CHAPTER 1
INTRODUCTION

Water is an important resource for human beings. People get water from two sources; surface water and groundwater. Among these, groundwater is the most reliable in terms of water quantity and quality. Groundwater plays a major role in many sectors, domestic consumption, agricultural and industrial uses, especially during a drought period. Groundwater shortages and low quality are problems in every sector; moreover contamination of groundwater has become a more serious problem recently in the Chiang Mai basin.

Due to rapid development of Chiang Mai Province, Lumphun Province, and vicinity, known as Chiang Mai basin, groundwater has been increasingly deployed for domestic, agricultural, and industrial purposes. Consequently, the groundwater level has dropped and groundwater quality has become degraded. Waste products from agriculture and industry have leaked and contaminated the groundwater in some places. Problems of groundwater contamination are critical in Chiang Mai basin. The most cost-effective way to protect groundwater from contamination is to construct a vulnerability map of aquifers where contamination sources may likely occur. Geographical information System and DRASTIC method were used as a source of hydrogeological data to delineate the vulnerability contamination map. Groundwater quality as measured by Total Dissolved Solids was also used to generate the vulnerability map.

1.1 Location of the study area

Chiang Mai basin is located in the northern part of Thailand; it is comprised of Chiang Mai Province and Lumphun Province. The study area of the groundwater vulnerability map of the Chiang Mai basin covers 38,992 square kilometers (Figure 1.1). Topography of the study area is classified into 3 major parts: high mountainous area in the northern part and western part; hill and rolling area in the southern part; and the plains area in the middle part (Figure 1.2). The highest elevation is about 2,500 meters above mean sea level at Inthanon Mountain, Chiang Mai Province.

