

# CHAPTER 1

## INTRODUCTION

Wisely used energy sources are critical to economic growth. The dramatic increase in energy demand for domestic development, urbanization and industrialization that had made the carbon dioxide emissions from fossil fuels burning, resulted in environmental pollution problems and global warming issues. Due to maintain a comfortable temperature inside a building are required a significantly amount of energy, to operate these systems, which come from electricity, fossil fuels or biomass. The warm earth that absorbed energy from sun, and groundwater below the surface provided a free renewable source of energy that could easily provide enough energy to heat and cool building in year-round.

Geothermal energy is a clean alternative energy which is one of the important renewable energy sources. It helps prevent the environment and also being the important source for heat pump system in several regions. Heat pump is a clean technology that transfers heat energy from a heat source to a heat sink against a temperature gradient. Ground source or geothermal heat pump provides a clean way to space heating and cooling. A geothermal heat pump could transfer heat stored in the earth into a building during the winter and transfer heat out of the building during the summer. For heating mode, the heat pump systems removed heat from the circulated fluid and transferred it to building. During the winter, heat energy from earth absorbed into groundwater and heat pump transferred heat to provide space heating. While in cooling mode, heat pump could operate by rejecting heat into the ground from the building and operate as air conditioner. During summer, the groundwater absorbed heat from living and moved it back underground. In several countries, groundwater temperature was measured for geothermal heat pump system due to the fact that groundwater was used as a main heat carrier to the groundwater heat pump that

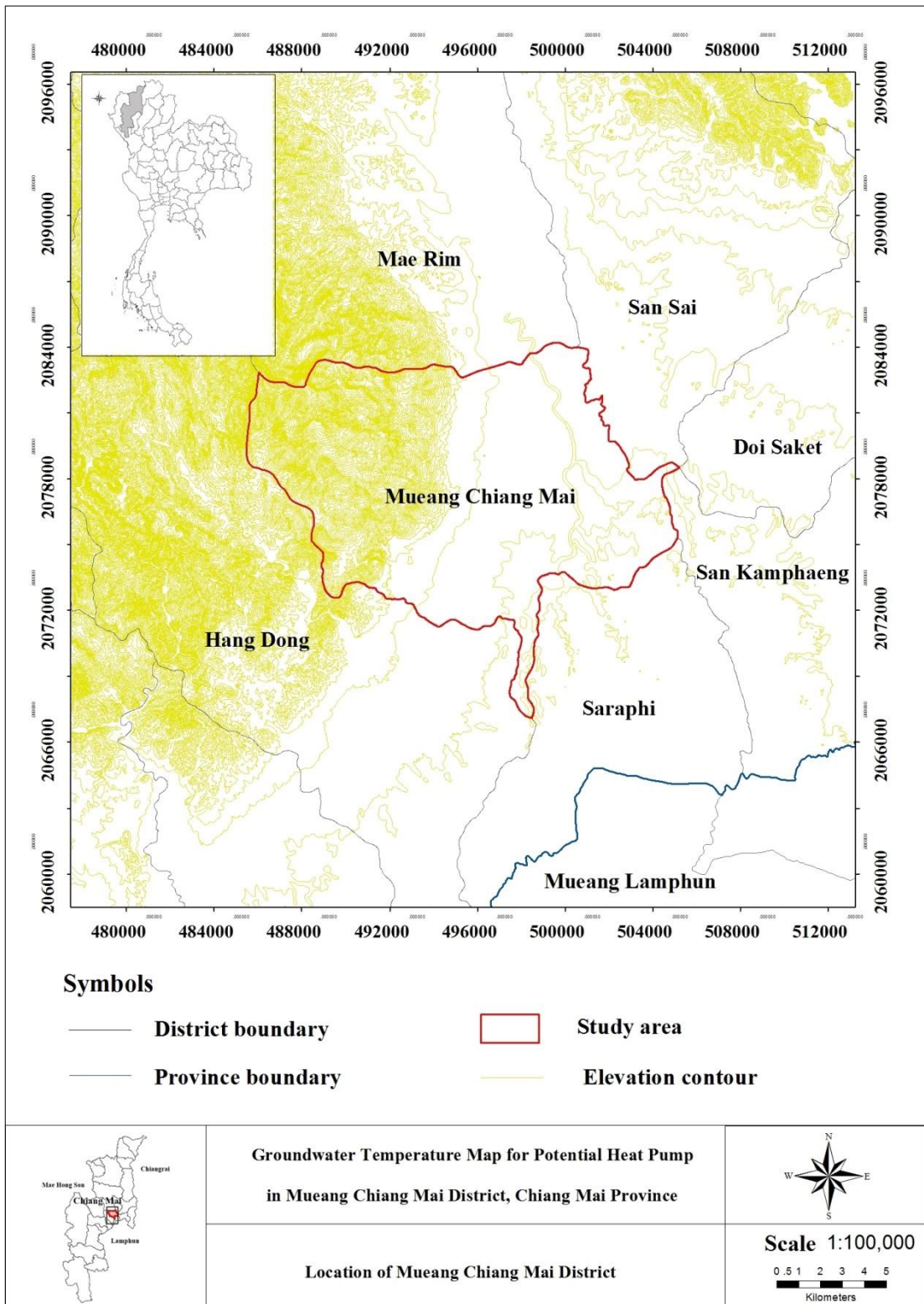
transferred heat from groundwater to provide space cooling. The performance of geothermal heat pump system depended on local geological conditions. Furthermore, groundwater flow transport heat and affects the heating and cooling performance for heat pump system.

