Integrated studies to investigate paleochannel aquifer in Dan Chang District, Suphan Buri Province, Western Thailand

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Abstract. Climate change is currently causing droughts in many parts of Thailand, especially in Dan Chang District, Suphan Buri Province where many areas are outside irrigation coverage and deep groundwater explorations are less successful due to groundwater shortages. Therefore, there is a need to explore other shallow groundwater (i.e. less than 15 m deep) resources to relieve the drought problems in the communities. This work uses integrated studies of remote sensing, geology and geophysics to identify the location of a paleochannel that contains shallow groundwater resources in the Nong Makha Mong Subdistrict, Dan Chang District, Suphan Buri Province. Potential sites were selected using preliminary remote sensing analysis along with field surveys. A high-resolution topography map from aerial photos was generated and 2D resistivity imaging surveys were conducted at the selected sites to delineate the location of the paleochannel. The drilled wells prove the success of the integrated study to identify the shallow groundwater in the paleochannel at a depth of 3 to 15 m with a groundwater yield of 4 m^3/h. The sediments from the borehole suggest that a combination of alluvial deposits and fluvial sediments. Due to the relative lower cost of drilling shallow wells, this work could be used as a pilot project for local communities to explore shallow groundwater aquifers in paleochannels in areas that face a severe drought crisis and have very little deep groundwater potential.

1. Introduction

Climate change is presently causing droughts in many parts of Thailand especially in the Western Thailand where irrigation systems are inaccessible and the decrease of rainfall. As a result, the local communities, especially in the agricultural areas have been suffered by water shortages. Groundwater is considered one of the important choices to alleviate water shortage problems, furthermore during the dry season which is the beginning of the cultivation season for farmers.

A buried paleochannel is an old water passage such as a channel or river that existed in the past that has been covered by the current sediments. Paleochannel has the potential to store shallow groundwater that can be used as an alternative water resource. A typical paleochannel can be distinguished by its low width to length ratio and can be tortuous in plain view [1]. Although paleochannels can be obscured on the subsurface due to covert by sediments or being transformed by human activities [2], they can be identified using various techniques. Aerial photos, digital elevation model (DEM) and other remote sensing data can be used to determine the preliminary locations of paleochannels [3]. Geophysical methods can then be applied to pinpoint the exact location of the paleochannels and to delineate their geometries such as width, length and depth. Several geophysics methods can be applied to determine the location and define the geometries of the paleochannels such as 1D and 2D electrical resistivity surveys, electromagnetic surveys [3], ground penetrating radar surveys (GPR) [4] or seismic refraction surveys [5].

As the study area has a geomorphology that indicates abundant paleochannels, we are interested in exploring the shallow groundwater resources from these buried paleochannels in Nong Makha Mong Subdistrict, Dan Chang District, Suphan Buri Province, Western Thailand. We integrate various techniques such as geology and remote sensing to preliminarily determine the locations of possible buried paleochannels and then we conduct a geophysical survey such as the two-dimensional resistivity imaging survey in the selected sites to delineate the precise locations of the paleochannels. Therefore, the shallow groundwater can be extracted.

2. Geological setting

Dan Chang District is located to the east of Suphan Buri Province and is portrayed as a gradually sloping basin from the west to the east. The geology of Dan Chang District consists of the Ordovician (O) limestone with partly marble and calc-silicate. There are also phyllite and slate (SD) and colluvial deposits of the Quaternary (Qc) and rock fragments and clay ([6]: figure 1). This area is considered as the upstream area of the Mae Klong river basin and the Tha Chin river basin with the Tanaosri mountain range to the west and there is considered one of the rain shadow areas of Thailand. As a result, the average rainfall in Dan Chang District is less than the average rainfall in Suphan Buri Province.

The Krasiao reservoir is one of the major water resources in the region (figure 1) but most communities in Dan Chang District have very little benefit from the Krasiao reservoir because the streams from the reservoir flow out of Dan Chang District into other Districts of Suphan Buri. Therefore, most communities in Dan Chang District have had ongoing problems with water shortages and they have to use deep groundwater for their needs instead.

The groundwater resources are widely developed in Dan Chang District, the confined aquifers are averagely more than 40 m deep with a limited groundwater yield of 1 to 10 m^3/h. In the Nong Makha Mong Subdistrict in Dan Chang District, there are many small streams and paleochannels that could have been buried due to the changes in sedimentary deposition environment and land uses in the past and can be potentially good shallow groundwater resources.

