CHAPTER 2
GENERAL CHARACTERISTIC OF THE STUDY AREA

2.1 Physiography

Chiang Mai basin is the biggest Cenozoic intermontane and structural basin in the northern part of Thailand. The topography of the study area is shown by 1:50,000 scale topographic map sheets, Changwat Chiang Mai (4746 I), San Sai (4846 IV), San Pa Tong (4746 II), and Changwat Lamphun (4846 III). It has a kidney-like shape and long axis in the direction of northeast-southwest. The basin is accompanied by mountain ranges. The Inthanon range (Doi Suthep-Doi Pui) bounds the western side, while the Khun Tan range bounds the eastern side. The highest peaks on the two ranges are 1,685 meters above mean sea level (m msl) at Doi Pui in the west side and 1,025 m msl at Doi Lao Luang in the east side.

The study area is relative flat, with elevations between approximately 360 and 280 m msl. Morphology of the study area can be divided into three areas. These are terraces, alluvial fans and flood plains.

Terraces are found at both sides of the study area. The ancient Ping River built up the terraces. The terraces are divided into high terrace and low terrace by its elevation. The altitude of high terrace varies between 330-450 m msl and in the western part of Chiang Mai basin is higher than in the eastern part. The low terraces are separated from the high terrace. It is mainly distinguished by its lower elevation (300-330 m msl).

Alluvial fans occur at the areas where the main rivers enter the basin. The stream velocity decreases and sediments are deposited at the foot of the mountain in the form of fans. The biggest fan of the basin is Mae Kuang alluvial fan in the north-eastern part.

Flood plains are flat areas covering the central part of the basin. Flood plains occur along both sides of the main river, especially on Ping River. These areas show meander scars and some oxbow lakes. They are the lowest areas and often flooded during monsoon seasons.

The drainage system of the study area has a dendritic pattern, with Ping River the biggest river in the area. Ping River flows from north to south, through the study area in the center and divides the area into two parts (western and eastern part). The river enters the basin at elevation of around 320 m msl in the north and leaves it at around 280 m msl in the south. The main western tributaries are Mae Rim, Mae Tha Chang and Mae Khan/Mae Ngan. These tributaries join the Ping River in the northern, middle and southern part, respectively. The main eastern tributary is Kuang River entering the basin in the north-east. Mae Kuang Dam controls flowing of Kuang River. The dam is located at the foot of the eastern mountain range. The main eastern tributaries of Kuang River are On, Thi and Tip Rivers.

2.2 Climatic condition

Chiang Mai basin has a tropical monsoon climate with three seasons: winter, summer and rainy season. The winter season is characterized by little rainfall, lower humidity, least cloudiness and low temperature. The cool and dry weather of the winter season occurs from November to February when the northeast monsoon passes the basin. The average temperature in the past 35 years (1967-2001) ranges from 3.7 to 17.2 Celsius.

The summer season occurs from February to April. South-easterly wind carries dry air masses from the South China Sea across the Gulf of Thailand to the basin. It produces a relatively high temperature, low humidity, higher rainfall, and cloudiness. The maximum temperature ranges from 32.1 to 41.4 Celsius (1967-2001).

The rainy season occurs between May and September when the southwest monsoon carrying moist air mass from the Indian Ocean move through the area. The highest rainfall occurs during August and September. The average monthly rainfall in these months are 236.22 and 207.85 mm and the average annual rainfall for the basin is 1,159.67 mm/y (1967-2001).

2.3 Geological conditions

2.3.1 Structural set up

Chiang Mai basin is an intermontane basin which was created during late Cretaceous and early Tertiary (between 141-1.8 million years). This was a period of trans–tensional faulting, caused by the collision of the Indian with the Eurasian Continent (Margane et al., 1998). As a result of the collision, the Indian continental plate was rotated clockwise and created a trans-tensional dextral shear regime. Under this condition the basin were formed as pull-apart structure, graben or half-grabens, with a longitudinal axis in N-S direction. Striking faults in NW-SE and NE-SE direction can be interpreted as dextral shear faults and sinistral shear faults. While N-S striking faults is related to extensional faults.

Interpretation from a LANDSAT TM Satellite image reflects the above-mentioned pattern of faults. Figure 2.1 shows the lineaments mapped from the satellite image and interpreted as faults. The shape of the basin is created by intersection of a set of faults of the three major directions: NW-SE, SW–NE and N-S. Lineaments are extending from the area of consolidated rocks into the basin. They are clearly visible in the Quaternary area. This provides evidence of neotectonic activies in the basin. Drainage pattern of the basin is also governed by these faults. It is evidenced that Mae Kuang River does not join Ping River at the upper stream (around San Sai District) but instead bends to the SE and flowing parallel to Ping River almost 40 kilometers before joining. This is probably related to a major fault zone in the NW-SE direction (Margane et al., 1998).

The depth of basement is varied from place to place. Wattananikorn et al. (1995) studied gravity data of the basin. This is the only available source of information about the deep structure. The Bouguer gravity anomaly map is shown in Figure 2.2. The structural lows or deeper parts of the basin are interpreted as down faulted blocks, with the Tertiary and Quaternary sediments have filled them up to more than 2,000 meters. According to the study of Wattananikorn et al. (1995), these faults might not active during late Tertiary and Quaternary, nevertheless the lineament from the satellite image clearly show the extension of faults from the surrounding mountains into the basin. For this reason, the tectonic movements might still occur until recently.

