CHAPTER IV

ENVIRONMENTAL GEOLOGY

Saraburi area is the important target of development for central region of Thailand. The present investigation is intended to apply the earth sciences information to assist in the future planning and development of the area. The environmental geological study specified involves collecting a thorough knowledge of geological resources as well as their capabilities and limitation for orderly development to effective urban and industrial growth in order to maintain a healthy living environment. The following discussion is intended to provide a pictorial and graphical presentation including explanation and data on various aspects of geology required for the development planning.

4.1 Physiographical setting

4.1.1 Climatology

The studied area has a tropical savanna climate "Aw" as Koppen classification which means that the climate has drought period with cool winter. The mean annual rainfall is 1252.7 millimeters. There is slightly rainfall in April and progressively higher every month through 6 months between June to October. Average rainfall days are about 91.4 days from 108.3 days per year. An average temperature is 28.4^{o} C with the mean highest temperature of

36.9° C in April and the mean lowest temperature of 19.1° C in January (Figure 4.1).

The seasons change due to the influence of the monsoon directions can be classified as follows :

a) The southwest monsoon is between May and October. During this period, the monsoon passes over the area and bring moisture from the sea to produce heavy rainfall. Therefore, this period is the rainy season.

b) When the southwest monsoon changes to northeast monsoon, the weather is cooled down called the cold season. The cold season lasts from November to February.

c) The summer, or hot season, lasts 3 months, extending from March to May.

The wind speed and direction recorded at Lop Buri meteorogical station were illustrated in Table 4.1.

Table 4.1 Mean Wind Speeds (m./sec.), Resultant Wind Directions (degree from north) and Maximum Wind Speeds (m./sec.).

February - April	May - July	August - October	November - January
3.1 (180°)	2.7 (180°)	2.3 (150°)	2.8 (45°)
Max. speed 25			

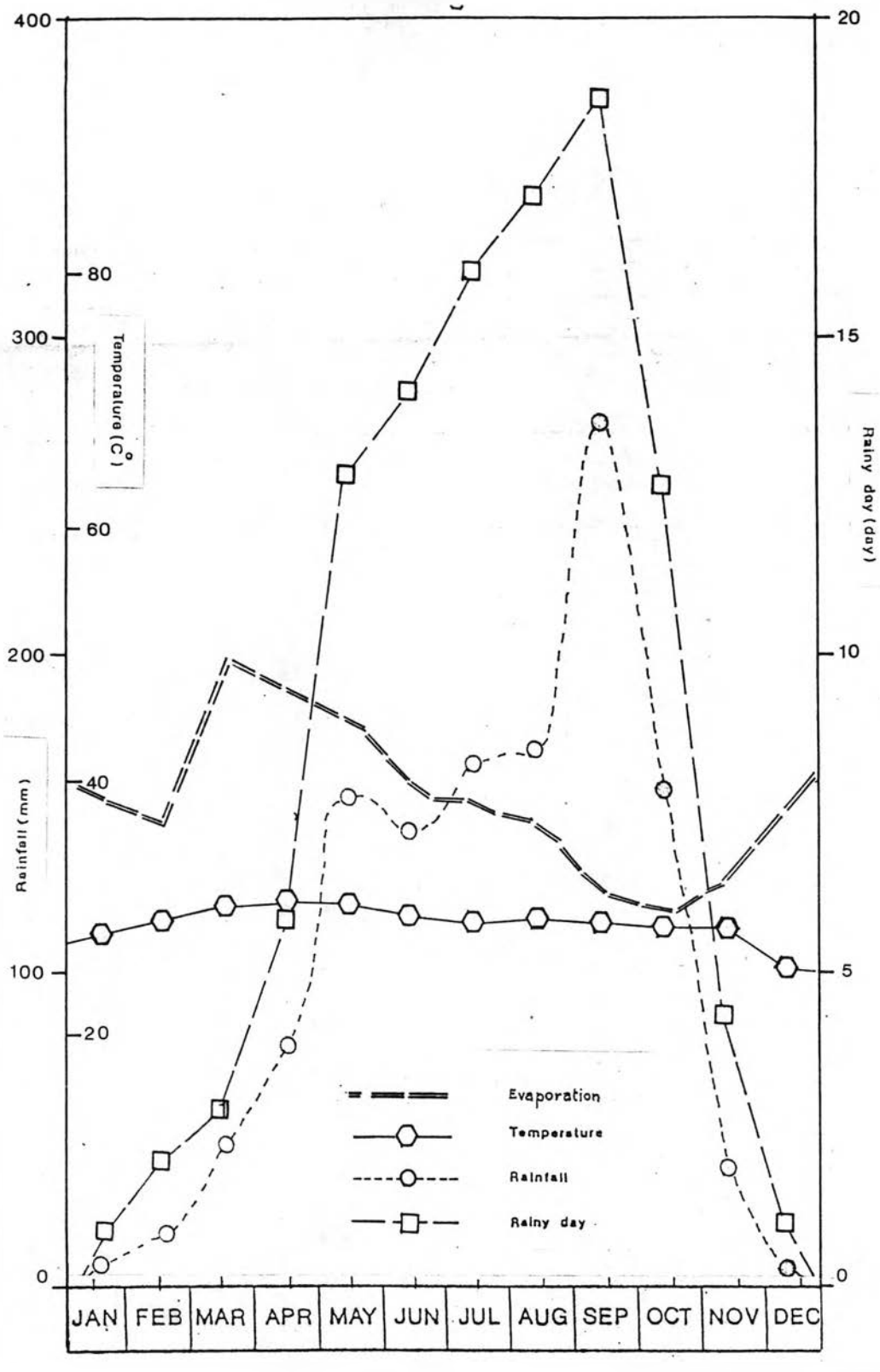


Figure 4.1 Average rainfall and rainy day, Temperature (1951-1989) and evaporation (1975-1989) of Changwat Saraburi (Modified from Pranom Kaosuta et al., 1986).

4.1.2 Drainage of the study area

The study area is drained by numerous short streams and one river. The Pasak River is the main stream in the area. Its tributaries include Haui Muak Lek, Huai Yang, Huai Yai, Huai Thai and etc.

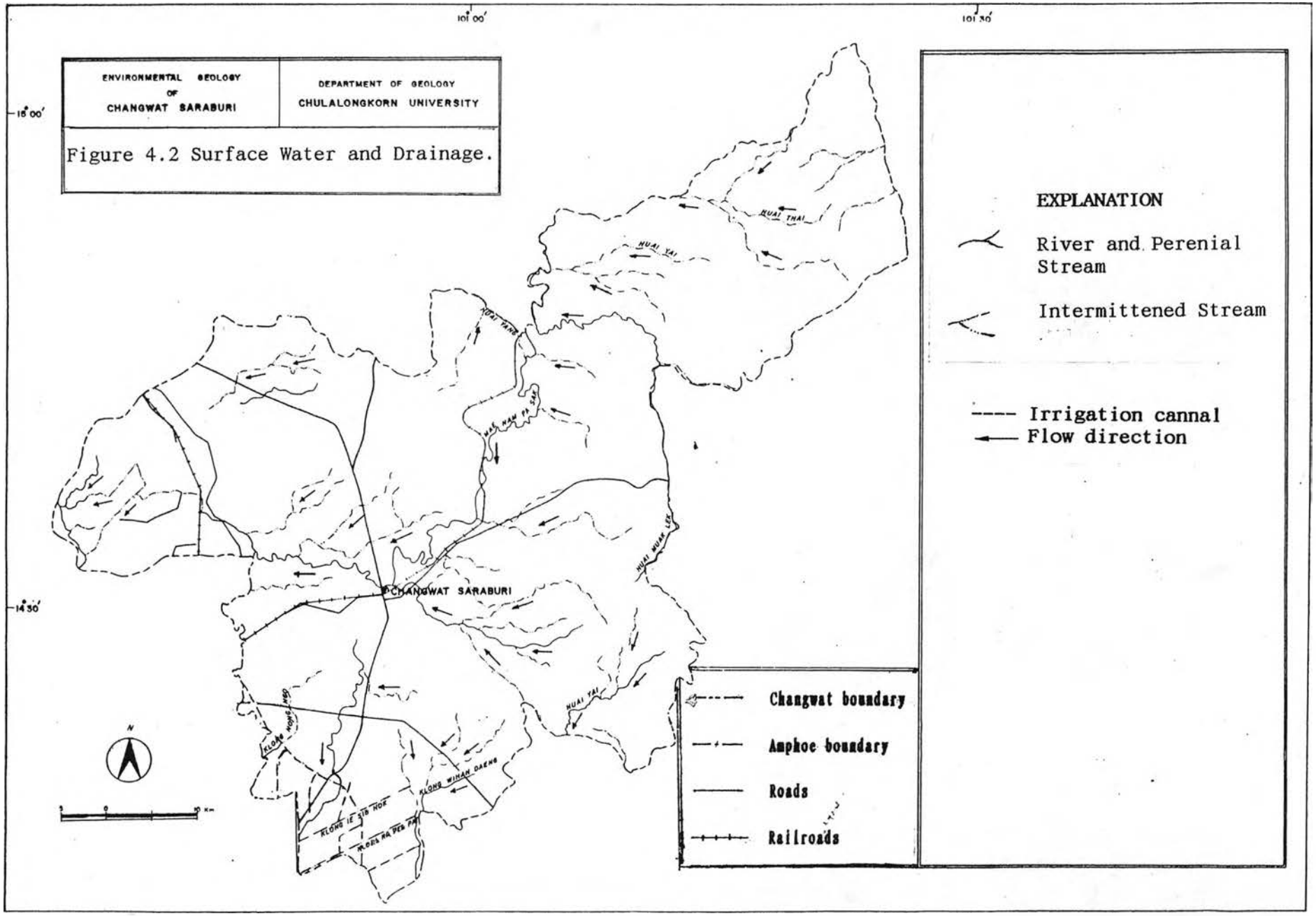
The Pasak River flow froms north to south and the direction change to west at Amphoe Kaeng Khoi to join the Chao Phraya River at Changwat Phra Nakhon Si Ayutthaya. In the western and southern part of Saraburi there are irrigation drainages which are used for cultivation and water supply (Figure 4.2).

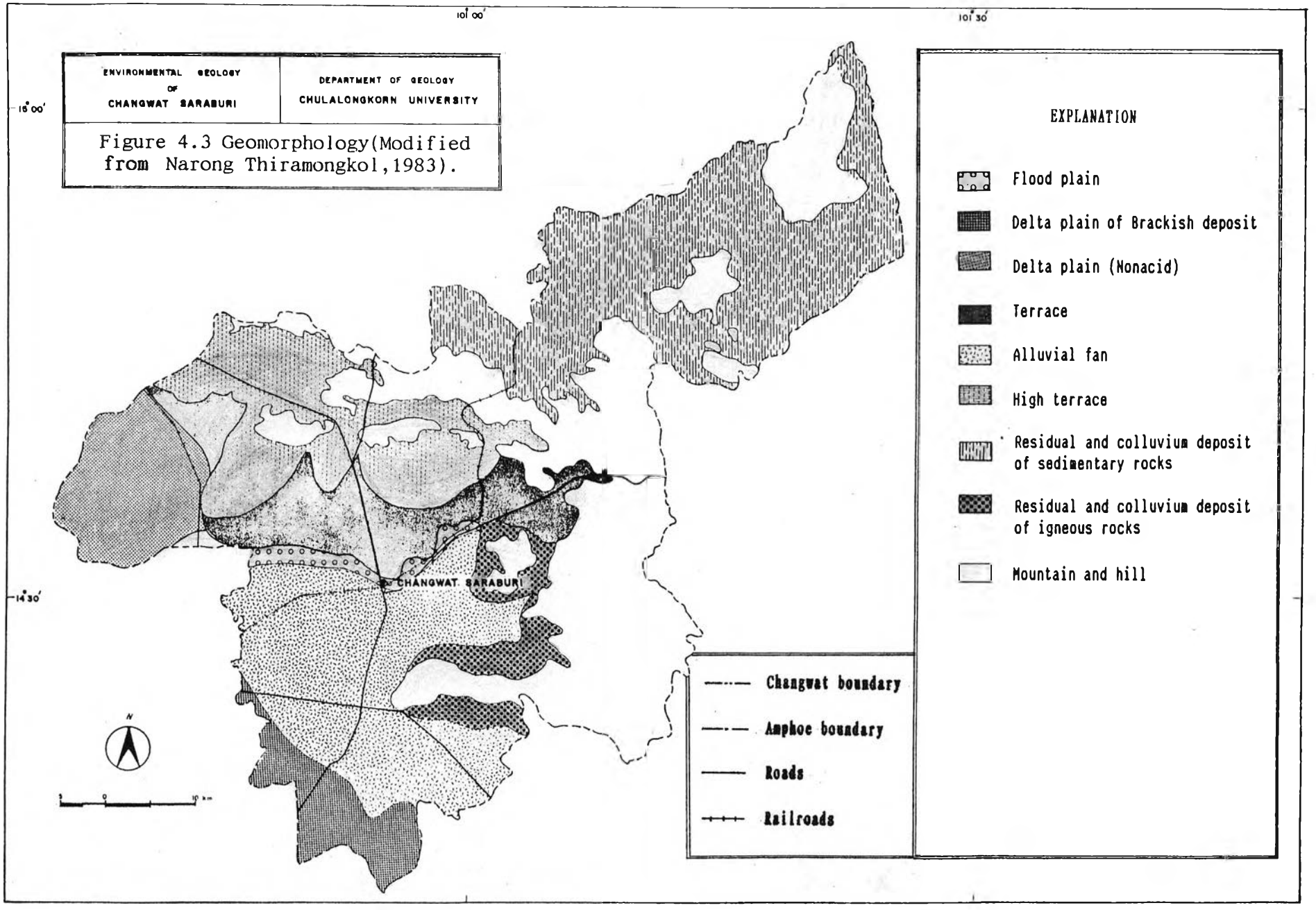
4.1.3 Geomorphology

The landform of the study area comprised mountain and hill, residual and colluvial deposits,terrace and high terrace, alluvial fan and flood plains and delta plains as shown in Figure 4.3

4.1.3.1 Flood Plains

The recent flood plain of Pasak River covers along the course of the river. The flat terrain consists of natural levee, oxbow lake and backswamp. The elevation of flood plain is about 10 meters above mean sea level. Both sides of The river are natural levee which is 1-2 meters higher than surrounding area. Backswamp and oxbow lake are also found and used as preserved water sources for village such as oxbow lake at Ban Bung, Amphoe Muang and Ban Bung Ngong Amphoe Sao Hai.


ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure 4.2 Surface Water and Drainage.
101°00'
101°30'
15°00'
14°30'
EXPLANATION
River and Perenial Stream
Intermittened Stream
Irrigation cannal
Flow direction
Changwat boundary
Amphoe boundary
Roads
Railroads
CHANGWAT SARABURI
HUAI THAI
HUAI YAI
HUAI KHAM PA SAK
HUAI MUAK LEK
KLONG WIHAM DAENG
N
5 0 5 Km


ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure 4.3 Geomorphology(Modified from Narong Thiramongkol,1983).
101°00'
101°30'
15°00'
14°30'
CHANGWAT SARABURI
EXPLANATION
Flood plain
Delta plain of Brackish deposit
Delta plain (Nonacid)
Terrace
Alluvial fan
High terrace
Residual and colluvium deposit of sedimentary rocks
Residual and colluvium deposit of igneous rocks
Mountain and hill
Changwat boundary
Amphoe boundary
Roads
Railroads
N

4.1.3.2 Delta Plains

The delta plains of Chao Phraya and Lop Buri river cover the western part of the study area. The areal extent of delta plain cover Amphoe Ban Mo, Nong Don and Don Put in the west and Amphoe Wihan Daeng, Nong Kae in the south. The elevation of this area is about 2-6 meters above mean sea level with slope less than 2 percent.

Takaya and Thiramongkol (1982) and Narong Thiramongkol (1983) concluded that these delta plains were formed by Chao Phraya River. The triangular shape delta has the apex at Changwat Chainat. In the western part of the study area the sediment deposits are non-acid or neutral while in the southern part, affected by influrence of brackish water, the jarosite was found (bright yellow crystal of sulfate salt).

4.1.3.3 Terrace

The terrace occurs along the margins of the structural terrace (Narong Thiramongkol, 1983) of Marl. It lies between 10 and 50 meters above mean sea level. The terrace is gently undulating with gentle slopes and low relief amplitude.

The sediment of the terrace commonly consists of clayey, silty and sandy layers often alternating with gravel beds. The lateritic layer of pisolitic concretions of iron oxide, thickness 10 to 30 centermeters thick, always found in the upper part with normally overlain by sandy layer of about 1 meter thick.

4.1.3.4 Alluvial Fan

The alluvial fan in the study area is the Pasak Fan at which the river emerged from mountaineous range at Kaeng Khoi and formed fan shape. It lies between 5 and 40 meters above mean sea level and form a gently undulating terrain.

The fan deposits commonly consists of alternating layers of clay, silt,sand and gravel. The top layer of the deposits, about 1 meterthick, is mainly composed of fine to coarse sand. The lateritic concretion of iron oxide of 5 to 15 cm. thick is commonly found underlying the top layer (Takaya and Norong Thiramongkol, 1982 Narong Thiramongkol, 1983).

4.1.3.5 High Terrace

A high terrace has elevation between 30 and 120 meters above mean sea level with a relief of up to 30 meters.