Chiang Mai Province is a rapid urban development province, especially in Mueang Chiang Mai District, that is expecting the increase of energy demand and environmental pollution. Geothermal energy is an alternative option to heat and cool a building, and can reduce urban heat island effect. For geothermal heat pump system design, groundwater information is very important for design heat pump which used for space cooling during hot season as air conditioning. The evaluation of the potential groundwater temperature distribution, constructing groundwater flow, and considered water quality in Mueang Chiang Mai District is the first step to estimate potential area for heat pump system installation. In this study, shallow groundwater information was gathered to interpret groundwater temperature and construct groundwater temperature map and groundwater flow pattern.

### **1.1 Location, climate and land use of study area**

The study area is Mueang Chiang Mai District which is located in northern part of Thailand and lies between  $18^{\circ} 40'$  and  $18^{\circ} 53'$  north latitude and between  $98^{\circ} 53'$  and  $99^{\circ} 03'$  east longitude. It covers approximately 152.4 square kilometers and has a population of 235,059. Topography of the study area is classified into 2 main types. It is bounded on the west by high mountain and in the central part, the plains is lying between high mountain of granite and metamorphic rock. The study area is illustrated in Figure 1.1.

The study area is characterized by a tropical monsoon climate, which is southwest and northeast monsoon, consist of dry season and wet season. Dry season occurs from November to April and during May to October is the wet season. An average meteorological data in thirty-year were provided by the Northern Meteorological center (1981-2010). The mean annual rainfall was 1140.2 millimeters.



**Figure 1.1** Topographic map of Mueang Chiang Mai District.

Long– term temperature averages varies between 12.5 – 38.0°C and mean annual temperature is 25.8 °C throughout the year. Average evaporation is about 1,605.80 millimeters. The relative humidity was 70.9%. Figure 1.2 and 1.3 illustrate monthly temperature and precipitation of Mueang Chiang Mai District between January – June in 2014.

Land use of Mueang Chiang Mai District is described by GIS Enterprise Access Database of Chiang Mai Province (2010) and it is classified into five types consist of urban, forests, agricultural, water resource and other. Over 46.64% of the 113,495.26 rai in Mueang Chiang Mai District were urban zones which were distributed at the central to east part of the area. The Forest areas covered 34.67% of study area which consisted of deciduous forest and evergreen forest. About 10.53% was agricultural and water resources covered 1.29% of study area. In the study, there is classified land use type of the study area into three main type consist of densely urban, agricultural and residential zone (Figure 1.4).