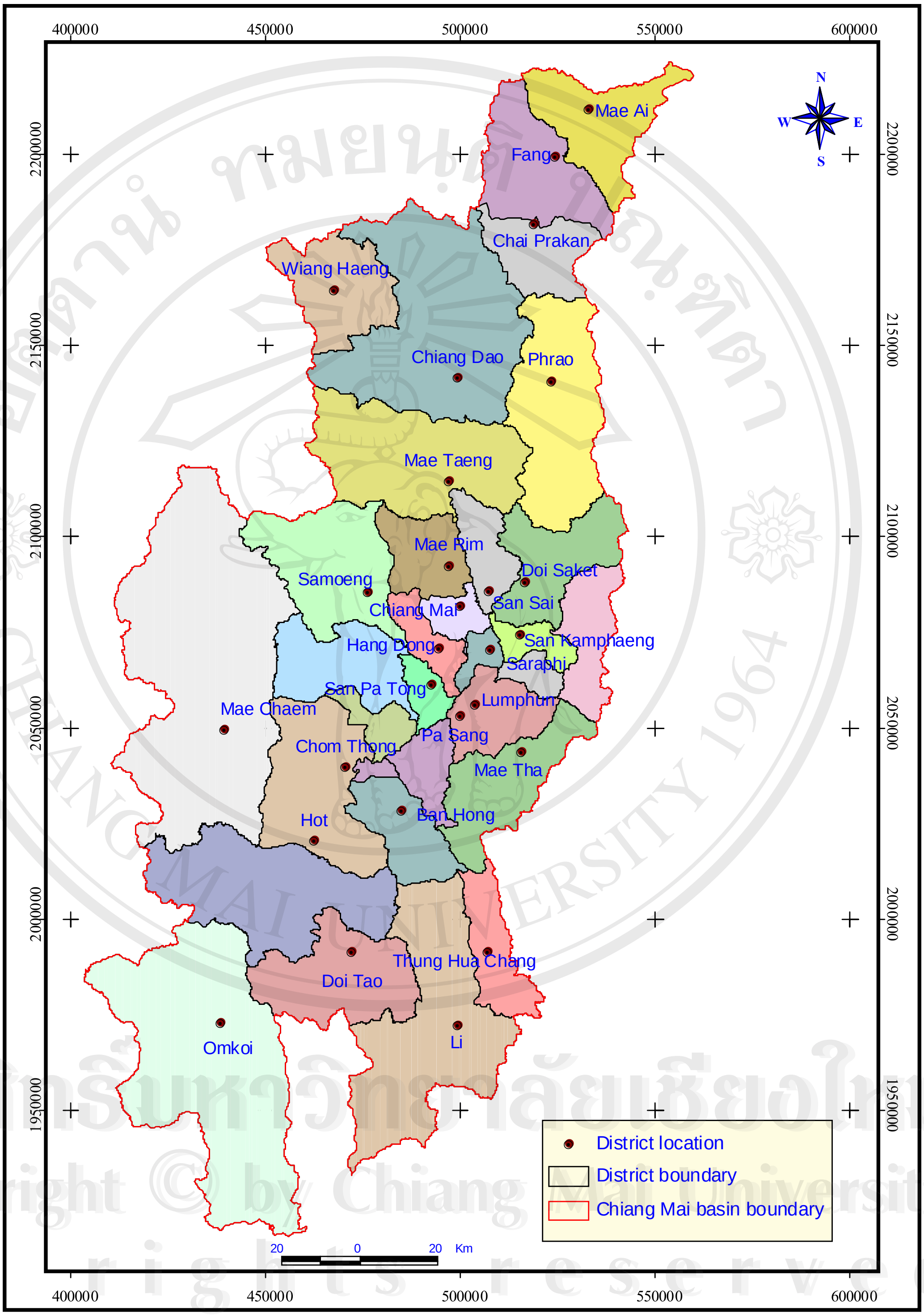

Figure 1.1 Map of Chiang Mai basin (Chiang Mai and Lumphun Province).