The deposits consist of clay and sity sand with concretions of iron oxide of 10-30 cm thick. In the west of Saraburi, the marl deposit is found instead of lateritic cap. The marl deposit consists of 2 to 3 meters thick of white to light gray nodular structure of loose and friable material. The lower part is composed of white massive material. The total thickness is at least 5 meters as observed in outcrop at Ban Mo.

4.1.3.6 Residual and Colluvial deposits

The residual and colluvial deposits covered the northern and some part of the eastern portion of the area. The deposits are found connected to mountain which is as the residual soil of shale and sandstone and igneous rocks in the southeast part. The elevation of this unit is about 100-300 m. above mean sea level.

The sediments comprised clay, silt and sand with thickness of about 1-3 meters.

4.1.3.7 Mountain and Hill

Mountain and Hill are monadnocks and mountainranges of limestone, shale and sandstone and igneous rocks will the elevation of more than 300 meters.

4.1.4 Slope

Slope is one of the important factor for land use planning especially in the case of road transportation and agriculture. The slope characters coupled with the nature of materials and vegetation that cover the area can be used in the assessment on the potential of soil erosion or its stability. Some critical slopes are given in Table 4.2.

In the present investigation, the slope character is classified, according to the suggestion of Crofts (1973), into 5

Table 4.2 Critical Slope Categories.

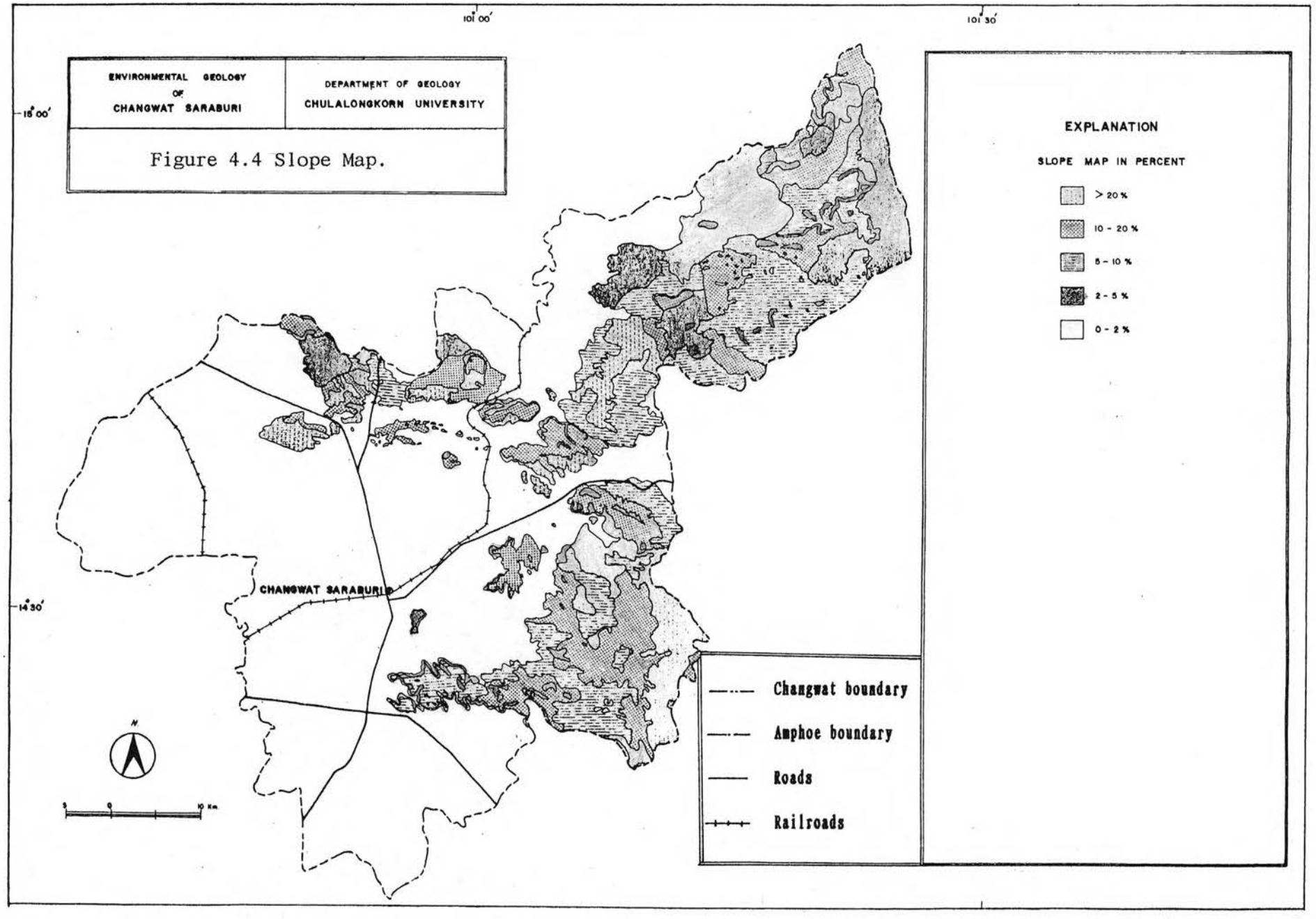
Steepness per cent	Critical for
1.	International airport runways.
2.	Main-line passenger and freight rail transport.
	Maximum for loaded commercial vehicles without speed reduction.
	Local aerodrome runways.
	Free ploughing and cultivation.
	Below 2 per cent flooding and drainage problems in site development.
4.	Major roads.
5.	Agricultural machinery for weeding, seeding.
	Soil erosion begins to become a problem.
	Land development (constructional) difficult above 5 percent.
8.	Housing, roads.
	Excessive slope for general development.
	Intensive camp and picnic areas.
9.	Absolute maximum for railways.
10.	Heavy agricultural machinery.
	Large-scale industrial site development.
15.	Site development.
	Standard wheeled Tractor.

Steepness per cent	Critical for
20.	Two-way ploughing.
	Combine harvesting.
	Housing-site development.
25.	Crop rotations.
	Loading trailers.
	Recreational paths and trails.

Source : Crofts (1973).

categories, namely, : 0-2%, 2-5%, 5-10%, 10-20% and >20+%. The slope map of the study area is illustrated in Figure 4.4. The area with slope of 2 percent or less cover about 70 percent of the study area. The flattest slope are mainly developed on Pasak-Lop Buri flood plain and the delta of Chao Phraya along northwest, west and south of the study area. This category of landslope on the plains are usually subjected to flooding, poorly drained and generally have a relatively high water table. Soil stability is generally good.

The area with slope of 2-5 percent composes of approximately 10 percent of the study area. It is the gentle to undulating terrains that cover in the north and north east portion of the study area.


ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure 4.4 Slope Map.
101°00'
101°30'
15°00'
14°30'
CHANGWAT SARABURI
EXPLANATION
SLOPE MAP IN PERCENT
> 20 %
10 - 20 %
5 - 10 %
2 - 5 %
0 - 2 %
Changwat boundary
Amphoe boundary
Roads
Railroads
N
0
5
10 Km.

The land with slope of 5-10 percent covers about 15 percent of the study area. The areal extent of this slope class is generally associated with the footslope of hilly and mountainous land. The soil erosion of fine-grained sediment on non-vegetated land is intensive.

The area with slope between 10 and 20 percent covers about 3 percent of the study area. They mainly occur on the midslope of the mountainous and hilly area. Generally, they are the highly susceptible to erosion particularly by means of gullying if the plant coveris removed. In this slope category, the erosion process plays a significantrole, therefore, the thickness of soil cover or depth to bed rock on this land is comparatively thin. However, the area in this slope category is mainly the part of Khao Yai National Forestry which the deforestation is controlled by the government.

The area with slope excesses 20 percent, the steepest category, covers about 2 percent of the study area. They mainly occur on the limestone and volcanic mountainous area as well as hilly terrain. The land wiht this slope category will create numereous problems in development sach as slope stability, especially in the area of weathered volcanic rocks. This area is mainly the forest preservation. Human encroachiment is not intensive to disturbed the equilibrium of slope.

4.1.5 Landuse Planning for Agriculture

The land use means man's activities on land which are

directly related to the land (Clawson and Stewart, 1961).

The land use, within the study area, is modified largely from the original data of the planned land use map of Saraburi by Pranom Kaosutha et al. (1990). The investigations of the area are undertaken by the Land use Planning Division, Land Development Department. The land use and land suitability map of the study area is illustrated in Figure 4.5.

According to Table 4.3 and Figure 4.5, there are 4 and 13 categories of first and second level, respectively. They will be discribed in more detail in the following.

Among the first level of land use categories within the study area, the agricultural land covers the wide extent which is approximately 55 percent of the area. This catagory can be divided into 5 classes of the second level,notably, paddy field in irrigated area. ditch horticultural in irrigated area. rainfed paddy field, field crop and fruit and tree land (perennial, crop land and horticultural crop). The paddy field is mainly covered the western area of study area in Amphoe Nong Don, Ban Mo, Sao Hai, Nong Sang, Muang, whiletheditched horticultured area is found on Amphoe Wihan Daengand Nong Kae. The rainfed paddy field is found on the middle of study area in Amphoe Phra Phutthabat, Muang, Kaeng Khoi and Muak Lek.

The forest area covers mainly in mountainous area which is catagorised into national park and outer national park. Each category is classified into primary and secondary forest. The areal

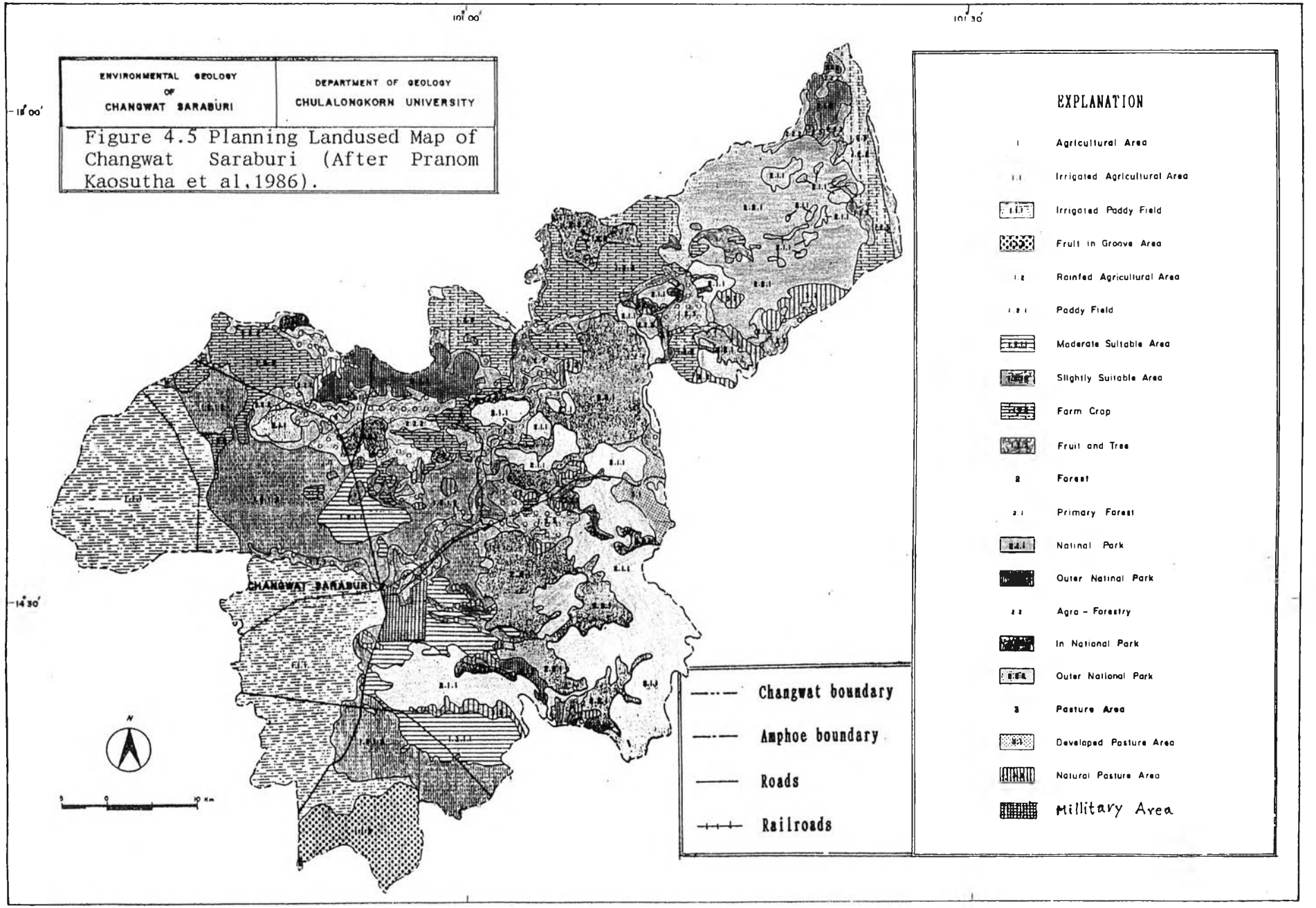


Figure 4.5 Planning Landused Map of Changwat Saraburi (After Pranom Kaosutha et al,1986).

Table 4.3 Land use classification systems within the studied area.

Level I	Level II
1. Agriculture land	1.1.1 Paddy field in irrigated area
	1.1.2 Ditch horticultural in irrigated area
	1.2.1 Rainfed paddy field
	1.2.1.1 Moderate suitable area
	1.2.1.2 Slightly suitable area
	1.2.2 Field crop
	1.2.3 Fruit and Tree (Perennial crop land and horticultural crop)
2. Forest	2.1.1 National Park, Primary Forest
	2.1.2 Outer national Park, Primary Forest
	2.2.1 National Park, Agro-Forestry
	2.2.2 Outer national park, Agro-Forestry
3. Pasture area	3.1 Developed Pasture area
	3.2 Natural Pasture area
4. Urban or built-up land	4. Industrial, Community and Recreation Area

extent of the forest is found mainly in the east, northeast and southeast in Amphoe Muang, Kaeng Khoi, Muak Lek, and Wihan Daeng.

The pasture area covers about 4 percent of the total area. It can be classified into developed and natural pasture land. The developed pasture land covers the area of Muak Lek Diary farm in Amphoe Muak Lek while the natural pasture land is found in Amphoe Muak Lek, Kaeng Khoi and Phra Phutthabat area.

The urban or built-up land comprises areas of intensive use with much of the land covered by structures. Included in this category are city, military area and industrial area. The urban land occupied about 1 percent of the study area.

4.2 Geological Setting

The geological setting of the area is compiled from previous investigations.

The feature of the area is the mountainous terrains of extrusive igneous rock which formed part of Khao Yai National Park at the Southwest and west. The carbonate and clastic sequences cover the north, northwest and southeastern part. The low lying unconsolidated sediment covers the rest. According to Hintong et al. (1976). the upper to lower Permian carbonate and clastic sequence of Ratburi Group consist of limestone with chert interbedded and some of dolomitic limestone and dolomite, the clastic rock consist of Shale. Siltstone and Sandstone which some part were metamorphosed to slaty shale, phyllite, phyllitic shale and schist. The older rock is revealed in the north and the younger rocks spreads through the south. Undifferentiated extrusive rocks of rhyolite, andesite,

rhyolitic and andesitic tuffs and agglomerate and volcanic breccia of Permo-Triassic age cover the west and southwest portion of the area.

The rest of the area is covered dominantly by Quaternary alluvial and terrace deposits.

Structurally, the Permian Ratburi Group has the trend in the direction of east-west and dip moderately to the south and southwest. The Khao Yai extrusive rock lying unconformably on Permian rock. Unconformities are obscured because of erosion and weathering and are subsequently concealed by the younger sediment. Faults are presumably widely present in Permian group occurred in two major trends, northwest-southeast and southwest-northeast. Thub Khwang thrust fault is found at cement factory at Thub Khwang and Phu Phe. The sketched generalized geological map of the study area is illustrated in Figure 4.6.

