

POSSIBLE UTILIZATION OF GROUND-COUPLED HEAT-PUMP SYSTEM IN TROPICAL COUNTRIES

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ABSTRACT

Possibility of ground-coupled (geothermal) heat-pump application in tropical Asia is studied based on groundwater temperature data. Although generally geothermal heat-pump system may not have thermal merit for space cooling in tropics, there may be some places in tropical regions where underground can be used as cold heat source. In order to confirm this possibility, groundwater temperature surveys were widely conducted in the Chao-Phraya plain, Thailand and in the Red River plain in Viet Nam to compare with climatic data. As a result, regional variation of subsurface temperature at depths from 20 to 50 m of 3.4K was observed in the whole Chao-Phraya plain and 2.0 K in the Red river plain. In some cities, subsurface temperature lower than surface one (monthly mean maximum) for 5K or more over four months was identified. Thus underground may be used as cold heat-source even in parts of tropical regions. Detailed underground temperature survey is essential for its promotion.

Keywords: geothermal heat-pump, space cooling, tropical Asia, groundwater temperature, Chao-Phraya plain, Thailand, Red river plain, Viet Nam

1. INTRODUCTION

Ground-coupled (geothermal) heat-pump installation has extensively grown in western countries in recent two decades. Geothermal heat-pump may achieve higher coefficient of performance (COP) than conventional air-source heat-pump that contribute to energy (electricity) savings and environmental protection. However, the current number of its installation in Asian countries, where significant economical growth in this century is expected so that energy saving and environmental protection will be major matters of importance, is quite limited. Therefore, rapid growth of geothermal heat-pump installation is desirable.

Geothermal heat-pump can be applied for both/either space heating and/or cooling depending on surface and underground temperature conditions. Although subsurface heat can be directly used without heat-pumps, application of heat-pumps enables us to extract more heat from underground. Therefore a heat extracting system from subsurface will be called as “geothermal heat-ump system” in this paper. Since it has been intensively installed in rather cold climate countries, the system is known as “applicable to anywhere in the world”. But it may not be true for tropical countries where the atmospheric temperature is almost stable through a year. Although space cooling is needed there, subsurface temperature may always be higher than atmospheric one because of geothermal gradient, and there is no thermal merit of geothermal heat-pump system.

However, still there is a possibility of thermal merit for tropical regions if 1) seasonal change of atmospheric temperature exist, 2) daily change of atmospheric temperature is rather high, and/or 3) the cooling effect of recharging groundwater flow is locally dominant than the heating effect of heat flux from a depth. Thus mapping of local underground temperature distribution may be the first step for an intensive installation of geothermal heat-pump system. Since the underground thermal regime is largely affected by groundwater flows, to understand the flow patterns of the groundwater at each study area is essential. For this purpose, vertical temperature profiling of observation wells were widely measured in Thailand and Viet Nam. The final aim of our study is to make a map of East Asia that indicates the available type of geothermal heat-pump system at any arbitrary location based on the surface and subsurface temperature conditions.

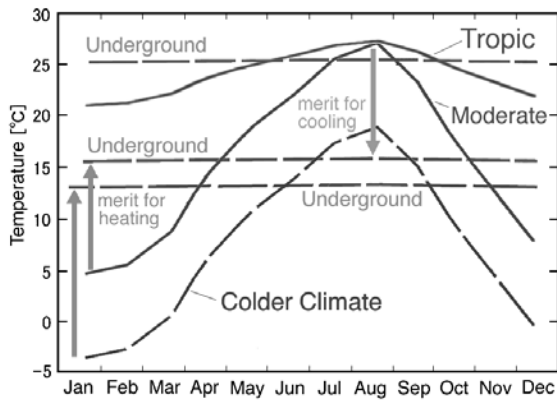


Fig. 1. Seasonal variation of subsurface and atmospheric temperature for various climates

