

CHAPTER 3

HYDROGEOLOGIC CHARACTERISTIC

Hydrogeologic characteristic in the study area is analyzed and interpreted from groundwater well data, depth of well, type of rock, groundwater quality and geophysical survey. These data are presented as map and cross-sections that define and classify the types, characteristic and distribution of aquifers, estimate hydraulic properties and analyze direction of groundwater flow.

3.1 Hydrogeologic unit

Geological data and geophysical survey are used to identify hydrogeological unit. Geological data, including lithologic log, is used to define and classify the types of aquifer. Geophysical survey is conducted using vertical electrical sounding (VES) and is used to determine aquifer type and thickness.

3.1.1 Lithologic log

Lithologic log data were recorded in 14 wells by the Department of Mineral Resources and the Department of Groundwater Resources, including 3 wells in the study area, 8 wells in Samet Nua Sub-district, and 3 wells in Tha Thong Lang Sub-district. The location of these data are shown in Figure 3.1 and Table 3.1. All lithologic log data are shown in Appendix A.

Stratigraphic correlation of geologic cross-section, A-A', B-B', and C-C', in the study area and its adjacent are shown in Figure 3.2, Figure 3.3, and Figure 3.4. Three identified hydrogeologic units are as follows:

(1) Unit 1

The unit is mostly composed of clay. Clay is brownish gray and yellowish brown, slightly plastic to plastic. Some area has interbedded silt, sand, and gravel. Gravel is subangular to subrounded, moderately sorted, composed of quartz.

The thickness of the unit ranges from 10 to 80 meters.

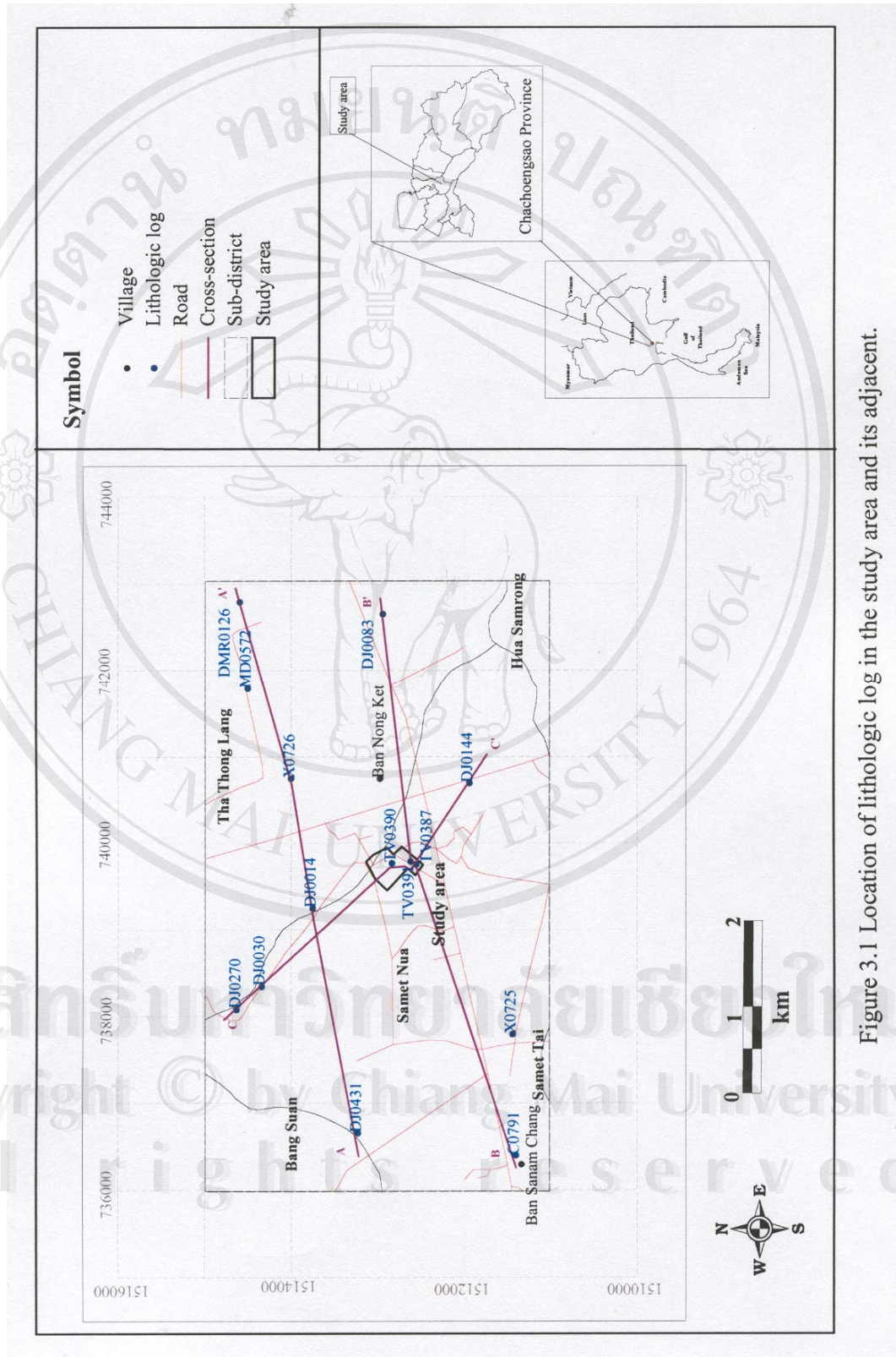


Figure 3.1 Location of lithologic log in the study area and its adjacent.

Table 3.1 Locations of well with lithologic logs (after Department of Groundwater Resources, 2003).