Hintong (1981) described the geological history in the study area as follows :

The area west of the Khorat Plateau, which is the study area, was intermittently invaded by sea throughout the Permian period. A thick sequence of marine sediment of the Ratburi Group was deposited. The Indosinian orogeny, started from the beginning of Triassic and reached its culmination probably in Jurassic, caused strong folding in such area with very little effect on the present-day Khorat Plateau. Igneous rocks were mostly formed during this period,

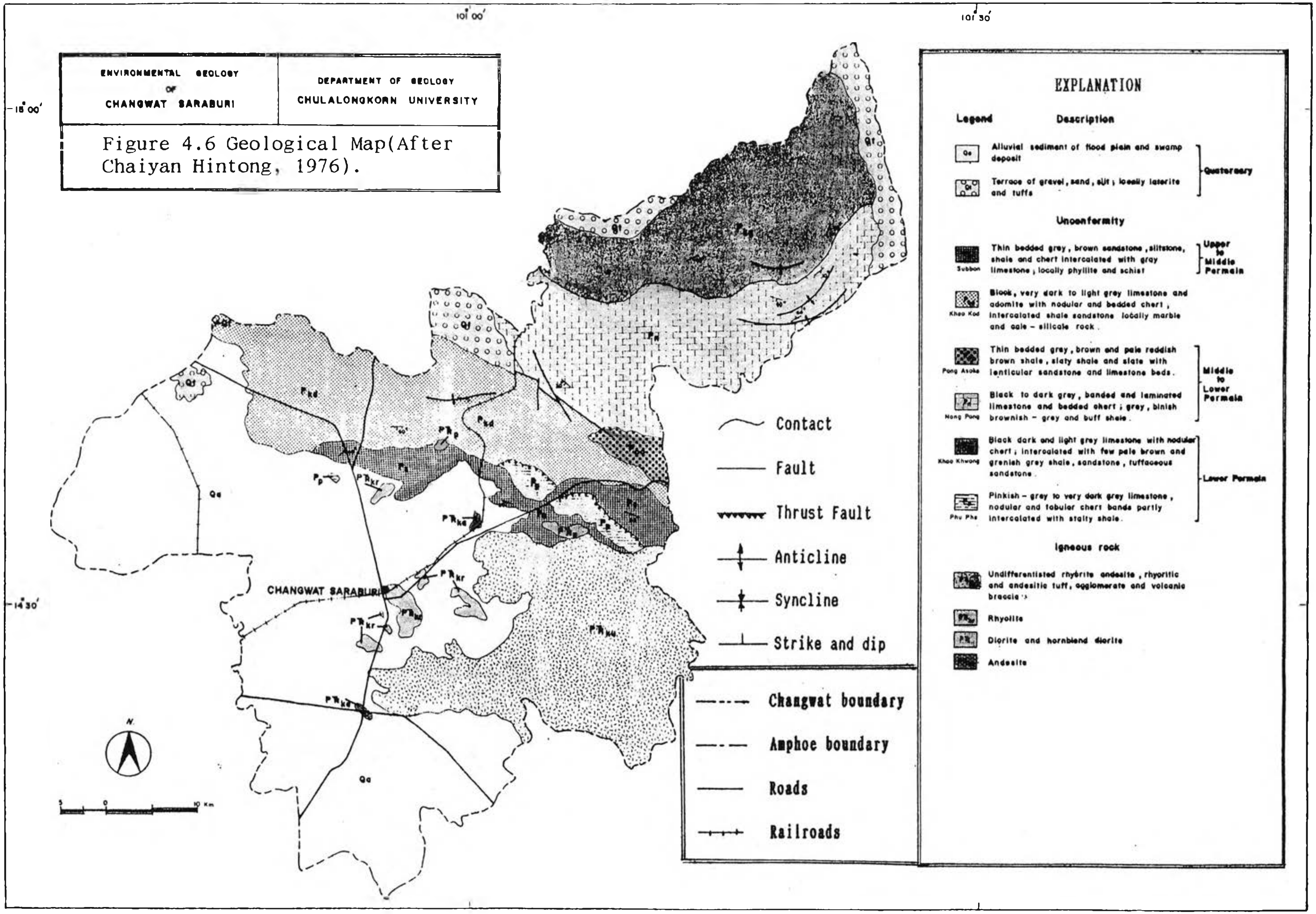


Figure 4.6 Geological Map(After Chaiyan Hintong, 1976).

especially in the southeastern portion of the study area. Consequently, the region become once a part of an enlarged stable land-mass. There had been no major folding since the concluding phase of this orogeny. Large areas were covered by inland sea during Mesozoic time in which red-beds of the Khorat Group were deposited. However, no records of Mesozoic and Tertiary depositions were found within this area. The final deposition was the formation of the Quaternary terrace and alluvial deposits which covered most of the northern, western and southern parts of the study area.

4.2.1 Palaeozoic Rocks

The oldest rocks in study area are Palaeozoic rocks Ratburi Group, Chaiyan Hintong (1981) categoried Ratburi Group into two subgroups based on lithology and fossil dating. These in cluded Lower Permian subgroup and Middle Permian subgroup. Lower Permian subgroup composed of two formations, namely, Phu Phae and Khao Khwang Formation. The former comprised gray to dark gray limestone, thick to medium bed with chert in irregular pattern to tabular parallel to bedding nodules with fusulinid fossil, and divided from the other by thrust fault (Borax and Stewart, 1966). The distribution of this formation show north east southwest trend from Khao Yai near Siam cement factory through Khao Krom Thang, Khao Nam Tok, Khao Kin Toi near Changwat Saraburi. The later comprised gray to dark gray limestone,thick to medium bed,chert nodule is always found with occasional thin bedded some shale, sandstone with tuff, the distribution of this formation is of Khao Kwaeng, Khao Lom , Khao Pong Sawang in the northern part of study area. Fossil fusulinids and brachiopods are always found.

The Middle Permian subgroup consists of four formations, namely, Nong Pong, Pang Asok, Khao Khad and Sab Bon Formations. Most of these formations have argillaceous sediments interbedded or intercalated with limestone. However, Khao Khad Formation comprised mainly limestone with interbedded argillaceous rocks. The distribution of these subgroup covered the northern and the north eastern part of the study area.

Nong Pong Formation comprises gray to dark gray limestone interbedded with gray shale and some chert nodule in limestone. The distribution is found in Khao Thong Yu, Khao In Thaya and Khao Mai Ruak, and the northern part of Khao Slaeng Pon.

Pang Asok Formation consists of grayish-brown to greenish brown shale interbedded with greenish gray,purplish to gravish brown sandstone with some slate,slaty shale. The distribution is found mainly in Amphoe Muak Lek from Thap Khwang railways station to Muak Lek and Ban Pang Asok.

Khao Khad Formation comprises mainly limestone, gray to dark gray, medium to thick bedded with chert nodule. The distribution is found in Khao Phra Phutthabat, Khao Prong Prap, Khao E-mod, Khao Phat Aek, Khao Nok Yung, Khao Makam Thao, Khao Ngop (Marble) from Na Phra Lan through Thap Kwang railway station, Khao Pang Ma to Muak Lek diary farm.

The upper most of the Middle Permian sandstone subgroup is Sab Bon Formation comprises of mainly shale, siltstone and minor

sandstone with limestone lens and chert nodule. The distribution of this formation covers Phu Khae botany garden, Ban Wong Jon and Agro-forestry Sab Bon.

Fossil found in these subgroup is Middle Permian as defined by mainly fusulinids (Pitakpaiwan, 1965; Toriyama and Konmera, 1968; Toriyama et al., 1974 and Tittirananda, 1976) and some brachiopod, and coral.

4.2.2 Palaeozoic - Mesozoic Rocks

In the study area, these rock composed mostly of igneous rocks which contain both intrusive and extrusive rocks. The intrusive rock composed mostly of diorite found at Khao Ta Put, Khao Sema, Khao Tan Thong Daeng, Ban Khlong Muang, Ban Thung Mai Daeng and Khao Nan near Thab Kwang. The extrusive rocks composed of rhyolite, andesite and rhyolitic and andesitic tuff. The distribution is found in the southeast of study area such as Khao Pong Rang, Khao Phra Phutthachai, Khao Sam Lan, Khao Phra, Khao Sung, Khao Phu Pang, Khao Mai Nuan, and Khao Intanee.

4.2.3 Cenozoic Rocks

The unconsolidated Cenozoic rocks composed of clays, silts, sand and gravel which can be divided into two categories of deposits, namely, terrace deposit and alluvial deposit. Terrace deposits consist of semiconsolidated gravels, sands, silts and clays. Laterite, lateritic soils and tuff are also present. The deposits are presumably Pleistocene in age.

Alluvial deposits of gravels, sands, silts and clays are found in floodplains. The deposits are presumably Quaternary in age.

4.3 Mineral Resources.

The potential mineral resources within the study area are classified into 2 groups, namely, non-metallic minerals andconstruction materials. Jumpon Kuentag (1979) studied marl deposit at Amphoe Ban Mo and Phra Phutthabat, Saraburi and in the vicinity of Ban Tha Khae, Lop Buri. Somwang Changsuwan and Anupan Kaedkaew (1991) reported the location and some engineering properties of limestone quarry in Central Thailand. Vivat Paijitprapaporn and Veeravat Thitisawan (1992) carried out the investigation on Carbonate rock for dimension stone and crushed rocks aggregate in Central Thailand (Figure 4.7).

4.3.1 Nonmetallic Minerals.

4.3.1.1 Dickite

Dickite or pyrophyllite $(Al_4(Si_4O_{10})_3(OH)_{12}.3H_2O$, is a mineral of Phyllosilicate group of the monoclinic crystal system. Its origin is closely related to hydrothermal replacement in acidic volcanic rock such as rhyolite. Dickite is similar to kaolinite in structure and chemical composition but is less important in constituting most of clay deposits. It can be distinguished from kaolinite by differential thermal and x-ray analyses. Generally, dickite can be used as raw materials in refractory bricks, saggar,

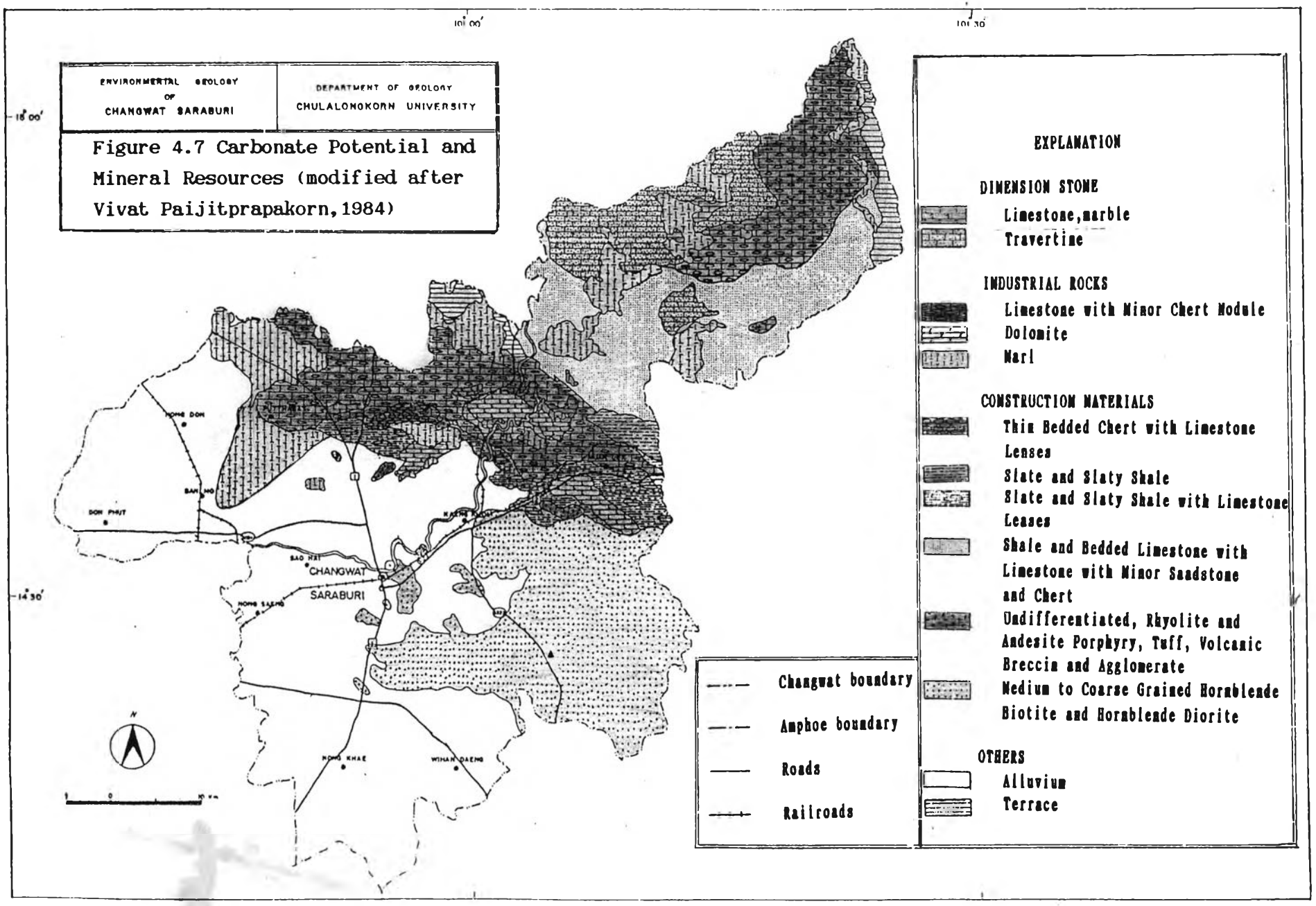


Figure 4.7 Carbonate Potential and Mineral Resources (modified after Vivat Paijitprapakorn, 1984)

electrical porcelains, pottery, mosaic tile, wall tile and white cement as well as filler in rubber and paint industries.

The 2 dickite deposits are located in study area, however, the largest deposit is in Nakhon Nayok at Khao Cha Ngok, where dickite occurs from hydrothermal replacement in rhyolite under the fracture control. For the 2 deposits in Saraburi, dickite is found in relatively smaller quantity and lower grade. Detailed description of these 2 deposits are summarized in Table **4.4**.

4.3.1.2 Marls

The term "marl" has various meaning and definitions. Howell (1957) states that marl is an old term of a considerable range of usage. In coastal plain geology of the United States, it has been used as a name for little indurated sedimentary deposit of a wide range of composition among which are slightly to highly calcareous clay and silt; fine-grained calcareous sand; clays, silts, and sand containing glauconite; and unconsolidated shell deposits. In the interior of the United State the name is used for the calcareous deposits of lakes in which the percentage of calcium carbonate may range from 0 to less than 30 percent. The name does not imply any particular composition.

Pettijohn (1957) explained that marls is semifriable mixtures of clay minerals and lime carbonate. The better indurated rocks of like composition are marlstones or marlite and are more correctly an earthy or impure limestone rather than a shale. Marl has been

Table 4.4 The Dickite Deposits Within the Study Area.

No.	LOCATION	Map Reference	Method of Mining	Use Ceramic Industries
1	Khao Mai Nuan Ban Cha-Om, Saraburi	265947 5237 IV	quarrying	White Cement
2	Khao Phu Phang Ban Cha-Om, Saraburi	273954 5237 IV	quarrying	Ceramic Industries Whit cement

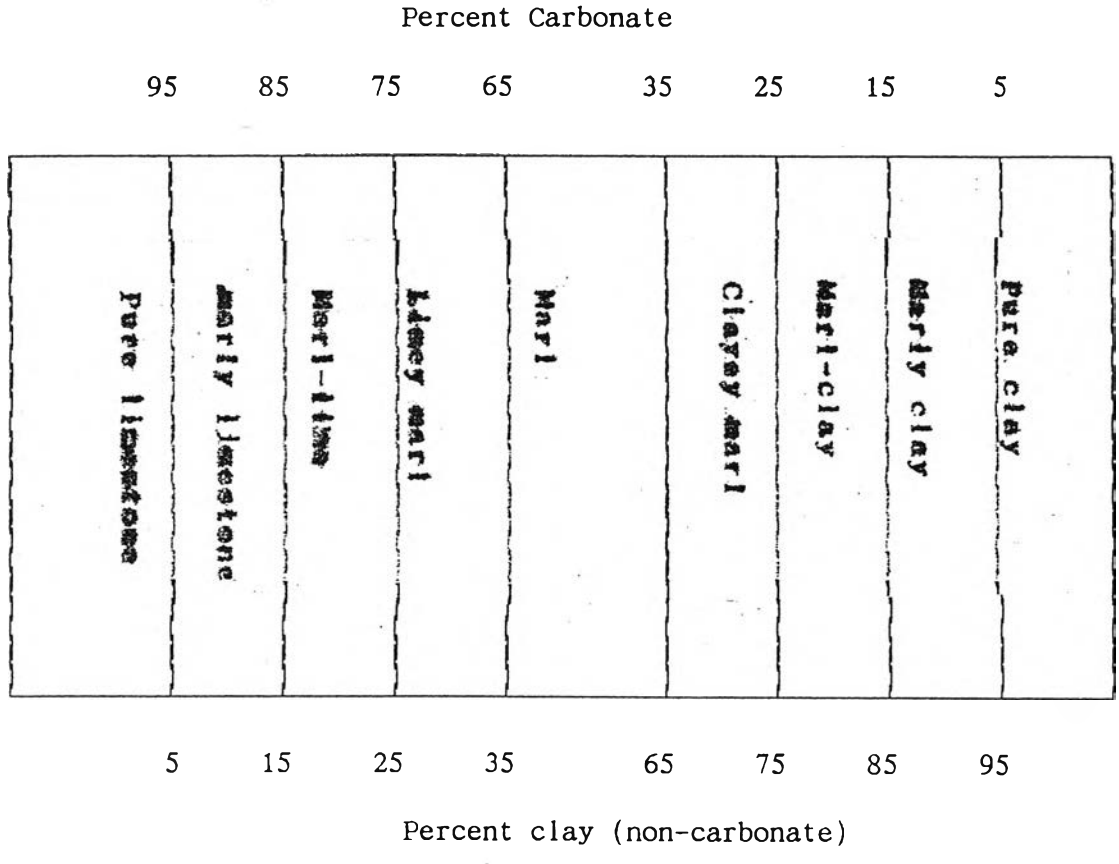
Source : Chaiyan Hintong (1981).

defined as a rock with 35 to 65 percent carbonate and a complementary content of clay.

Correns (cited by Kirsch, 1968) calls "marl" when soil or rocks has carbonate and clay content ratio about 35-65 percent as shown in Table 4 5 a

Chumphon Kuentag (1979) studied marl deposit in Saraburi at Amphoe Ban Mo and Amphoe Phra Phutthabat and concluded that both deposits were characterized by white, loose, porous, and tufa-like material with occasional limestone gravel, and carbonate content more than 90 percent. Besides, he suggested that they should rather be called marly limestone. The genesis is believed to be related to the deposition of limestone weathered products around those areas in

Table 4.5 a Classification of Marl and Related Soil and Rock.



the beginning of Quaternary period. The chemical composition of both deposits are presented in Table 4.5 b.