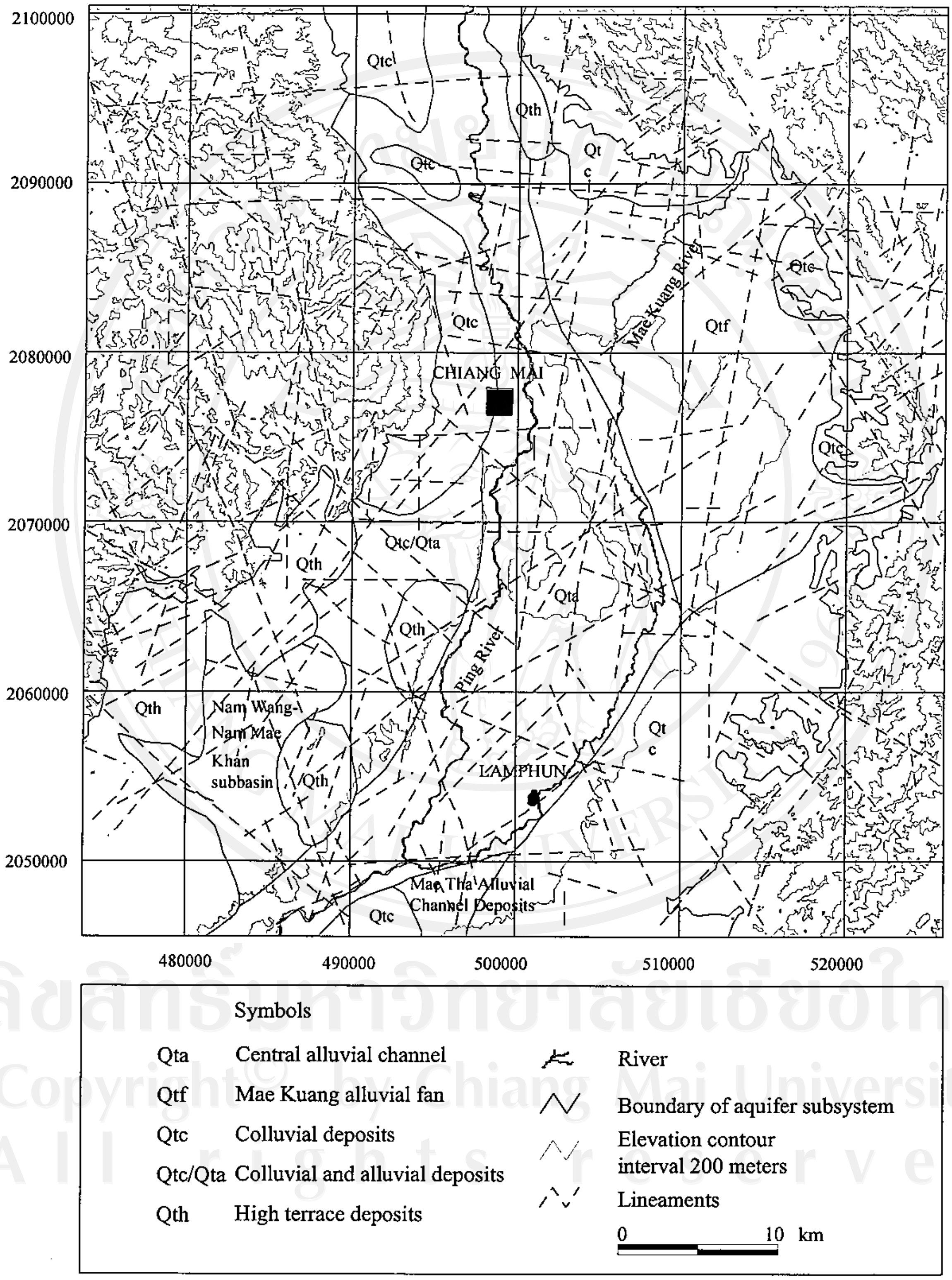

Figure 2.1 Lineament interpretation from Landsat TM satellite image (06/04/91) (modified from Tatong, 2000).

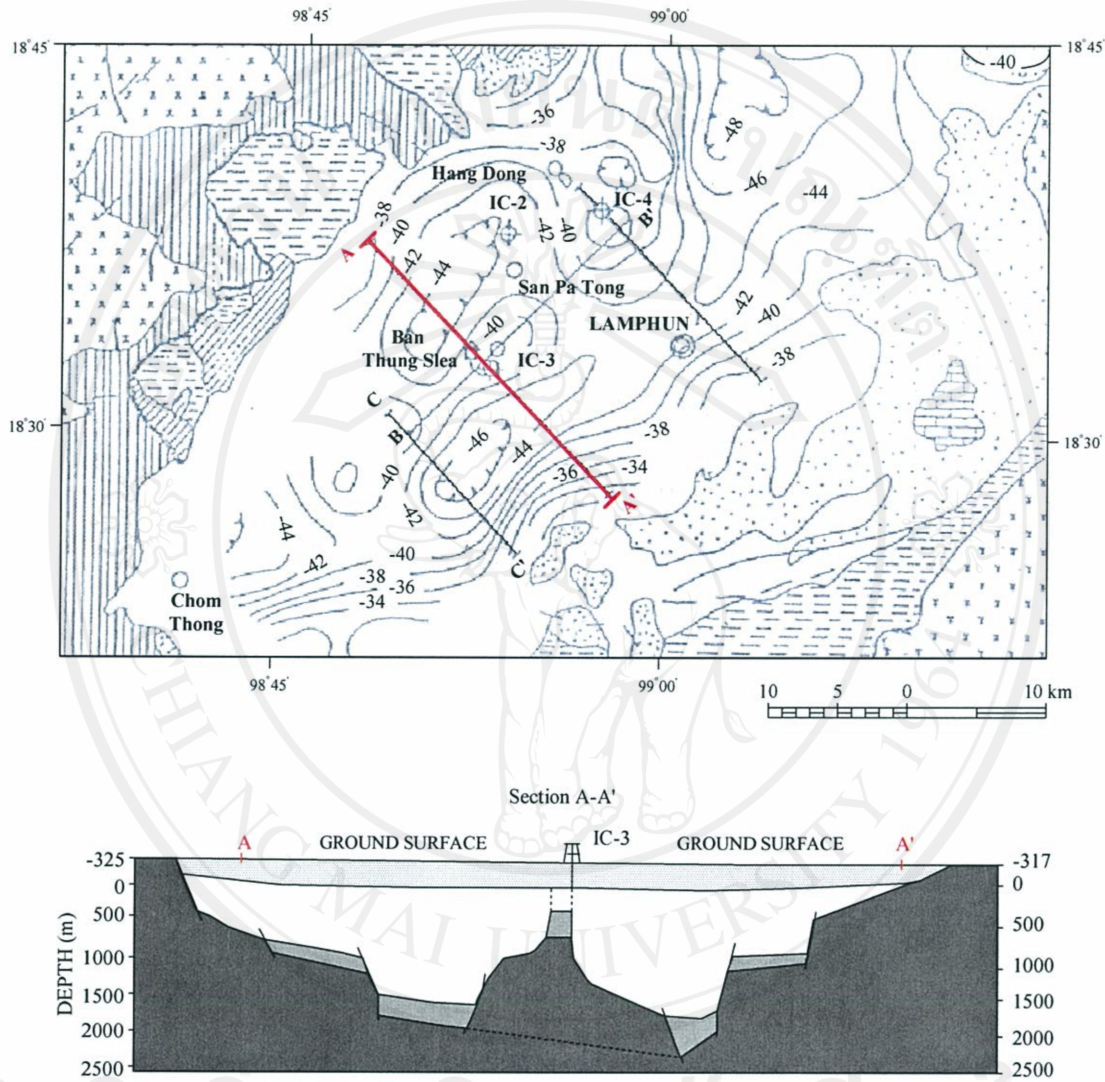

Figure 2.2 Structure interpretation of Bouguer gravity (modified from Wattananikorn et al., 1995).

