angle
μ	Pore Pressure
Abbreviation	
CPT	Cone Penetration Test
LL	Liquid limit
LOI	Loss on Ignition
N	SPT N Value
OC	Organic content
SPT	Standard Penetration Test
JMG	Jabatan Mineral dan Geosains Malaysia
msl	Mean sea level
PSF	Peat swamp forest
CRS	Constant Rate of Strain
CD	Drained triaxial test
CU	Consolidated undrained triaxial test

CHAPTER 1: FORMATION AND DISTRIBUTION OF PEAT LANDS

1.1 Introduction

Peat is found in many countries throughout the world and peatlands constitute about 3% of the land surface of the Earth. Table 1 - 1 shows the distribution of peatlands around the world.

Table 1 - 1. Distribution of peat deposit around the world (Mesri and Ajlouni, 2007)

Country	Area (km^2)	Country	Area (km^2)
Canada	1,500,000	Germany	16,000
U.S.S.R (the former)	1,500,000	Brazil	15,000
United States	600,000	Ireland	14,000
Indonesia	170,000	Uganda	14,000
Finland	100,000	Poland	13,000
Sweden	70,000	Falklands	12,000
China	42,000	Chile	11,000
Norway	30,000	Zambia	11,000
Malaysia	25,000	26 other countries	220 to 10,000

More than 95% of the total peatlands of the world are concentrated in the temperate climates of the Northern Hemisphere, which Canada and Russia having the greatest concentration of peatlands with a combined area of over 300 million ha.

Peat also can be found in the tropical climates, wherever the conditions are favourable for its formation. The tropical peatlands are scattered in a few areas in Africa and parts of Central America, but two thirds of its world’s total area of 30 million ha is reported to be found in Southeast Asia.

The largest area of tropical peatland is located on the islands of Borneo and Sumatra. It can also be found significantly in other parts of Indonesia, Malaysia, Vietnam, Thailand and Philippines.

1.2 Formation of Peat

In the tropics like Malaysia and Indonesia, peat deposits occur in both highlands and lowland areas. They are generally termed as basin and valley peat respectively. However, the lowland or basin peat is more extensive and occurs in low-lying poorly drained depressions or basin in the coastal areas. Basin peat is usually found on the inward edge of the mangrove swamps along the coast. The individual peat bodies may range from a few to 100,000 ha and they generally have a dome-shaped surface. The peat is generally classified as the ombrogenous or rain fed peat, and is poor in nutrients (oligotrophic). Due to coastal and alluvial geomorphology they are often elongated and irregular, rather than having the ideal round bog shape. The depth of the peat is generally shallower near the coast and increases inland, locally exceeding more than 20m. The coastal peat land is generally elevated well above adjacent river courses. Steep gradients are found at the periphery while the central peat plain is almost flat. Water plays a fundamental role in the development and maintenance of tropical peat. A balance of rainfall and evapotranspiration is critical to their sustainability. Rainfall and surface topography regulate the overall hydrological characteristics of the peat land. Peat land is also generally known as wetland or peat swamp because of its water table, which is close to, or above the peat surface throughout the year and fluctuates with the intensity and frequency of rainfall. Peat swamp is an important component of the world’s wetlands – the dynamic link between land and water, a transition zone where the flow of water, the cycling of nutrients and the energy of the sun combined to produce a unique ecosystem of hydrology, soils and vegetation. The build-up of layers of peat and the degree of decomposition depend principally on the local composition of the peat and the degree of waterlogging (Figure 1 - 1).

Peat formed in very wet conditions accumulates considerably faster and is less decomposed than peat accumulating in drier places. The peat acts as a natural sponge, retaining moisture at times of low rainfall but, because it is normally waterlogged already, with a very limited capacity to absorb additional heavy rainfall during periods such as a tropical monsoon. Peat swamp forests develop on these sites where dead vegetation has become waterlogged and is accumulating as peat. Water in peat swamps is generally high in humic substances (humus and humic acids) that give a typically dark brown to black colour to the water. Peat swamps are characterized by diverse features that relate to the nature of the water supply, such as flooding by surface or groundwater, or solely from rainfall; type of landscape in which the peat swamp occurs, such as shallow depressions close to rivers; type of landscape that the swamp creates, such as accumulation of peat above groundwater level so that vegetation, often with prominent aerial roots, becomes wholly dependent on rainfall.