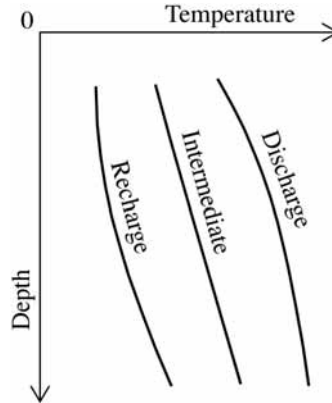


Fig. 2. Schematic temperature profiles for different zones



Fig. 3. Locations of Chao-Phraya River and Red river

2. SUBSURFACE TEMPERATURE

Subsurface temperature at a depth of 20 m or deeper is stable through a year and generally higher than average atmospheric temperature (in time) of its corresponding ground surface. Fig. 1 schematically shows seasonal variation of atmospheric and subsurface (at a depth of about 50 m) temperature. For colder climate region, subsurface temperature is mostly higher than atmospheric one, so that the utilization of geothermal heat-pump is quite suitable for space heating. For moderate climate region, subsurface temperature is higher in the winter and lower in the summer, so that geothermal heat-pump is useful for both space heating and cooling. For tropics, where space cooling is preferred, subsurface temperature is higher or approximately equal to atmospheric one and no thermal merit of geothermal heat-pump can be seen.

However, groundwater flow, which is controlled by topographies of the ground surface and the subsurface boundaries where permeability drastically changes, may perturb the subsurface thermal regime. While ground water lingers in subsurface layers, it is gradually heated by heat flow from a depth. As a result, groundwater at recharge zone is cooler than at discharge zone at same depth. This phenomenon is shown in Fig. 2 as different types of temperature profiles. Thus temperature change of few K may be achieved by groundwater flow. If the subsurface layers are effectively cooled by groundwater flow, thermal merit of geothermal heat-pump for tropics may occur. Therefore understanding of subsurface temperature distribution is significantly important to judge which kind of subsurface thermal utilization, such as space cooling and/or hot water supply, is possible or not at each local district.

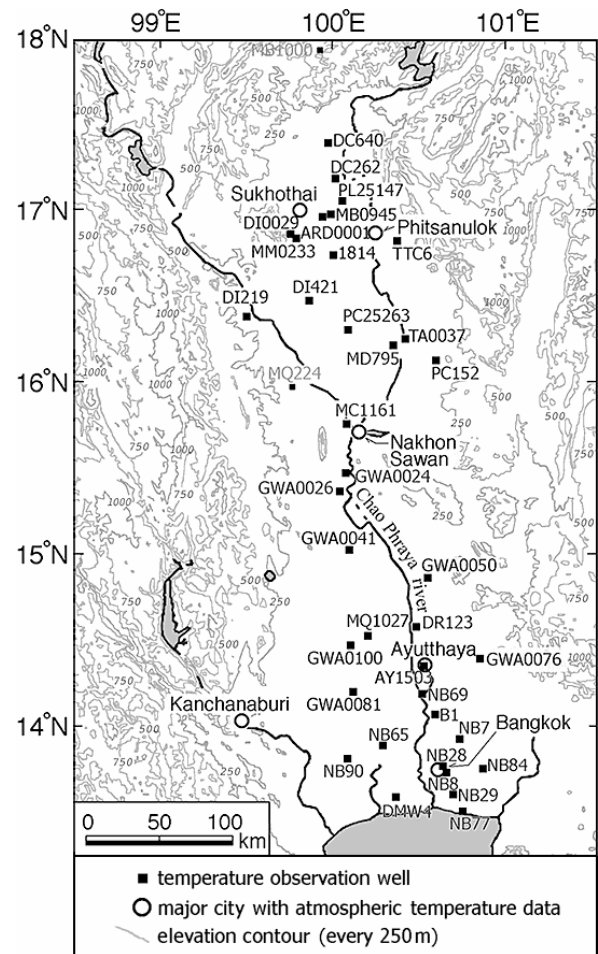


Fig. 4. Locations of temperature observation wells in the Chao-Phraya Plain

3. TEMPERATURE MEASUREMENTS AND RESULTS

3.1 Chao-Phraya Plain, Thailand

Temperature measurement at the Chao-Phraya plain, Thailand is described in this section. Since water is mainly supplied from groundwater in Thailand, control and maintenance of groundwater is an important issue. To avoid subsidence of groundwater level due to excess of water pumping, Department of Groundwater Resources (DGR), Thailand settled a number of observation wells in the country for monitoring purpose. Authors have been conducted temperature measurements in these observation wells since 2000 by collaboration with DGR.

Locations of observation wells, for which temperature profiles are obtained, are shown in Fig.4. Topographically Chao-Phraya plain consists of upper plain (north of Nakhon Sawan) and lower plain (south of Nakhon Sawan) with a border around N15°40', which is also identified by separate shallow groundwater flows by Uchida et al. (2004). Fig. 5 shows the observed temperature profiles for the wells. Temperature at depths between 20 to 50 m ranges from 27.8 °C (GWA0026, DI219) to 31.5 °C (NB77, GWA0081).