2.3.2 Geological set up

The geology of Chiang Mai basin and its surroundings can be separated into two groups. These are well consolidated rocks of the Pre-Cambrian and Paleozoic age, and poorly consolidated to unconsolidated rocks of Tertiary and Quaternary age. The geological map of Chiang Mai basin is shown in Figure 2.3.

Group 1: Well consolidated rocks

The well consolidated rocks underlie the western range, Doi Suthep, and eastern mountain range, which are forming great relief and steep slopes. The rocks are composed of metamorphic, sedimentary and igneous rocks. The well consolidated rocks in the study area and surrounding areas have been reported by Beshir (1993) and Tatong (2000). Accordingly, classification of well consolidated rocks using their ages and lithology are as follows:

Pre-Cambrian metamorphic rocks (570-4,600 million years) The rock unit is named Lang Sang Gneiss. They are forming Doi Suthep Mountain in the western part of the study area. The Lang Sang Gneiss group consists of para and ortho gneiss, which are very coarse grained, black and white banded, good foliation and feldspar augens. They are interbedded with schist, migmatite, cal-silicate and marble lenses. The rocks were metamorphosed by high grade and regional metamorphism. They were in contact with Paleozoic rocks. The rock types are regarded as meta-sedimentary rocks with wide range of composition, affected to large degree by anatexis and derivation of acid to intermediate magma with tectonic and metamorphic modification taking place subsequent to emplacement.

Cambrian rocks (500-570 million years) The rocks are well bedded to massive, fine to coarse grained sandstone, increasingly argillaceous toward the top, locally quartz schist and quartz-mica schist. The age is given by the stratigraphic position and similarity in lithology to rocks containing Saukid Trilobites and orthid brachiopods recognized in the Peninsular (Beshir, 1993).

Ordovician Hod limestone (435-500 million years) The Ordovician Hod limestone occurs only in the western mountain range. The rocks can be divided into three parts: lower, middle and upper part. The lower part of this unit consists of beds of argillaceous limestone. The middle part consists of slaty shale, sandstone and interbedded limestone. The upper part is massive limestone, which is grey to dark grey in colour. It is interbedded with argillaceous deposits.

Silurian-Devonian meta-sediments (345-435 million years) These are named Don Chai Group or Silurian Don Chai Group. The rocks consist of slate, which is black to dark grey in colour, dense to thinly bedded and partly interbedded with greywacke and limestone lenes. The Don Chai Group is found on the western side of the mountainous area. Attempts have been made to divide into formation of non-metamorphosed and slightly metamorphosed character. Their distribution and stratigraphic relations are unsolved.

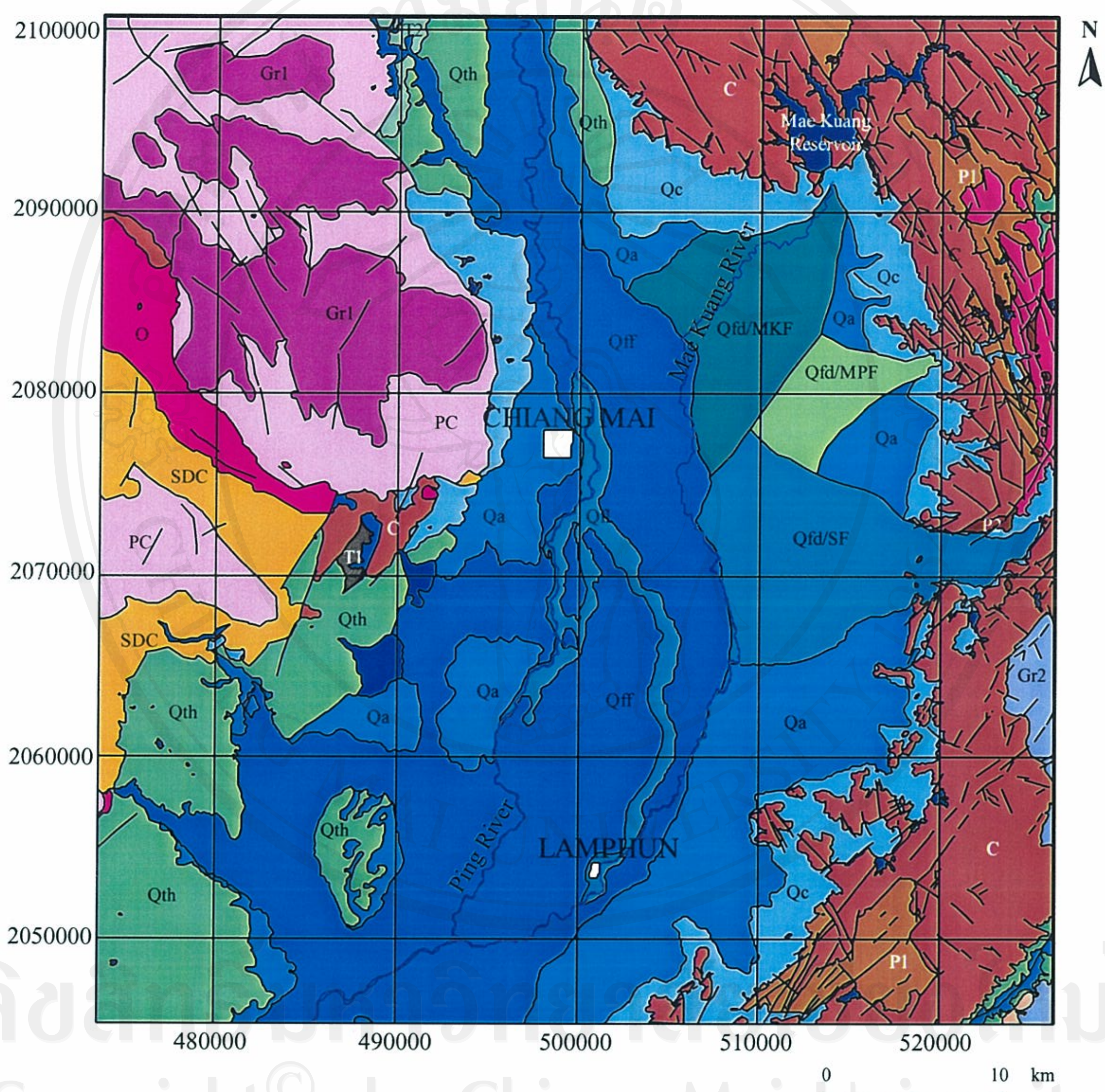

Figure 2.3 Geologic map of Chiang Mai basin (modified from DMR, 2001).