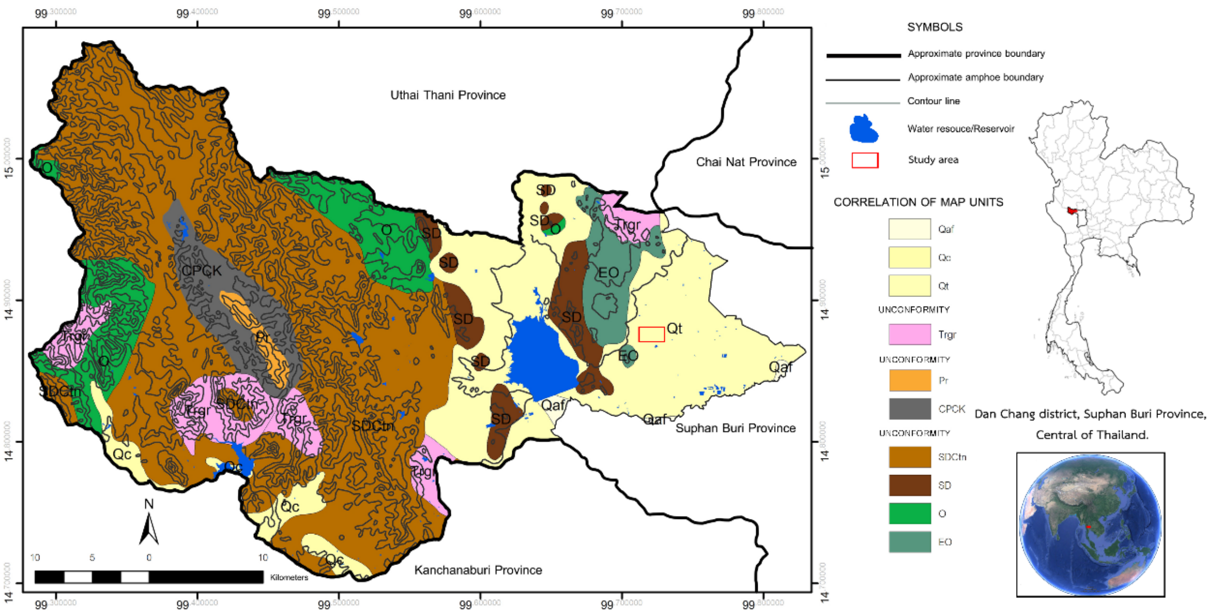


Figure 1. Geology of Dan Chang District, Suphan Buri Province [6] and location of study area.

3. Methodology

3.1. Identification of Potential Paleochannels

A paleochannel is an old channel that consists of unconsolidated sediments deposited in the past or they could be inactive rivers or channel systems [2]. These infilled deposits consist of clay and silt on the top with interbedded sand and clayey sand. The sequence of infilled sediments expresses the geologic history [7].

This work used aerial photos from Google Earth ® time-lapse to identify gross locations, directions and orientations of paleochannels in Nong Makha Mong Subdistrict, Dan Chang District, Suphan Buri Province, Western Thailand. The high-resolution satellite imageries show the different colors of various vegetations that can be used to preliminarily identify the locations of potential paleochannels in the study area (figure 2).

The example high-resolution aerial photos from Google Earth ® in figure 2 show the different colors of various vegetations which indicate the possible locations and directions of paleochannel at various times. Over time, the study area has been transformed by human activities to the agricultural areas. These aerial photos interpretations can be used to identify the preliminary locations of potential paleochannels in the study area.