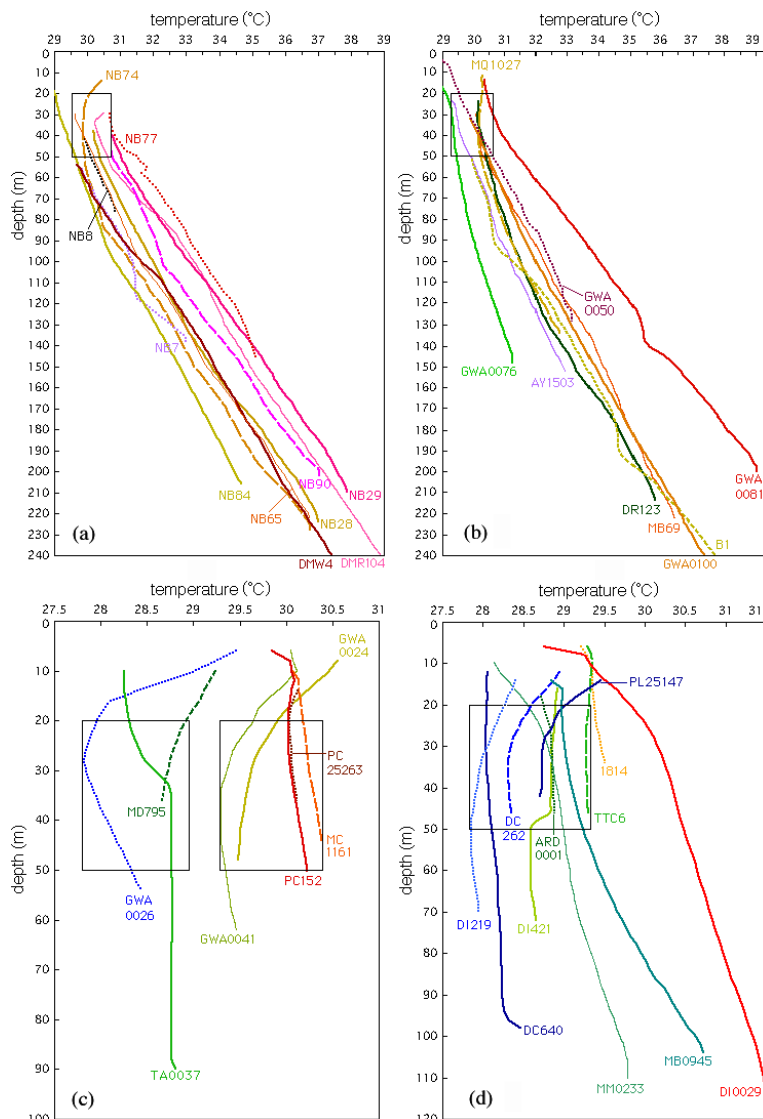


Fig. 5 Temperature profiles of wells around (a) Bangkok, (b) Ayutthaya, (c) Nakhon Sawan and (d) Phitsanulok-Sukhothai areas, respectively

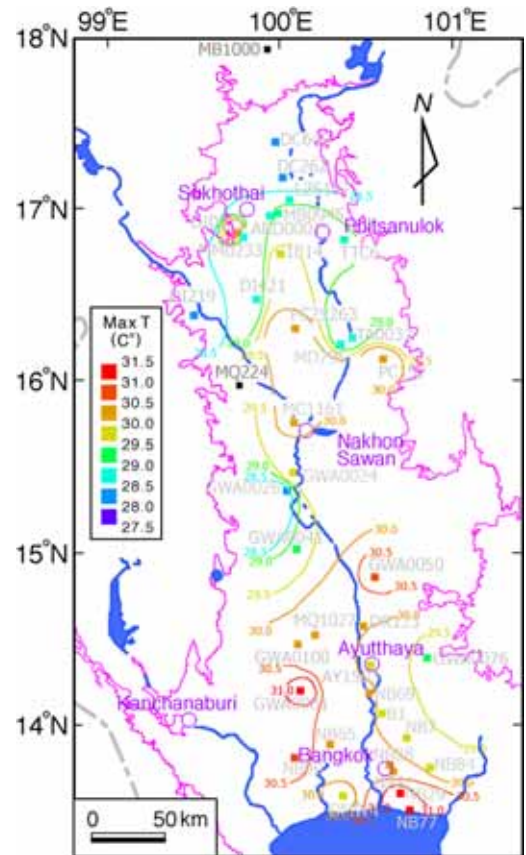


Fig.6 Contour map of maximum temperature at depths of 20 to 50 m (°C)
A contour line of 250 m above sea level is shown indicating approximate shape of the Chao Phraya plain.