4.3.1.3 Carbonate Rocks

The term "carbonate rock" is used to include limestone, dolomite and marble. The name limestone is limited to sedimentary carbonate rock which are mainly composed of calcite ($CaCO_3$) and the double saltofcalcium and magnesium carbonate ($CaMg(Co_3)_2$), white calcite being the most abundant. Dolomite is sedimentary rock composed mostly of the mineral dolomite ($CaCO_3$ $MgCO_3$). Marble is a metamorphic rock composed essentially of calcite and/or dolomite.

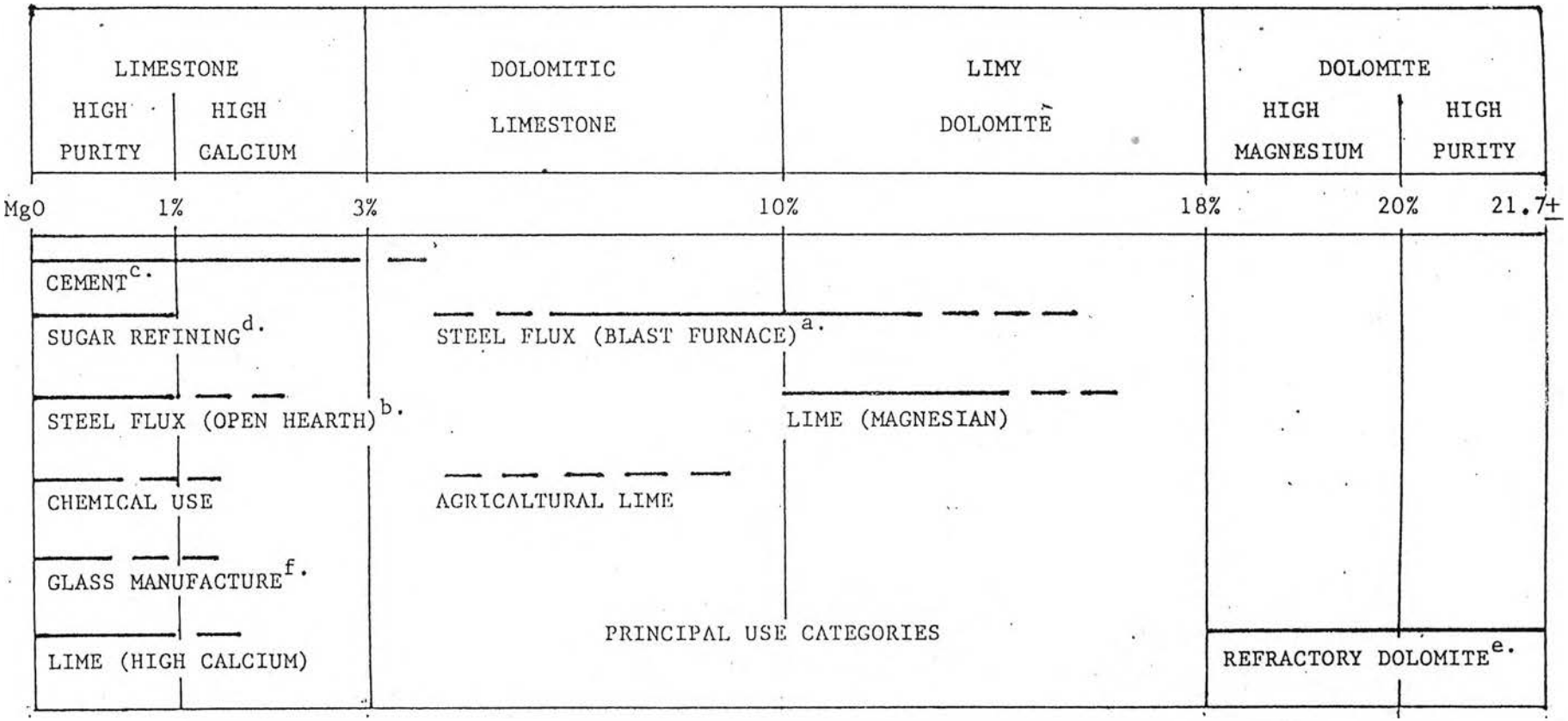
Table 4.5b The Chemical Composition of Marls in Saraburi.

Location	Chemical Composition (per cent by weight)							
	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	$MgCO_3$	$CaCO_3$	$MgCO_3 + CaCO_3$
Nong Bau, Ban Mo	2.57	1.63	0.80	0.14	51.95	0.15	92.71	92.86
Ban Mo	5.40	1.35	0.73	0.04	51.04	0.43	91.09	91.52

Source : Kuentag (1979).

These carbonate rock are extremely valuable raw materials and widely used throughout industry. They are the basic building blocks of the construction industry. The material from which aggregate, cement, lime and building stones are made. Carbonate rock and derived products are used as fluxes, glass raw material, refractors, fillers, abrasives, soilconditioner, ingredientsa host of chemical processes, and much more. Carbonate rocks as construction material will be discussed in the next item for the other used of carbonate rocks. There are many of the particular specifications for the particular uses. However, Evans (1977) presented the schematic chart as shown in Table 4.6. Table 4.6 shows the nomenclature of carbonate rock which is based on MgO content and is designated to fit industrial use categories. The chemical contents concerning in this general specifications are CaO, MgO, SiO_2 Fe_2O_3, Al_2O_3, P_2O_5 and total alkalies.

Table4.6 Chart showing carbonate rocks defied to fit indrustrial use catagories. (After Evans, 1977)



a. SiO_2 < 5%, PREFERABLY < 3%, Al_2O_3 < 2%, P_2O_5 MUST NOT EXCEED TRACE AMOUNTS (i.e. 0.005-0.006%)

b. P_2O_5 MUST NOT EXCEED TRACE AMOUNTS

c. TOTAL ALKALIES < 0.5%

d. SiO_2 < 1.0%, Fe_2O_3 < 0.5%

e. SiO_2, Fe_2O_3 AND Al_2O_3 NOT TO EXCEED 1.0% EACH

f. Fe_2O_3 < 0.05%, PREPERABLY < 0.02%

Within the study area, The carbonate rock potential is Khao Khad Formation. Chaiyan Hintong (1981) reported that Khao Khad Formation comprises black, very dark to the light gray limestone, argillaceous limestone and dolomite with nodular and bedded chert, intercalated shale, sandstone, and rare volcanics. There are locally marble and calc-silicate rock. Fusulinids, coral, brachiopods and algae are common. This formation has trending in East-West but slightly northeast-southwest. The distribution spreads from Lop Buri, Phra Phutthabat to Muak Lek through Amphoe Pak Chong Changwat Nakhon Ratchasima. The Siam Cement, Nakhon Luang Cement and TPI cement are used carbonate rock of this formation as raw material for cement production. In addition Khao Khad Formation within the study area are high potential for development as it near the highways and railways.

Changwat Saraburi has a lot of limestone deposits which is closer to Bangkok than the other limestone deposits in the country, thus, the region has long been a major supplier of cement and other building materials. This is a seed of long term industrialization because of the infrastructures so far developed for limestone mining and cement industries,the agglomeration of cement related industries, which the possible demand expansion are in the northeastern region as well as further neighboring country.

The chemical composition of carbonate rocks along Khao Khad Formation are presented in Table 4.7.

Table 4.7 Chemical Composition of Carbonate Rocks within Khao Khad Formation.

Localities	Map sheet	Grid Reference	Chemical composition (%)				Chemical Composition (%)				
			CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	Ig. loss	$CaCo_3$
Khao Nok Yung A.Muang	5138II L7017	018236	49.00	0.40	12.01	0.52	0.30	0.01	0.01	37.49	87.46
Khao Ngop,A.Muang	"	023248	55.56	0.32	0.53	0.116	0.12	0.004	0.004	43.08	99.16
Khao Phat Aek,A.Muang	"	019261	54.45	1.10	0.50	0.15	0.15	0.008	0.002	43.41	97.18
Khao Yai,A.Muang	"	030256	54.91	1.23	0.14	mil	0.19	0.004	0.002	43.46	98.00
Khao Yao,A.Muang	"	002248	55.02	0.50	0.30	0.06	0.23	0.02	0.005	43.64	98.20
Khao Sap Pla Kang A.Phra Phutthabat	"	991245	55.49	0.15	0.06	0.14	0.14	0.006	0.02	43.98	99.04
Khao Wong A.Phra Phutthabat	"	974226	55.40	0.45	0.08	0.09	0.05	0.002	0.002	43.80	98.88
Khao Phat	"	962221	55.99	0.15	0.05	0.02	0.05	nil	0.001	43.58	99.93
Khao Phlong	"	929235	55.47	0.42	0.13	0.07	0.08	0.002	0.001	43.75	99.00
Khao Lieo A.Phra Phutthabat		929247	54.90	0.97	0.02	0.26	0.13	0.002	0.001	43.58	97.98
Khao Thamnop Sithanon Chai,A.Phra Phutthabat	"	945267	55.27	0.66	0.09	0.06	0.09	nil	0.012	43.61	98.84
Khao Phraputthabat A.Phra Phutthabat	"	932275	54.96	0.72	0.02	0.04	0.06	0.004	0.002	43.86	98.09

Table 4.7 (cont.) Chemical Composition of Carbonate Rocks within Khao Khad Formation.

Localities	Map sheet	Grid Reference	Chemical composition (%)				(%)				
			CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	Ig. loss	$CaCo_3$
Khao Boraphet A.Phra Phutthabat	5138 II	945278	54.47	1.08	0.31	0.02	0.11	nil	0.003	43.68	97.22
Khao Tham Prathum A.Phra Phutthabat	L7017	943267	55.40	0.50	0.01	0.04	0.08	nil	0.005	43.70	98.88
Khao Prong Prap A.Phra Phutthabat	"	953268	54.48	0.40	1.01	0.01	0.10	0.002	0.01	43.74	97.24
Khao Than Thong Daeng A.Phra Phutthabat	"	958287	54.74	0.57	0.26	0.09	0.10	nil	0.003	43.95	97.70
Khao Tham Krabok A.Phra Phutthabat	"	964267	55.14	0.53	0.02	0.06	0.09	nil	0.005	43.93	98.41
Khao Sap Cha-om A.Phra Phutthabat	"	991252	55.48	0.42	0.04	0.028	0.13	0.002	0.005	43.75	99.02
Khao Tham Si Wilai A. Muang	"	037272	55.14	0.52	0.32	0.068	0.12	0.002	0.001	43.75	98.91
Khao Yot Iang A.Muang	"	006255	54.71	0.43	1.48	0.03	0.11	0.004	0.01	43.09	97.65
Khao Khao A.Muang	"	079291	54.57	0.45	2.05	0.12	0.03	0.003	0.04	42.54	97.40

Table 4.7 (cont.) Chemical Composition of Carbonate Rocks within Khao Khad Formation.

Localities	Map sheet	Grid Reference	Chemical composition (%)				Chemical Composition (%)				
			CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	Ig. loss	$CaCo_3$
Khao Ban Kon A.Kaeng Khoi	5238II L7017	199295	55.75	0.35	mil	0.01	0.12	nil	0.04	43.71	99.50
Khao Nong Kob A.Kaeng Khoi	"	212208	55.64	0.33	0.14	0.02	0.05	0.002	0.01	43.59	99.31
Khao Hin Dat A.Kaeng Khoi	"	171274	34.51	18.66	0.22	0.10	0.42	0.01	0.008	45.97	61.59

Source : Vuthigan Suksorm (1988) and Vivat Paijitprapaporn (1984).

4.3.2 Construction Materials

Construction Material include crushed stones, sand and gravel and laterite/lateritic soil. Crushed stones,sand and gravel are aggregates and relatively inexpensive material. However, transportation costs are added

4.3.2.1 Crushed stones

Limestone is the most common rock to be used. The fresh limestone is tough,bound aggregate which meet the general requirement of crushed stone of uniform, non porous, and free of organic matters and pyrite.

Within the study area, the Khao Khad Formation, there are plenty of rock quarries for crushed stone and marble factory such as at Khao Khad and Khao Phra Phutthabat Noi and travertine dimension stone located at Ban Sap Haeng, Amphoe Kaeng Khoi (Vivat Pijitprapaporn and Veeravat Thitisawan, 1992). The 24 production quarries for crushed stone are located at Khao Khao, Khao Phat Aek, and Khao Yai Ban Na Phra Lan (Somwang Changsuwan, 1991). Some engineering properties of these crushed stones sample are presented in Table 4.8.

The Los Angeles Abrasion (LAA) Test specification of rock for highways base course should not more than 40 percent (DOH, 1967). It is shown in Table 4.8 that the LAA value of crushed limestone is good for base-course.

Table 4.8 Some Engineering Properties of Crushed Stone.

Ref no	Location	LAA %	PLS Kg/Cm^2
	Route no.1 Saraburi-Lob Buri		
L-1	Right of km 127+410	24.2	60
L-2	Left of km. 128+600	27.9	67
L-3	2,000 m. Right of km.128+600	25.0	75
L-4	Right of km. 128+850	27.9	57
L-5	Right of km. 128+900	26.1	63
L-6	Right of km. 128+900	27.4	63
L-7	RIght of km. 128+980	26.7	66
L-8	Right of km. 129+050	25.2	60
L-9	Right of km. 129+100	31.8	58
L-10	Left of km. 129+400	25.3	66
L-11	Right of km. 129+400	24.9	64
L-12	Right of km. 125+600	23.4	59
L-13	Left of km. 129+700	28.7	60
L-14	Right of km. 129+750	30.3	64
L-15	2,500 m Left of km.130+700	24.0	72
L-16	2,000 m Left of route no.3022 (Phra Phutthabat-Tha Rua)	24.7	77
L-17	Left of km.5+450 route no.21 (Phu Khae-Lam Narai)	22.6	70

Table 4.8 (cont.) Some Engineering Properties of Crushed Stone.

Ref no	Location	LAA %	PLS Kg/Cm^2
	Route no.3385 (Na Phra Lan-Nong Jan)		
L-18	300 m. Left of km. 2+800	26.4	66
L-19	Left of km. 2+900	27.9	74
L-20	Right of km. 0+700	25.8	56
L-21	Right of km. 1+450	29.6	63
L-22	Right of km. 1+500	22.4	62
L-23	Left of km. 1+500	26.6	66
L-24	500 m. right of km.4+500	24.8	57

Source: Somwang Changsuwan and Anuphan Kaedkaew,1991 (department of Highways)

Note : LAA- Los Angeles Abrasion

PLS- Point Load Strength index, Is (50)

4.3.2.2 Sand

Sand is used for asphaltic portland cement concretes, as subbase for pavement, as fill where good drained is need (such as around structures). The major use of it is as aggregate in portland cement concrete, since it contain 80 to 85 percent aggregate by weight. Some properties of sand deposits are geven in Table 4.9.

Table 4.9 Some Properties of Sand Deposits.

Location	Sieve Analysis % Passing					Organic Impurity
	9.5	#4	#10	#40	#200	
Route no.3022 (Amphoe Kaeng Khoi - Ban Na)						
1. 300 m. left of km.35	100	98.5	92.5	38.9	11.4	over standard
2. 150 m. left of km.33+500	100	99.0	95.8	48.6	7.6	over standard

Source : Thapanit Aimasiri et al. (1990).

4.3.2.3 Laterite,Lateritic Soil/Weathered Rocks

Laterite is suitable as subbase and shoulder of road, subbase of airfield and the course for medium traffic road. Within the study area, laterite deposits and weathered rock have been used as soil aggregate for subbase and shoulder of road. The potential for laterite/lateritic soils resources are Sap Bon Formation which described by Chaiyan Hintong (1981) as thin-bedded, gray, brown, buff, sandstone, siltstone, shale, siliceous shale, and chert intercalated with gray limestone ,locally phyllite and schist.

Considering the engineering uses of laterite and lateritic soils,the significant properties should be tested, include gradation, Atterberg limits (liquid limit, plastic limit, and plastic index), compaction test, and California Bearing ratio (CBR). Table4.10 shows some engineering properties of laterite, lateritic soil and weathered rocks tested by the Department of Highways.

From Table 4.10 and 4.11, the seive analysis data show that sample numbers L1, L2, L3, L6, L10 and L11 are grouped in grade B while sample numbers L4, L8, L9 can be grouped in grade D. Sample numbers L5, L7, L12 are not acceptable to the specification.

4.4 Water Resources

4.4.1 Surface Water

The Pasak River is the main source for suface water in Saraburi. The river flows in the north-south direction to join the Chao Phraya River at Changwat Phra Nakhon Si Ayutthaya. Another source of surface water is from Chai Nat-Pasak irrigation cannal which is distributed in the study area in the west low land partion.