EXPLANATION FOR FIGURE 2.3

SEDIMENTS, SEDIMENTARY ROCKS AND METAMORPHIC ROCKS

Qff	Qff : Mae Ping flood plain deposits
Qfl	Qfl : Mae Ping channel deposits
Qfd	Qfd : Alluvial fan deposits
Qfd/MKF	Qfd/MKF : Alluvial fan deposits
Qfd/MPF	Qfd/MPF : Alluvial fan deposits
Qfd/SF	Qfd/SF : Alluvial fan deposits
Qa	Qa : Alluvial complex
Qc	Qc : Colluvial deposits
Qth	Qth : Mae Taeng group
T2	T2 : Huai Luang formation
T1	T1 : Huai King formation
P2	P2 : Pha Huat formation
P1	P1 : Kiu Lom formation
C	C : Mae Tha group
SDC	SDC : Kanchanaburi formation
SD	SD : Don Chai group
O	O : Hod limestone
PC	PC : Langsang gneiss

IGNEOUS ROCKS

Gr2	Gr2 : Porphyritic biotite granite
V	V : Volcanic rocks
Gr1	Gr1 : Granite

Symbols

Fault

River

Mae Kuang Reservoir

Carboniferous sedimentary rocks (280-345 million years) The rock unit is Mae Tha Group. They can be categorized into two parts: lower and upper part. The lower part, which unconformably overlies the older rock consists of conglomerate, sandstone, siltstone, shale and mudstone. These were deposited in a terrestrial environment. The upper part consists of slaty shale of blackish grey to greenish grey colour. The shale contents decrease upward and are substituted by sandstone and greywacke. The uppermost units are composed of shale interbedded with limestone. The age is given due to the rocks conformably underlying the lower Permian limestone. Middle Carboniferous is a period of major uplift accompanied by magmatic activity. The area shows clear separation of depositional environment into basin and ridge. Red beds and volcanic sequences are of uncertain age within the Carboniferous. There are fairly well developed foliated granite, locally associated with intrusion of diorite, grabbro and pyroxenite.

Permian sedimentary rocks (230-280 million years) Permian sedimentary rocks occur mainly in the eastern part of Chiang Mai basin. The rocks are divided into two Formations: Pa Huat Formation (lower part) and Kiu Lom Formation (upper part). The lower part consists of sandstone and siltstone, which are partly tuffaceous sandstone contain fossils, tuff and agglomerate. The upper part is a thick bedded to massive limestone with dark grey to black colour and interbedded with shale. The Permian rocks show great variation in lithology and thickness. In many areas, these are overlain by Permo–Triassic volcanic sequence.

Triassic rocks (195-230 million years) The upper Triassic rocks composed of thick sequence of massive and conglomeratic limestone, siltstone, shale, sandstone and conglomerate with volcanic pebbles and pebbles of terrestrial origin sandstone, shale and tuffaceous sandstone. There are medium-griticained, porphyritic, adasellite or granodiorite, intermediate to acid effusive (andesite, rhyolite, rhyodacite) and associated tuff in the age of upper Triassic and Jurassic.

Cretaceous rocks (65-141 million years) These are named Khorat Group with the thickness of more than 240 meters. The rocks are pebble, cobble beds that are derived from Doi Ti-Doi Saket Formation. They were compacted, overlying on alternated beds of sandstone and black shale.

Igneous rocks These rocks can be separated using their rock type into three groups. These are porphyritic biotite granite, equigranular porphyritic granite and volcanic rocks. They are in the same age. Porphyritic biotite granite occurs in the south east of the mountainous area. It has white to light grey in colour, medium grained with K-feldspar phenocrysts. Major minerals in the granites are quartz, feldspar and biotite. Minor minerals are hornblend, muscovite, zircon, apatite and fluorite. Equigranular porphyritic granite are forming high mountains in the north west of the basin. There are metamorphosed and gneissic granites in some parts. It has medium to coarse grained with slightly foliation. There are dykes and sills cutting through the rocks. Volcanic rocks occur only in a small area in the north east of the basin. The volcanic rocks consist of basaltic/andesitic lava, tuff, lapilli and tuff breccia. There is lateritic soil and clay rich at the surface because the rocks are weathered deeply.

Group 2: Poorly consolidated rocks and unconsolidated rocks

The poorly consolidated rocks of the Tertiary age are found only in the western rim of the basin. The unconsolidated sediments of the Quaternary age are covering most areas inside the basin.

Tertiary rocks (1.8-65 million years) The Tertiary sediments were deposited in the lacustrine environment and tropical climate. The rock unit in the lower part is named Chaiprakarn Unit. The rocks compose of sandstone of various origins. Thickness of the rock is about 30 meters. The upper rock unit is Mae Sod Formation and transitional zone of Mae Sod Formation. Their thickness is about 180- 210 meters and 90 meters, respectively. Mae Sod Formation consists of alternation of clay, clay stone, brown compact, and trace of oil show. Transitional zone of Mae Sod Formation consists of clay, sandy clay, brown with a few beds of thin bedded sand with appearance of oil show. The Tertiary rocks show definite tectonic displacement. The rocks are known in other isolated basins with similar lithology.

Quaternary sediments (present-1.8 million years) The Quaternary sediments can be built up in the alluvial environment. In early period, these sediments were deposited in dry cool and wet warm weathers. Then, they were deposited in wet and warm weathers later. The Quaternary sediments can be classified into 6 units, based on shallow bore hole data with depth less than 6 meters and their morphology. These units are described as follow:

High terrace deposits (Q_{th}) The high terrace deposits occur on both sides of the basin. They are distributed especially along the western rim over a large area. The sediments composed of sand, sandy clay, silty clay and gravel. The sand varies from fine to coarse grain with gravelly. It is sub-angular and poorly sorted. There are iron and manganeous abundantly in the sand layer. The hard layers of laterite (plinthite) are frequently found up to 1.5 meters thick. The clay layers are yellowish brown to reddish brown in color. The gravel layers consist of sandstone, quartzite, quartz and chert fragments, which are sub-rounded to rounded. Sandstone and quartzite boulders are found in many places. From the field observation, these sequences usually overlie erosional surface of Pre-Quaternary rock, Tertiary rocks in the west rim and the Carboniferous rocks in the east rim (Chaimanee, 1997). Therefore the relative time of high terrace deposits is Pleistocene age.