Fig. 6 is a contour map of maximum temperature at these depths. Generally the wells in the upper basin have lower subsurface temperature than those in the lower basin. However, GWA0041 (Fig. 5(c)) and GWA0076 (Fig. 5(b)) in the lower basin have rather low temperatures with profiles characteristic to recharge zone. These wells are considered to be located in local recharge zones of the lower basin for shallow groundwater flow. Shallow local flows may exist in upper and lower basins, respectively.

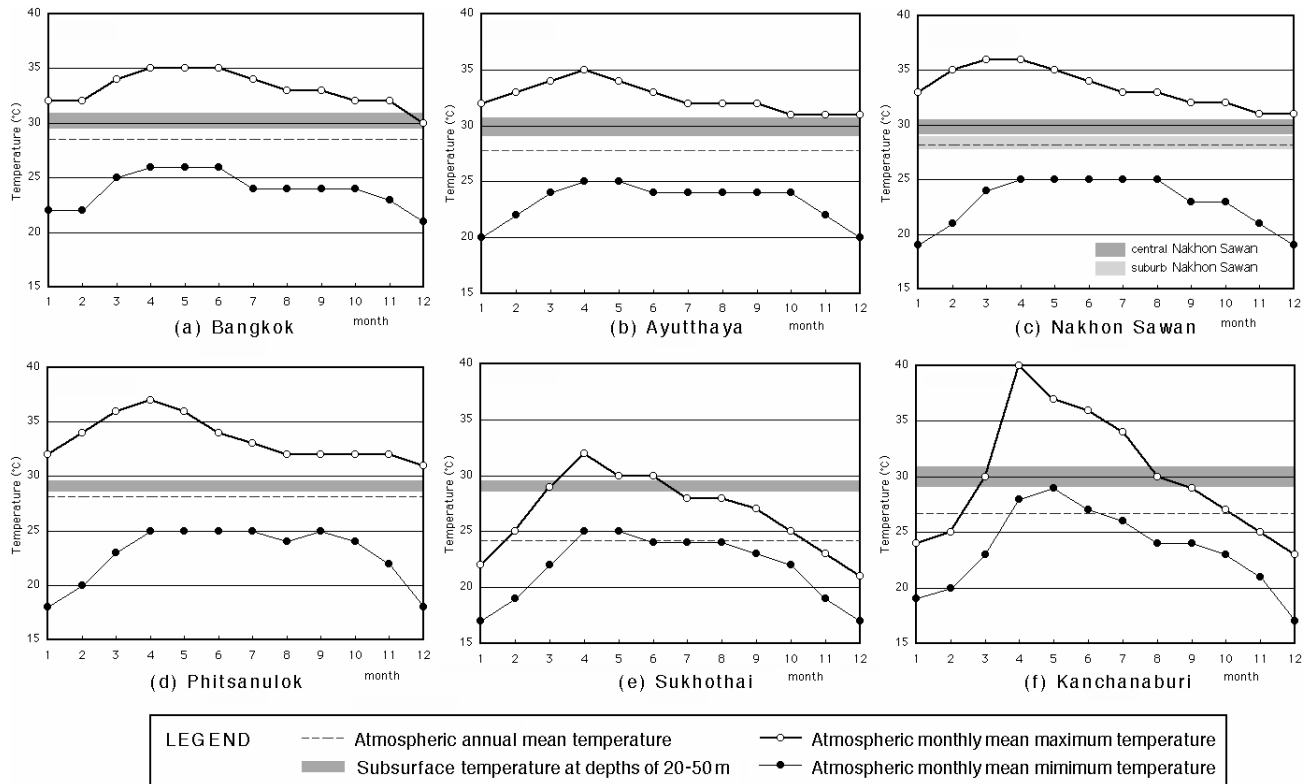


Fig. 7 Comparison of atmospheric and subsurface temperature at each region in Chao-Phraya plain

*Subsurface temperature data from the wells NB29 and NB77, both located near the sea with extremely high temperature, are eliminated for Fig. 4(a). ** Subsurface temperatures shown in (d) and (e) are identical because they are based on data from the same region, while the atmospheric temperatures are different. *** Subsurface temperature shown in (f) is that in Ayutthaya, which may be higher than that in Kanchanaburi.