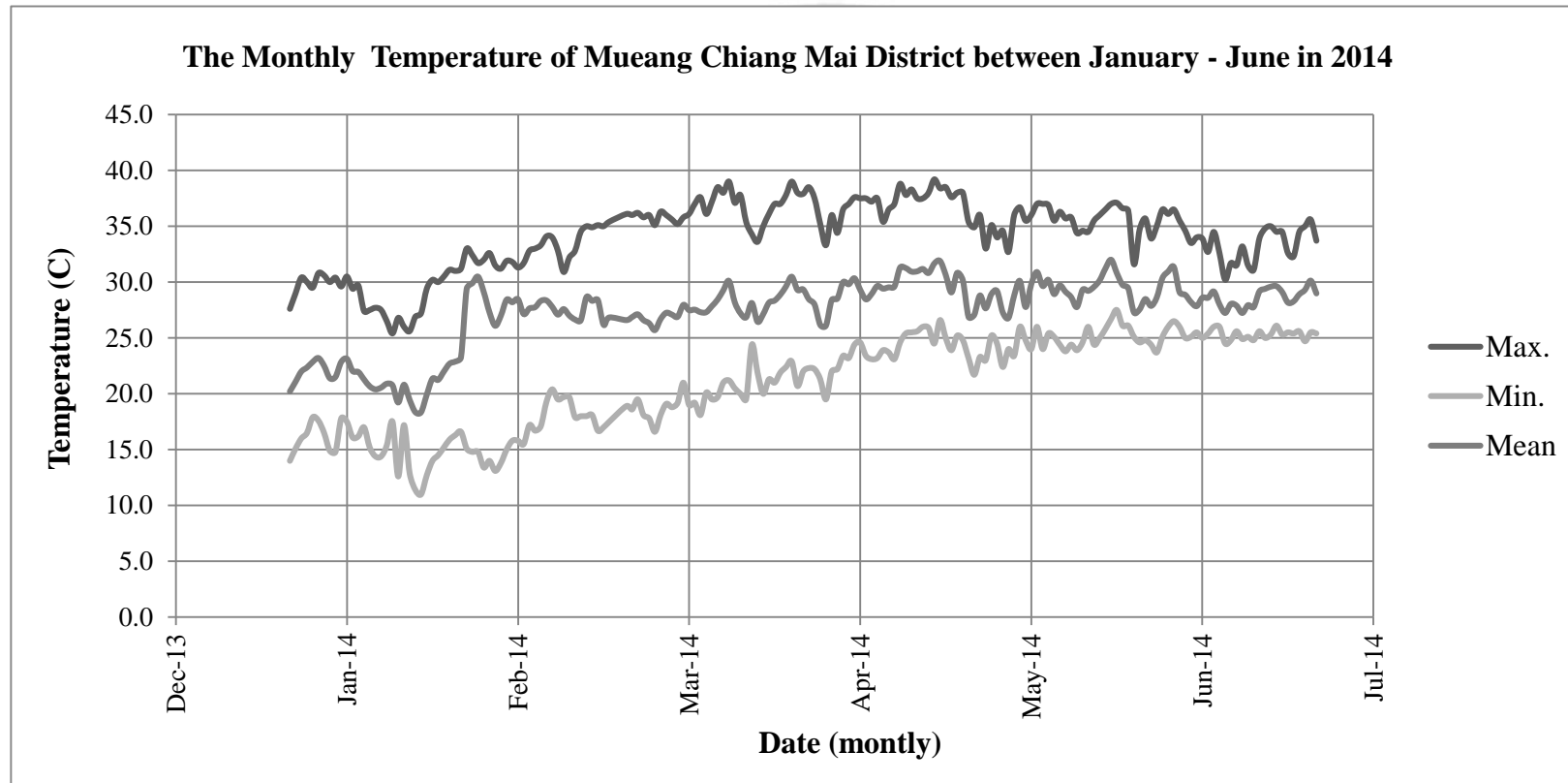
## **1.2 Purpose of the study**

- (1) To study groundwater temperature distribution, groundwater quality and groundwater level of Mueang Chiang Mai District.
- (2) To construct groundwater temperature map for potential heat pump that can be used for designing a groundwater heat pump system in cooling mode in the future.