Colluvial deposits (Q_{cl}) The colluvial deposits occur along the footslope of the mountain range at the east rim of the basin. Gravity and water transported the deposits with the short distance from the parent rocks. The extension of colluvial sediments depends on the degree of weathering of the parent rocks and the tectonic setting. The reflecting areas are in the eastern area such as San Sai, Doi Saket districts and Doi Ti near Lamphun province. The sediments consist of loosed sand with very fine grain, overlain by lateritic pan and mottled clay with rock fragments in angular shape. There is no sedimentary structure. The deposits directly overlie on the bedrock in east rim of the basin, Lamphun area, and on the high terraces in the northern part of the basin (San Sai area). Therefore, the age of the colluvial deposits should be equivalent or slightly younger than the high terrace.

Alluvial complex (Q_a) The alluvial complexes are forming broad plains of low relief on both sides of the basin. The alluvial plains were partly eroded by tectonic uplifting in combination with the recent Ping River activities. Therefore, the sedimentary development is in doubt. The alluvial complexes consist of clay, silt and sand. Loose silt or silty clay are light grey color, homogeneous without any sedimentary structure and compacted. Fine sand layers, which are slightly to very clayey in light grey to dark brown color, are found abundant of the pisolite and/or lime nodule. Fine sand layers, which are slightly to very gravelly, can occur in some areas. These layers indicated the fluvial cycle of channel and overbank deposit. The thick and homogeneous silt and silty clay in this formation might reflect a low energy and continue deposition as lacustrine of lake environment.

Alluvial fans (Q_{fd}) The alluvial fans are extensively distributed in the eastern part (from San Sai toward San Kampaeng areas). Three alluvial fans are found in the east: Mae Kuang fan in the upper north, Mae Pong fan in the middle and San Kampaeng fan at the southern most. Mae Kuang fan is the largest fan. The sedimentary deposits occur laterally from place to place. The sediments consist of coarse sand and gravel in the main channel zone. While fine to medium sand occur on the both sides. Clay and/or silt layers alternate in the lower part. Sand layers of the middle alluvial fan usually contain some clay, probably due to the short distance of transportation from the source material. These sedimentary deposits of the southern alluvial fans overlie on compacted silty clay probably of alluvial complex. The formation of these fans is likely related to the climatic optimum during middle Holocene (present–0.01 million years) when precipitation increased and caused high sediments flux from the mountain area toward the low alluvial plain. These sediments were transported by river system and eventually forming fans (Chaimanee, 1997).

Central flood plains (Q_{ff}) Central flood plains or Mae Ping flood plains are found mainly along the present Ping River. There are remaining of Mae Ping paleochannel. The river is shifting from east to west. The central flood plains consist of silty clay, brown to dark grey color, alternating with loose fine to medium sand. Plant remains and mica can be observed in this unit. Silty clay with slightly sandy, light grey to light greenish grey color, are found in lower part of this sequence. Pisolite and mottles are common in this unit. The sediments of central flood plain show clearly the depositional environment as over bank and swamp. The loose sand alternation in this unit contributes to the shifting of channel through time.

Mae Ping channel (Q_{fl}) The Mae Ping channel deposits consisting of loose sand and silt layers. The sand is brown to light brown color with abundant mica. The sediments are well sorted. Interbedded clay occur in some parts of this unit.

Generalized stratigraphy of Chiang Mai basin and surrounding areas, modified from Beshir (1993) and Tatong (2000), is summarized in Table 2.1. Stratigraphic section of the study area is derived from the interpretation of the lithologic description. The Quaternary deposits in the basin are relative age. There is no absolute dating data. The age of the unconsolidated sediments can be estimated from comparison the sedimentary lithology and sequences of the sediments.

2.4 Hydrogeological conditions

Hydrogeological conditions is defined as the geological conditions dealing with origin, distribution, movement, quality, and potential evaluation of groundwater (DMR, 2000). Characteristic and compositions of rocks, geological structures, and geological environments are significant parts to determine the hydrogeological properties especially in storage and discharge properties. The difference of the geological conditions results in different hydrogeological properties.

The hydrogeological units in unconsolidated rocks, Quaternary sediments, of Chiang Mai basin have been divided into three units, mainly based on interpretation of lithologic logs and geophysical borehole logs (DMR, 2000). These are (1) alluvial sediment aquifer (Q_{cp}) or floodplain deposits, (2) Young terrace sediments aquifer (Q_{cr}) or low terrace deposits, and (3) old terrace sediments aquifer (Q_{cm}) or high terrace deposits.

(1) Alluvial sediment aquifer The alluvial sediment aquifer consists of gravel, sand, silt and clay. These are deposited along the flood plain and meander belts of Ping River. The average depth to the aquifer is 20-40 m. Well yield is more than 20 m^3/hr.

(2) Young terrace sediments aquifer The young terrace sediments aquifer consists of gravel, sand, silt, and low terrace deposited along narrow terrace next to the floodplain which mainly consist of thick clay with some gravel and sand socket to thick gravel and sand bed. The average depth to the aquifer is 30-100 m. Well yield is 10-20 m^3/hr.

(3) Old terrace sediments aquifer The old terrace sediments aquifer consists of gravel, sand, silt, and clay deposited along area higher than young terrace deposits. The average depth to the aquifer is 50-250 m., and around 300 m. in some area. Well yield is 2-10 m^3/hr.

The aquifer units are shown in Figure 2.4. However, this classification comprises only the uppermost Quaternary strata, visible at the surface. Lithological classification presently is only possible for the shallow part of the basin, around 200 m. depths. Surface geophysical measurement, geoelectric soundings or seismic profiles, are not available (DMR, 1998).

Table 2.1 General stratigraphy of Chiang Mai basin and surrounding area (modified from Beshir, 1993; and Tatong, 2000).