Fig. 7 compares atmospheric and subsurface temperature at depths of 20 to 50 m around (a) Bangkok, (b) Ayutthaya, (c) Nakhon Sawan, (d) Phitsanulok, (e) Sukhothai and (f) Kanchanaburi regions. At Pitsanulok and Nakhon Sawan, subsurface temperature is lower than monthly mean maximum atmospheric temperature through a year and the difference is bigger than 5K over four months. Also at Kanchanaburi, subsurface temperature is lower for 5K or more over four months and the difference is as big as 10K in April. Geothermal heat pump system may be used in these areas for space cooling. In Bangkok and Ayutthaya, subsurface temperature is lower for most of a year, but the difference is not bigger than 5K, so the geothermal heat pump is less effective in these regions. In Sukhothai, where subsurface temperature is higher for most of the year, geothermal heat pump for space cooling may not be effective at all.

3.2 Red River Plain, Viet Nam

Water supply in Viet Nam is also dependent to groundwater. Department of Geology and Minerals of Vietnam (DGMV) operates 250 observation wells in the Red river plain. Authors measured temperature profiles of 25 wells around the river in February 2005 by collaboration with DGMV. As a fact this region is not a tropical area, so it can be assumed that geothermal heat-pump systems are applicable in this area even before temperature measurement. Nevertheless, it is important to know the subsurface temperature distribution in order to compare with southern part of the country and draw a border of applicable types of geothermal heat-pumps in a map. Location of observation wells in this area, for which temperature profiles are obtained, are shown in Fig. 8.

Fig. 9 shows the observed temperature profiles for these wells. The color of each profile corresponds to that of wells in Fig. 8. In the south of the Red River, temperature profiles of the wells near the sea (Q108, Q109, Q110) have higher temperature gradient than those at Hanoi (inner land), indicating the difference of discharge and recharge zones shown in Fig. 2. However in the North of the Red River, the wells near the sea (Q156, Q158, Q159, Q131, etc.) have lower temperature gradient than those in Hanoi. It suggests that the groundwater system in the north is different from that along the Red river.