Well No.	Grid		Depth (m)	Elevation (m)
	UTM_E	UTM_N		
C0791	736400	1511400	105	3
DJ0014	739250	1513750	105	3
DJ0030	738340	1514340	105	2
DJ0083	742650	1512940	111	4
DJ0144	740696	1511940	139.5	3
DJ0270	738075	1514630	123	2
DJ0431	736654	15130230	76	4
DMR0126	742790	1514590	48	3
MD0572	741790	1514500	72	4
X0725	737790	1511440	99	2
X0726	740750	1514000	99	4
TV0387	739751	1512553	178	2
TV0390	739768	1512834	120	2
TV0391	739790	1512617	162	2

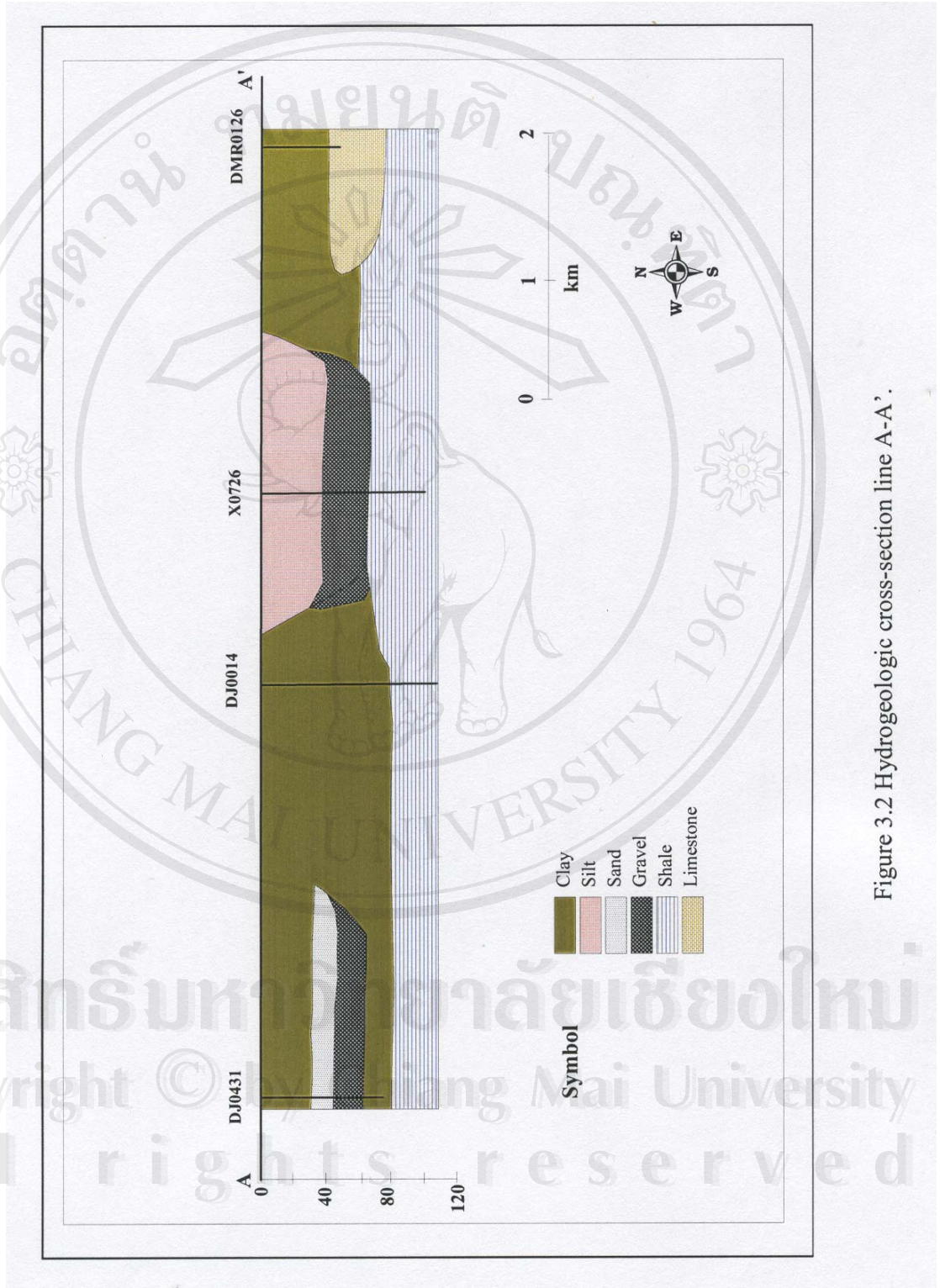


Figure 3.2 Hydrogeologic cross-section line A-A'.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright © Chiang Mai University
All rights reserved