Period	Epoch	Time (million years)	Geological Unit	Thickness (m)	Lithology	Remarks	Igneous Activity
Quaternary	Holocene or Recent	Present	Flood Plain Deposits	10-60	Unconsolidated; well sorted sand and gravel overlain by clay and silt.	Thick layer of coarse grained gravel and pebble was deposited behind natural levee. This grades into coarse silt at the natural levee and fine silt and clay within the backswamp deposit.	-
	Middle to Upper Pleistocene	0.01	Low Terrace Deposits	> 150	Unconsolidated; gravel, sand and clay.	Mostly form high dissected surfaced terrace.	-
	Lower Pleistocene	?	High Terrace Deposits (Mae Fang Formation) Unconformity	> 760	Semi to unconsolidated; sand, sandy clay, clay, minor gravel bed.	Partly formed dissected surfaced terrace but mostly concealed under sediments.	-
Tertiary	Miocene-Pliocene	1.8	Transitional zone of Mae Sod Formation	~ 90	Clay, sandy clay, brown with a few beds of thin bedded sand with appearance of oil show.	The rocks show definite tectonic displacement and are known in isolated basins with similar lithology.	-
			Mae Sod Formation	180-210	Alternation of clay, clay stone, brown compact, trace of oil show.		
			Chaiprakarn Unit Unconformity	~ 30	Sandstone of various origin.		
Cretaceous		65	Khorat Group	> 240	Pebble, cobble beds of rock derived from Doi Ti-Doi Saket Formation; compacted, overlying on alternated beds of sandstone and black shale.	-	-
		141					

Table 2.1 General stratigraphy of Chiang Mai basin and surrounding area (continued).

Period	Epoch	Time (million years)	Geological Unit	Thickness (m)	Lithology	Remarks	Igneous Activity
Jurassic		141 / 195	-	-	-	-	Medium-griticained, porphyritic, adasellite or granodiorite, intermediate to acid effusive (andesite, rhyolite, rhyodacite) and associated tuff.
Triassic	Upper	195 / ?	-	-	Thick sequence of massive and conglomeratic limestone, siltstone, shale, sandstone and conglomerate with vocanic pebbles and pebbles of terrestrial origin sandstone, shale and tuffaceous sandstone.	Basal conlomerate marks transition from non-marine to marine. Local intercalation of clastic red beds and upper Triassic marine facies in upper parts suggests the beginning of uplift.	
	Lower	? / 230	-	-	-	-	Extrusion of andesite, rhyolite, agglomerate and associated tuff.
Permian	Upper	230 / ?	Kiu Lom Formation	-	Interbeded sandstone and shale, limestone and tuffaceous contains fossils.	The rocks of Permian age show great variation in lithology and thickness. In many areas these are overlain by Permo-Triassic volcanic sequence. The upper Permian rocks are only found in Lampang area.	-
	Lower	? / 280	Pa Huat Formation	-	Fossiliferous light gray massive limestone with minor sandstone, locally clastic and volcanic rocks with intercalation of thin fossiliferous bedded limestone.		
Carboniferous		280 / 345	Mae Tha Group	-	Dark grey sandy shale, sandstone, conglomeratic arkose graywacke, with minor limestone and chert locally pyroclastic red beds.	The age is given because the rocks conformably underlie the lower Permian limestone. Middle Carboniferous is a period of major uplift accompanied by magmatic activity. The area shows clear separation of depositional environment into basin and ridge. Red beds and volcanic sequences are of uncertain age within the Carboniferous.	Fairly well developed foliated granite, locally associated with intrusion of diorite, gabbro and pyroxenite.

Table 2.1 General stratigraphy of Chiang Mai basin and surrounding area (continued).

Period	Epoch	Time (million years)	Geological Unit	Thickness (m)	Lithology	Remarks	Igneous Activity
Devonian to Siurian	-	345	Silurain-Don Chai Group	-	Thick series of shale, sandstone, graywacke and chert with minor limestone, locally phylite, slate, quartz-feldspathic schist, chert and tuffs.	Attempts have been made to divide into formations of non-metamorphosed and slightly metamorphosed characters. Their distribution and stratigraphic relations are unsolved.	-
Ordovician	-	435	Ordovician Hod limestone	-	Lower part consists of thin beds of argillaceous limestone, slaty shale, sandstone and interbedded limestone in middle part. Massive dark grey limestone and minor sandstone and claystone.	Occur only in the western mountain range.	-
Cambrian	-	500	-	-	Well bedded to massive, fine to coarse grained sandstone, increasingly argillaceous toward the top, locally quartz schist, quartz-mica schist.	The age is given by the stratigraphic position and similarity in lithology to rocks containing Saukid Trilobites and orthid brachiopods recognised in the Peninsular	-
Precambrian		570 4,600	Lang Sang Gneiss	-	Medium to high grade para and ortho gneisses, schist, marble and calc-silicate rock.	Rock types are regarded as meta-sedimentary rocks with wide range of composition, affected to large degree by anatexis and derivation of acid to intermediate magma with tectonic and metamorphic modification taking place subsequent to emplacement.	-

Based on the structural interpretation (Margane et al., 1998), Chiang Mai basin consists of a number of subsequently down-faulted blocks which have their own sedimentary patterns. Consequently the aquifer system is delineated into five systems. The subdivision of the aquifer system is shown in Figure 2.5. Although these aquifers are different from one place to the other, at the boundaries between them, interfingering between the different types of sedimentation certainly occurs. Surface area of the aquifer system, the unconsolidated area, is approximately 62 % of the total area, while the consolidated area is about 38 % of the study area. Table 2.2 shows the calculated surface area of Chiang Mai basin aquifers.

Table 2.2 Calculated aquifer surface area of Chiang Mai basin.

Aquifer zone	Area[1] (km^2)	Area[2]	
		(km^2)	% of total area
Total area of Chiang Mai basin	2,917	2,771	100
1. Unconsolidated area	1,795	1,705	61.53
1.1 Central alluvial channel	579	550	19.85
1.2 Colluvial deposits	452	429	15.48
1.3 Mae Kuang alluvial fan	305	290	10.47
1.4 High terrace	259	246	8.88
1.5 Colluvial and alluvial deposits	99	94	3.39
1.6 Nam Wang-Nam Mae Khan subbasin	82	78	2.81
1.7 Mae Tha alluvial channel deposits	19	18	0.65
2. Consolidated area	1,122	1,066	38.47

where Area[1] is calculated from the topographic maps.
Area[2] = Area[1] - (Area[1] × 5%) where 5% is allowable error of the map.

The delineated aquifer subsystems of different hydrogeological character are described as follow:

(1) Central alluvial channel The central alluvial channel is the zone, where according to the structural interpretation, the main down-faulting occurs. It is dominated by sand and gravel deposits, which are transported by high energy of Ping River. Clayey layers are present throughout the central alluvial sequence, but form only a very minor component. Groundwater wells in this area are relatively shallow (around 30 meters). Specific well capacities per meter of filter length are between 10 and more than 100 m/d. Average hydraulic conductivity from pumping test evaluations are between 20 and more than 200 m/d. Average filter length is around 6 m. Groundwater wells in this area have been reached around the top 20 meter of the sediments. Groundwater quality is commonly very good, with total dissolve solid (TDS) values mostly less than 250 mg/l.