## **1.3 Scope and Methodology**

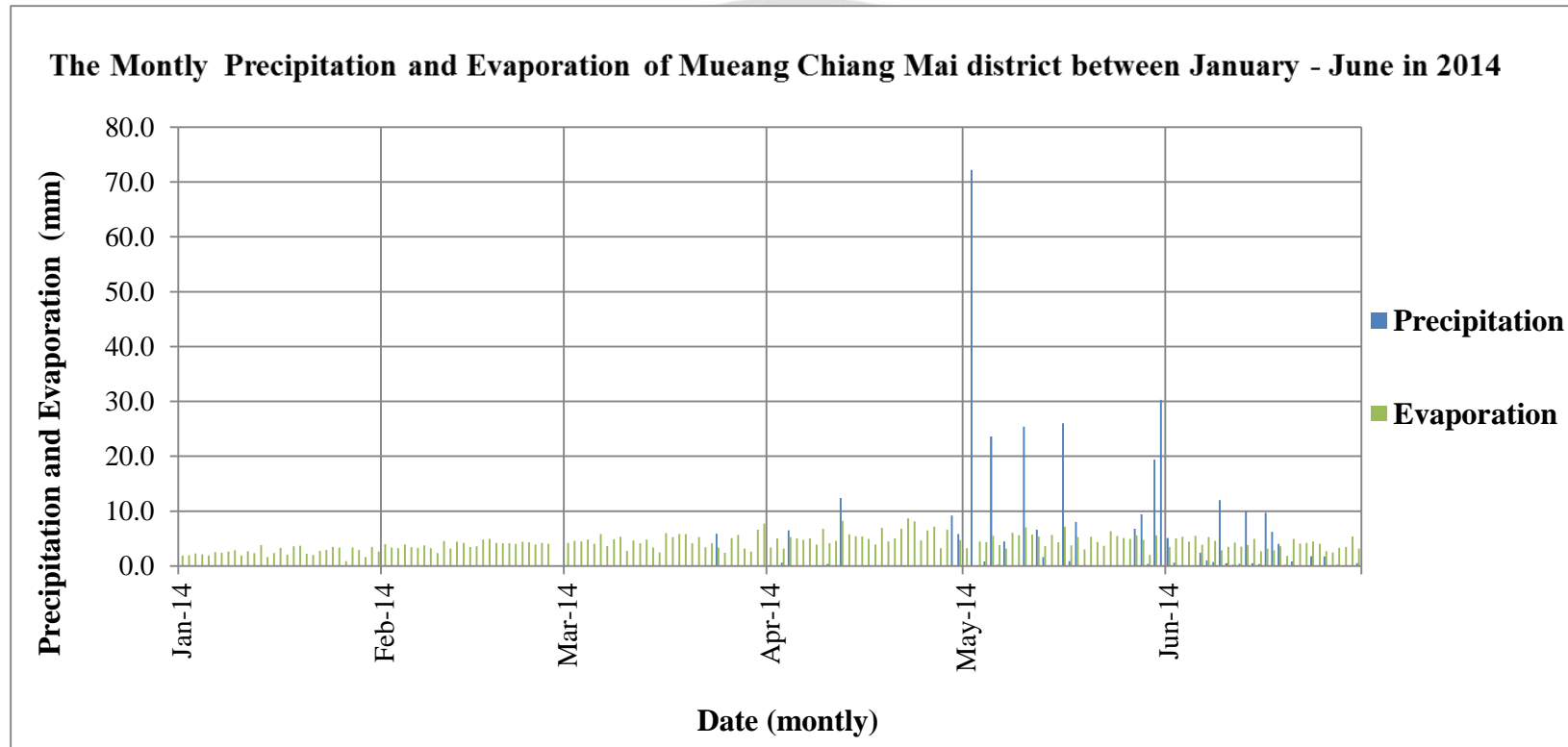
### **1.3.1 Scope**

This study focuses mainly on groundwater temperature distribution which is groundwater temperature of shallow wells at depth approximately less than 10 meters, groundwater quality and groundwater level in Mueang Chiang Mai District for potential heat pump in cooling mode.

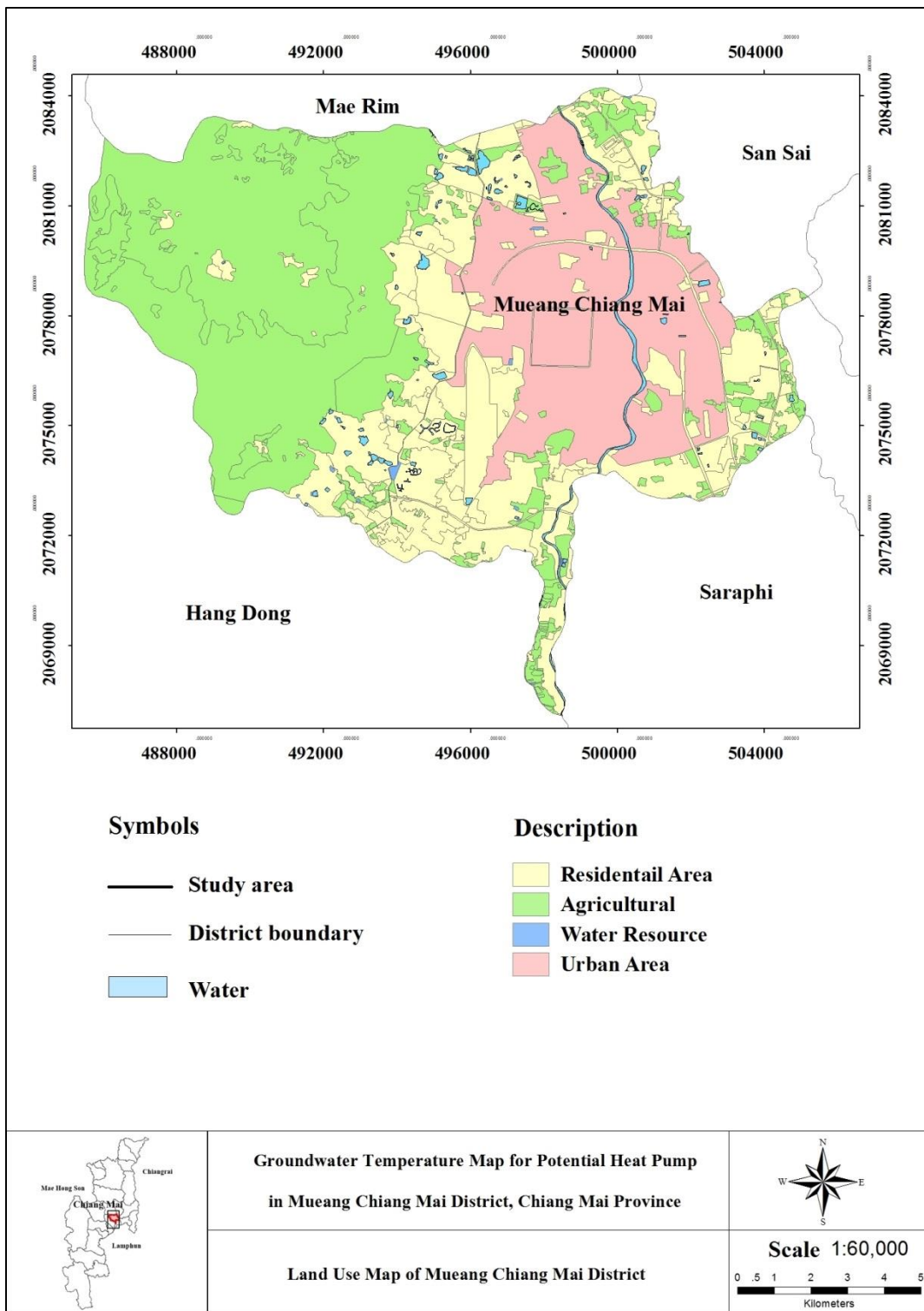


**Figure 1.2**

The monthly temperature of Mueang Chiang Mai District between January – June in 2014 (Modified from the Northern Meteorological center, 2014).



**Figure 1.3** The monthly precipitation and evaporation of Mueang Chiang Mai District between January – June in 2014 (Modified from the Northern Meteorological center, 2014).