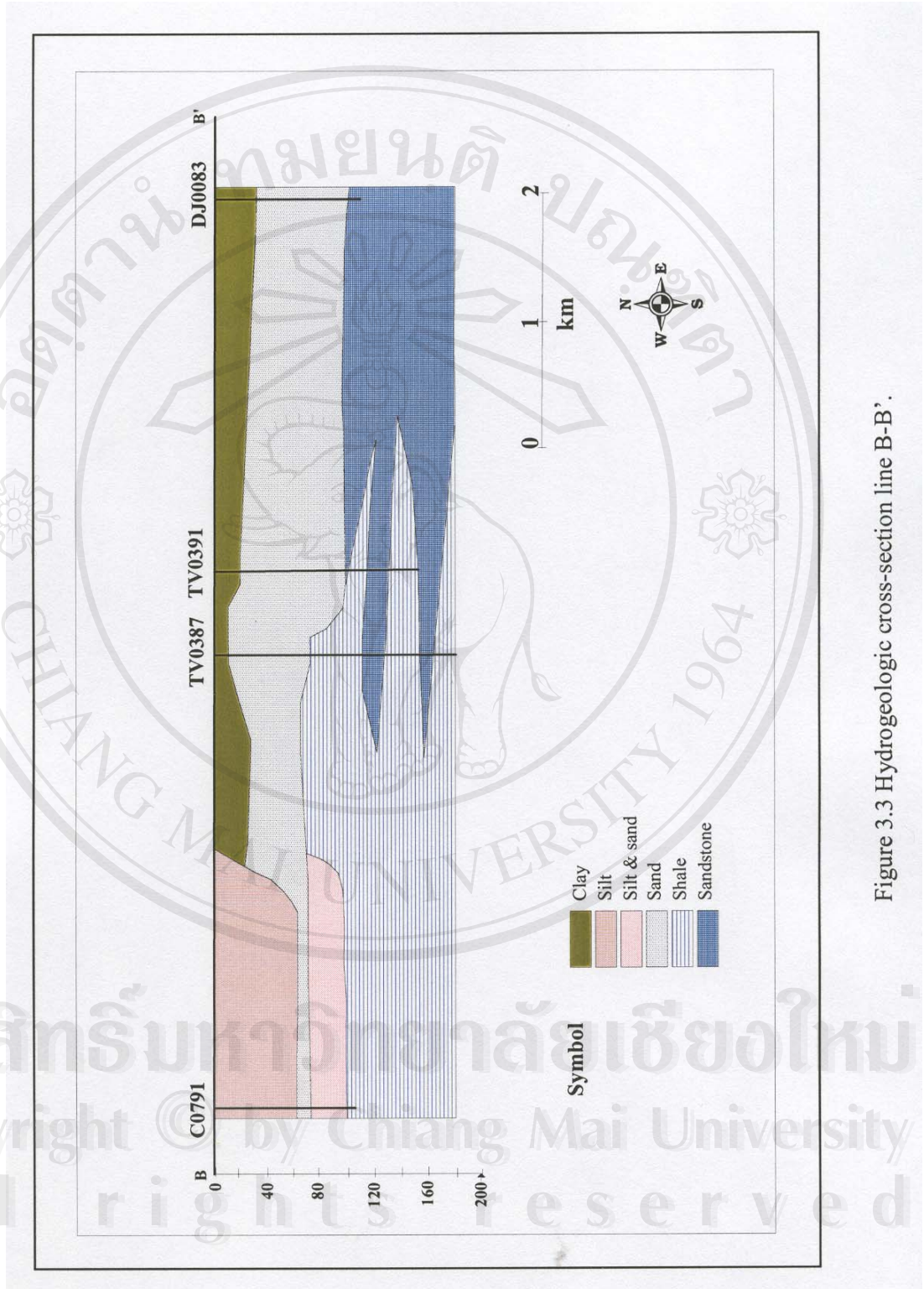


Figure 3.3 Hydrogeologic cross-section line B-B'.

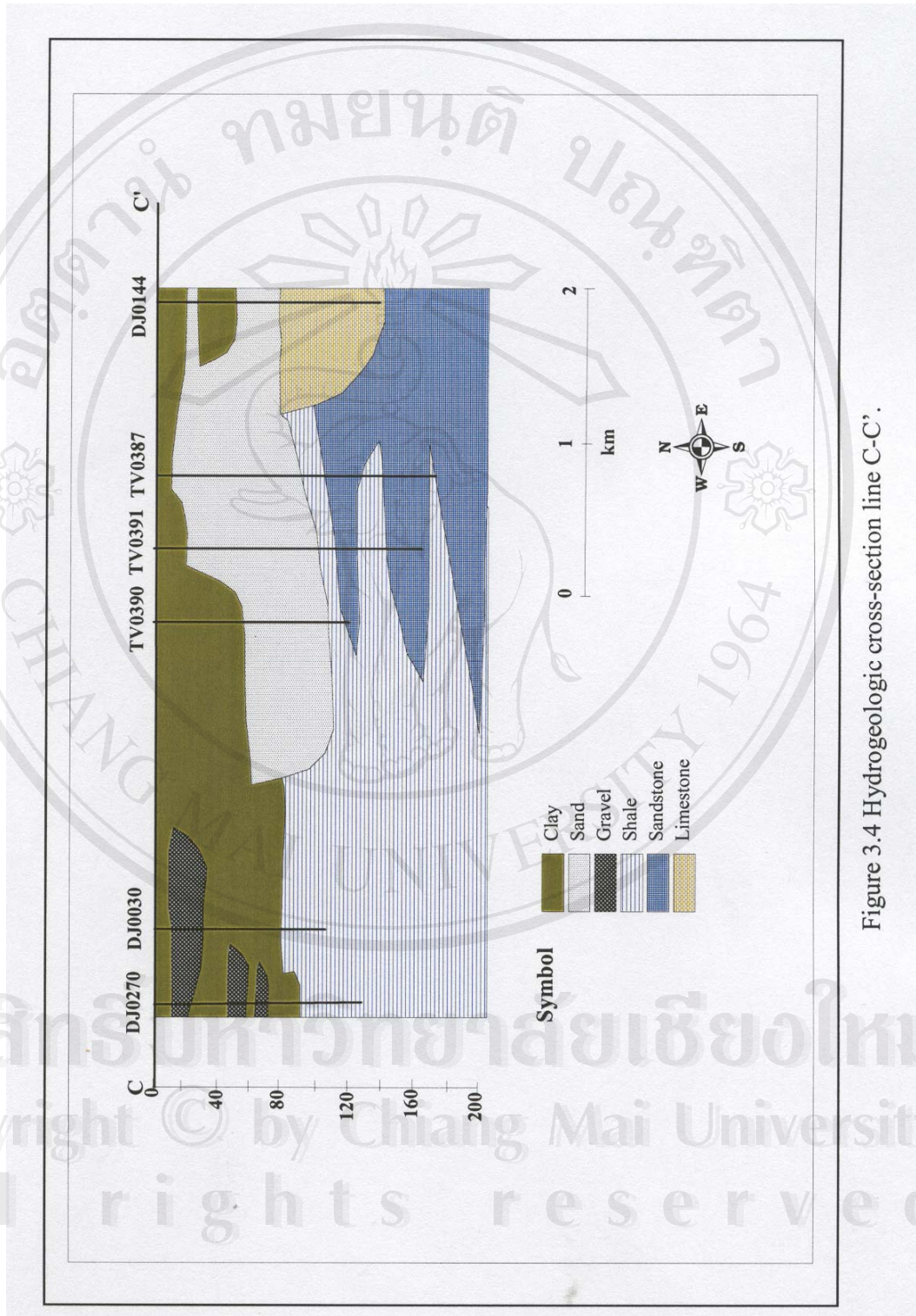


Figure 3.4 Hydrogeologic cross-section line C-C'.

The unit is composed of fine sand to medium sand, subangular to subrounded, poorly sorted to moderately sorted, composed of quartz and feldspar. This unit in some area has silt interbedded.

The thickness of the unit ranges from 10 to 90 meters.

(3) Unit 3

The unit is composed of shale, interbedded with sandstone. Shale is black, slightly weathered to moderately weathered. Sandstone is gray, composed of quartz, feldspar, and dark minerals, hard to very hard. Some area has limestone lens.

In the study area, three similar hydrogeologic units are recognized but with slight lithologic differences, as follows:

(1) Unit 1

The unit composed mainly of clay. The thickness range from 9 to 21 meters.

(2) Unit 2

The unit is composed of fine sand to medium sand that are subangular to subrounded, composed of quartz. The thickness ranges from 10 to 100 meters.

(3) Unit 3

The unit is composed of shale interbedded sandstone. Shale is gray to black, slightly weathered to moderately weathered. Sandstone is gray, composed of quartz, feldspar, and dark minerals, hard to very hard.

3.1.2 Resistivity surveys

The resistivity method is a geophysical tool used in groundwater exploration. The method can assist in determining aquifer types and thickness of aquifer.

In the resistivity survey, a direct current or low frequency alternating current is sent through the ground between two electrodes. The voltage in the ground is measured between another two electrodes, also driven into the ground. Knowing the intensity of the current flowing through the ground and the potential difference of voltage between the electrodes, it is possible to compute the resistivity of the materials between the electrodes (Figure 3.5).