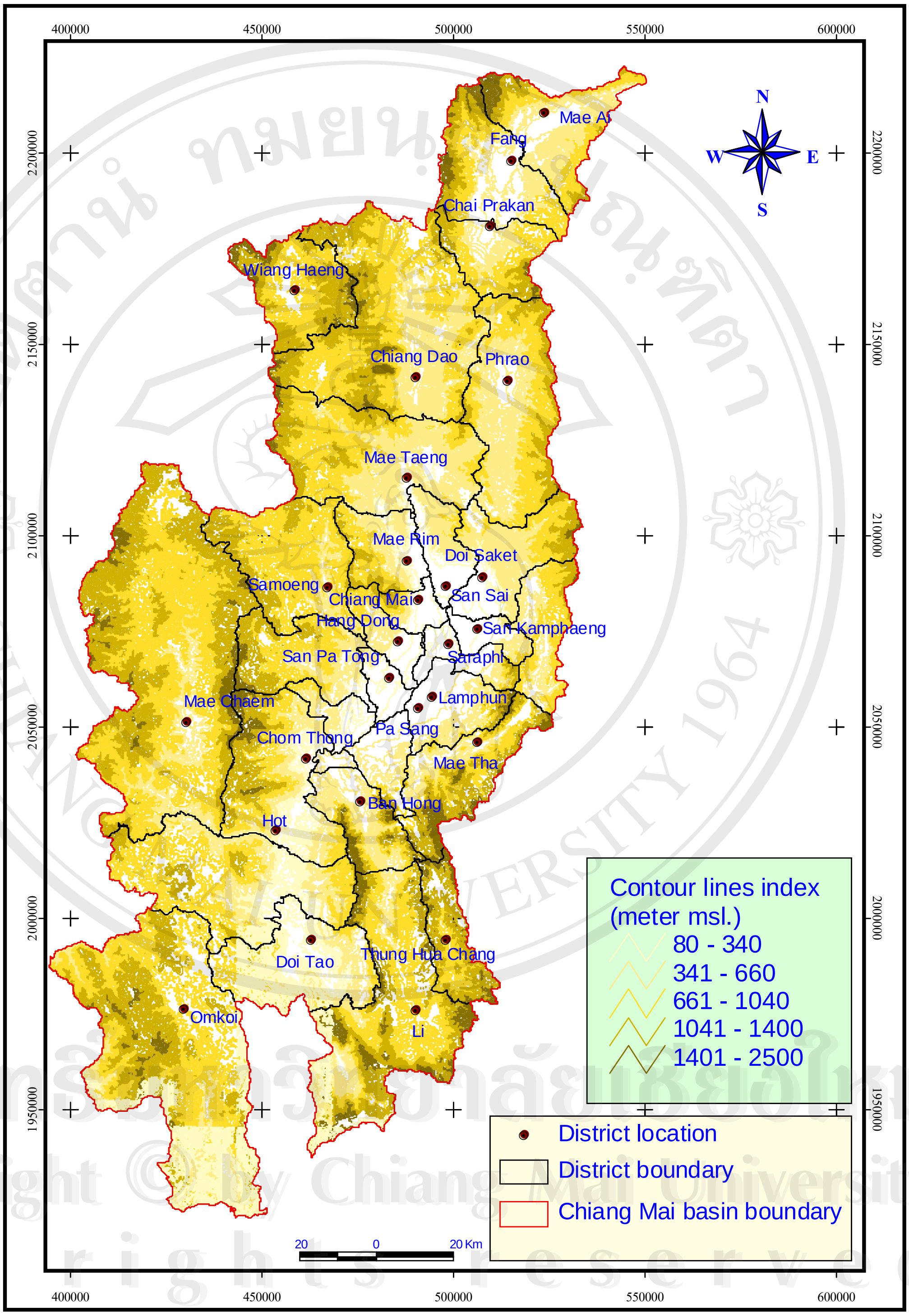

Figure 1.2 Topographic map of Chiang Mai basin.

1.2 Objectives and scope

The objectives of this research are: 1) to assess groundwater vulnerability using DRASTIC method; and 2) to evaluate DRASTIC method results with respect to uncertainties in input data and contaminant sources.

The study area was compried of the Chiang Mai basin, which covers 38,992 square kilometers in Chiang Mai and Lumphun Province. Vulnerability assessment was done using the DRASTIC method and Geographic information system data.

1.3 Methodology

1) Prepare hydrogeological data according to the DRASTIC method requirements in geographic information system form. The required data are depth to aquifer, net recharge, aquifer media, soil media, percent of topographic slope, impact of vadose zone, and hydraulic conductivity.
2) Apply the DRASTIC method with available prepared data.
3) Evaluate the groundwater vulnerability and present the results as a vulnerability map.
4) Evaluate the applicability of the results with respect to the source of key contaminant types of the area.
5) Evaluate the uncertainty of input data and the sensitivity of the DRASTIC index to data uncertainty.

1.4 Literature review

1.4.1 Geology setting and hydrogeology

The geology of Chiang Mai basin (DMR, 2001) and its surroundings were separated into two groups. 1) Consolidated rocks of the Pre-Cambrian and Paleozoic age underlie the western range, Doi Suthep and eastern range, which form a great relief and steep slopes. The rocks are composed of metamorphic, sedimentary and igneous rocks. 2) Semi-consolidated to unconsolidated rocks of Tertiary and Quaternary age. The semi-consolidated rocks of the Tertiary age are found only in the western rim of the basin. The unconsolidated sediments of the Quaternary age cover the center of the basin (Figure 1.3).