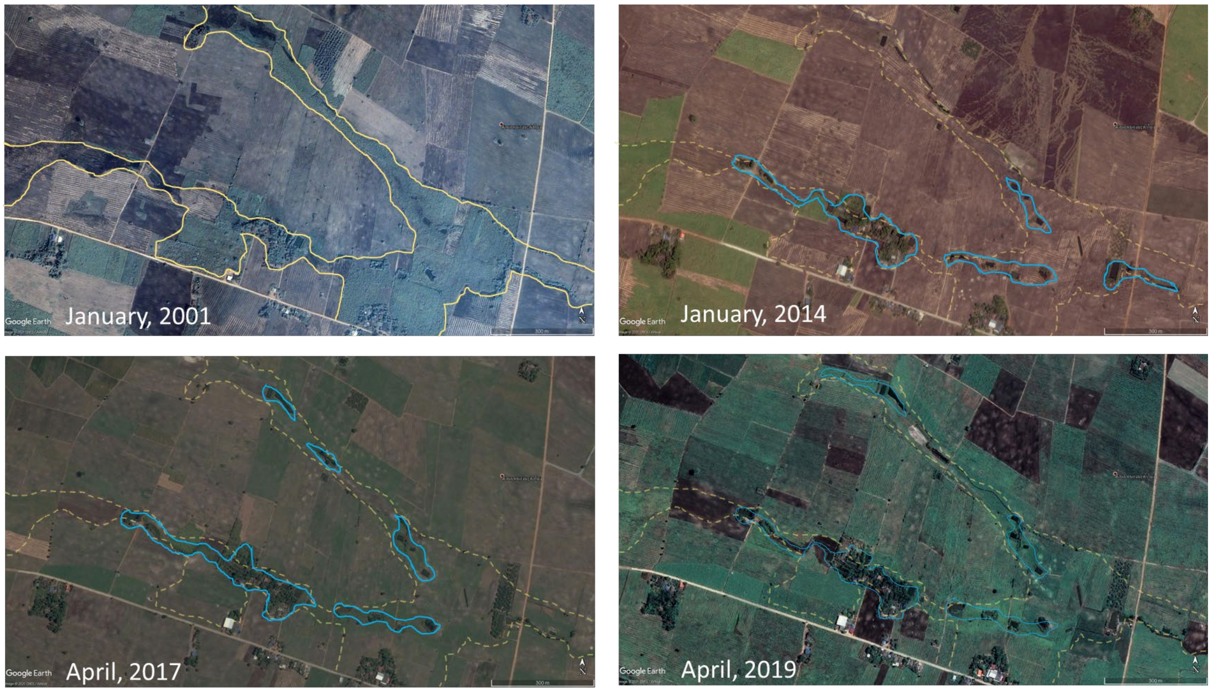


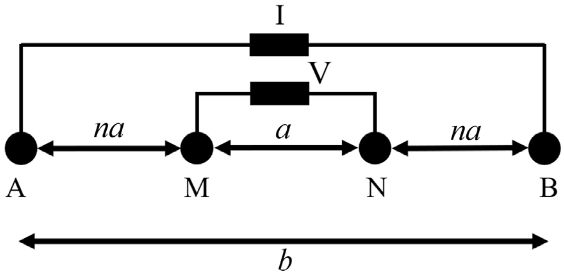
Figure 2. Examples of interpretations of time-lapse aerial photos from Google Earth ® for the selected site to locate the preliminary potential paleochannels for further investigations. The yellow and blue dashed lines show the boundaries of paleochannel.

3.2. 2D resistivity imaging surveys

2D resistivity imaging survey is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the subsurface electrical resistivity and distribution of the surrounding soils and rocks [8].

2D resistivity imaging surveys with the Wenner-Schlumberger electrode configuration (48 to 72 electrodes with 5 m electrode spacing) for a total length of 1,415 m (figure 3) were performed and the apparent resistivity can be calculated by using equation (1) given in ([9]: figure 4).

Figure 3. 2D-resistivity survey lines consist of 5 lines with total length of 1,415 m and locations of drilled wells (DC-1 and DC-2) on survey lines.



$$\rho_a = \frac{2\pi as}{(s-a)}R \qquad (1)$$

Figure 4. The Wenner-Schlumberger electrode configuration used in 2D resistivity imaging survey in this work [9].

When $s=(a^2+b^2)^{0.5}$ and R is the measured resistance. a, is the distance between the current electrodes pair A-M (or N-B) and the potential pair M-N. The "n" is the ratio of distance between the A-M (or N-B) electrodes and when the "n" factor is equal to 1 that is similar to the Wenner electrode configuration (distance between electrode = a). b, is the spacing between the A and B electrodes. ρ_a is the apparent resistivity value for Wenner-Schlumberger array [9,10]. The acquired data were inverted to obtain the 2D cross sections of subsurface resistivity values by the Res2Dinv® software.

4. Results and discussion

4.1. 2D-resistivity imaging profiles

The results of 2D resistivity imaging survey indicate a potential paleochannel with a width from about 50 to 160 m (could extend up to a few hundred meters) and about 10 to 20 m deep which is clearly shown on survey lines 1, 2 and 3 (figure 5).

Resistivity values from survey lines 1, 2 and 3 can be separated into 3 zones. The top zones of each profile (at depth from 0 to 5 m) represent low resistivity about 5 to 10 ohm.m. The resistivities then increase to moderate values of 10 to 50 ohm.m in the middle zone underlying the top zone at depths of 5 to 15 m. The bottom of profiles show high resistivity values of more than 100 ohm.m.