The ability of rock to conduct an electrical current depends on three factors (Driscoll, 1989): (1) the amount of open space between particles (porosity), (2) the degree of interconnection between those opened spaces, and (3) the volume and

conductivity of the water in the pores. Figure 3.6 shows the range of resistivity expected for common material.

The VES data are collected using Schlumberger array. It is a linear array with potential electrodes placed close together. Current electrode, A and B, is set equal to or greater than five times the value of potential electrode, M and N. For the resistivity survey, the expansion of the current electrodes was such that one half the separations ($AB/2$) between the electrodes varied from 1 to 150 meters (Figure 3.7). The sounding location consists of 35 locations that are shown in Figure 3.8 and Table 3.2. Figure 3.9 shows the area of resistivity survey. All resistivity field data are presented in Appendix B.

The computed apparent resistivity values for the VES data were processed using RESIS 87[®] computer program. This program is produced by Vander in 1988 to process resistivity sounding data. It computes resistivity-electrode spacing curves with master curves for various ratios of resistivity. Example of the result of process is shown by one-dimensional resistivity model (Figure 3.10). In the study, a root mean square-error of 5 percent was considered as a reliable model. All resistivity model data is shown in Appendix B.

The interpretation of resistivity data were done by computer modeling to obtain layer resistivity and thickness. The resistivity values were correlated with geologic and hydrogeologic condition in the study area. The resistivity data interpretation is shown in Appendix B.

Each material type has a range of resistivity values but these ranges can be used to indicate lithologic types. Therefore, correlation of 3 lithologic logs and 8 resistivity location have been used to determine the range of resistivity values for identifying hydrogeologic unit. This correlation is shown in Table 3.3.

Resistivity interval classification was done to determine the lithology of each resistivity location. This was used to classify the 8 resistivity location. After that, the correlation between these 8 resistivity location and other 35 resistivity location was carried out.

The study area is mainly consisted of unconsolidated sediment including clay, sandy clay, clayey sand, and sand. Shale is found in a limited area. In some layer, the

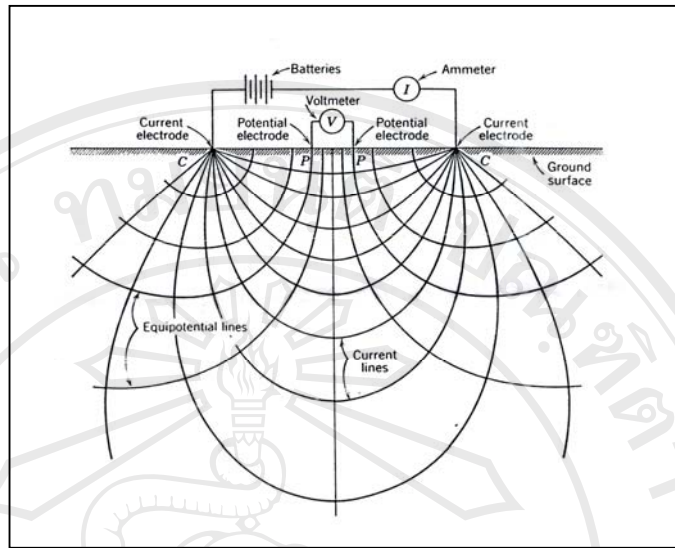


Figure 3.5 Electrical circuits for resistivity determination and electrical field for resistivity survey (from Todd, 1980).

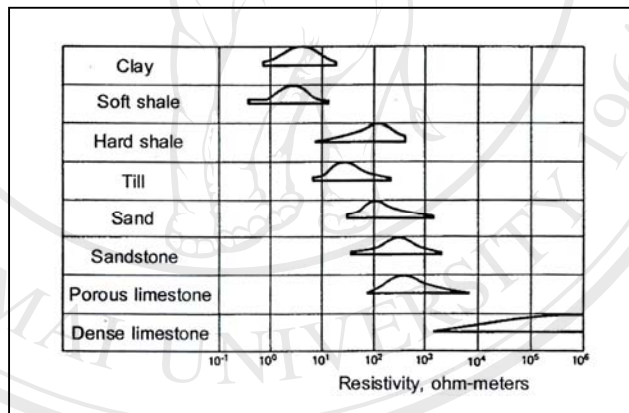


Figure 3.6 The range of resistivity values of common material (from Todd, 1980).

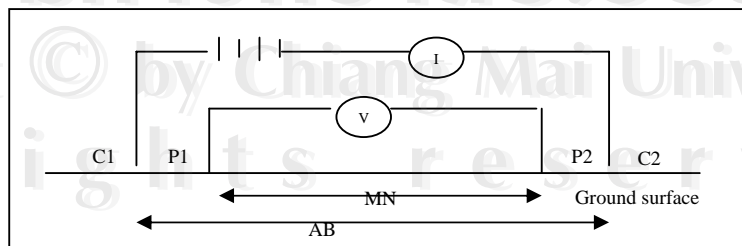


Figure 3.7 Schlumberger electrode array (modified from Davis and Dewiest, 1966).

Table 3.2 Resistivity survey location.

Location	Grid		Line bearing
	UTM_E	UTM_N	
ST1	739717	1512544	N-S
ST2	739736	1512595	N-S
ST3	739717	1512544	N-S
ST4	739763	1512595	N-S
ST5	739790	1512632	N-S
ST6	739833	1512673	N-S
ST7	739850	1512693	N-S
ST8	739879	1512788	N-S
ST9	739854	1512762	E-W
ST10	739818	1512806	E-W
ST11	739779	1512837	E-W
ST12	739732	1512872	E-W
ST13	739704	1512910	E-W
ST14	739667	1512935	E-W
ST15	739615	1512969	N-S
ST16	739651	1512575	N-S
ST17	739714	1512648	N-S
ST18	739632	1512754	E-W
ST19	739581	1512777	E-W
ST20	739500	1512847	E-W
ST21	739492	1512917	N-S
ST22	739561	1512990	N-S
ST23	739632	1513043	N-S
ST24	739722	1513094	N-S
ST25	739802	1513117	N-S
ST26	739864	1513043	N-S
ST27	739907	1512964	N-S
ST28	739927	1512873	N-S
ST29	739877	1512809	N-S
ST30	739935	1512739	E-W
ST31	739909	1512655	N-S
ST32	739854	1512602	N-S
ST33	739787	1512519	N-S
ST34	739703	1512498	N-S
ST35	739682	1512927	E-W