The PasakRiversupplieswaterof 74 m^3/second which is equal to 2352 million cubic meter (MCM) per year. The rainfalls in the area start to increase from April and reaches its maximum volume in September or October. The surface water availability related to rainfall intensity could be separated into wet and dry seasons. The wet season is from July to December and dry season from January to

Table 4.10 Engineering properties of Laterite, Lateritic soil /weathered rocks.

no. Location	Seive Analysis(%Passing)								Plasticity		standard proctor		Lab	Abrasion	Durability
	50	25	19	9.5	#4	#10	#40	#200	LL.	PI	OPT. MC%	RD gm/CC	CBR %	%	
Route no.1 Saraburi-Phu Kae L1:5600 m.right of km 123+400	100	99.3	95.6	78.5	47.4	27.3	127	16.1	20.4	7.4	8.8	2.137	47.0	41.2	57.5
L2:6400 m.right of km. 123+400	100	98.2	95.5	74.3	46.7	25.6	16.3	13.8	33.4	6.2	6.8	2.119	72.6	40.0	60.0
L3:6100 m.right of km. 123+400	100	95.3	91.6	75.5	50.3	30.5	21.4	19.5	30.3	9.4	7.0	2.159	75.0	40.6	59.5
L4:6000 m.right of km. 123+400	100	99.4	96.3	88.3	63	43.7	30.5	19.5	28.0	7.2	9.2	2.126	39.7	41.8	56.8
L5:6600 m.right of km. 123+400	100	98.6	95.7	82.3	52.9	37.9	30.6	27.7	34.6	13.8				40.4	56.8
L6:1700 m.right of km. 123+400	100	942	85.5	65.9	49.6	32.6	22.7	19.1	20.0	5.8	9.2	2.093	53.0	38.6	64.7
Route no.3385 Phra Phutthabat -Ban Nong Jan L7:500 m.left of km. 5+100	100	96.0	92.9	70.3	38.7	19.0	11.3	9.7	---	N.P.-	—			43.8	53.7

Table 4.10 (cont.) Engineering properties of Laterite, Lateritic soil /weathered rocks.

no. Location	Seive Analysis(%Passing)								Plasticity		standard proctor		Lab	Abrasion	Durability
	50	25	19	9.5	#4	#10	#40	#200	LL.	PI	OPT. MC%	RD gm/CC	CBR %	%	
L8:1400 m. left of km.7+600	100	97.2	96.2	82.7	54.8	31.9	14.4	12.3	33.2	9.1	9.7	2.040	73.0	37.6	67.7
L9:800 m. left of km. 2+650	100	96.8	95.0	7o.3	44.2	30.4	24.4	22.6	46.4	23.7	-	-	-	43.4	54.8
L10:2600 m. right of km. 6+650	100	98.9	942	73.3	51.2	34.1	22.2	17.0	21.1	4.6	7.2	21.65	58.5	38.8	63.6
L11:1500 m. right of km. 8+650	100	987	92.5	76.6	59.4	47.2	34.1	31.9	47.4	19.7	-	-	-	40.3	-
Route no.3222 A.Kaeng Khoi A.Ban na									53.2	23.2	-	-	-	48.0	45.3
L12:3,100 right of km. 31+100	-	-	100	94.2	64.9	52.8	43.4	37.5							

Table 4.11 The Specification of Laterite Subbase.

Seive openning	% Passing				
	A	B	C	D	E
2"	100	100	-	-	-
1"	-	-	100	100	100
3/8"	30-65	40-75	50-85	60-100	-
No.10	15-40	20-45	25-50	40-70	40-100
No.40	8-20	15-30	15-30	25-45	20-50
No.200	2-8	5-20	5-15	50-20	6-20

Liquid Limit (LL) Less than 35

Plasticity Index (PI) Less than 11

Percentage of wear Less than 60 (Test by LAA method)

Lab C.B.R. value As design specification

June. In wet season the stream run-off is about 2,146 MCM and in dry season is 206 MCM (JICA, 1990).

The irrigated area in Saraburi covers 404,829 Rais which are mainly in Amphoe Nong Kae, Wihan Daeng, Nong Sang, Sao Hai, Nong Don, Don Put and Muang. The area receives water from Chainat-Pasak irrigation cannal and from the Pasak River.

There are 45 small scale irrigation projects constructed by Royal Irrigation Department. The project could provide water for irrigation of about 2-5 million cubic meters.

The information of surface water quality in the area is limited. The Envirtech consultant (1992) presented The DO (Dissolved Oxygen in Water) value of the Pasak River at Kaeng Khoi and Saraburi in 1987 were 8.4 and 7.0 milligram/lit (mg/l), respectively. While the minimum standard DO value is 2 mg/l (Narong Na Chiangmai, 1991). This appeared that the quality of water is quite higher than minimum standard. In general, the surface water quality is good for domestic agricultural and industrial uses. However, the expansion of industries as proposed in the National Economic and Social Development Plan number 7 will require a lot of water supply. Water shortage and water quality problems will also arise.

4.4.2 Ground Water

Ground water is intensively used in Saraburi especially for industrial and rural domestic supply (JICA, 1990). Approximately 42 percent of industrial water supply come from groundwater. Another source of water supply come from urban water supply and river water. Considering the geological characteristics of the area it has high potential for ground water supply in Permian carbonate rock and in unconsolidated sediments of Quaternary age. Charoen Phiancharoen et al. (1976) prepared the hydrogeological map of western lower central and eastern Thailand which included the study area. The aquifer type, water bearing properties including quality as well as

recommendations described in this investigation are base largely on this report together with limited information from well logs recorded by ground water division, Department of Mineral Resources (DMR). The hydrogeological map of the area is illustrated in Figure 4.8.

Within the study area, there are two types of aquifers, namely, porous rock aquifers and jointed massive rock aquifers.

4.4.2.1 Ground Water in Porous rocks

The ground water in porous rocks comprised three types of aquifers, namely, (i) Chao Phraya aquifer (Qcp), (ii) concealed (concealed Chao Phraya aquifer) (iii) Chiang Rai aquifer (Qcr).

The Qcp aquifer composed of alluvium of small valleys and shallow buried channels of sandy, minor gravelly and clay beds. The thicknesses of the aquifers are commonly not exceeding 200 feet with the yield of 20-100 gallon per minute (gpm). Water Quality is usually fresh. In the study area the Qcp aquifers spread along the narrow strip of the valley plain in Amphoe Muak Lek.

The concealed Qcpare the multiple aquifers which consists of unconsolidated to semiconsolidated sand and gravel in clay matrix, poorly to moderately sorted intercalated or interbedded with compacted clay beds. Range of thickness is from a few meters to more than 200 meters. The aquifers yield upto the maximum of 20 gpm. Yields are low to maximum 20 gpm. Water quality is usually fresh but

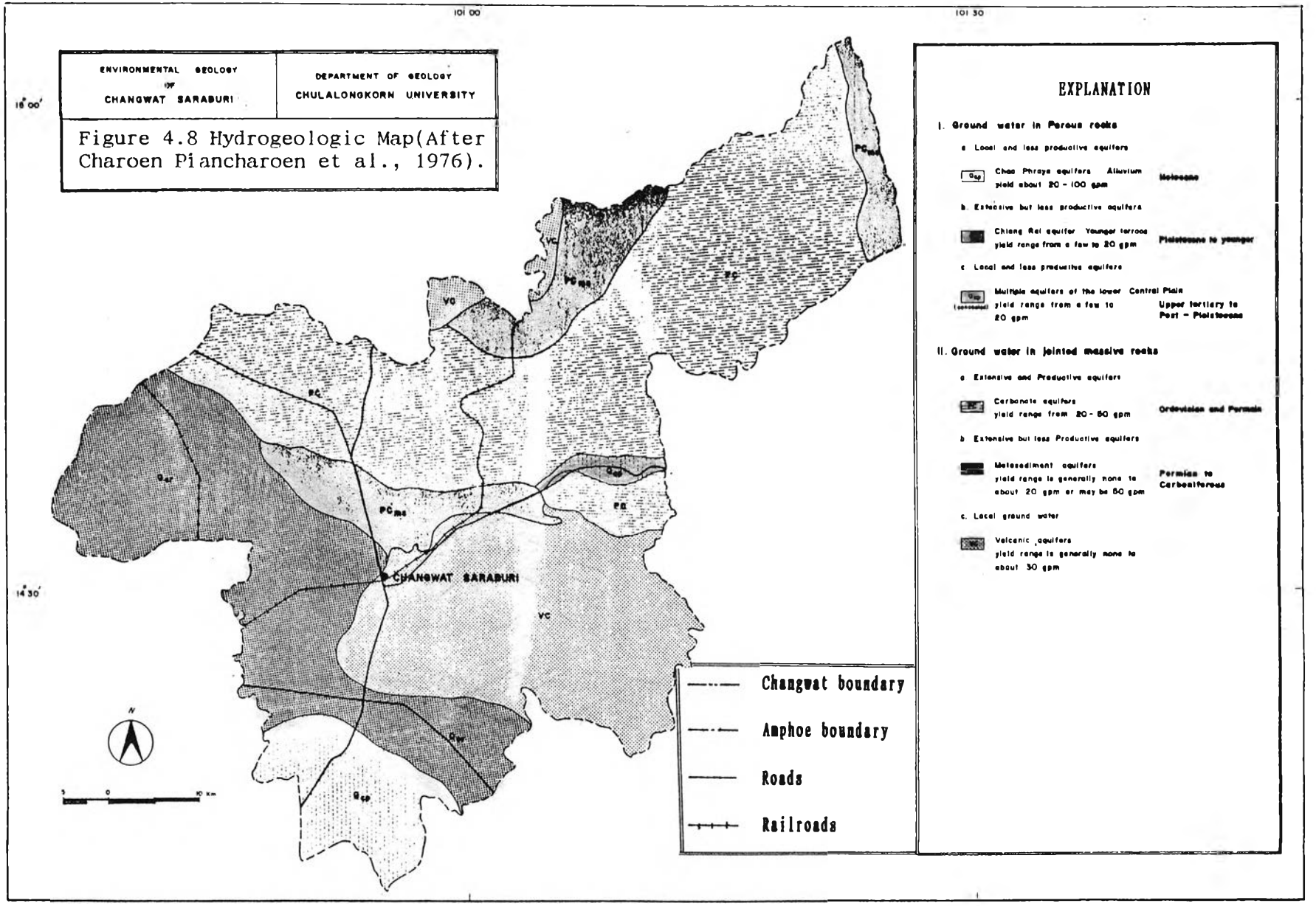


Figure 4.8 Hydrogeologic Map(After Charoen Piancharoen et al., 1976).

high in iron content.

The Ocr aquifer consists of younger terrace with relatively flat surfaces. The deposits composed of thick clay beds, mixed sand and gravel in clay matrix. The thickness of the deposits ranges from about 15 meters to more than 60 meters. The yield ranges from a few to 20 gpm. Water quality is usually potable with high iron content.

4.4.2.2 Ground water in jointed massive rocks

The ground water in jointed massive rocks is classified into 3 categories based on rock types, namely, carbonate aquifer (PC), metasediment aquifers (Pcms) and Volcanic aquifers (VC).

The carbonate aquifers (PC) consist of the limestone Ratburi Group. This unit composed of massive, bedded and cavernous limestone with intercalating shale and chert beds. Relatively large quantity of ground water occur in solution cavities and also in its secondary fractured zones. Average yield is 100 gpm but the yield may be up to 500 gpm. The water quality is generally moderately hard.

The metasediment aquifers (Pcms) consisted of sedimentary rocks which includedsandstones and phyllitic to slaty shale. The groundwater occurs only in the secondary openings. The average yield is about 20 gpm. Water quality is generally good but high iron concentration may be found.

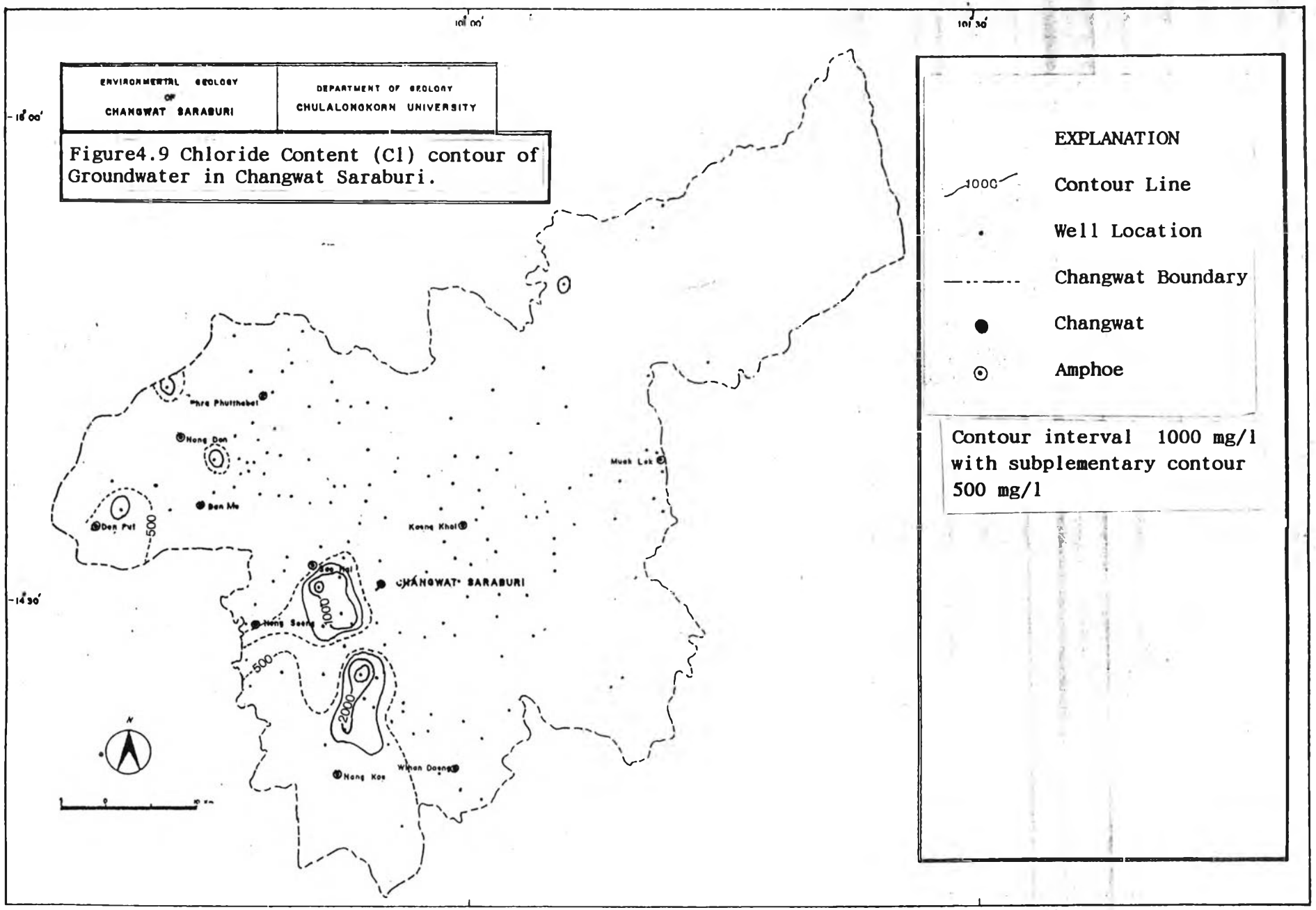
Volcanic aquifer (VC) consisted of andesite, rhyolite and pyroclastic rocks. Small amount of ground water can be obtained from joints and fractures. Yield range is generally non to about 30 gpm.

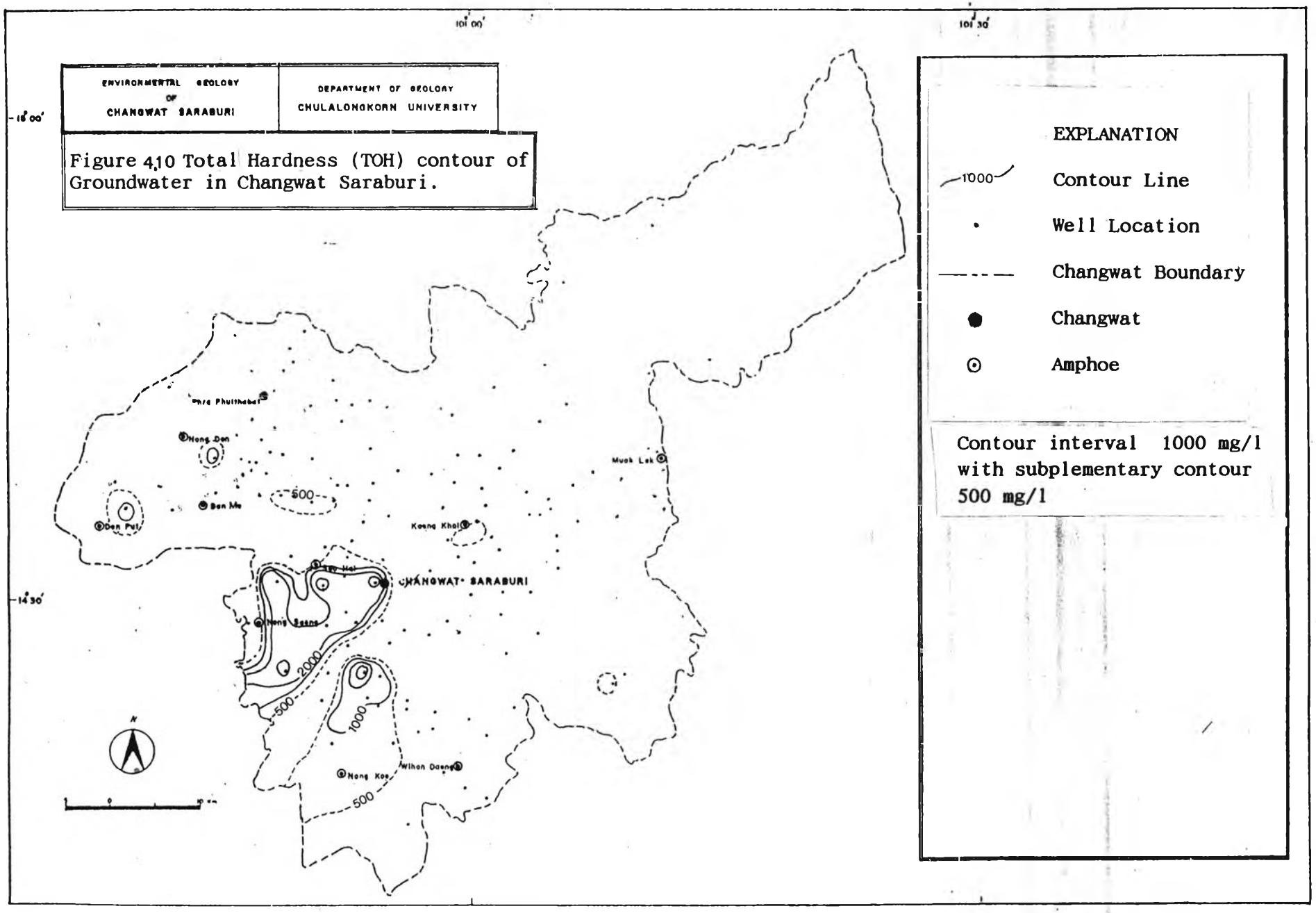
The chloride (Cl) content, total hardness (TOH) and static water level data from the record of wells published by The Division of Groundwater (1958-1991), Department of Mineral Resources, were used to construct contour map of these data as shown in Figure 4.9, 4.10 and 4.11, respectively.