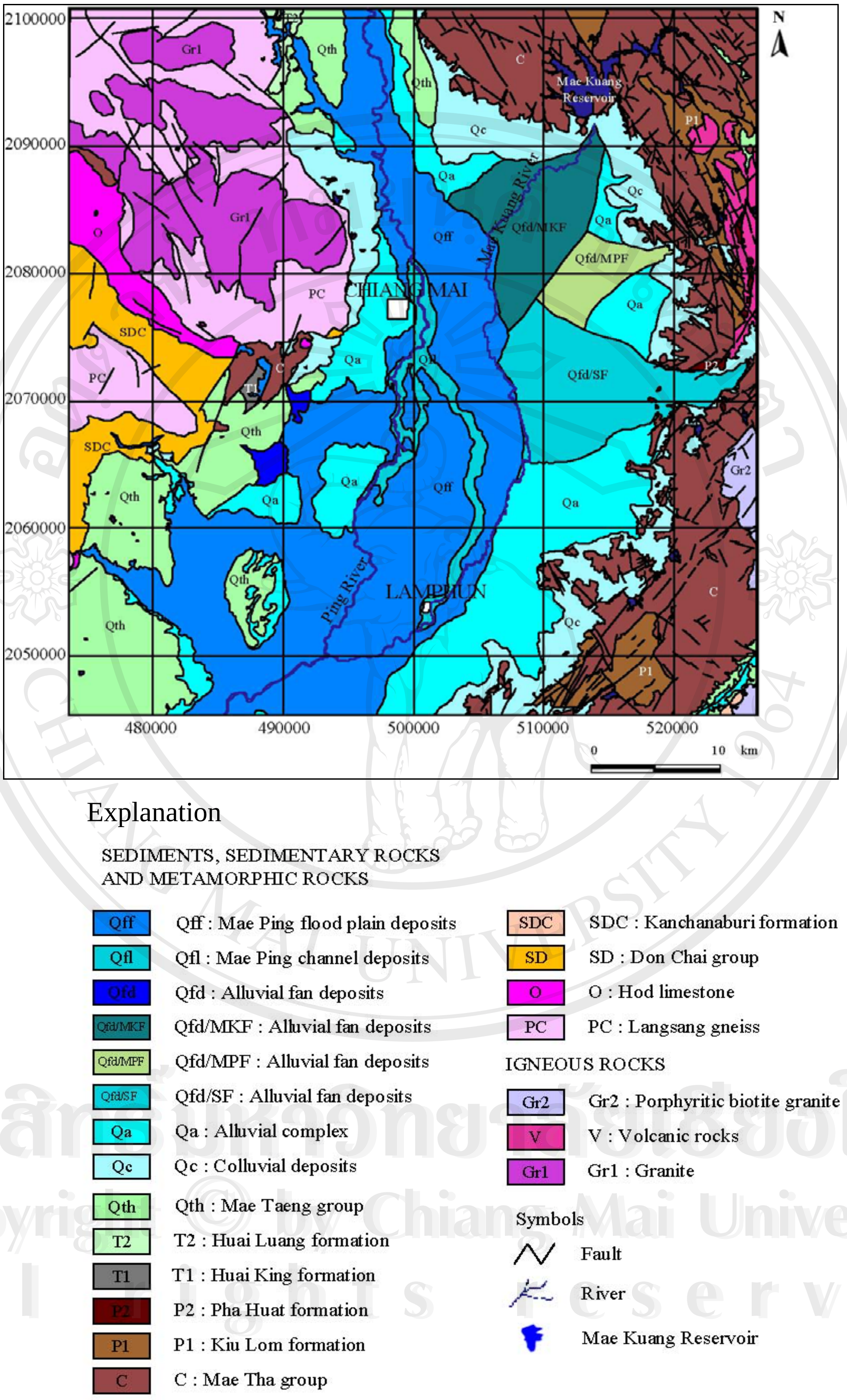

Figure 1.3 Geologic map of Chiang Mai basin (modified from DMR, 2001).

Hydrogeological conditions are defined as the geological conditions dealing with origin, distribution, movement, quality and potential evaluation of groundwater (DMR, 2001). Variance of the geological conditions results in different hydrogeological properties. Chuamthaisong and Intrasutra (1992) divided aquifers into four types, unconsolidated aquifers, semi-consolidated aquifers, consolidated aquifers and carbonated rocks aquifers according to groundwater yielding characteristics. A provincial groundwater availability map of Chiang Mai basin was constructed by DGR, 2002 in order to serve the resources user and stakeholders.

The provincial groundwater availability map (DGR, 2002) of Chiang Mai Province consisted of records of wells (location, yield and water quality) and well logs constructed at the scale of 1:100,000. The map shows both groundwater yield and groundwater quality in the form of a matrix of tones of colors and shades of colors. Dark tones indicate high yield whereas light tones represent lower yield. Groundwater quality is represented in the form of Total Dissolved Solids (TDS). Blue green and orange colors represent good, moderate and poor quality respectively (Figure 1.4). Most of high groundwater yield was obtained from Quaternary alluvium (gravel and sand) of the flood plain of the Ping River due to its high porosity and permeability. The rest was obtained mainly from secondary porosity, fracture zones of consolidated aquifers and solution cavity of carbonate aquifers. Evaluation of groundwater vulnerability within this study was based on the information presented in the provincial groundwater availability map.