**Figure 1.4** Land use map of Mueang Chiang Mai District (Modified from Geoinformatics and Space Technology Centre Northern Region: GISTNORTH, 2013).

### 1.3.2 Methodology

(1) Literature review which is reinterpreting previous geological and hydrogeological data of the study area and field survey planning. This included selection shallow and deep observation wells for collected groundwater data and water sampling.

(2) Field survey. Groundwater temperature and groundwater level were collected from 45 shallow observation wells with depth interval less than 10 meters and 2 deep observation wells with a depth of more than 30 meters at frequency twice per month for 10 times. Twenty-eight groundwater samples were collected from representative shallow and deep wells for chemical analysis.

(3) Data processing and constructing map. Hydrochemical data were processed using AquarChem4.0<sup>®</sup>. Groundwater temperature and groundwater level data were constructed temperature distribution and flow pattern map using Surfer<sup>®</sup> and ArcMap<sup>®</sup> program.

(4) Groundwater temperature map for potential heat pump. All data process were constructed groundwater temperature map that suited for install groundwater heat pump in Mueang Chiang Mai District using weighted overlay method and ArcMap<sup>®</sup> program.

### 1.4 Geologic setting

Chiang Mai basin is the largest rift basin in Northern Thailand and reaches a maximum thickness of 2 – 2.5 kilometers. It is elongated shape having the long axis in the direction of northeast-southwest. The basin has high mountain range on west sides which is Inthanon range and the Khun Tan range bounds the east side. Tatong (2000) can be separated Chiang Mai basin into 2 groups that consist of well consolidated rocks (Pre-Cambrian and Paleozoic age) and poorly consolidated to unconsolidated rocks (Tertiary and Quaternary age). Well consolidated rock range on the mountainous area

and surrounding basin are composed of metamorphic, sedimentary and igneous rocks. While poorly consolidated and unconsolidated rocks

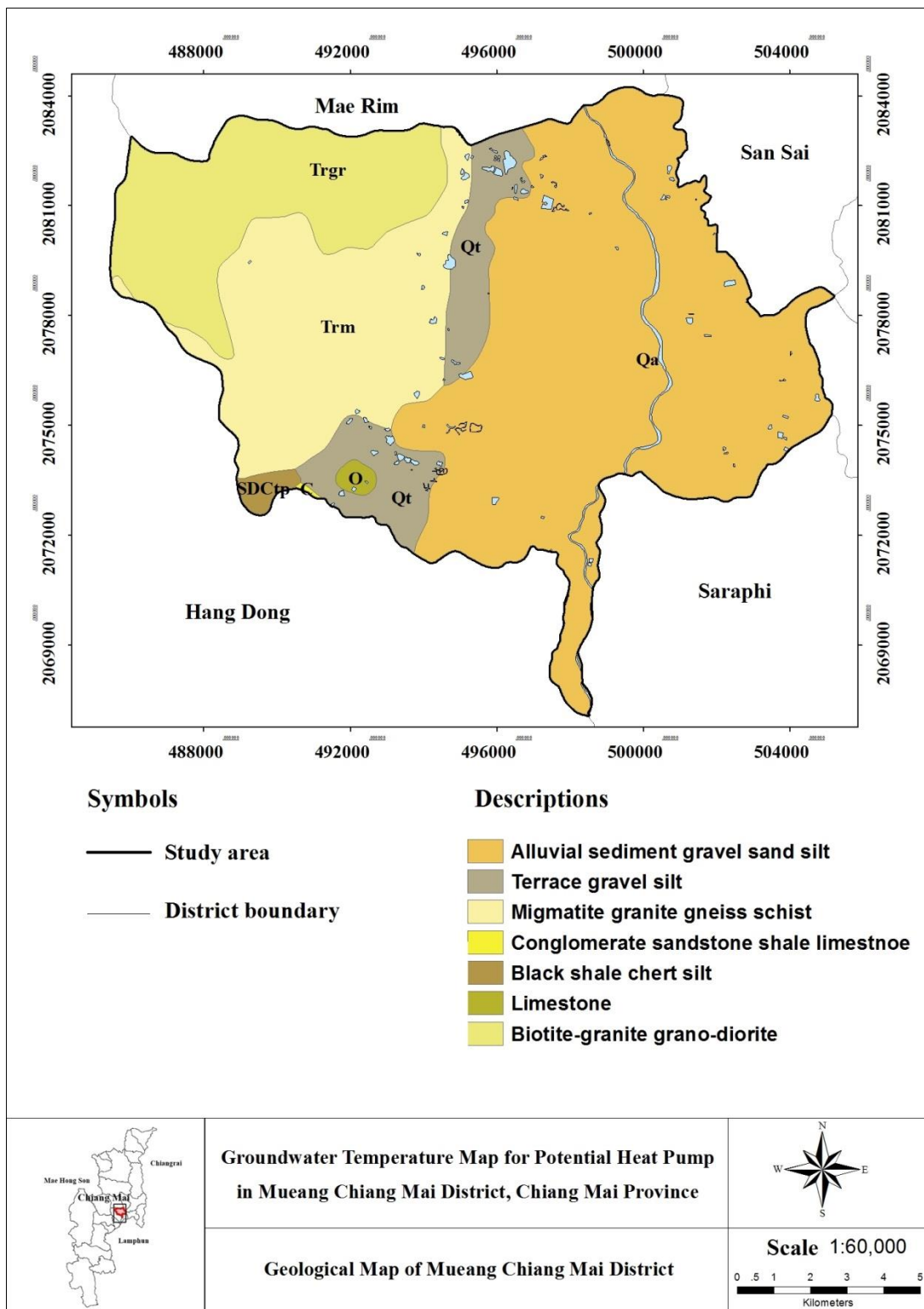
The study area is the part of the Chiang Mai basin that is cover by consolidated and unconsolidated rocks. The consolidated rocks consist of gneiss, schist, shale, chert, siltstone, limestone and granite. It occurs in high and sloping western mountain range of this study area.