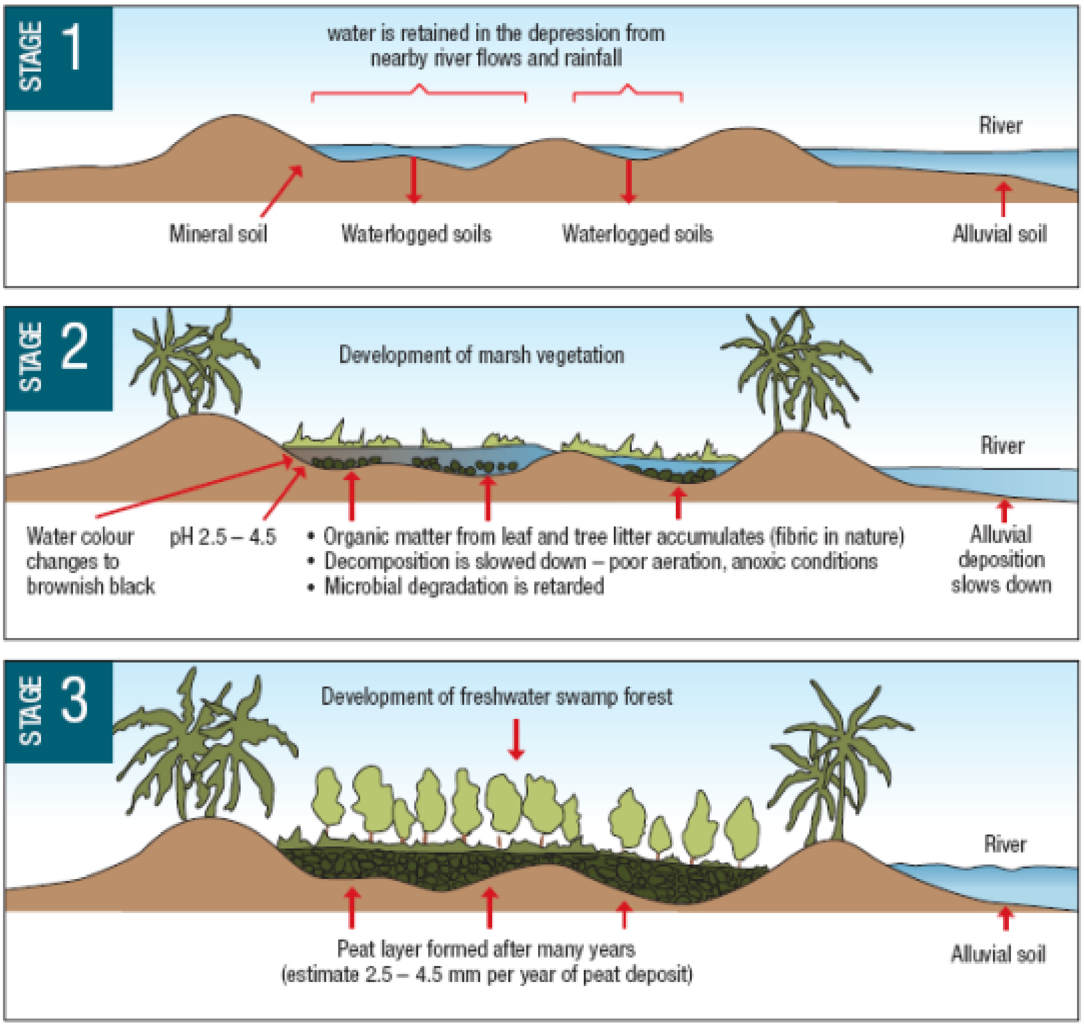

Figure 1 - 1. Peat swamps formation (Leete, 2006)

Basin peat form domes, which according to Mutalib *et al*., (1991), are up to 15 m high whilst valley peat is flat or interlayer with river deposits. Normally, sandy ridges bound basin peat at their seaward side or they gradually merge into muddy coastal flats. Low lying levees flank these domes along the rivers. The complexity of the domes becomes more pronounced as the distance from the sea increases as shown in Figure 1 - 2.