(2) Mae Tha alluvial channel deposits The Mae Tha alluvial channel deposits is separated from the central alluvial channel by down-faulted block, which is interpreted from satellite image and gravity data. It may be the same hydrogeologic condition like the central alluvial channel.

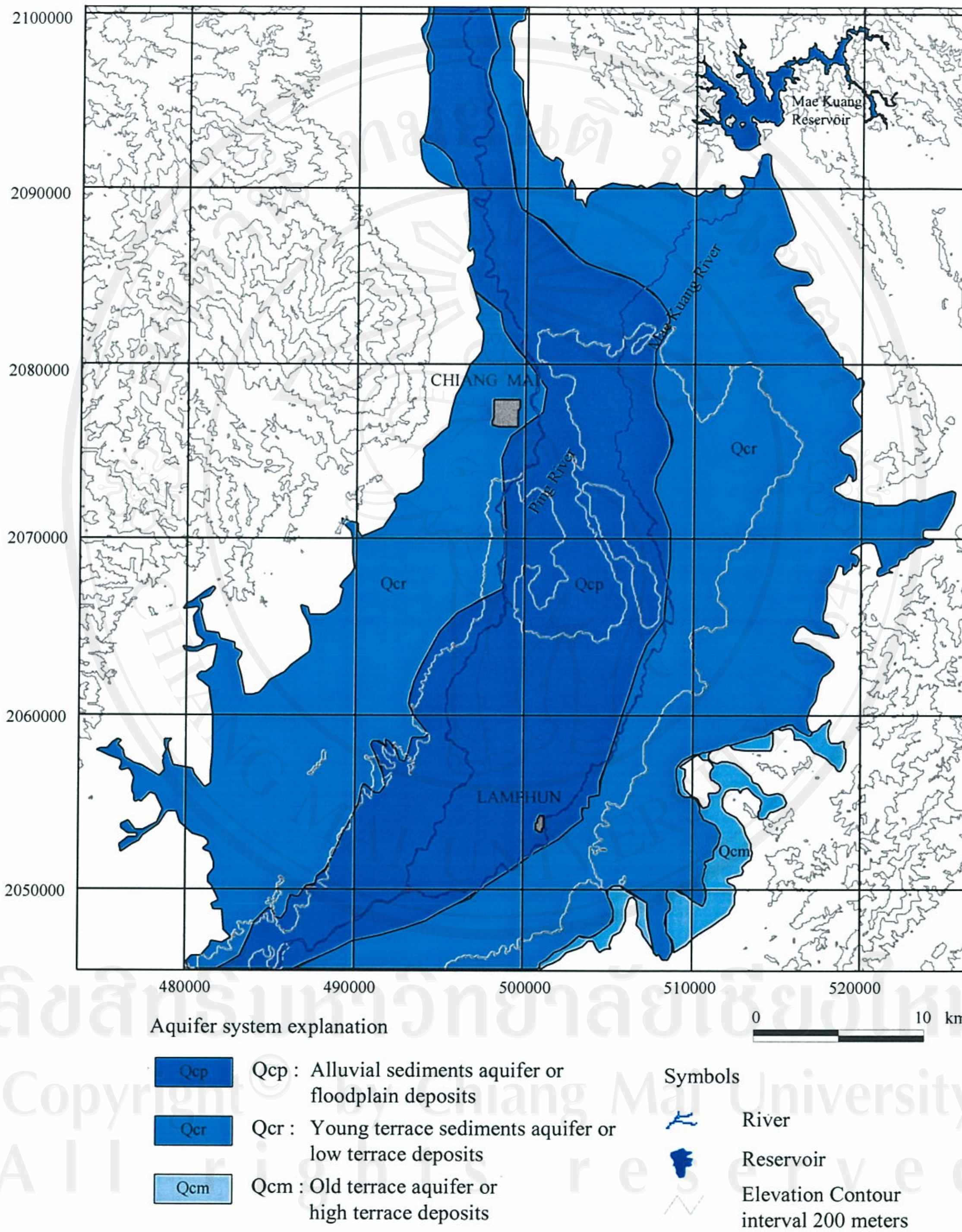

Figure 2.4 Aquifer systems of Chiang Mai basin based on interpretation of lithologic logs and geophysical borehole logs (modified from DMR, 2000).