In addition, the resistivities of survey lines 4 and 5 show high values on the top zone (in the center to the north end) and low resistivity (2 to 10 ohm.m) below the top zone which are different than those of survey lines 1, 2 and 3.

The sediments collected lithology log from boreholes on survey lines 2 and 3 correspond well with the 2D resistivity imaging survey results (figure 6).

4.2. Comparing interpreted 2D-resistivity profiles and lithological log of boreholes

The results of interpreted 2D resistivity imaging surveys help identify the paleochannel and lead to precise locations of drilled wells. Depositional cross-section models were interpreted based on both grain size of sediments and electrical resistivity values.

The survey line 2 cross-sectional model displays the deposition of paleochannel in the SN direction. The results of electrical resistivity values and grain sizes from the DC-1 well can be distinguished into three zones. Low to moderate resistivity of the top layer from 1 to 3 m associated with silty-clay and clay of the topsoil layer. The middle layer of the cross-sectional model at about 3 to 15 m deep represents sand and silty clay of paleochannel deposits which are related to low to middle resistivity values. The bottom of the profile is interpreted as granite weathered bedrock.

The survey line 3 cross-section model shows several paleochannels in the SN direction. The average thickness of paleochannels is less than that of the survey line 2. Silty clay and clay are the main compositions in paleochannel deposits here. The bottom of the profile is interpreted as granite weathered bedrock at about 2 to 15 m deep from the surface.

The discovery wells detect shallow groundwater in this paleochannel at a depth of 5 to 9 m in the DC-1 well and 3 to 12 m in the DC-2 well with a groundwater yield of 4 to 4.2 m^3/h. The sediments from boreholes suggest that alluvial-fluvial deposits (figure 6).