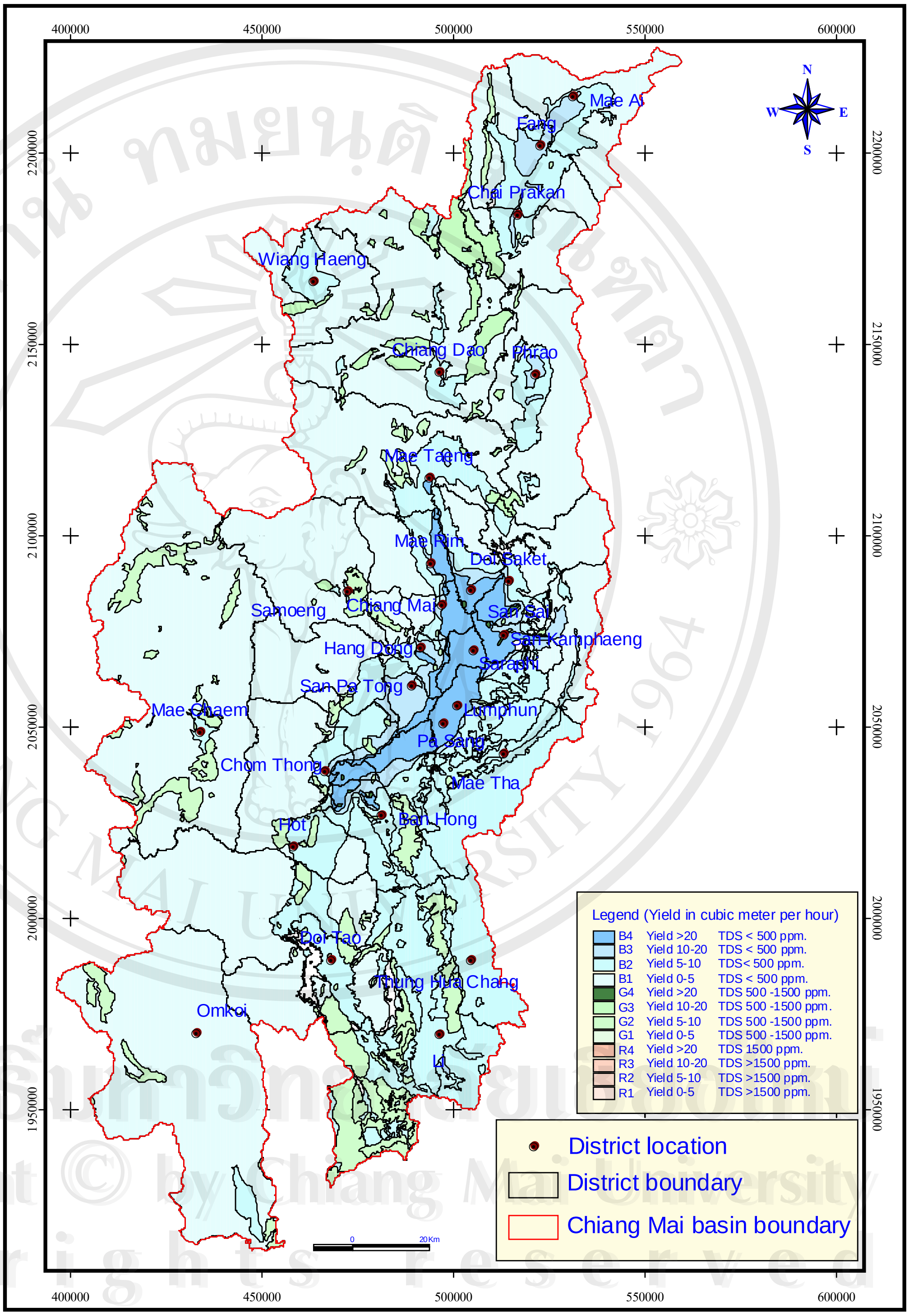

Figure 1.4 Groundwater availability map of Chiang Mai basin (DGR, 2002)

