

# The Ancient Water Management Systems in Thailand

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## Abstract

*Within currently Thailand territory, there were different cultures existed in different periods of time from the north to the south, and from the west to the east. In this paper, we will survey ancient water management systems of each culture in the territory. We will illustrate their function related to ritual and believe as well as for the wellbeing of the community. The cultures that will be surveyed include Dvaravati (Mon), Khmer, Srivijaya, Thai (Sukhothai, Lanna, Ayutthaya, Thonburi and Rattanakosin). From the archaeological, anthropological evident, and geo-informatics related evident, the ancient water structures were always related to 1. Ritual and Believe 2. Wellbeing of the community and 3. Ritual and believe as well as wellbeing of the community. The objective of this study is to learn about the wisdom related to water of each culture, what was their ritual, believe related to water, as well as how the water was managed and utilized by each culture. This is a part of the research project to study the relationship between human and environment in the past. How was the environment modified to fit with human requirement to live? The focus will be on the knowledge and method of water management as well as the relationship of water to the ritual and believe in different period and area in the Mainland Southeast Asia. The area of study will be in the area of Myanmar, Thailand, Cambodia, and Vietnam. Currently, there are still the problems exist from the lack of water resources, especially in remote area. The future step of this study is aiming to improve water management system in remote area by revitalizing and utilizing the ancient water management system in the area. The concept of this study is adapted from the late King Rama IX's royal suggestion to Thai people about the relationship between human and environment in the past. The focus will be on the knowledge and method of water management in different period and area. The plans and suggestions to the local communities will be mutually shared. The outputs will be also used as educational material for young student research program, so that they could learn about their local culture and environment. This will assist the locals and students to learn about their cultural heritage as well as how to prevent flood and drought at present.*

## 1. Introduction

“Water Resource,” has always been the determinant of human’s way of life, which is considered to be crucial element for a community’s activities, as well as it is always a main resource for inhabitants of every ancient city around the world (Mithen, 2012). When people started to settle down in an appropriate distance to water resource, they had to face with water-crisis, therefore water strategies wisely or as it’s called “Water Management” needed to be considered and developed properly. The water management system has no fixed method according to different natural conditions of the cities. Each city’s location, geography, geology and hydro-ecology were the important conditions for human to build their surroundings appropriately (Steward, 1955). The question is ‘Might water management has begun within the earliest Neolithic farming communities?’ ‘May it have developed by hunter-gatherers?’ or ‘May it has appeared long before, since the first human was born?’

In Thailand, the country known as the “Hydraulic Society,” the human ability to live with distinctive water conditions both harmoniously and sustainably has been well evidenced and demonstrated, for example, moat and/or mound settlement, baray structure (pond/ reservoir), embankment, weir, dam, reservoir, and canals which are all physical evidences of how past-human managed water within particular conditions. According to background of the prior archaeological studies in Thailand for over a decade, there have been numerous researches of the water management and its systems. The earliest evidences of water management in Thailand could be traced back into prehistoric period at least in Iron Age (around 2,500 – 1,500 years ago). Most of the prehistoric sites located in parts of alluvial plains in the country showing that we are in the hydrographic society living in ‘Rice Monopoly Culture’ for thousand years (Surarerks, 2001). However, in this survey of ancient water management in Thailand will focus on the early historic period to the present

approximately. Here, the chronology of ancient water management can be divided into 2 periods: 1) the prehistoric period to 13<sup>th</sup> century CE period and 2) from 13<sup>th</sup> century CE to the present days.

## 2. The Prehistoric Period to 13<sup>th</sup> Century CE Period

Over the previous years, successive remote-sensing projects have offered crucial new insights into the archaeological landscape of Thailand. The ancient settlements are recognized on aerial photograph, invisible through evidences and man-made features which are the simplest forms to be seen on aerial imagery, includes “moat and/or mound” and “baray,” the two types of ancient settlement patterns.

**Moat and/or Mound Settlements:** the features are found in most regions of mainland Southeast Asia, especially common in the northern, central, and northeast Thailand (Saraya, 1994). By the environment factors, the moated settlement is classified into two types, which can be described using the terms “topographically controlled” and “non-topographically controlled” (Supajanya, 2001). Some sites may have been built from the prehistoric period, but most had been appeared during the early historic period (Dvaravati Period - during 6<sup>th</sup> – 10<sup>th</sup> century CE and Srivijaya period - during 7<sup>th</sup> – 12<sup>th</sup> century CE) (Suksom, 2002).

Since the past years, a plethora of theories have emerged to explain the function of moats surrounding these sites, for instance the defensive function, the agriculture function, the symbolic function, the flooding mitigation function, and the water storage function (Fine Arts Department, 2007: 86), however, the exact function and purpose of the moats is still debated.