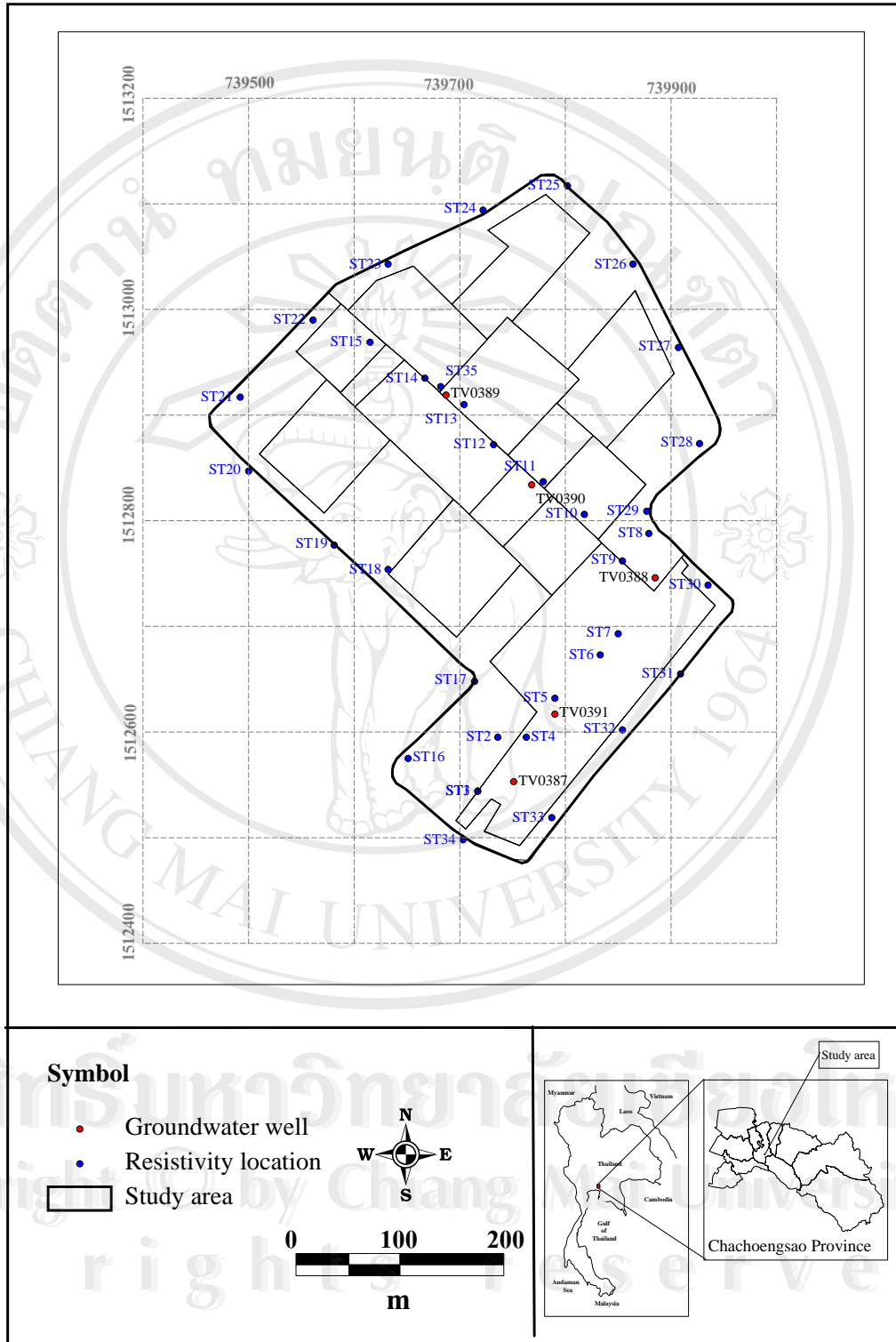


Figure 3.8 Location of resistivity survey in the study area.



Figure 3.9 Resistivity survey in the study area.

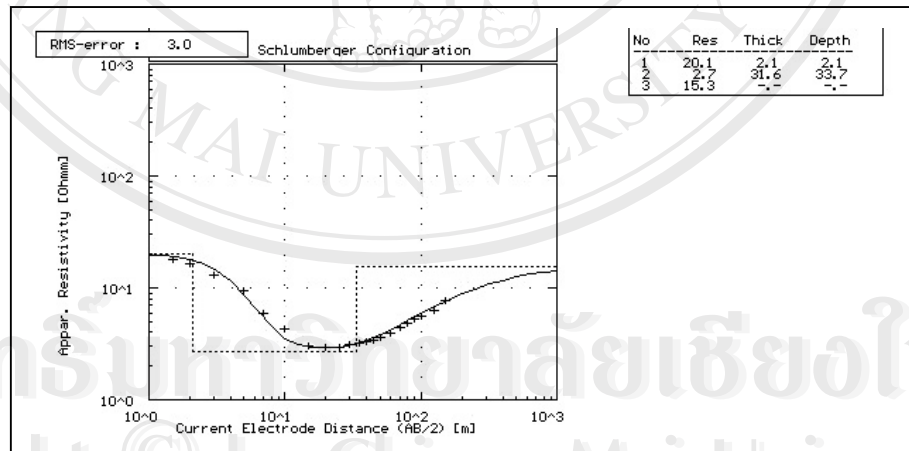


Figure 3.10 Vertical electrical sounding curves using model.

Table 3.3 The correlation of resistivity with lithologic log in the study area.

Resistivity (ohm-m)	Interpretation
<7	Clay
8-20	Sandy clay
21-35	Clayey sand
2-80	Sand
>200	Shale

resistivity value of sand is very low, range from 2.2 to 2.7 ohm-m, which might suggest that it is the wet and possibly brackish water zone.

Resistivity values of top soil range from 125.2 to 2337.5 ohm-m, that of unconsolidated sediment from 1.6 to 88.2 ohm-m, and that of shale from 154.8 to 756.1 ohm-m.

Resistivity values of clay, common in the study area, range from 1.8 to 7.3 ohm-m, sandy clay range from 5.7 to 18.4 ohm-m, clayey sand range from 20.1 to 36.8 ohm-m, and sand range from 1.6 to 88.2 ohm-m.

The thickness of unconsolidated sediment layer varies between 0.5 to 76.2 meters, thickness of clay range from 0.9 to 76.2 meters, sandy clay range from 0.9 to 5.0 meters, clayey sand range from 0.6 to 2.5 meters, and sand range from 0.5 to 76.2 meters.