1.4.2 Groundwater vulnerability

Dorn and Tantiwanit (2002), the Thai German Technical Cooperation Project, established tools for a waste management systems. These included a searching process for waste disposal sites. The waste disposal problem of the Chiang Mai Municipality is due to about a 30 percent increase in waste during the past 4 years, up to 250 tons per day. However, suitable disposal sites for this amount of waste are very limited and involve political issues. Locating disposal sites can be justified using hydrogeological data of the Chiang Mai basin; such as thickness of impermeable layers and porosity. The rocks that have a high potential of water barrier properties should act to hinder water and contaminants from infiltrating into underlying aquifers. The most preferable properties of a geological barrier are low permeability, low effective porosity, high natural retention capacity for hazardous substances, Clay thickness must be 5 meters or more with a high amount of clay and silt (Figure 1.5).

The waste disposal site searching method as mentioned above is a method of vulnerability mapping. The waste disposal site used thick beds of clay and geological barriers as criteria for selecting the best sites where there was no evidence of groundwater contamination form waste, whereas groundwater vulnerability mapping used seven hydrogeological properties and geographical data to determine the worst places of groundwater contamination. The vulnerability mapping area for the waste disposal site area is opposite to the vulnerable groundwater area. Hence, the waste disposal site map was used for calibration in the groundwater vulnerability mapping method.