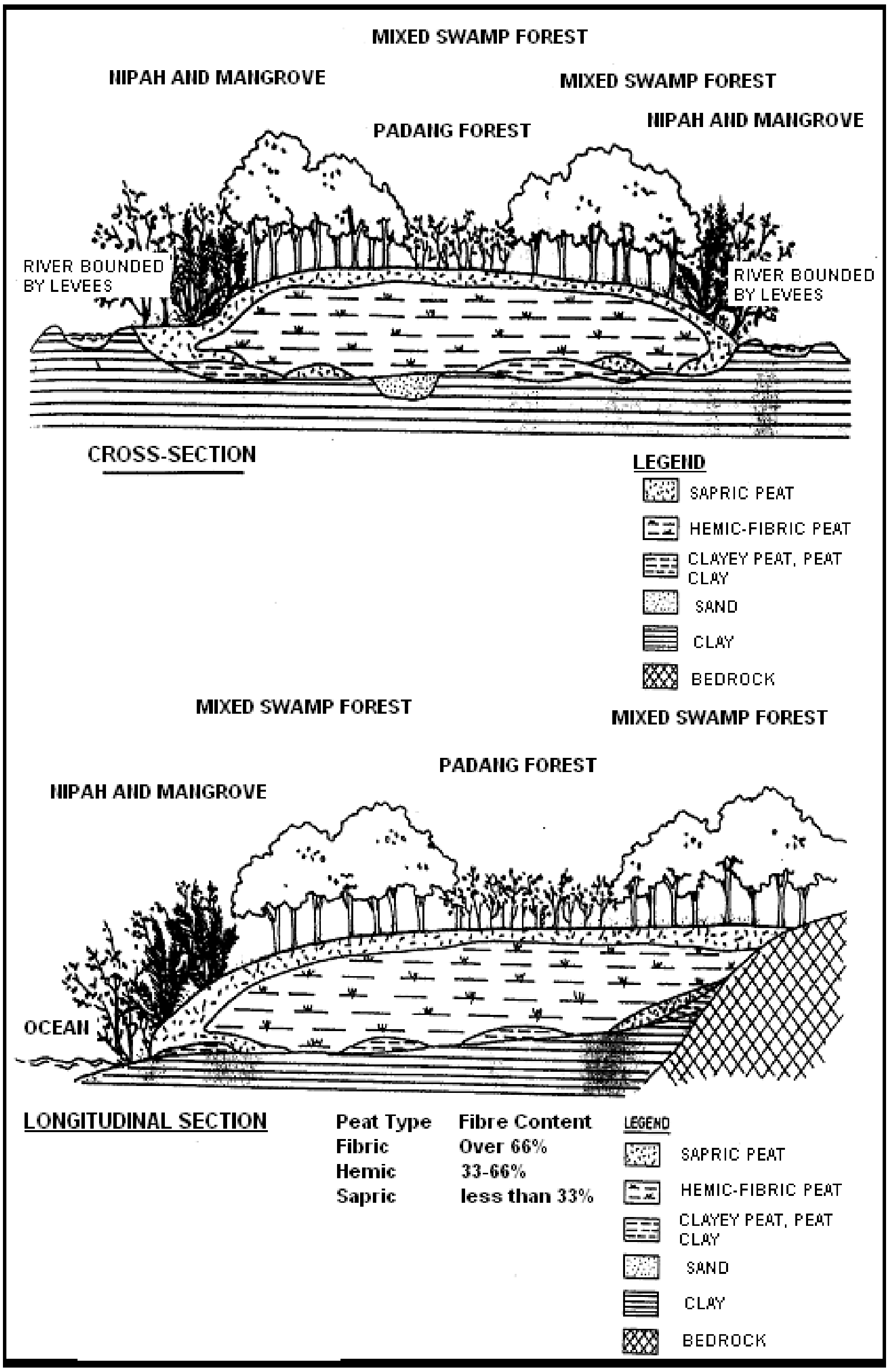

Figure 1 - 2. Typical cross section and longitudinal sections of a basin peat (Yogeswaran, 1995)

Tropical (basin) peat domes are found to have typically well-developed internal stratification. An example is shown in Figure. 1 - 3. Peat deposit is shown to be lenticular and dome surfaced with a typical concave base. The centre of the dome however is usually flat. The internal stratification is typically three fold with a fine grained hemic/ sapric layer overlying a thick zone of fine to medium grained woody hemic - fibric, over fine grained hemic peat. The base of the peat dome is typically dark grey clay and sand with a thin layer of clayey peat or peaty clay.