The chloride content contour map indicates that salt water interfere the groundwater quality as shown in the south of Amphoe Sao Hai and Nong Saeng. The chloride content in these areas are more than 3,000 milligram/liter (mg/l) where as the spot of high chloride content also occur at Amphoe Don Put and Nong Don. The maximum acceptable chloride content by WHO (1971) is 500 mg/l. So in the areas of high chloride content, groundwater use should be limited to prevent the salt water intrusion.

From total handness (TOH) contour map, it is indicated that the pattern of high TOH is similar to that of the chloride content. The maximum acceptable total handness by WHO (1971) is 500 mg/l. The TOH value of greater than 3,000 mg/l is observed in the area south of Amphoe Sao Hai, Nong Saeng, west of Amphoe Muang, and in the north of Amphoe Nong Khae.

The peizometric map of the groundwater in the area indicates that groundwater is intensively used in Amphoe Muang, Kaeng Khoi,


ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure4.9 Chloride Content (Cl) contour of Groundwater in Changwat Saraburi.
EXPLANATION
1000 Contour Line
Well Location
Changwat Boundary
Changwat
Amphoe
Contour interval 1000 mg/l with subplementary contour 500 mg/l
101°00'
101°30'
14°30'
15°00'
Phra Phutthabat
Nong Don
Muak Lek
Ban Mo
Don Pui
Kaeng Khoi
Sao Hai
CHANGWAT SARABURI
Nong Saeng
Nong Koe
Wihan Daeng
500
1000
2000
N


ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure 4.10 Total Hardness (TOH) contour of Groundwater in Changwat Saraburi.
101° 00'
101° 30'
18° 00'
14° 30'
EXPLANATION
1000
Contour Line
Well Location
Changwat Boundary
Changwat
Amphoe
Contour interval 1000 mg/l with subplementary contour 500 mg/l
Phra Phutthabat
Nong Don
Muak Lek
Ban Mo
500
Don Puti
Kaeng Khoi
Sao Hai
CHANGWAT SARABURI
Nong Saeng
2000
500
1000
Nong Kae
Wihan Daeng
500
N

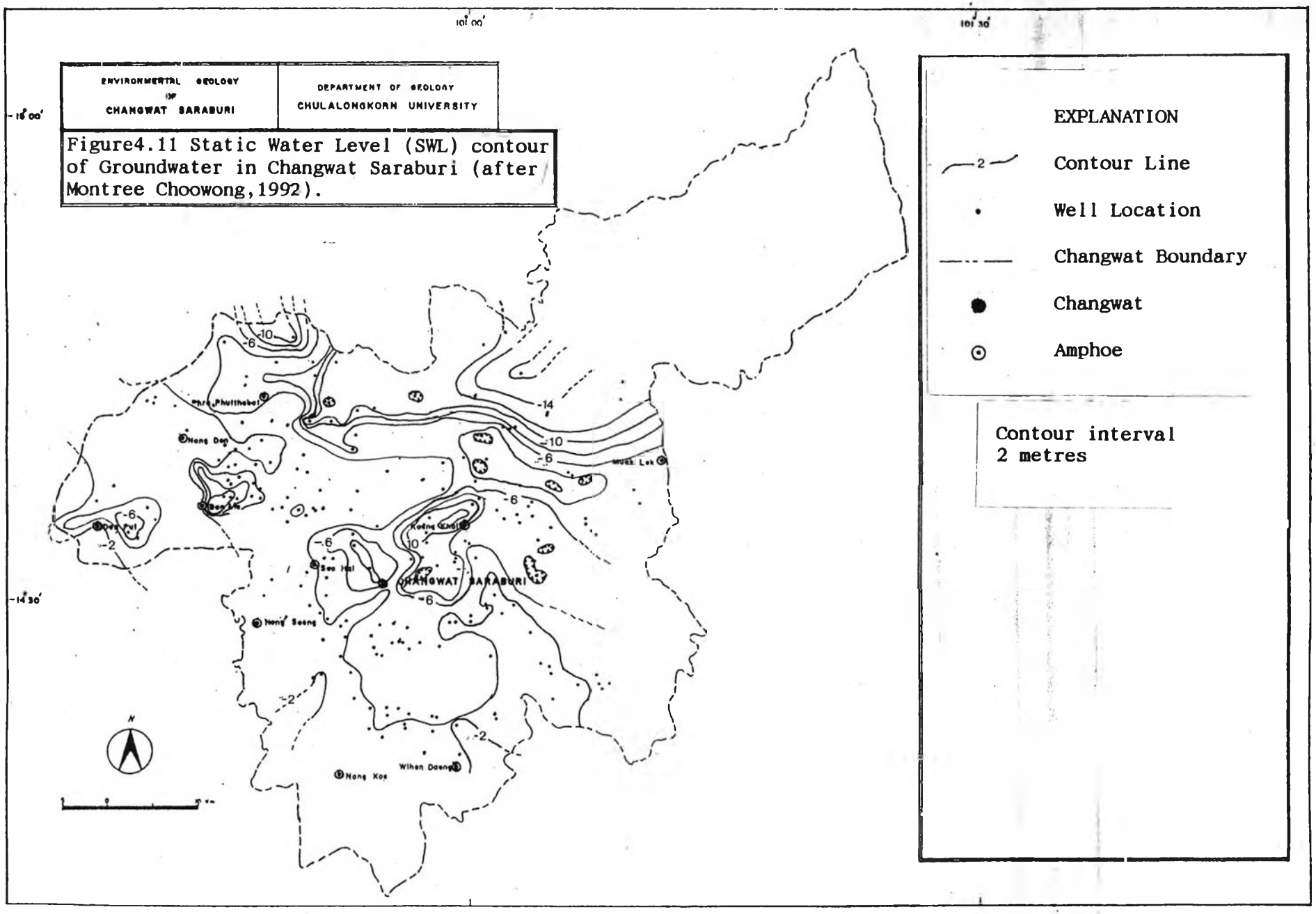


Figure4.11 Static Water Level (SWL) contour of Groundwater in Changwat Saraburi (after Montree Choowong,1992).

Ban Mo, Don Put, Phra Phutthabat and Sao Hai which is shown by the depression lines.

From the chloride concentration, total hardness and peizometmaps, it is indicated that groundwater problem potential areas are identified in the west of Saraburi in Amphoe Nong Saeng, Nong Khae and Don Put. The intersive use of groundwater may cause salt water encroachment problem. The use of groundwater in these areas should be controlled. In the area of Amphoe Kaeng Khoi where the groundwater is extracted from carbonate rock, the problem of land subsidence might be expected due to the collapse of the covities in limestone.

4.4.3 Water resources development

Due to development in the Pasak River basin,the demand for water supply for community, agriculture and industry was increased so much. The average annual run off of the Pasak River is 74 m^3 /sec. but in dry season the run off down to below 10 m^3/sec for 3 to 5 months in most years (JICA, 1990).

The Pasak Dam sites were proposed for feasibility study in 1991. The proposed sites were at Kaeng Khoi and pattern Nikhom (Figure 4.12).

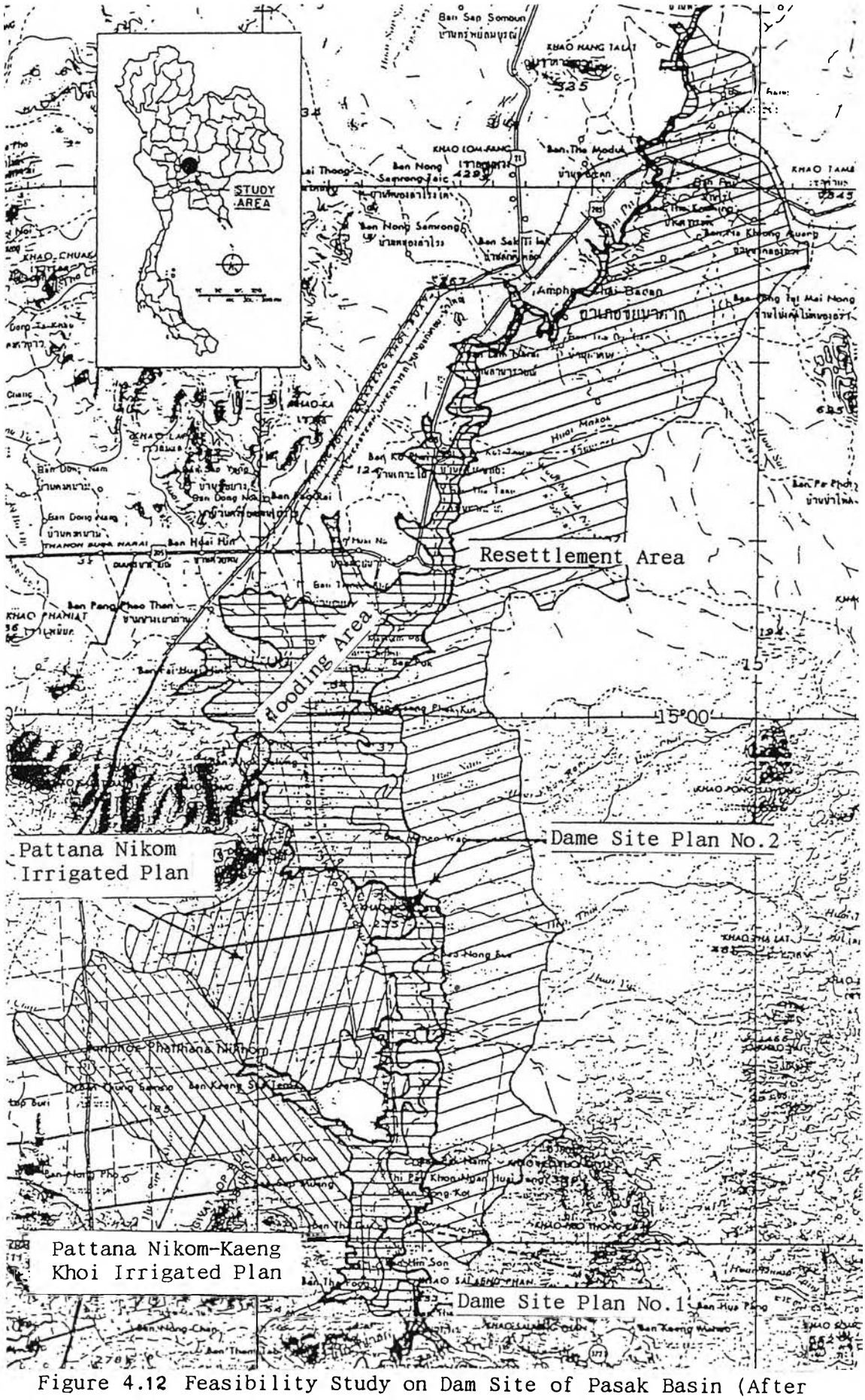


Figure 4.12 Feasibility Study on Dam Site of Pasak Basin (After RID, 1991).

4.5 Hazards

4.5.1 Seismic Hazards

Earthquakes are the detectable shaking of the earth's surface resulting from seismic wave generated by sudden release of strain energy from within the earth. Surface effects can include damage to or destruction of structure;faults and crustal warping, subsidence, liquefaction and slope failures off shore or onshore, and tsunami (Hunt, 1984).

Prinya Nutalaya et al. (1985) defined seismic source zone and produced maximum earthquake intensity map of Thailand and adjacent area (Figure 4.13 and 4.14). It is shown in the map that the study area is situation the non-seismic zone.

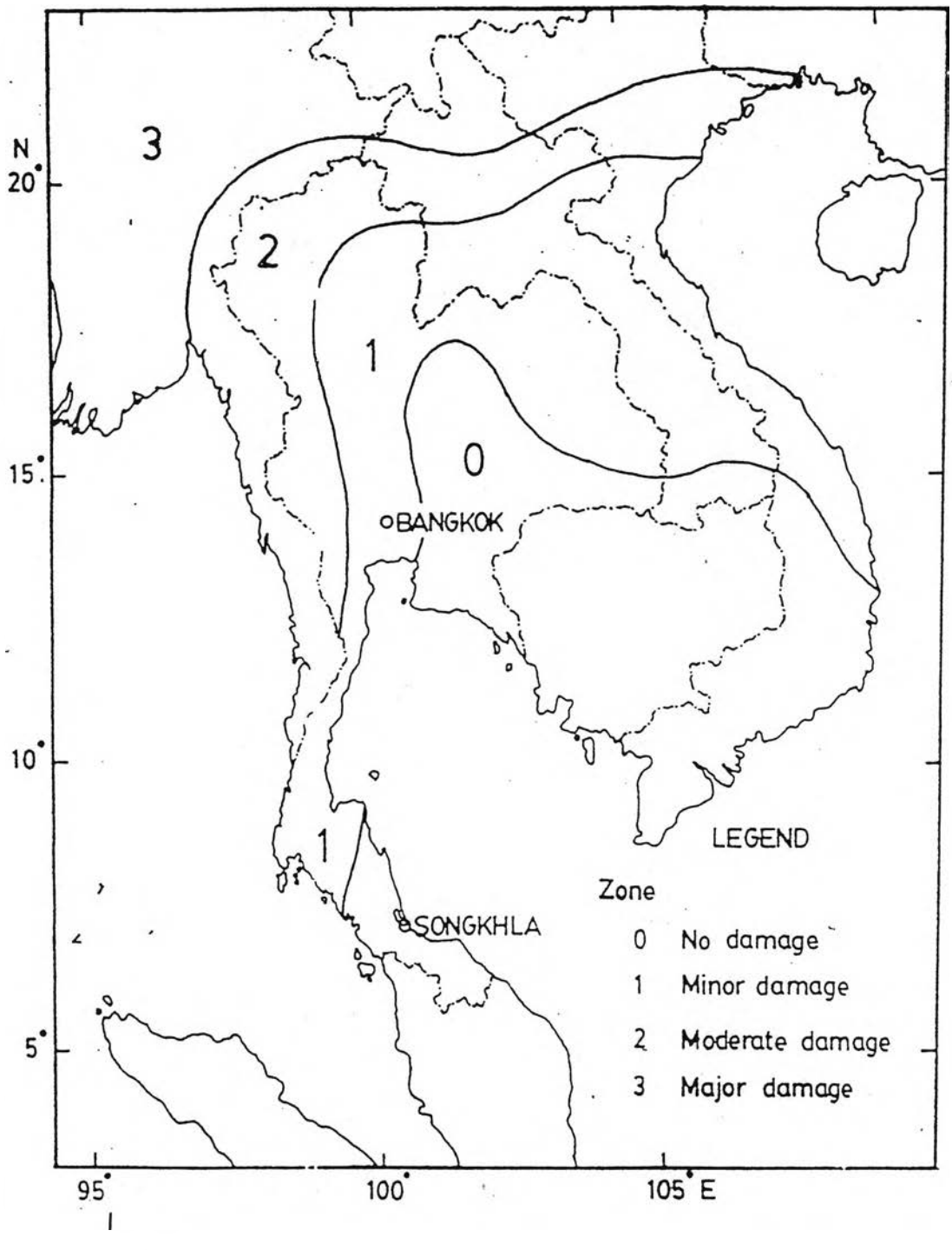


Figure 4.13 Seismic Zoning Map of Thailand and Adjacent Areas (After Prinya Nutalaya et al.,1985).