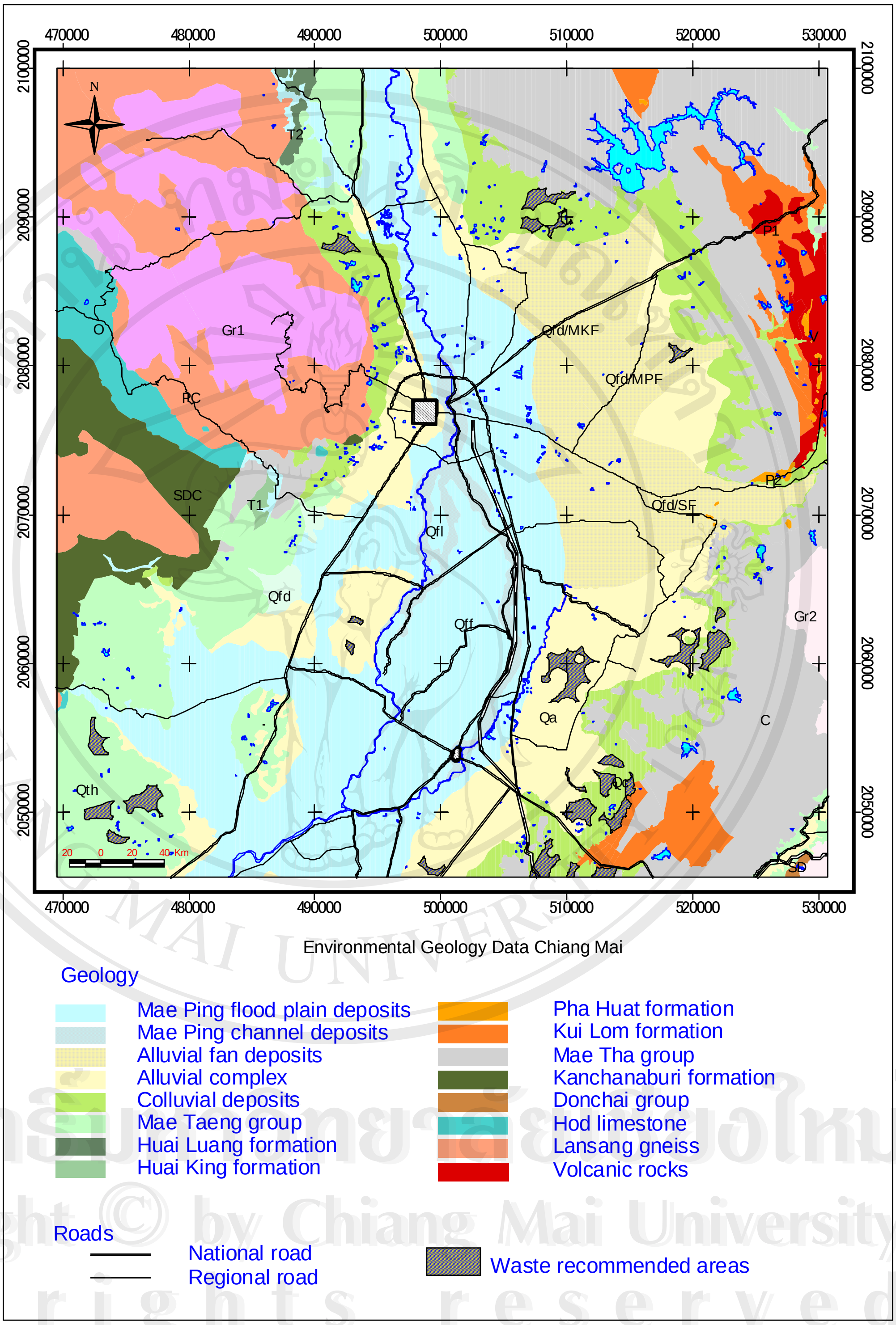

Figure 1.5 Recommended waste disposal site map of Chiang Mai Province (modified from Dorn and others, 2002).

Margane and others (1998) found that the vulnerability of groundwater in the Chiang Mai basin depends on the thickness and lithological compositions of clay and silt sediments, layering at the shallow depth and at the top of the aquifers.

1.4.3 DRASTIC method

The DRASTIC model was developed for the U.S. Environmental Protection Agency (EPA) at the Robert S. Kerr Environment Research Laboratory in 1985. Aller and others (1987) have used the DRASTIC method of seven hydrologic factors to produce maps in many parts of the United States (United States Geological Survey, 1999, Harman and others, 2000, Osborn and others, 1998, and Kumar and others, 2003).

Lilly et al. (2001) has developed a method for the designation of groundwater nitrate vulnerable zones in Scotland. The vulnerability to contamination estimation was based on simple classification of land used, soil leaching potential and aquifers permeability. However, the reliance on the application of weight and scores within the models are often subjective. The amounts of leachable nitrate were scaled and estimated. A thematic map of leachable nitrate was added to the DRASTIC parameters to identify the greatest risk of contamination by nitrate.

Lars (1994) study of DRASTIC classification methodology, with special emphasis on Swedish conditions, indicated both favorable and unfavorable properties of the system. The critical parameters and their relative weights in DRASTIC were established by an expert committee, referred to as the Delphi (consensus) approach. Statistical properties are applied to evaluate hydrogeologic settings with a fairly large number of parameters. It is evident that the DRASTIC parameters in several cases are not independent, but correlated and somewhat redundant.

DRASTIC study in Thailand

Ratana (2000) has studied groundwater vulnerability mapping using geographic information technology in the Lam Pao area, Mahasarakam and Kalasin Provinces. Aquifers in these areas are siltstone and claystone (Lower Phutok Formation), rock salt (Mahsarakam Formation), siltstone, and fine calcareous conglomerate (Khok Kruat Formation), which has low hydraulic conductivity. Among seven parameters used in the DRASTIC groundwater vulnerability assessment index, depth to groundwater table is the most significant parameter.The low laying land along the rivers showed extremely high vulnerability caused by a shallow water table and the fact that the land surface is cover by unconsolidated materials.

Kwansirikul and others (2004) have used geographic information system and the DRASTIC method to assess the vulnerability of groundwater resources to contamination in Lampang basin. The DRASTIC, which uses seven hydrogeologic factors in its assessment, shows the area covered by unconsolidated sediments; the quaternary aquifers units have the highest DRASTIC indices and are the most vulnerable to contamination. The lowest contamination vulnerability is underlain by unconsolidated to semi-consolidated Tertiary sediments.

Kaewka (2005) used the DRASTIC method to assess the vulnerability of groundwater resources in Phuket Island using Geographic Information System (GIS). 73 shallow groundwater wells, a digital groundwater availability map of DGR, 2003 and a topographic map were used in the DRASTIC method. The vulnerability map shows the beach sand aquifers unit in the northwestern part of the island as the most vulnerable to contamination. The flood plain aquifers unit has moderately high vulnerability.