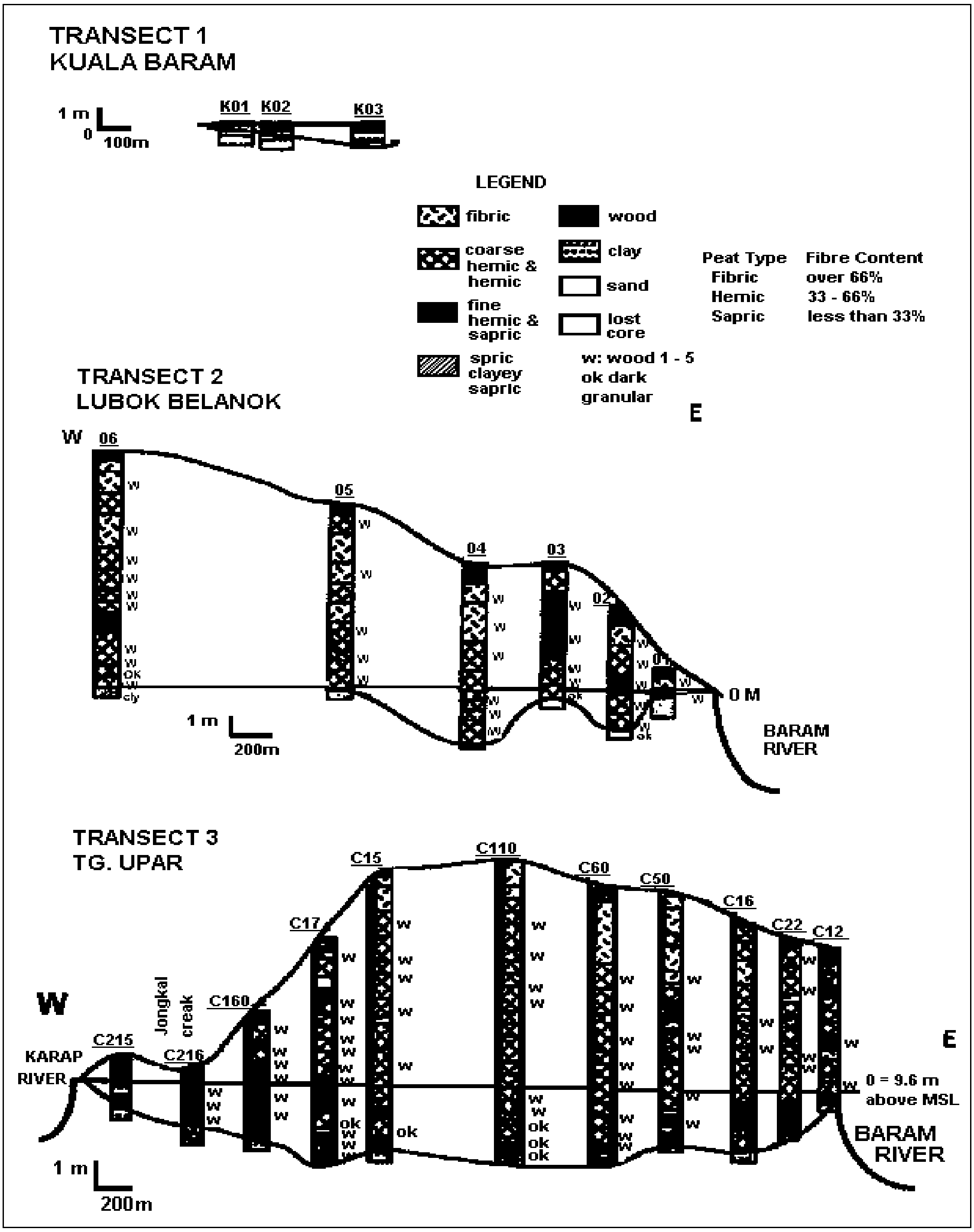

Figure 1 - 3. Vertical profile of a basin peat dome (Esterle *et al.*, 1991)

Lam (1989) postulates the possible event leading to the development of peat deposits as a result of sea level changes. The last global glaciations resulted in rapid denudation and deep incision of the parent rock formation. After the last maximum glaciations (some 20,000 years BP), sea level rose rapidly and reached a maximum level 5,500 years BP. This affected the result in transportation and deposition of a large amount of sediment, which formed deltas and flood plains. Peat swamps were initiated in the depression and basin between isolated hills and levees, and in the deltas. During the initial stage, plants developed in mineral soils. The areas were still under influence of rivers with influx of clastic (mineral) sediments during flood. The accumulation of clastic sediments and plant remains resulted in formation of clayey peat (topogenous peat). As plant remained accumulated, the ground surface levels were elevated. This led to formation of peat, which was free or low of the clastic sediments (ombrogenous peat), and highly acidic (Huat *et al*., 2014).

The peat forming vegetation consists mainly of large trees, resulting in high lignin content which is twice that of the bog peat. Figure 1 - 4 illustrates the geological development of a riverine depositional model leading to the deposition of the basin peat.