Unconsolidated rocks cover in the central part and eastern part of the study area. Previous work can be divided unconsolidated rocks into three group include High terrace deposits, Low terrace deposits and Flood plain deposits as described by Intrasuta (1983), Wongpornchai (1990), Tatong (2000), Uppasit (2004) and Klaytae (2005). The geologic map of Mueang Chiang Mai district is shown in Figure 1.5.

High terrace deposits (Upper Tertiary to Lower Pleistocene) shows a typical characteristic of high elevation, in comparison with the paddy field. They are composed mostly of sandy clay, sand and minor gravel bed. The gravel derived from weathering and erosion of the nearby country rock which broken into fragments, sub-rounded to rounded. Grain size in sand is varies from fine to coarse and is sub-angular and poorly sorted. The thickness of formation varies depending upon the hard rock underlain with about more than 760 meters. High terrace deposits partly extends under the younger sediment in the central plain where most part of it exposed along the western part of the study area.

Low terrace deposits (Middle to Upper Pleistocene) is distinguished from high terrace deposits by the lower elevation, 300 – 320 meters with relatively flat surface. Low terrace and flood plain deposits can be practically separated by the 300 meter contour above mean sea level. It composes of fine grained sediments, gravel, sand and clay. The thickness of low terrace is about more than 150 meters.

Flood plain deposits (Holocene) is characterized by flat surface along the eastern part of the study area and composes mainly of well sorted sand and gravel



**Figure 1.5** Geological map of Mueang Chiang Mai District (Modified from Department of Mineral Resources, 2007).

overlain by clay and silt. The lateral variation of flood plain deposits is predominant. A thick layer of coarse grained gravel and pebble was deposited behind natural levee. This gravel grades into coarse silt at the natural levee and fine silt and clay within the back swamp deposit. Thickness varies from 10 to 60 meters.