3.1.3 Integrated Interpretation

According to the previously described lithologic log, 3 unit including clay unit, sand unit, and shale interbedded sandstone unit can be divided. Clay and sand are unconsolidated sediment with the thickness range from 9 to 100 meters. The interpretation of resistivity survey is similar to the lithologic log. The resistivity data can be classified into 2 units, including unconsolidated sediment and shale. The unconsolidated sediment included clay, sandy clay, clayey sand, and sand. The thickness of unconsolidated sediment layer varies between 0.5 to 76.2 meters. The integrated interpretation is shown in Figure 3.11.

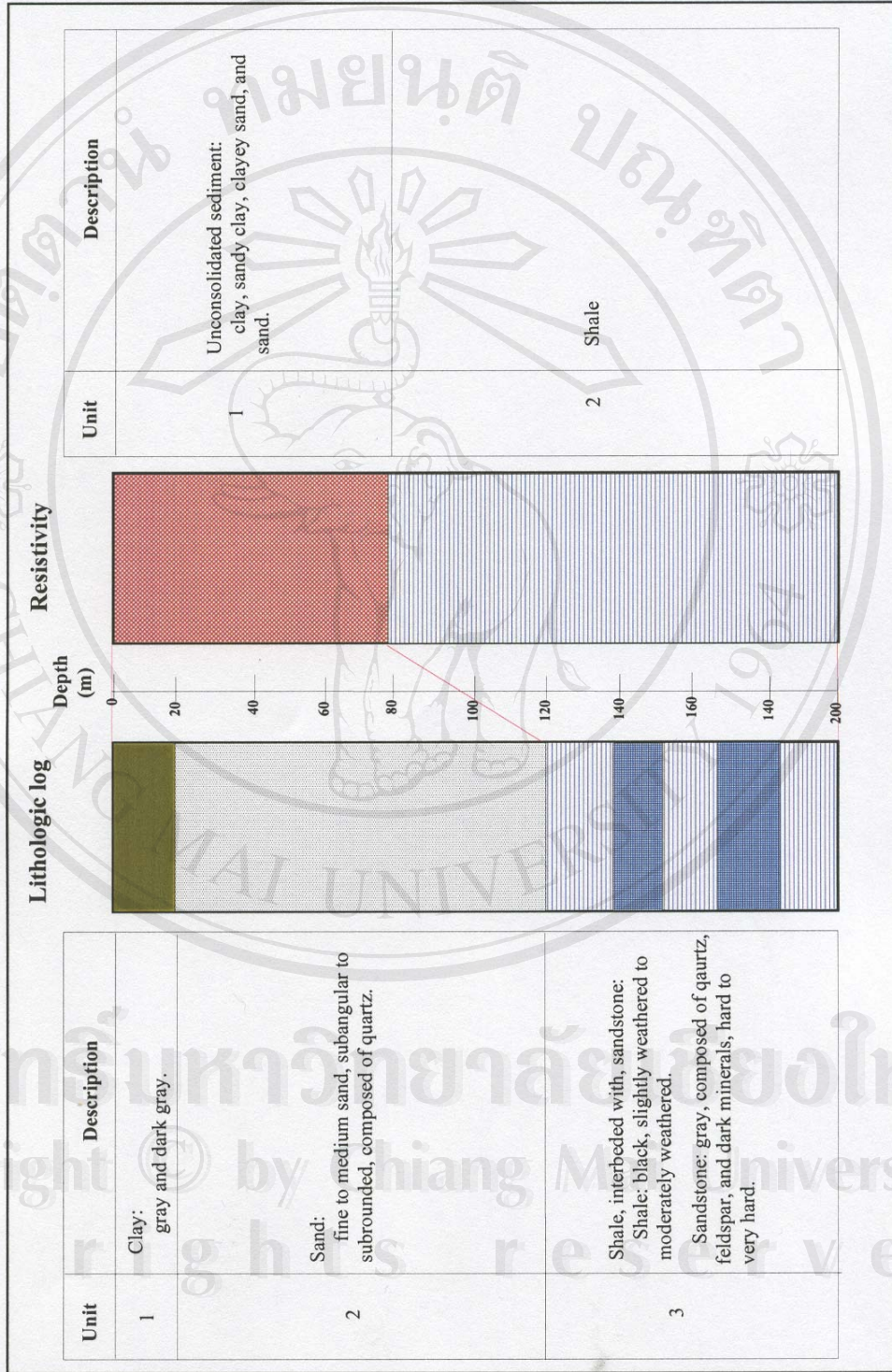


Figure 3.11 Integrated interpretation of lithologic logs and resistivity surveys.

3.2 Hydraulic properties

Hydraulic properties of aquifer that are of important for groundwater flow study include: hydraulic conductivity (K), transmissivity (T), and storage coefficient (S).

Hydraulic conductivity (K) is defined as the quantity of water flowing in one unit time through a face of unit area under a driving force of one unit of hydraulic head change per unit length (Domenico and Schwartz, 1990). Transmissivity (T) is a measure of the amount of water that can be transmitted horizontally through a unit width by the full saturated thickness of the aquifer under a unit hydraulic gradient. Therefore, transmissivity is the product of the formation thickness and hydraulic conductivity. The storage coefficient, or storage coefficient (S), is the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head. It is a dimensionless quantity (Fetter, 1988).

Pumping test data is analyzed to determine the hydraulic properties of aquifer and specific capacity. The three types of pumping test most often uses are: the bailer test, constant-rate pumping, and step-drawdown pumping test. In the study area, constant rate pumping test were used to obtain the hydraulic properties. Various methods can be used to evaluate pumping test data, such as Thiem method that is applicable to steady state condition, Theis method and Cooper & Jacob method that is applicable to non-steady state or non-equilibrium condition.