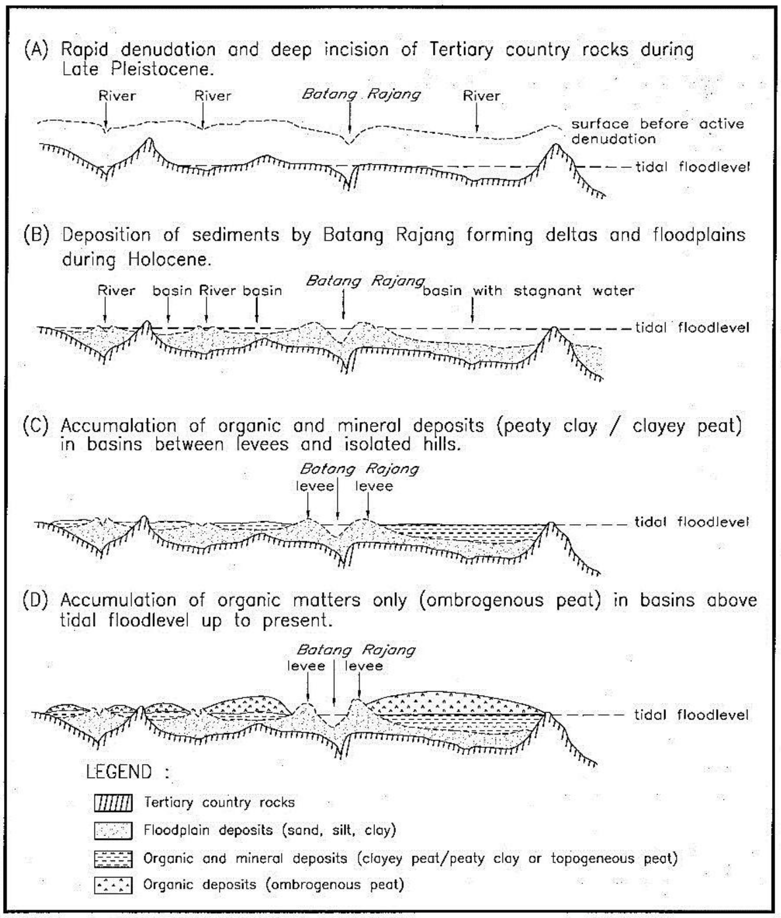

Figure 1 - 4. Geological development of a riverine depositional model (Chen *et al*., 1989)

1.3 Distribution of Peatland in Malaysia

Peat and soft soil are two integral components of the Quaternary deposits which are generally found in the coastal plains of Malaysia as shown in Figure 1 - 5 and Figure 1 - 6. Peat commonly occurs as the uppermost layer of these sediments.