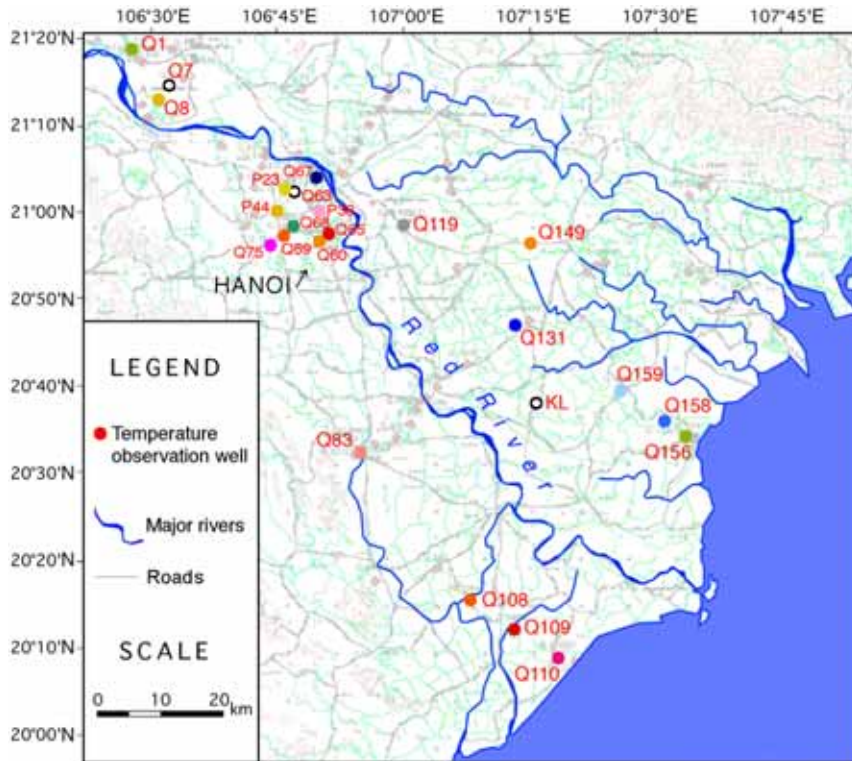


Fig. 8 Locations of temperature observation wells in the Red river plain

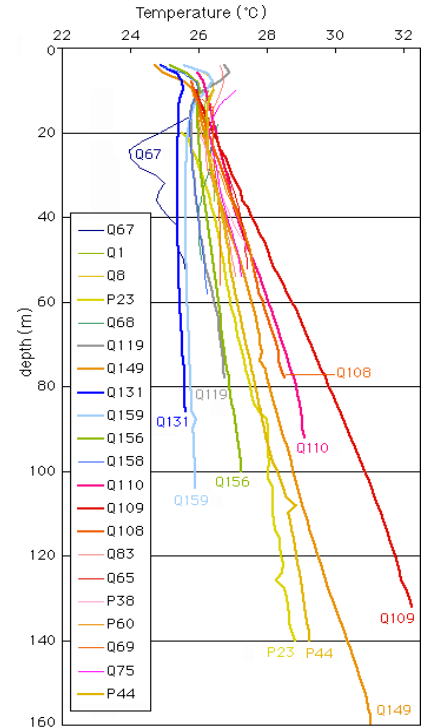


Fig. 9 Temperature profiles of the wells around Hanoi area

Fig. 10 shows monthly mean maximum and minimum atmospheric temperature at Hanoi and groundwater temperature at depths of 20-50m observed in the wells indicated as HANOI in Fig. 8. In Hanoi, subsurface temperature is lower than monthly mean maximum atmospheric temperature from May to October. Therefore, underground has a thermal merit as a heat source for space cooling in the summer season. On the other hand, in the winter season, underground temperature is higher than atmospheric temperature and it can be used as hot heat source. Although winter air temperature in Hanoi is not so low, humidity is so high that geothermal heat-pump (as heating system) would be useful for drying.

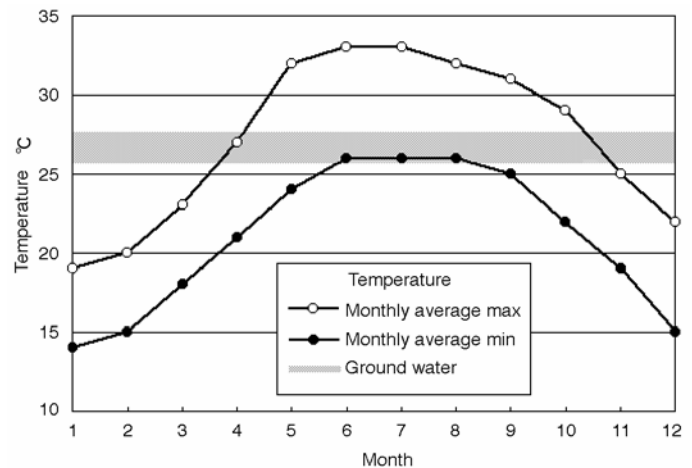


Fig. 10 Comparison of atmospheric and subsurface temperature around Hanoi

4. DISCUSSION

According to the temperature observation results in Thailand and in Viet Nam, possibility of geothermal heat pump application for space cooling is identified in some places where subsurface temperature becomes lower than atmospheric temperature in some season or time of a day. For real applications of air-conditioners, operation plans will be important to get higher COP, such as operation hours a day, humidity control and combination with hot water supply. These elements change the performance of the system.

Hanoi, Viet Nam is not a tropical region, however, the observation results obtained in this study would be valuable as base data for potential mapping of geothermal heat-pump applications in this country. Geothermal heat-pump as heating system would be useful for drying things and space in humid winter season in Hanoi. Thus new application of geothermal heat-pump may be found through climatic and subsurface data.

5. SUMMARY

Possibility of ground-coupled (geothermal) heat-pump application in tropical Asia is studied based on groundwater temperature data. Groundwater temperature surveys were widely conducted in the Chao-Phraya plain, Thailand and in the Red river plain in Viet Nam to compare with climatic data. As a result, regional variation of subsurface temperature at depths from 20 to 50 m of 3.4K was observed in the whole Chao-Phraya plain and 2.0 K in the Red river plain. In Nakhon Sawan, Pitsanulok, Kanchanaburi and Hanoi, subsurface temperature lower than surface one (monthly mean maximum) for 5K or more over four months was identified. Also in Bangkok and Ayutthaya, subsurface temperature is lower than average maximum temperature of a month almost through a year. Thus underground may be used as cold heat-source even in parts of tropical regions. Detailed underground temperature survey is essential for its promotion.

REFERENCES

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