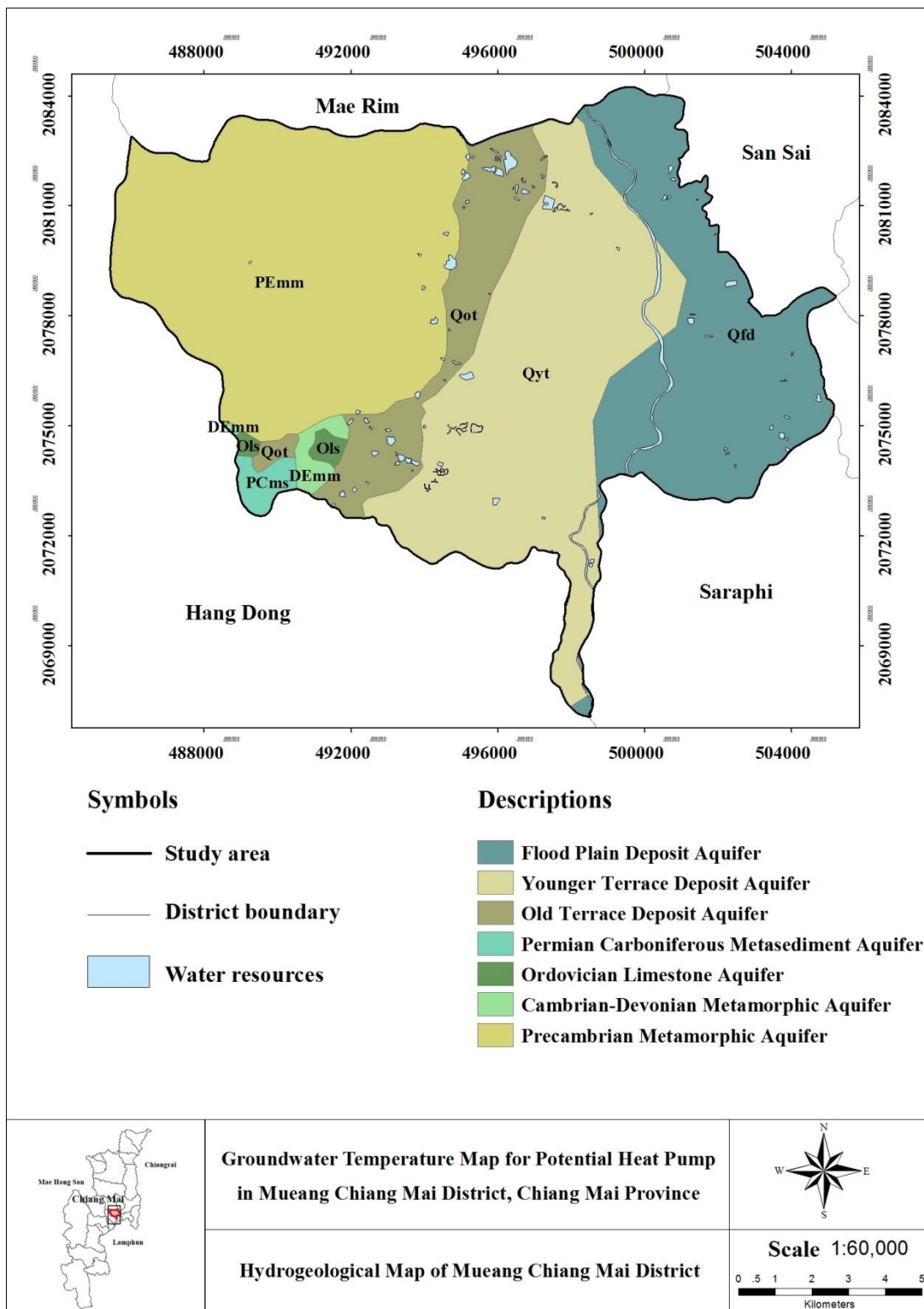
## **1.5 Hydrogeologic setting**

Hydrogeologic condition is defined as the geologic condition with groundwater including origin, distribution, flow pattern, amount and potential of groundwater at each area. Hydrogeology of Mueang Chiang Mai District consists of Tertiary to Quaternary deposits and it is apparent that unconsolidated and consolidated rocks are the main aquifer of the study area (Figure 1.6). The consolidated rocks consist of granite and carbonate which forming a mountain area in the western part. Unconsolidated rocks cover the central and eastern part of study area. Generalized hydrologic unit of Mueang Chiang Mai District is summarized and shown in Table 1.1

### **1.5.1 Hydrogeologic unit in unconsolidated rock**

Previous works were divided unconsolidated rocks into three hydrogeological units, namely; (1) Flood plain deposits aquifer (2) Young terrace deposits aquifer and (3) Old terrace deposits aquifer. The hydrogeological units division of Mueang Chiang Mai District was described by Intravuta (1983), Wongpornchai (1990), Tatong (2000), Klaytae (2005), Department of Groundwater Resources (2008) and Seanton (2010).

Flood plain deposits aquifer (Qcp) cover 25% of the area and deposited along the flood plain with an average thickness of about 20 – 50 meters. It cover all of Tambon Nong Hoi, Tambon Tha Sala, Tambon Nong Pa Khleng, Tambon Fa Ham, Tambon San Pee Sua and majority of Tambon Chang Khleng and part of Tambon Pa Tan, Tambon Pa Daet, Tambon Wat Ket. It consists of well-sorted sand and gravel overlain by clay and silt. Thick layer of coarse grained gravel and pebble was deposited behind natural levee. The alluvial sediment aquifer is an unconfined aquifer and well yields is more than 20 m<sup>3</sup>/hr.



**Figure 1.6** Hydrological map of Mueang Chiang Mai District (Modified from Department of Groundwater Resources, 2001).

**Table 1.1** Generalized hydrologic unit of Mueang Chiang Mai District (modified from Lerdthusnee, 1982; Intrasuta, 1983; Tatong, 2000; Sarapirom, 2001; Subtavewung; 2006).

Lithologic unit	Hydrogeologic unit	Description	Lithology	Groundwater conditions
Unconsolidated Rock	Qfd	Flood Plain Deposits Aquifer	Recent alluviums of flood plain, meander belts and channel fills including clays, silts, sands and gravels	Moderated to high yield with fair to good water quality. Local water well yields at a rate >20 m <sup>3</sup> /hr
	Qyt	Young Terrace Deposits Aquifer	Loose sediment of Pleistocene to Holocene, thick clay bed with intercalation of sand and gravel lense	Moderated to high yield with good water quality
	Qot	Old Terrace Deposits Aquifer	Old alluvium of upper Tertiary to Pleistocene, thick sand and gravel beds with minor clay lense. Gravel consist of gneiss, sandstone, quartzite with sandy clay metrix.	Low - moderated yield with fair to good water quality

**Table 1.1** Generalized hydrologic unit of Mueang Chiang Mai District (continued.).

Lithologic unit	Hydrogeologic unit	Description	Lithology	Groundwater conditions
Matasedimentary Rock	PCms	Permian - Carboniferous Metasediment Aquifer	sandstone, shale, chert, limestone, slate, mudstone, quartzite and phyllite	Groundwater is stored in cracks, fractures and bedding planes. The average depth is about 12 – 30 meters and yield is less than 2 m <sup>3</sup> /hr
Carbonate Rock	Ols	Ordovician Lime stone Aquifer	Lower part consists of thin beds of argillaceous limestone slaty shale sandstone and interbedded limestone in middle part. Occur only in western mountain range.	Produce smaller quantity than the Permian limestone.
Granitic Rock	DEmm	Cambrian – Devonian Metamorphic Aquifer	quartzite, schist, phyllite and gneiss	The average thickness is 30 – 40 meters and well yield is generally less than 2 m <sup>3</sup> /hr.
Metamorphic Rock	PEmm	Pre-Cambrian Metamorphic Aquifer	Medium to high grade para & ortho gneisses and schist	Yield range is less than 2 m <sup>3</sup> /hr, from the jointed systems or decomposed zones