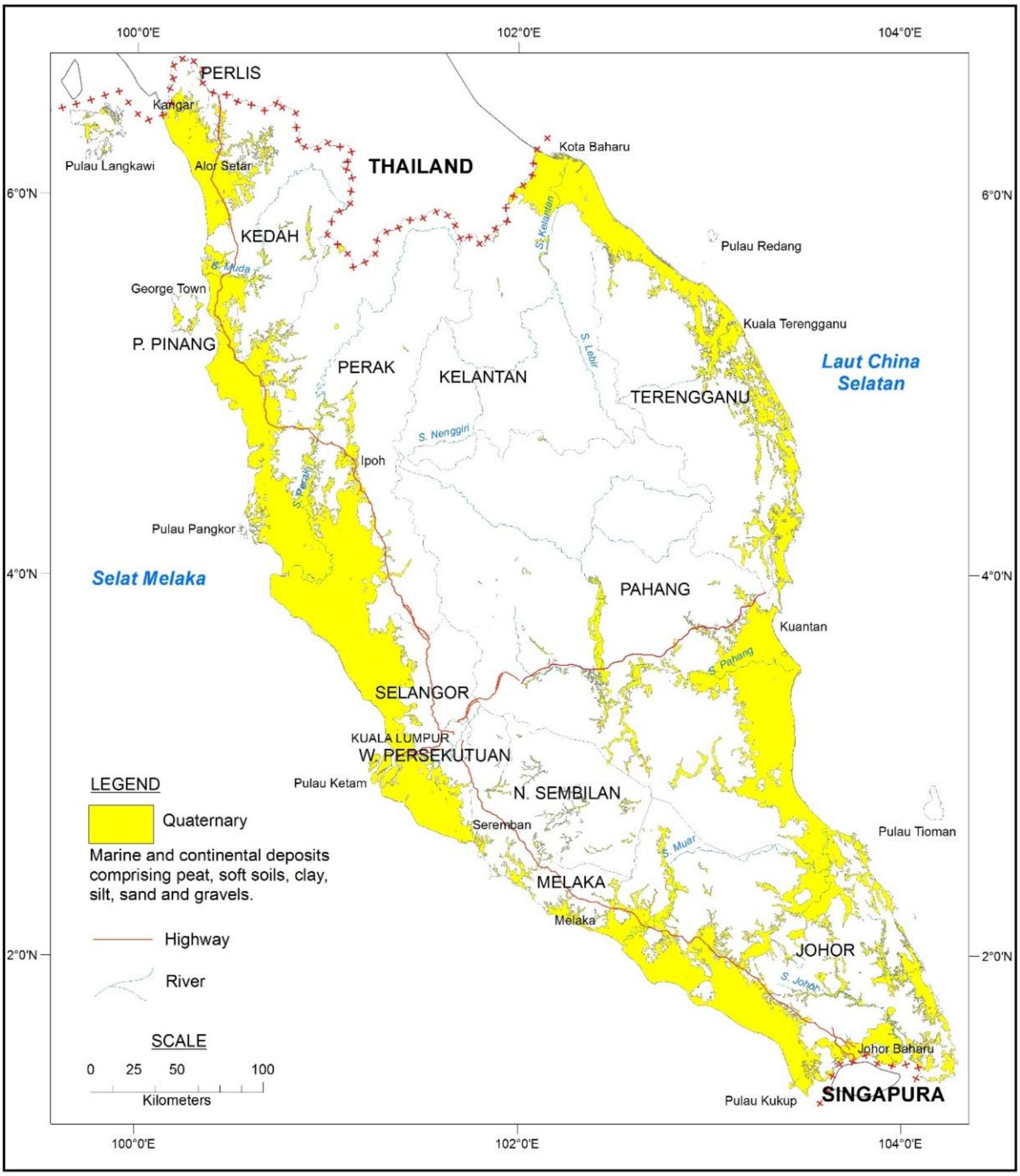

Figure 1 - 5. General Distribution of Quaternary Deposits including Peat and Soft Soils in Peninsular Malaysia (modified after Geological Map of Peninsular Malaysia, 9th. Edition, Minerals and Geoscience Department Malaysia, 2014)