In the present study, four pumping test data carried out by Department of Groundwater Resources in 2003 are analyzed. Location of pumping test well in the study area is shown in Figure 3.12. Analysis of the pumping test data to determine the transmissivity (T) and storage coefficient (S) were carried out by Theis method and Cooper & Jacob method, using aquifer test Version 2.5 Software from Waterloo Hydrogeologic Inc.. An example of the analysis is shown by graph (Figure 3.13). All analysis with Theis method and Cooper & Jacob method are presented in Appendix C. Hydraulic conductivity of the aquifer can be calculated from equation (3.1):

$$K = \frac{T}{b} \quad (\text{Eq. 3.1})$$

Where K = hydraulic conductivity (L/T; m/d or ft/d)

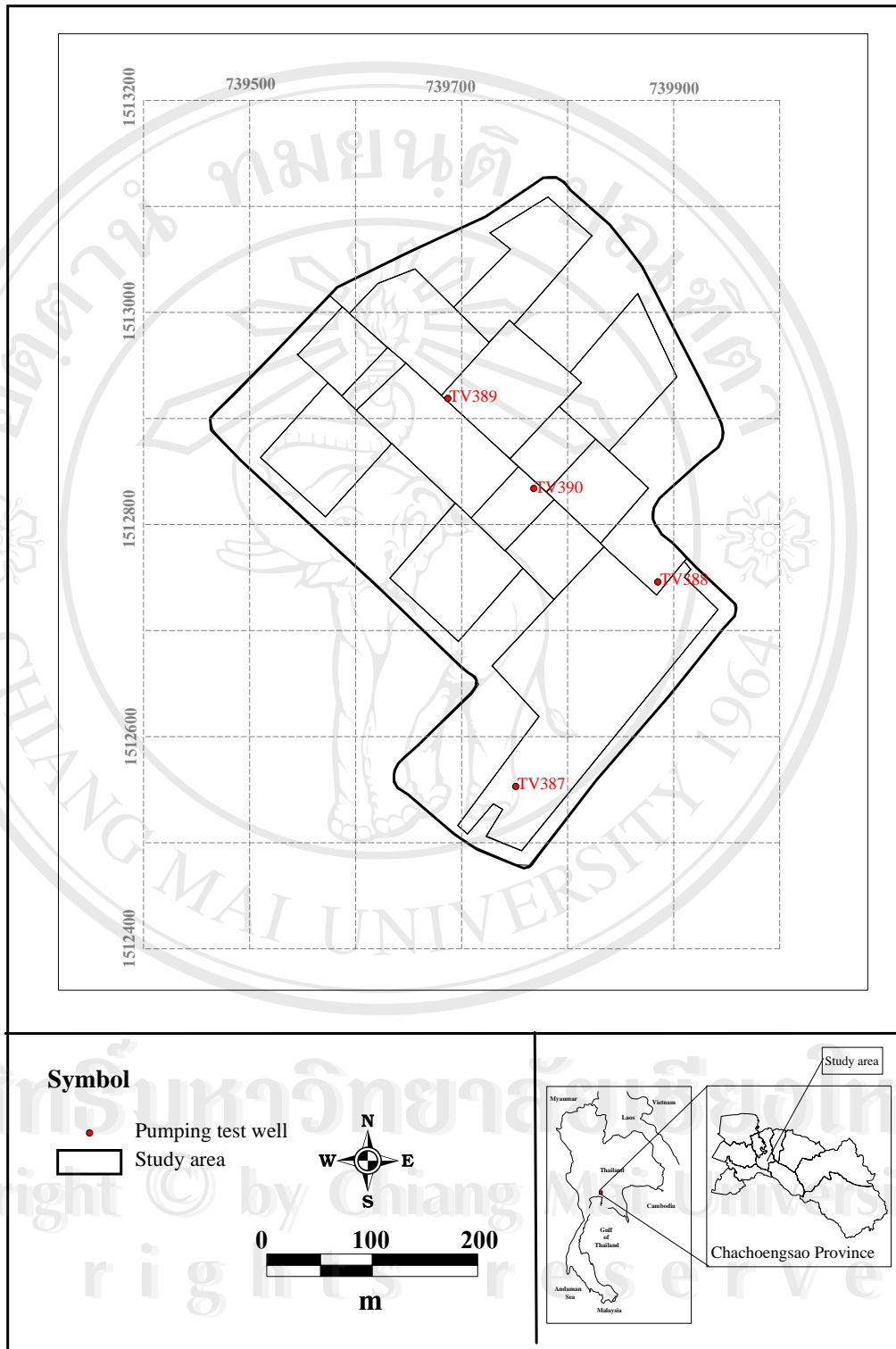


Figure 3.12 Location of pumping test well in the study area

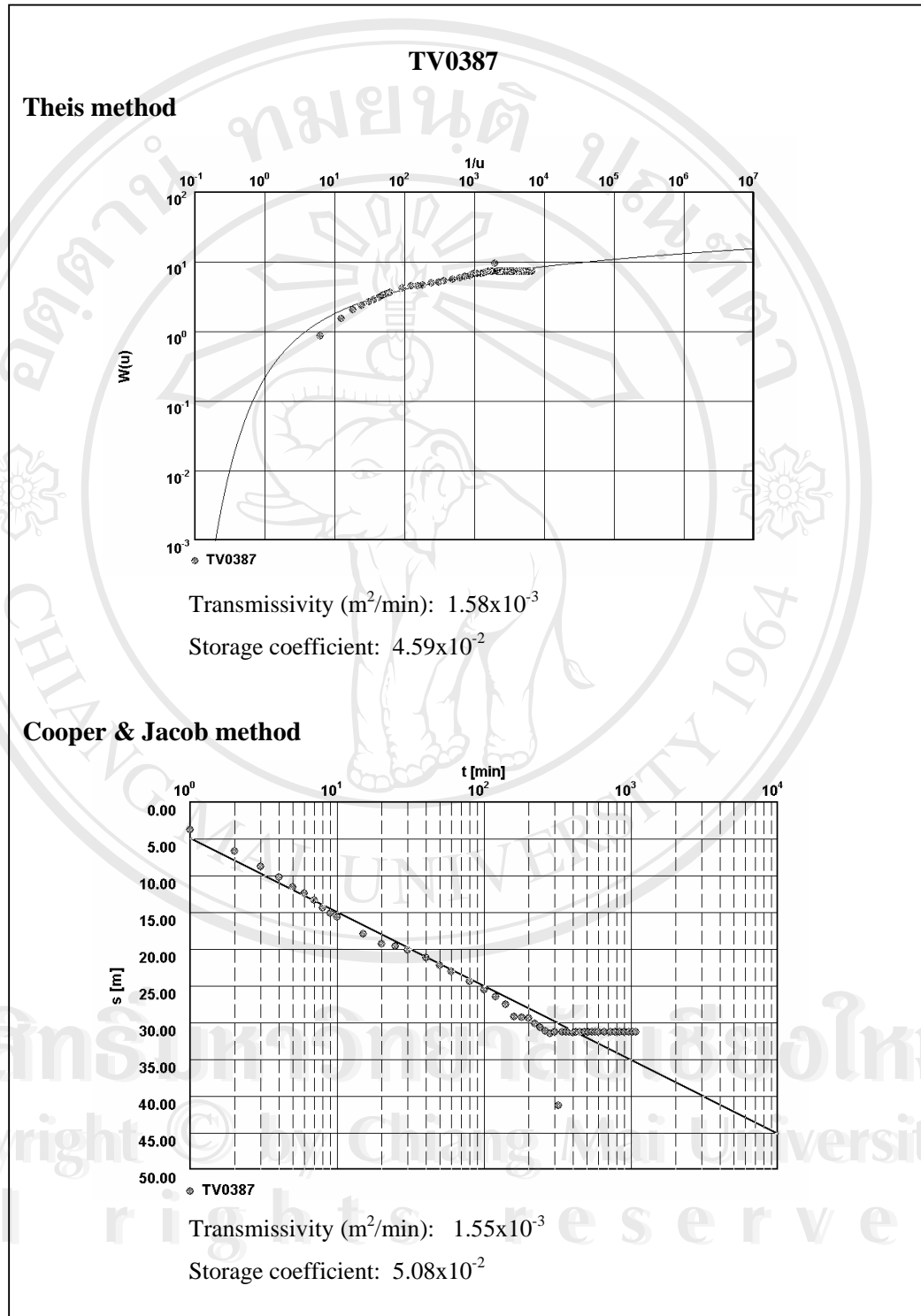


Figure 3.13 Pumping test data analysis using Theis and Cooper & Jacob method.

T = transmissivity (L^2/T ; m^2/d or ft^2/d)

b = the aquifer thickness (L ; m or ft)

Hydraulic properties including hydraulic conductivity (K), transmissivity (T), and storage coefficient (S), as interpreted from the pumping test analysis are presented in Table 3.4. Transmissivity range from 1.75×10^{-4} to $1.55 \times 10^{-3} m^2/min$ (0.252 to $2.232 m^2/d$). Storage coefficient range from 8.7×10^{-3} to 1.41×10^{-2} . Hydraulic conductivity range from 2.13×10^{-6} to $1.43 \times 10^{-5} m/min$ (3.07×10^{-3} to $0.02 m/d$).

3.3 Groundwater flow pattern

Flow occurs because the potential energy head drives the water from areas of higher head to areas of lower head. The construction of flow net consist of two lines (Figure 3.14): one of curves represents flow line, which indicate the direction of groundwater flow in the area, can be determined by using groundwater elevation data from a minimum of 3 wells. Intersecting the groundwater flow line at right angles is called equipotential lines, which are lines of equipotential lines. Flow net is used to define area of recharge and discharge, that flow lines diverge in areas of recharge and converge in areas of discharge, and locate new wells.