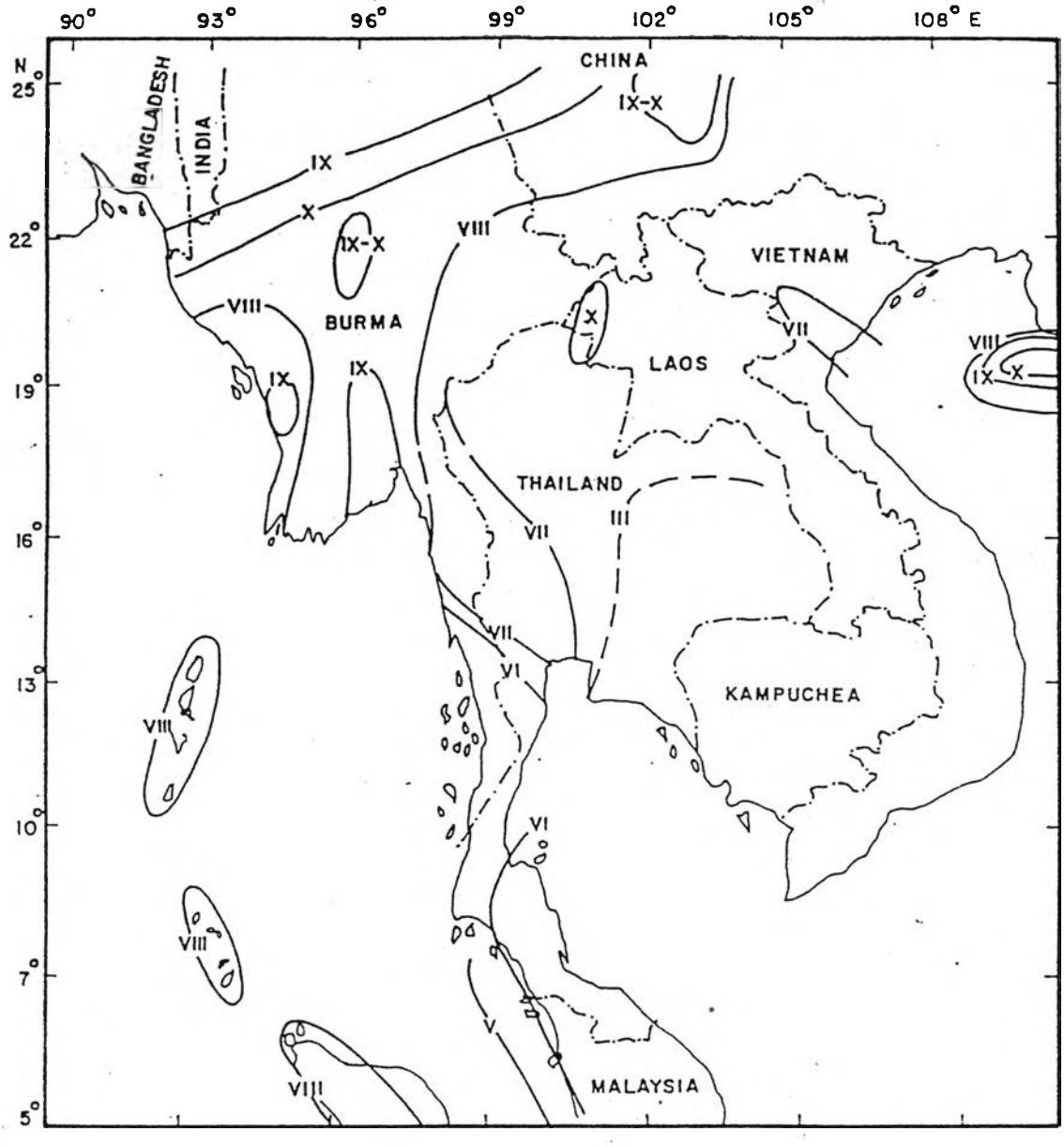


Figure 4.14 Maximum Earthquake Intensity Map of Thailand and Adjacent Areas(After Prinya Nutalaya et al., 1985).

Table 4.12 Flood Fequency Analysis.

Recurrence of flood frequency (year)	QTr Probability distribution (m^3/sec)	QTr Plotting position (m^3/sec)	Stage height (m.)
2	527	528	12.8
5	759	777	15.0
10	913	917	16.2
25	1,107	1,120	18.0
50	1,252	1,260	19.4
100	1,359	1,400	20.4
200	1,538	1,540	21.8
1,000	1,868	1,869	

4.5.2 Flooding

4.5.2.1 Flood Frequency Analysis

Schultz (1973) concluded that by using probability analysis of log Pearson type III or Gumbel's extreme value type I, the probability of occurrence of floods of various magnitudes at the site could be determined from annual peak discharge for all years of record at the site

Sabur (1982) studied basins in Thailand and suggested that Gumbel's probability analysis is quite fit to those river basin.

In this study an attempt has been made to evaluate flood frequency analysis by using Gumbel's probability distribution and Gumbel's plotting position (Veerapol Taesombat, 1988) for comparison as shown in Table 4.12, 4.13 and Figure 4.15. Couple the stage height graph (Figure 4.16) wiht known elevation along river, the flood hazard map could be constructed (Limerinos, 1977).

4.5.2.2 Flood Inundated Map

Ohkura, et al. (1989) used LANDSAT images in wet and dry season in Lower Central Plains to construct geomorphological map showing flood-inundated area (Figure 4.17).

The flood inundated map show the features of flooding such as fan when the area is flooded. The area occupied the eastern part of Saraburi, Amphoe Nong Saeng, Nong Khae and Wihan Daeng. The valley plain unit when submerged at flood time, the water drain off well. This unit covers along the Pasak River side in Amphoe Sao Hai, Muang and Kaeng Khoi. The delta unit cover the western area in Amphoe Nong Don and Don Put. This area will be submerged during flooding and remain submerged for long time. The back-marsh unit covers the southern most part of the study area in Amphoe Nong Khae and Wihan Daeng. This area will be submerged during rainy season and remain submerged for a long time with deep water. The swampy area covers small part of the study area. This unit will be submerged during flooding for long time and remain swampy in the dry season.

Table 4.13 Flood Frequency Analysis
of Pasak river at Kaeng Khoi (S2)

Year	Q.Max.	Order	Rank	Recurrenc	Pr
2518	691	1519	1	63.00	1.59
2517	378	1420	2	31.50	3.17
2516	292	996	3	21.00	4.76
2515	888	974	4	15.75	6.35
2514	274	927	5	12.60	7.94
2513	420	897	6	10.50	9.52
2512	974	888	7	9.00	11.11
2511	90	886	8	7.88	12.70
2510	449	840	9	7.00	14.29
2509	687	813	10	6.30	15.87
2508	491	768	11	5.73	17.46
2507	1519	767	12	5.25	19.05
2506	927	751	13	4.85	20.63
2505	996	739	14	4.50	22.22
2504	384	733	15	4.20	23.81
2503	463	729	16	3.94	25.40
2502	702	708	17	3.71	26.98
2501	404	702	18	3.50	28.57
2500	733	691	19	3.32	30.16
2499	443	687	20	3.15	31.75
2498	292	642	21	3.00	33.33
2497	566	625	22	2.86	34.92
2496	320	588	23	2.74	36.51
2495	310	578	24	2.63	38.10
2494	323	577	25	2.52	39.68
2493	768	566	26	2.42	41.27
2492	625	566	27	2.33	42.86
2491	522	550	28	2.25	44.44
2490	433	540	29	2.17	46.03
2489	495	522	30	2.10	47.62
2488	840	513	31	2.03	49.21
2487	813	510	32	1.97	50.79
2486	510	495	33	1.91	52.38
2485	897	493	34	1.85	53.97
2484	147	491	35	1.80	55.56
2483	458	490	36	1.75	57.14
2482	493	463	37	1.70	58.73
2481	550	458	38	1.66	60.32
2480	751	449	39	1.62	61.90
2479	392	446	40	1.58	63.49
2478	739	443	41	1.54	65.08
2477	577	435	42	1.50	66.67
2476	324	433	43	1.47	68.25
2475	435	420	44	1.43	69.84
2474	376	411	45	1.40	71.43
2473	767	404	46	1.37	73.02
2472	327	392	47	1.34	74.60
2471	446	384	48	1.31	76.19
2470	411	378	49	1.29	77.78
2469	578	376	50	1.26	79.37

2468	374	374	51	1.24	80.95
2467	566	327	52	1.21	82.54
2466	642	324	53	1.19	84.13
2465	729	323	54	1.17	85.71
2464	490	320	55	1.15	87.30
2463	886	310	56	1.13	88.89
2462	206	292	57	1.11	90.48
2461	708	292	58	1.09	92.06
2460	1420	274	59	1.07	93.65
2459	588	206	60	1.05	95.24
2458	513	147	61	1.03	96.83
2457	540	90	62	1.02	98.41

Flood Frequency Analysis
Gumbel's Distribution Calculation

QTr=Q'-0.45SQ-0.7797SQln[-ln(1-(1/Tr))]
Q'=Sum of Qi / N
SQ=square root{[(sum Qi*Qi)-N(Q')]/(N-1)}

Recurrence	-ln[-ln(1-(1/tr))]	Q'-0.45SQ"	QTr(m3/sec
2	0.367	451.81	527.09
5	1.500	451.81	759.49
10	2.250	451.81	913.32
25	3.199	451.81	1107.98
50	3.902	451.81	1252.17
100	4.600	451.81	1359.35
200	5.296	451.81	1538.11
1000	6.907	451.81	1868.55

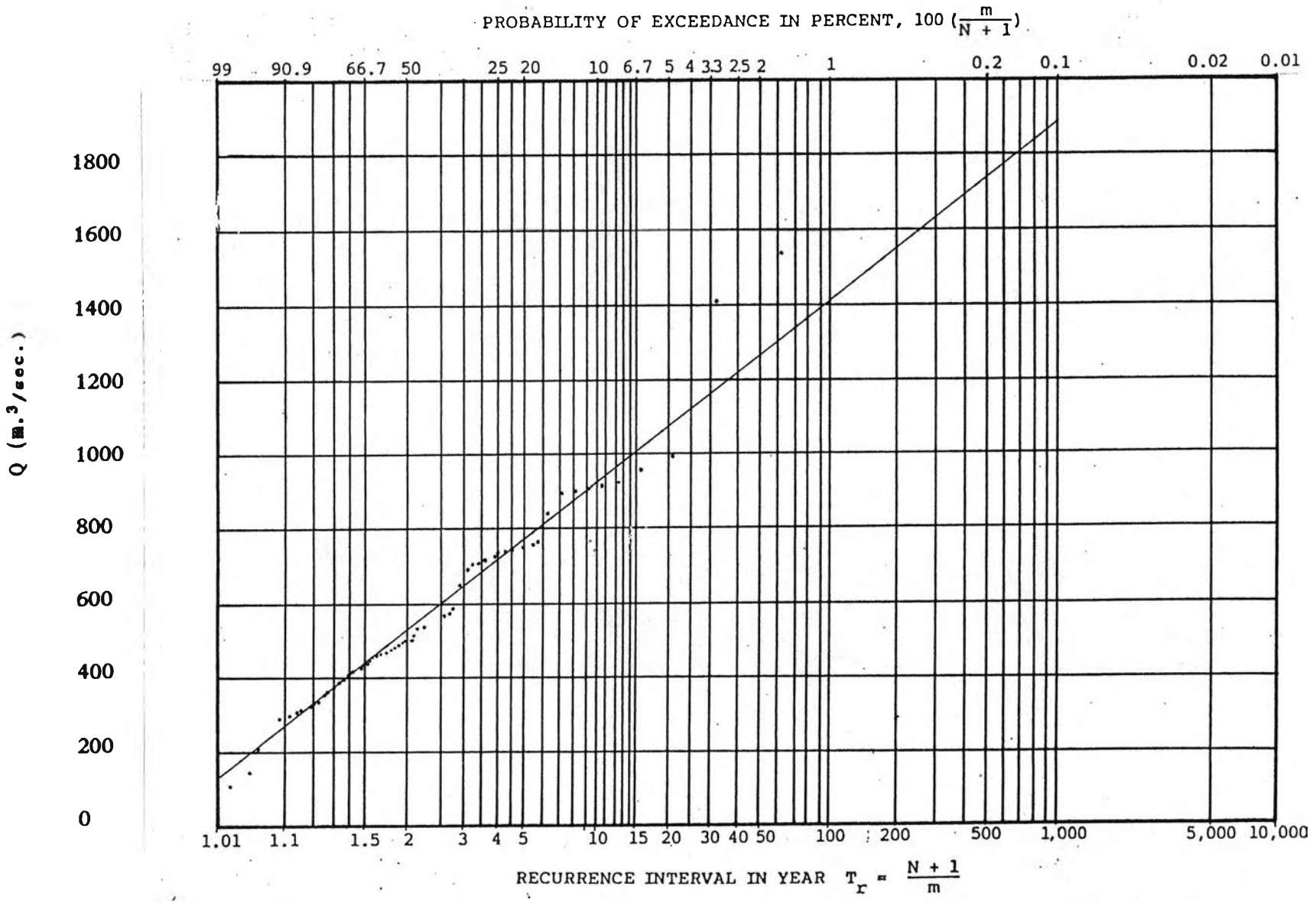


Figure 4.15 Flood Frequency Analysis.

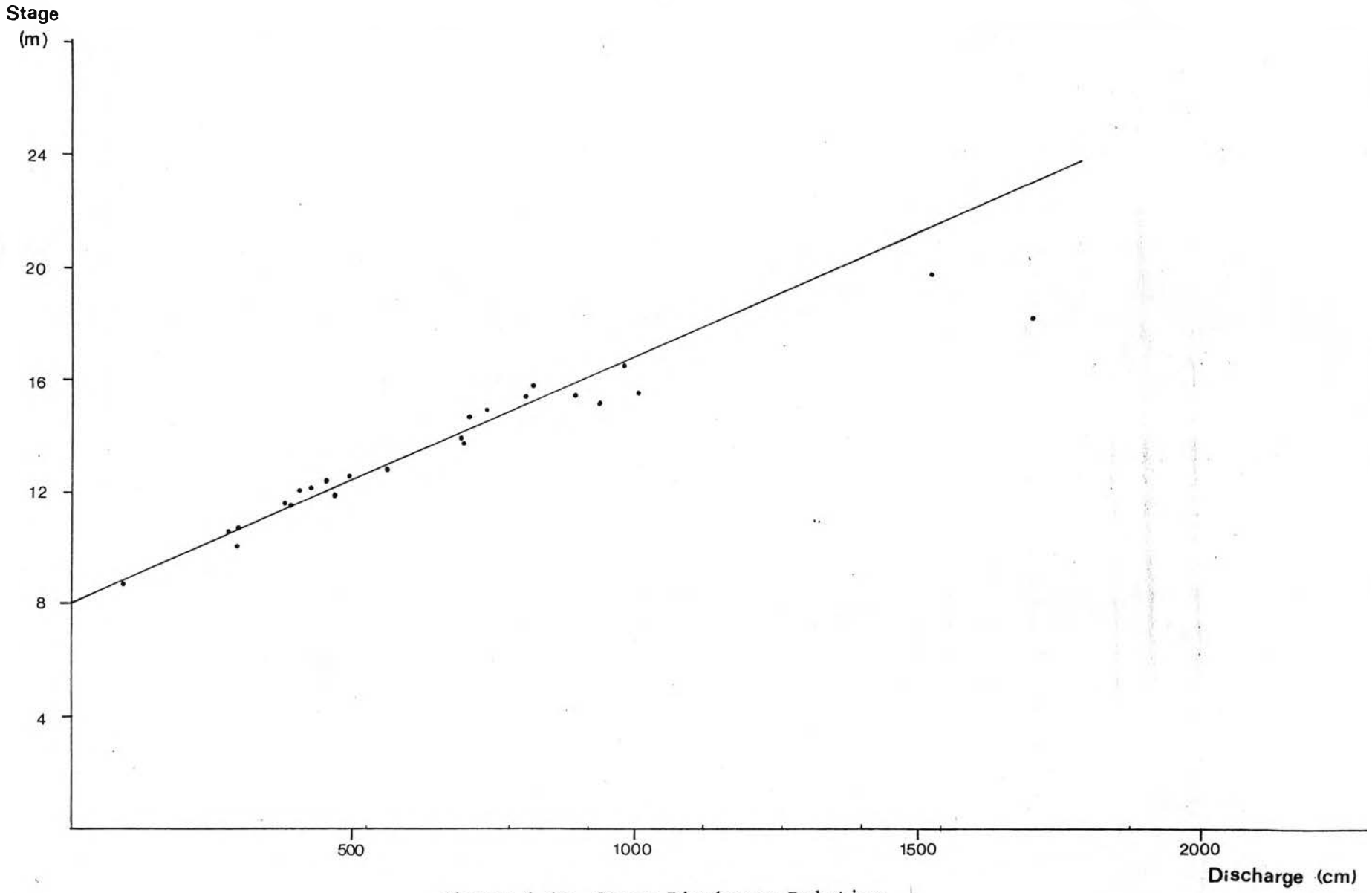
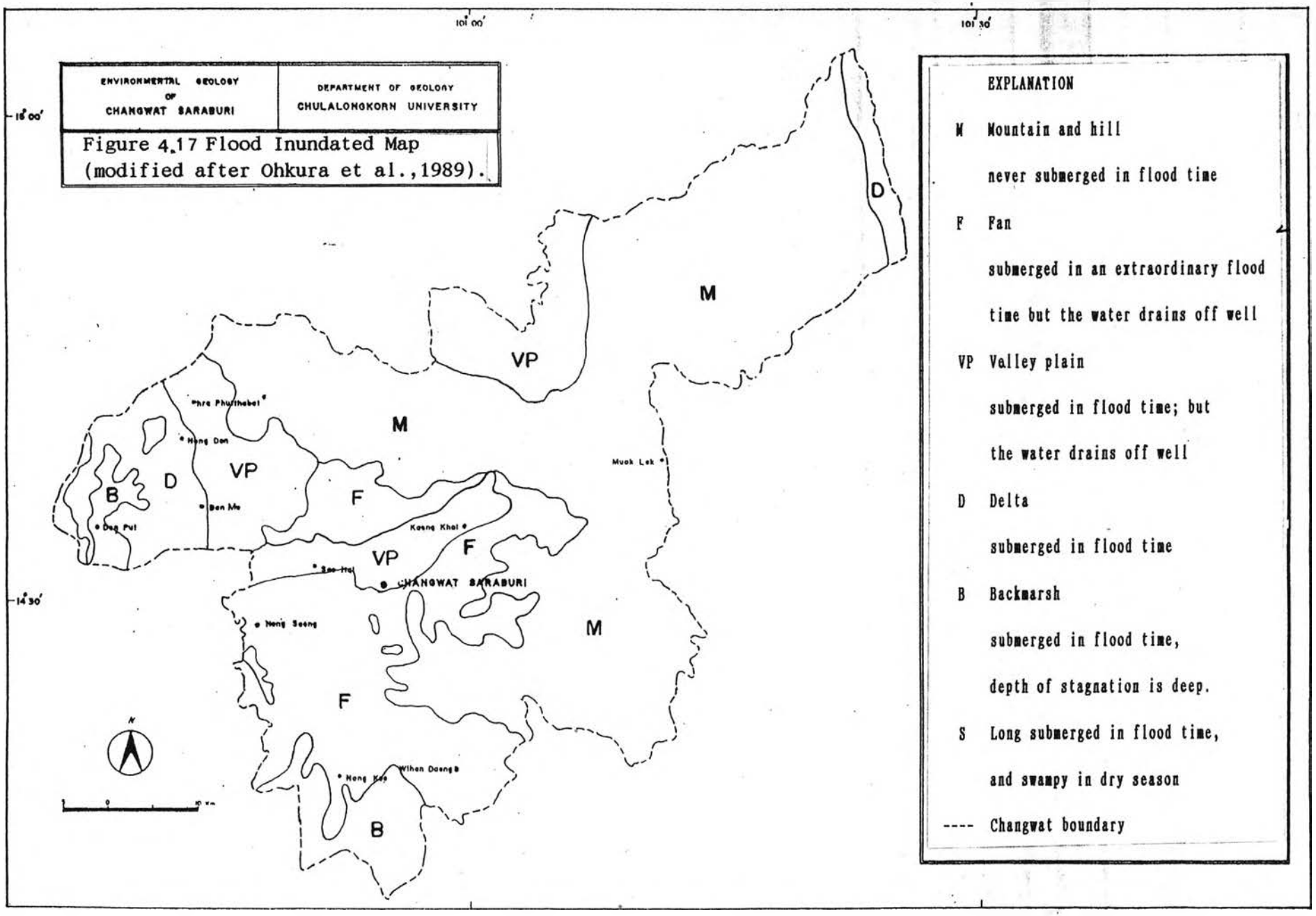