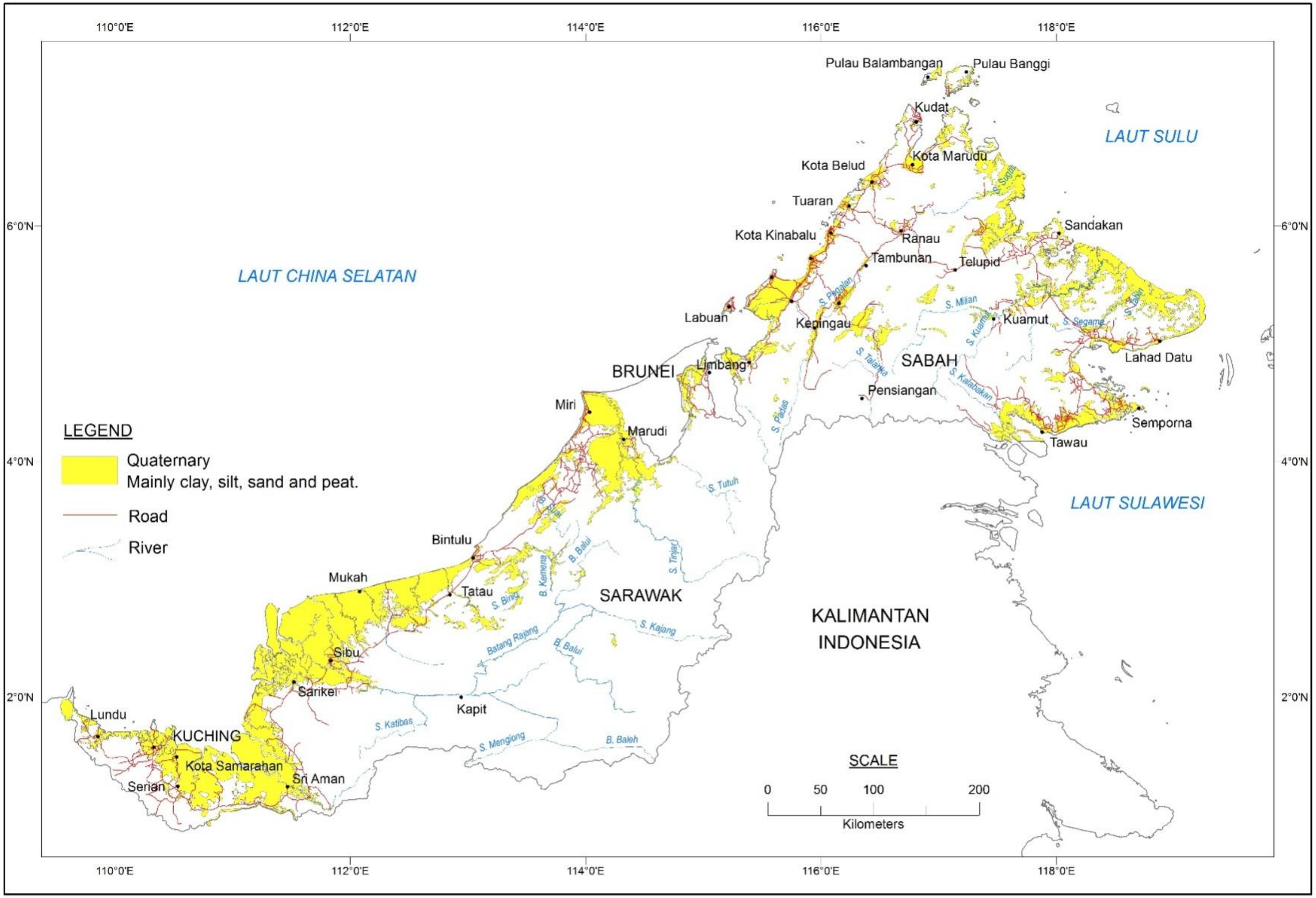

Figure 1 - 6. General Distribution of Quaternary Deposits including Peat and Soft Soils in Sabah and Sarawak (modified after Geological Map of Sarawak and Sabah, 5th Edition, Geological Survey of Malaysia, 1992)

Geographically, tropical peat deposits are commonly found in poorly – drained lowlands such as the river valleys and estuaries. Some can also be found on small isolated areas in steep mountainous region above 1000m from mean sea level (msl). The former is known as basin peats, while the latter is called valley peats.

Most of the lowland peatland in Malaysia initially formed behind mangrove swamp forest along the coast, and later developed as far as 100km in land on the alluvial plains between rivers flowing to the sea.