Young terrace deposits aquifer (Qcr) is the Pleistocene to Holocene age and cover 30% of the area. It widely distribute along narrow terrace next to the Ping river's flood plain which cover all of Tambon Mae Hia, Tambon Phra Sing, Tambon Sri Phum, Tambon Chang Moi and most of Tambon Pa Tan, Tambon Pa Daet, Tambon Hai Ya and part of Tambon Wat Ket, Tambon Su Thep and Tambon Chang Khlan. It is cover 900 km<sup>3</sup> and high about 290 – 320 meters above mean sea level. This consists of thick clay bed with intercalation of sand and gravel lense. Mostly form relatively low flat surfaced terrace. The average thickness of sediment range from 30 – 70 meters and well yield is 5 – 10 m<sup>3</sup>/hr.

Old terrace deposits aquifer (Qcm) is upper Tertiary to Pleistocene and covers 9% of the area that about 1400 km<sup>3</sup>. It distribute in the high terrain next to Young terrace sediments till the hilly area which cover part of Tambon Chang Phuak and Tambon Su Thep. It consists of pebble, sand, silt, gravel bed with minor clay lense. Partly formed high dissected surface terrace but mostly concealed under younger sediments. It deposited along area higher than young terrace deposit. The average thickness of old terrace sediment is 200 – 500 meters and 300 meters in some area. Well yield is 2 – 10 m<sup>3</sup>/hr.

### **1.5.2 Hydrogeologic unit in consolidated rock**

Most groundwater is stored in spaces of various geologic structures. The consolidated rock of Mueang Chiang Mai District can be divided into four units as follows;

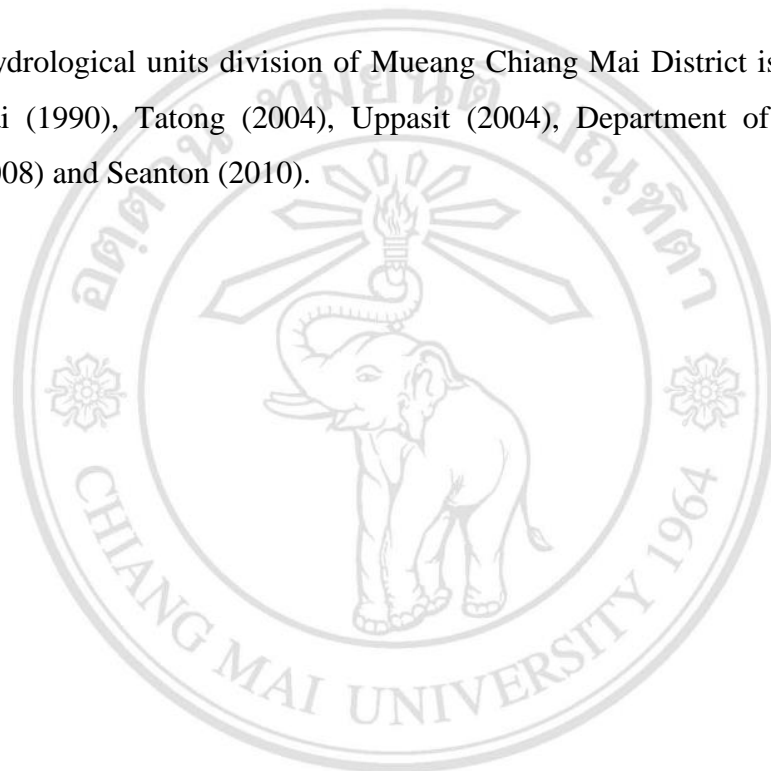
Permian – Carboniferous metasediment aquifer (PCms) consists of sandstone, shale, chert, limestone, slate, mudstone, quartzite and phyllite. Groundwater is stored in cracks, fractures and bedding planes. The average depth is about 12 – 30 meters and yield is less than 2 m<sup>3</sup>/hr.

Ordovician Limestone aquifer (Ols) consists of gray to dark gray, recrystallized, laminated, and argillaceous limestone with interbedded shale in the lower part. Thickness is range from 30 – 70 meters and yield is 2 – 10 m<sup>3</sup>/hr.

Devonian – Cambrian metamorphic rocks aquifer (DEmm) consists of quartzite, schist, phyllite and gneiss. The average thickness is 30 – 40 meters and well yield is generally less than 2 m<sup>3</sup>/hr.

Pre-Cambrian metamorphic aquifer (PEmm) deposited in the mountain on the west of Mueang Chiang Mai District.

The hydrological units division of Mueang Chiang Mai District is described by Wongpornchai (1990), Tatong (2004), Uppasit (2004), Department of Groundwater Resources (2008) and Seanton (2010).



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