Figure 4.16 Stage-Discharge Relation.

4.16


ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure 4.17 Flood Inundated Map (modified after Ohkura et al.,1989).
101°00'
101°30'
14°30'
EXPLANATION
M Mountain and hill
never submerged in flood time
F Fan
submerged in an extraordinary flood time but the water drains off well
VP Valley plain
submerged in flood time; but the water drains off well
D Delta
submerged in flood time
B Backmarsh
submerged in flood time, depth of stagnation is deep.
S Long submerged in flood time, and swampy in dry season
---- Changwat boundary
Muak Lek
Kaeng Khoi
CHANGWAT SARABURI
Nong Saeng
Nong Kae
Wihan Daeng
Ban Mo
Dong Pui

From the flood inundated map, Saraburi has little chance for a long time flooding but sheet flood may be expected. The area of high chance for flooding spreads along the swampy area, back-marsh and delta, respectively and when flooding occurs the water remain for long time due to low flat lying topography.

4.5.3 Soil Problems

According to the soil map by the Land Development Department (Pranom Kaosuta, 1990), soil problem areas can be found as acid soil and soil erosion.

4.5.3.1 Acid Soil

The acidic soil can be identified from the accumulation of jarosite within the land surface. The acidic soil can be treated by line to neutral soil. These areas are located at Ban Mo and some area are developed for the orange growing.

4.5.3.2 Soil Erosion

Soil derived from volcanic rock and situated on steep slope along footslope of the mountain are severely affected by erosion because the soil is dominantly composed of cohesionless silt and sand grains couple with steep slope topography. This situation would could be accelerate soil erosion. The area subjected to soil erosion problem are mainly situated along the steep slope terrains in Amphoe Wihan Daeng, Muang Kaeng Khoi and Muak Lek areas (Figure 4.18). Erosion control by using vegetation should be applied in these areas.

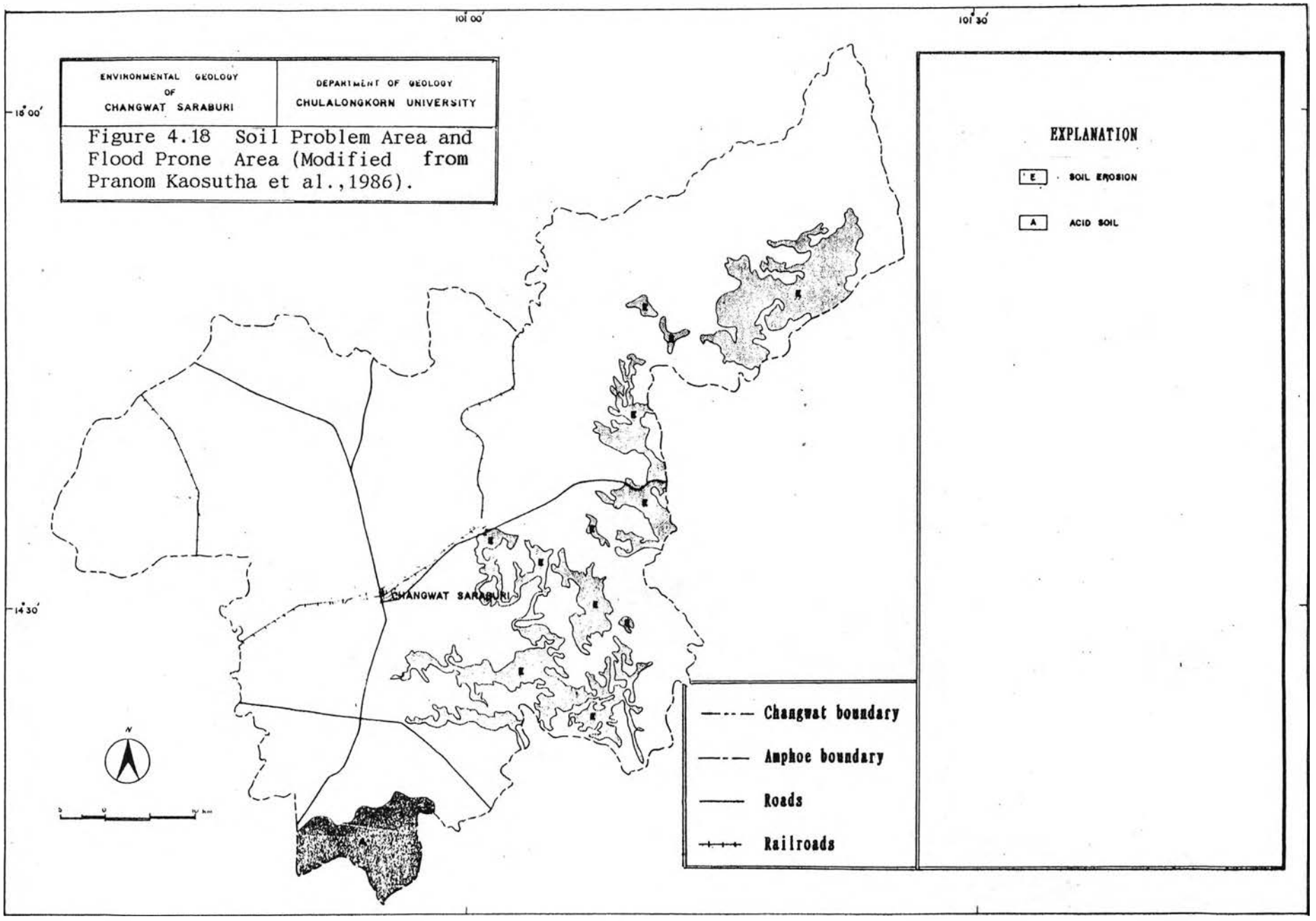


Figure 4.18 Soil Problem Area and Flood Prone Area (Modified from Pranom Kaosutha et al.,1986).

4.6 Recreation

Changwat Saraburi has various types of recreation, namely, natural, historical and religious and cultural types. The popular recreation type is historical and religious such as, Phra Phuttabat (the Buddha's foot print) and Phra Phuttachai (the Buddha's image), and the natural type such as Muak Lek waterfall, Jed Sao Noi waterfall,Muak Lek Diary Farm and Pasak river floating. Due to Saraburi is close to Bangkok, tourist are usually spend one day touring.

The recreation sites mainly situate in 4 Amphoe, namely, Muang, Phra Phutthabat, Kaeng Khoi and Muak Lek. The historical and religious types are located in Amphoe Muang and Amphoe Phra Phutthabat where as the natural type is is located in Amphoe Muak Lek and Amphoe Kaeng Khoi (Figure 4.19, Table 4.14).

The accessibility to these recreation types can be conveniently made all year round. The cultural type is available only in the festival seasons.

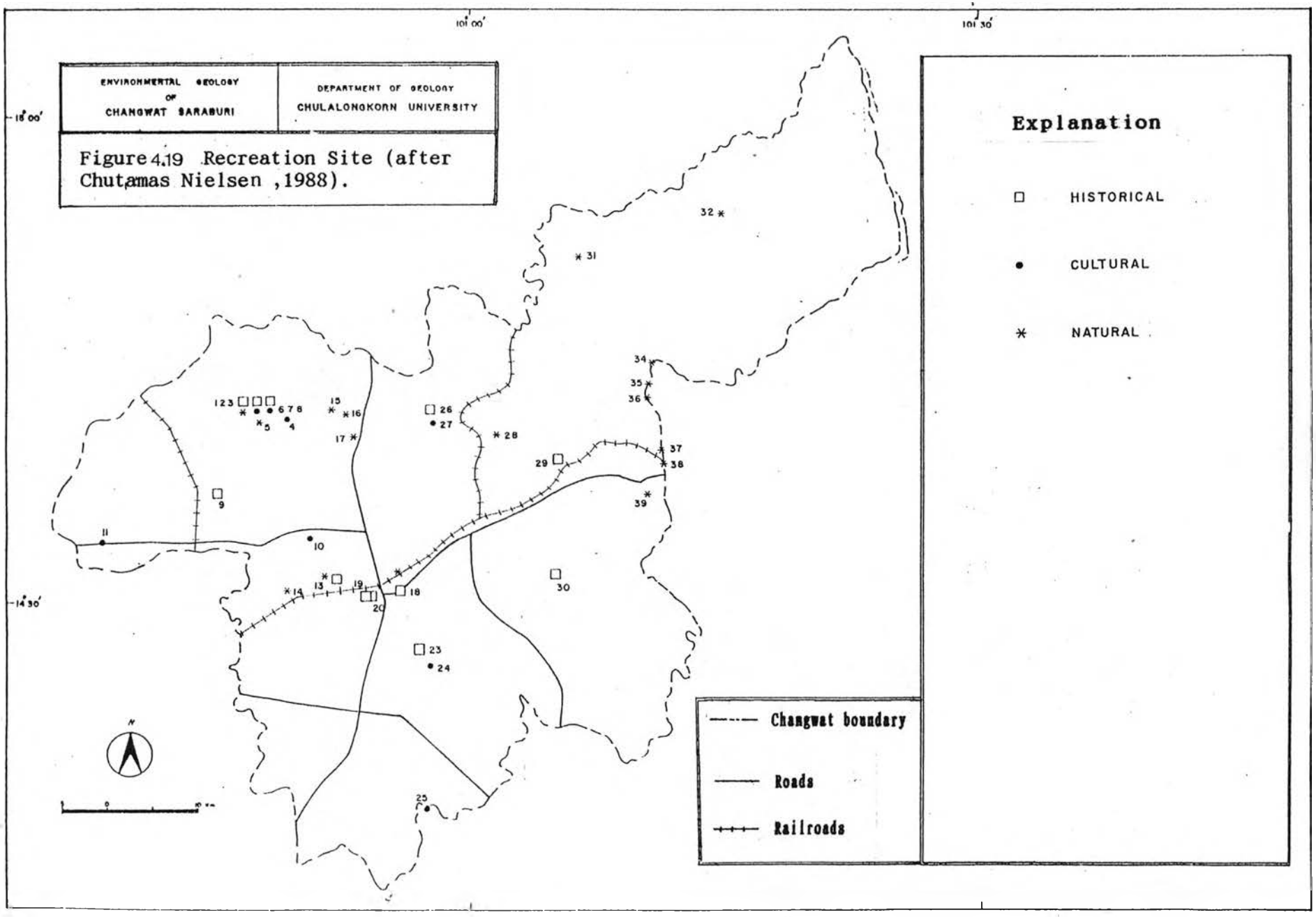

ENVIRONMENTAL GEOLOGY OF CHANGWAT SARABURI
DEPARTMENT OF GEOLOGY CHULALONGKORN UNIVERSITY
Figure 4.19 Recreation Site (after Chutamas Nielsen ,1988).
101°00'
101°30'
18°00'
14°30'
Explanation
HISTORICAL
CULTURAL
NATURAL
Changwat boundary
Roads
Railroads
N

Table 4.14 The Recreation Site in Changwat Saraburi.

No.	Name & Location	distance from changwat	Type	inter-esting
	In Amphoe Phra Phutthabat			
1.	Buddha's foot print T.Khun Klone	28	H & R	High
2.	National Meseum Saraburi "	28	H & R	High
3.	Bo Pran Lang Nua "	28	H & R	High
4.	Tham Kra Bok Priest Camp Site "	25	Cult	High
5.	Phra That Cave "	36	Nature	Low
6.	Tak Bat Dok Mai Festival "	28	Cult	Mod.
7.	Hae Phra Keaw Kaew "	28	Cult	Low
8.	Chao Phoa Khao Tok Festival "	28	Cult	Low
	In Amphoe Ban Mo			
9.	Muang Kid Kin T. Ban Mo	33	H & R	Low
	In King Amphoe Don Put			
10.	Snake trading T. Don Put		Cult	Low
	In Amphoe Sao Hai			

Table 4.14 (cont.) The Recreation Site in Changwat Saraburi.

no.	Name & Location		distance from changwat	Type	inter-esting
11.	Sao Rong Hai	T.Sao Hai	8	H & R	Mod
12.	Wat Samuha PraditTaram	T.Sao Hai	8	H & R	Low
	In Amphoe Sao Hai				
13.	Native Weaving	T.Ton Tanm	5-7	Cult	Mod.
14.	Bung Ngog	T.Muang Koa	12	Nature	Low
	In Amphoe Muang				
15.	Tham Pra Thun	T.Nha Pra Lan	22	Nature	Low
16.	Tham Sri Wi Lai	"	22	Nature	Low
17.	Phu Khae Botany	T. Phu Khae	17	Nature	Mod.
18.	Wat Pasak	T. Dao Rueng	2	H & R	Low
19.	Wat Sala Daeng	T. Klong Prew	-	H & R	Low
20.	San Chao Pao Lak Muang	"	-	H & R	Low
21.	Klong Prew Reservoir	"	-	Nature	Mod.
22.	Wat Phra Phuttachai	T.Nong Pla Lai	12	H & R	High
23.	Jom Pung Farm	"	13	Cult	Mod.
24.	Khao Sam Lan National Park	"	16	Nature	Mod.

Table 4.14 (cont.) The Recreation Site in Changwat Saraburi.

no.	Name & Location	distance from changwat	Type	inter-esting
	In Amphoe Wihan Daeng			
25.	Jedi Phra Khun Mae T. Nong Mu	42	Cult	Low
	In Amphoe Kaeng Khoi			
26.	Phra Phutthabat Noi T.Song Khon	28	H & R	Mod
27.	Tham Phra That Charoen Tham "	28	Cult	High
28.	Pasak River floating T.Tha Klo	15	Nature	High
29.	Pha Sa Det T.Tab Kwang		H & R	Low
30.	Tham Phra Pho Ti Sat T.Tab Kwang	32	H & R	Mod.
	In Amphoe Muak Lek			
31.	Phu Kao waterfall T. Wang Muang		Nature	Low
32.	Tham Dao Khao Kaew T.Lam Praya Klang	75	Nature	Low
33.	Pak Klong waterfall T. Muak Lek	-	Nature	Low
34.	Jed Sao Noi waterfall "	45	Nature	Mod.
35.	Rest area along highway no.2 "	43	Nature	Low
36.	Kusuma Karden "	42	Nature	Mod.

Table 4.14 (cont.) The Recreation Site in Changwat Saraburi.

no.	Name & Location	distance from changwat	Type	inter-esting
37.	Muak Lek Botany "	37	Nature	Mod.
38.	Thai-Denmark Diary Farm "	38	Nature	Mod.

Source : Tourist Authority of Thailand.

Note; H & R is Historical and Religion recreation type

Nature is natural recreation type

T. is tambon

Cult. is cultural recreation type

Mod. is moderately interesting