The inland peat typically developed as a dome-like structure underlain by a thick mineral soil as illustrated in Figure 1 - 7, but some may be fairly uniform in depth and elevation.

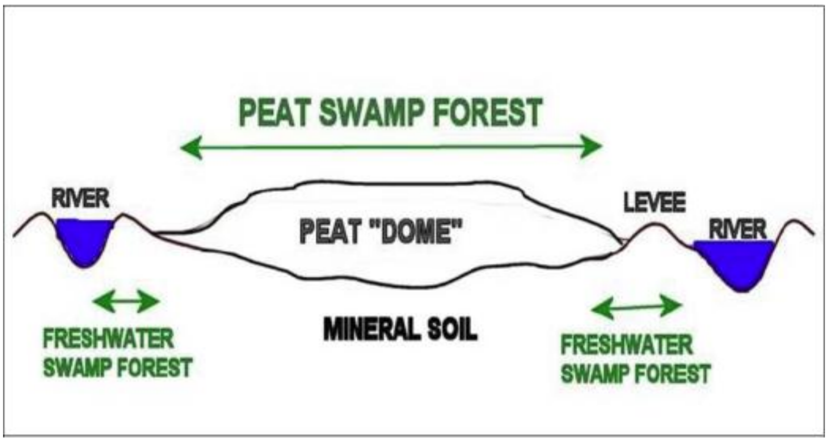

Figure 1 - 7. Highly – developed inland peat dome (Wetlands International, 2010).

In Malaysia, approximately 8% amounted to about 2,457,730 ha of the 32,975,800 ha of the country total land area is covered with peat. The extent and distribution of peat areas in Malaysia is summarised in Table 1 - 2.

Table 1 - 2. The area (ha) of peat soil in Peninsula Malaysia, Sarawak and Sabah (Wetlands International, 2010)

Region	Total Area of Peat (ha)	%
Sarawak	1,697,847	69.08
Peninsular Malaysia	642,918	26.16
Sabah	116,965	4.76
Total	**2,457,730**	