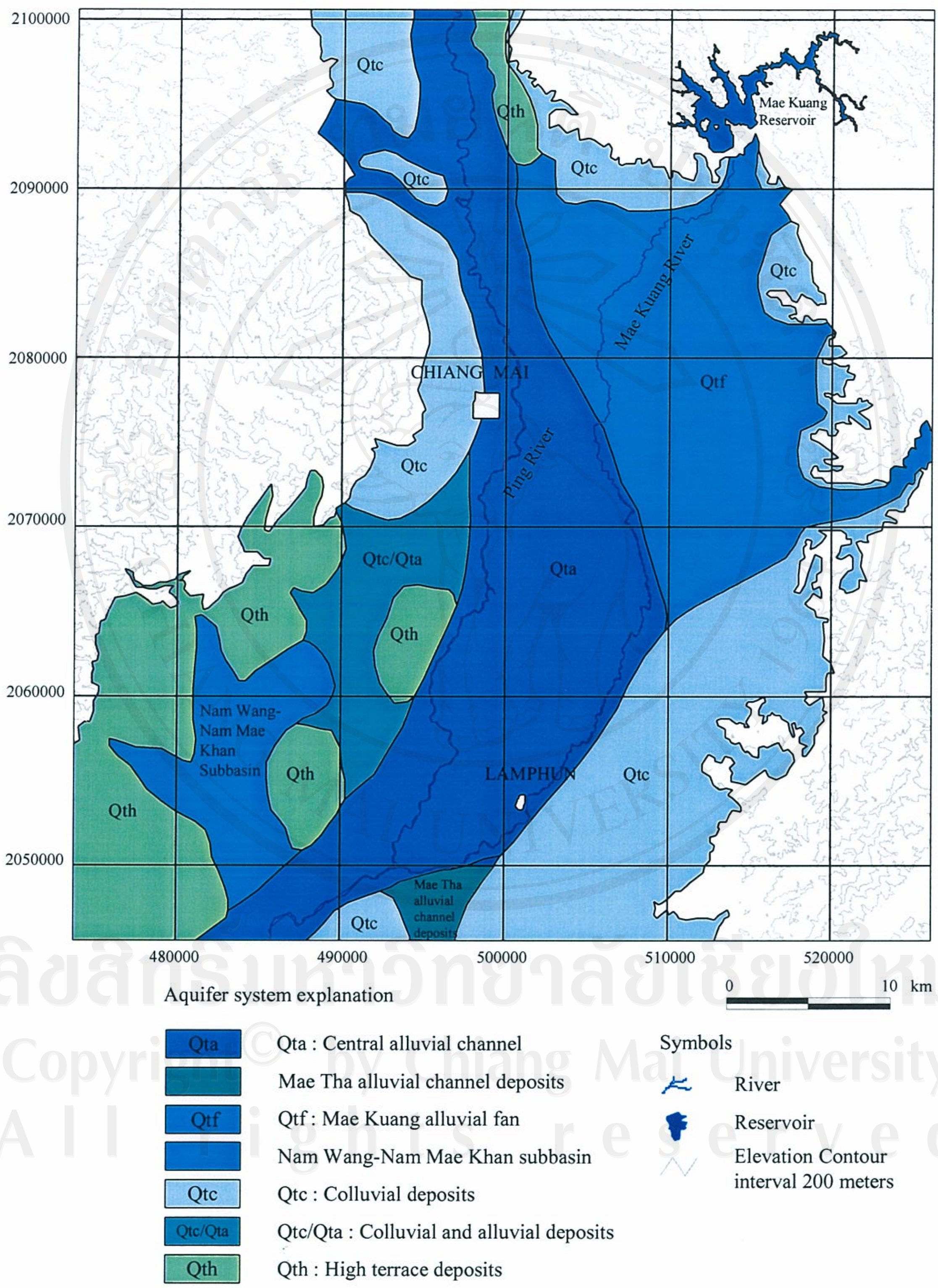

Figure 2.5 Aquifer systems of Chiang Mai basin based on structural interpretation (modified from Tatong, 2000).

(3) Mae Kuang alluvial fan The Mae Kuang alluvial fan is situated in the east of the basin. It was created by Mae Kuang and Hai Bon Rivers. Sand and gravel deposits are interfingered with silty and clayey deposits. The average depth of groundwater wells is around 50 meters. The specific well capacities and hydraulic conductivity are highly variable from one area to the other. The specific well capacities ranges between less than 1 to more than 20 m/d and hydraulic conductivity ranges from less than 5 to more than 100 m/d (Margane et al., 1998). These high variations are believed to be created by the sedimentary pattern of the fan. Average filter length is around 12 m. Average top filter of wells are at 20 meter depth below ground. TDS values are mostly less than 250 mg/l.

(4) Nam Wang-Nam Mae Khan subbasin The Nam Wang-Nam Mae Khan subbasin is subdivided from the main basin by down-faulted block, which is interpreted from satellite image and gravity data. It is believed that this subbasin is accumulated by high energy deposits, which are predominantly sand and gravel. This interpretation is supported by hydrogeological data, which indicate high specific well capacities per unit length of screen (more than 50 m/d) and quite different from one point to the other. Average total depth of wells are around 50 m. Average filter length is around 12 m. Average top filter of wells are at 15 meter depth below ground. TDS values are mostly less than 350 mg/l.

(5) Colluvial deposits Colluvial deposits have been mapped in many areas along the foothills of mountain ranges. The biggest colluvial deposit zone occurs east of Lamphun. There are dominated by clayey and silty colluvial deposits. Sand and gravel layers occur only in small area such as channel deposits of the eastern tributaries. Groundwater wells in this area are often quite deep (more than 200 meters) and filtered at several depth intervals. There are a few wells which reach bedrock. This indicates that the basin here is shallower than in other parts. Average total depth of wells is around 80 m. General specific well capacities and hydraulic conductivity values are low. The specific well capacities per meter unit length ranges between less than 0.1 and 3 m/d. However, the higher values might be found in the former tributary channel. Hydraulic conductivity values are generally less than 1 m/d. Average filter length is around 18 m. Wells have been reached within the top 50 m. of the sediments. The high fluoride content in this area is up to 16 mg/l (Margane et al., 1998). TDS values range from more than 250 mg/l to less than 1000 mg/l.

(6) Colluvial and alluvial deposits The colluvial and alluvial deposits is a ination of the colluvial deposits and the central alluvial channel. No details hydrogeological character of this deposits are reported.

(7) High terrace deposits The high terrace deposits occur all along the south-west margin and small area in the north-east rim. The deposits consist of sand and gravel beds intercalated with silty and clayey sediments. These sediments are deposited possibly during late Pliocene to early Quaternary. The sand and gravel layers have a relatively high clay content (mainly kaolinite), which is derived from feldspar weathering. Therefore the sediments are highly endured by the clay. Groundwater wells drilled in this area are relatively deep. They have a very low specific well capacity, which is clearly reflect the high clay content in the aquifer. The specific well capacity per unit length screen is usually less than 1 m/d. Average total depth of wells are around 80 m. Average filter length is around 18 m. Wells have been reached within the top 50 m of the sediments. TDS values range from 250 mg/l to less than 1000 mg/l. Summary of the hydrogeological characteristics of the aquifer systems is shown in Table 2.3.

Table 2.3 Characteristics of the aquifer complexes in the Chiang Mai basin (Margane et al., 1998).

Aquifer System	Average Total Depth of Wells (m)	Average SC/Filter Length (m/d)	Average Hydraulic Conductivity (m/d)	Average Filter Length (m)	Average Top 1st Filter (m bgl)	Average TDS (mg/l)
Central Alluvial Channel	~ 30	10 - > 100	20 - 200	~ 6	~ 20	< 250
Mae Kuang Alluvial Fan	~ 50	< 1- > 20	< 5 - > 100	~ 12	~ 20	mostly < 250
Nam Wang-Nam Mae Khan Subbasin	~ 50	> 50	-	~ 12	~ 15	Mostly < 350
Zone of Colluvial Deposits	~ 80	< 0.1 - 3	< 1	~ 18	~ 50	> 250 - < 1000
Zone of High Terrace Deposits	~ 80	< 1	-	~ 18	~ 50	250 - < 500

The aquifer systems used in the present study are based on the aquifer complexes as described by Margane et al. (1998) (Table 2.3). Chiang Mai basin, structurally, consists of a number of subsequently down-faulted blocks which have their own sedimentary patterns. While the aquifer systems classified by DMR (2000) comprises only the uppermost Quaternary strata, visible at the surface.