Groundwater level were collected from 14 wells, including 5 wells in the study area, 3 wells in Tha Thong Lang Sub-district, and 6 wells in Samet Nua Sub-district as shown in Table 3.5. Groundwater flow pattern are constructed from groundwater level of July 2003, as all groundwater level were recorded. The groundwater flow pattern is shown in Figure 3.15. Groundwater contour (equipotential line) range from 3 to 21 meters above MSL. The flow pattern is mainly topographically controlled.

The general direction of groundwater flow is from the central to the rim of the area.

Table 3.4 Hydraulic properties as interpreted from pumping test data analysis.

Well No.	Depth (m)	Screen (m)	Transmissivity (m^2/min)		Storage coefficient		Hydraulic conductivity (m/min)
			Theis method	Jacob method	Theis method	Jacob method	
TV0387	178	94-178 (open hold)	1.58×10^{-3}	1.55×10^{-3}	4.59×10^{-2}	5.08×10^{-2}	1.84×10^{-5}
TV0388	180	70-80	1.43×10^{-4}	1.43×10^{-4}	7.35×10^{-3}	7.61×10^{-3}	1.43×10^{-5}
TV0389	168	86-168 (open hold)	1.76×10^{-4}	1.75×10^{-4}	1.43×10^{-2}	1.41×10^{-2}	2.13×10^{-6}
TV0390	120	115-120 (open hold)	1.08×10^{-4}	1.08×10^{-4}	8.80×10^{-3}	8.70×10^{-3}	2.16×10^{-5}

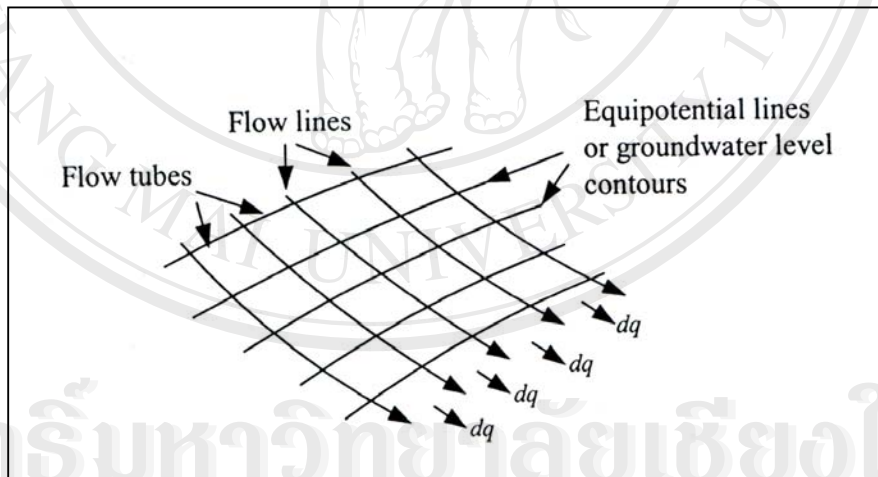


Figure 3.14 Flow net in two dimensional approximation
(from Hamill and Bell, 1986).

Table 3.5 Groundwater level in the study area and its adjacent.

Well No.	Grid		Depth (m)	Elevation (m)	Groundwater level (m)			
	UTM_E	UTM_N			Jun-2003	Jul-2003	Aug-2003	May-2004
C0791	736400	1511400	105	3		8.30	8.90	9.22
DJ0013	742750	1514150	75	4	18.50	8.72	9.85	10.37
DJ0083	742650	1512940	111	4	7.01	12.44	12.30	12.87
DJ0144	740696	1511940	139.5	3		20.00	25.75	33.66
DJ0270	738075	1514630	123	2		18.00	18.04	19.06
DJ0431	736654	1513023	76	2		7.00	5.25	16.95
MD0572	741790	1514500	72	4		15.28	17.83	15.19
X0725	737790	1511440	99	2		3.38	3.51	13.87
X0726	740750	1514000	99	4	16.20	16.50	17.30	20.01
TV0387	739751	1512553	178	2		17.29		
TV0388	739885	1512746	180	2		10.70		
TV0389	739687	1512919	168	2		7.10		
TV0390	739768	1512834	120	2		11.80		
TV391	739790	1512617	162	2		21.00		