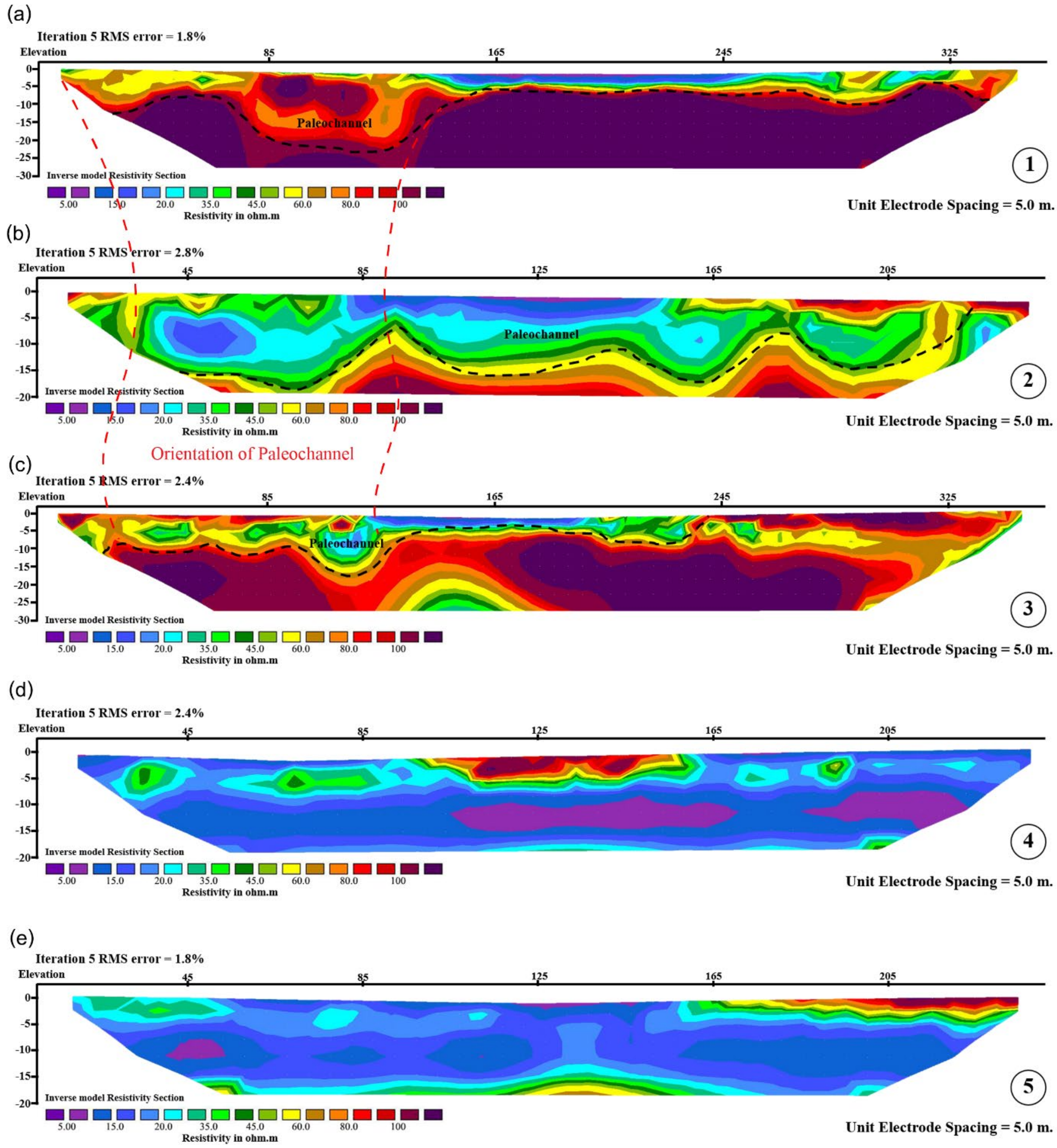


Figure 5. A result of 2D resistivity imaging surveys. (a) the survey line 1, (b) the survey line 2, (c) the survey line 3, (d) the survey line 4 and (e) the survey line 5. The black and red dashed lines indicate the boundaries of potential paleochannel in the study area.

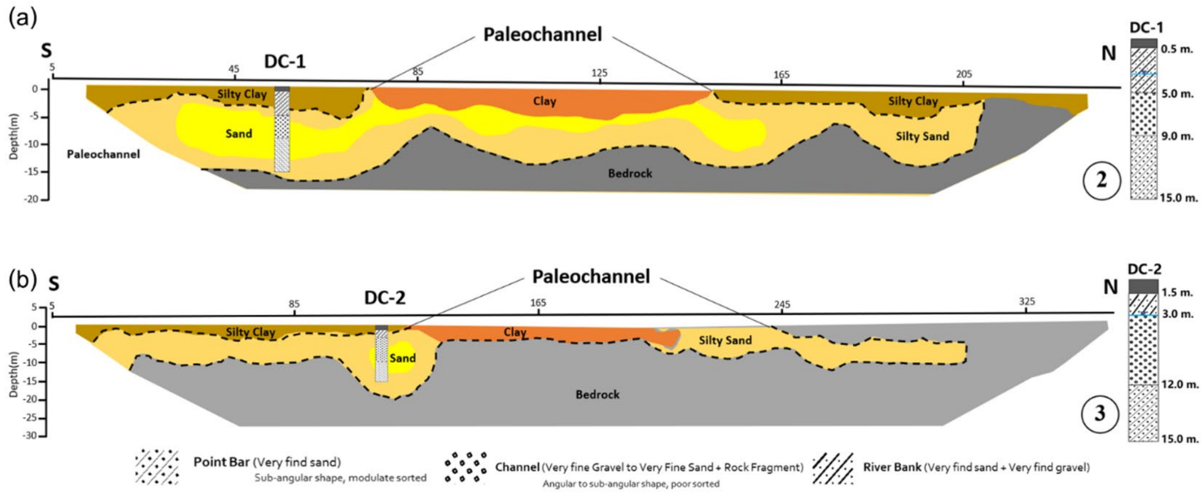


Figure 6. Integrated interpretation of paleochannel from 2D resistivity imaging survey based on subsurface resistivity and lithology log from borehole data. (a) the survey line 2 interpretation of the profile with DC-1 lithology log from the borehole and (b) the survey line 3 interpretation of the profile with DC-2 lithology log from the borehole.

5. Conclusion

Integrated studies of remote sensing, geology and 2D resistivity imaging surveys were used to identify the location of a paleochannel in Nong Makha Mong Subdistrict, Dan Chang District, Suphan Buri Province. The results of the 2D resistivity imaging survey indicate a clear paleochannel. The discovery groundwater wells detect shallow groundwater from this paleochannel depth of 3 to 15 m with a groundwater yield of about 4 m^3/h. This work can be used a pilot project for local communities to search for shallow groundwater resources in paleochannels in areas that encounter very severe drought crisis and have very little deep groundwater potential or surface water resources.

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