**Baray Structure (Pond/ Reservoir):** the man-made forms of artificial body of water which is a common element of architectural components in ancient Khmer culture during the Khmer Empire of Southeast Asia. The meaning and functions of barays have been defined and interpreted in two functions; the first definition – baray was the primarily spiritual in purpose, as symbolizing the sea of creation surrounding mountains, and another - baray were made for water management of fields (Sangwan, 1981).

The central Thailand was the most suitable and reasonable environment for cultivation in the country. Thus, many ancient communities had been dispersed in the river basins since the prehistoric

period and from archaeological evidences suggest that the number of settlements have emerged and seem to increase moderately high during Dvaravati period. The most settlement pattern in this period were built with moats and mounds surrounding and the shapes of patterns were different according to different natural conditions in where each city's located (Supajanya, 2001) (Figure 1). The Northeastern Thailand is the largest region of the country including two plateaus, Khorat plateau and Sakhon Nakhon plateau, where the evidences illustrated the feature of human's settlement was, at least, possibly from Neolithic period and have developed continuously until the early historic period during the culture from the central region (Dvaravati culture during 6<sup>th</sup> – 10<sup>th</sup> century CE) and the ancient Khmer culture (10<sup>th</sup> century CE) encountered. The Moat and/or mound settlements, which most located in the Khorat plateau (Kijngam et al., 1981) often had developed in three stages, starting to build small towns with moats and/or mounds (no fixed shapes) and expanding the town areas afterwards in some case. The last stage coming with ancient Khmer culture, at least one large “Baray,” was in rectangle shapes, had been built in or near the towns (Moore, 1988) (Figure 2).

The Northern Thailand in which is on a terrace deposit with a mountainous area. Traditionally, the natural features made possible several different types of agriculture, including wet-rice farming in the valleys and shifting cultivation in the uplands. Thus, the geography characteristics generated various hydrological effect to land, especially the slope area could let water from the higher areas flow to lower areas (Praicharnjit et al., 1996). This structure was suitable to create the water system as known as “weir water management system (Tanabe 1975: 80-94),” found in the early Haripunchai period (7<sup>th</sup> – 13<sup>th</sup> century). Moreover, the form of moat and/or mound settlements, so called “Wiang”, also were found in the northern Thailand and distributed along the river plains (Inthrawut, 1993) (Figure 3).

The Southern Thailand, the earliest evidences of water management was indicated by the form of moat and/or mound settlements in Srivijaya period (7<sup>th</sup> – 12<sup>th</sup> century CE). This settlement pattern was found along the east coast rather than the west coast (Walipodom, 1982). Most of the city was rectangular, which was probably influenced by Brahmanism. Moreover, the feature of rectangular man-made ponds, so called “Phang,” also had been found and it was another mean to control water, presumably constructed for use in rituals and daily life (Phiyakul, 1999) (Figure 4).

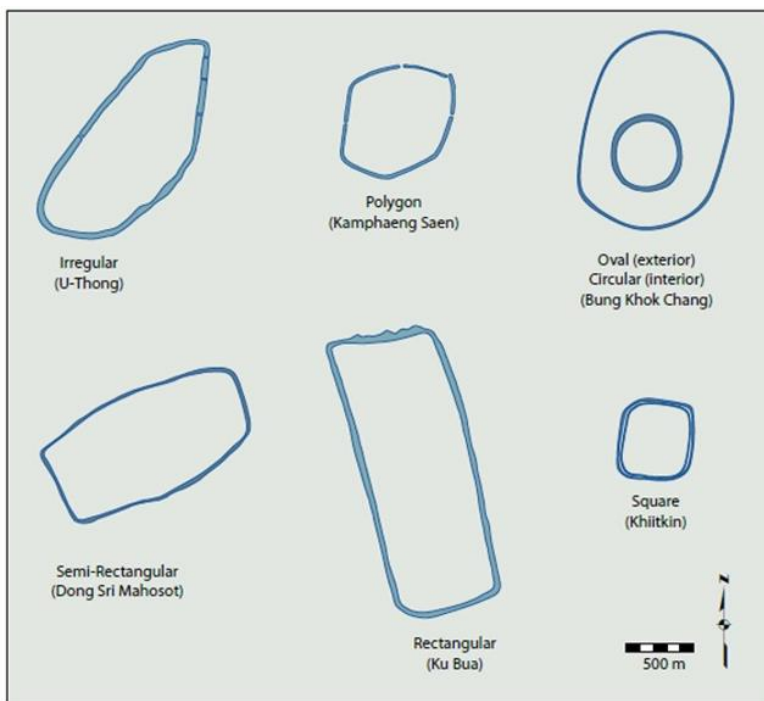


Figure 1: The shapes of settlement patterns during Davarati Period. Source: Gallon, Mathew D. (2013)

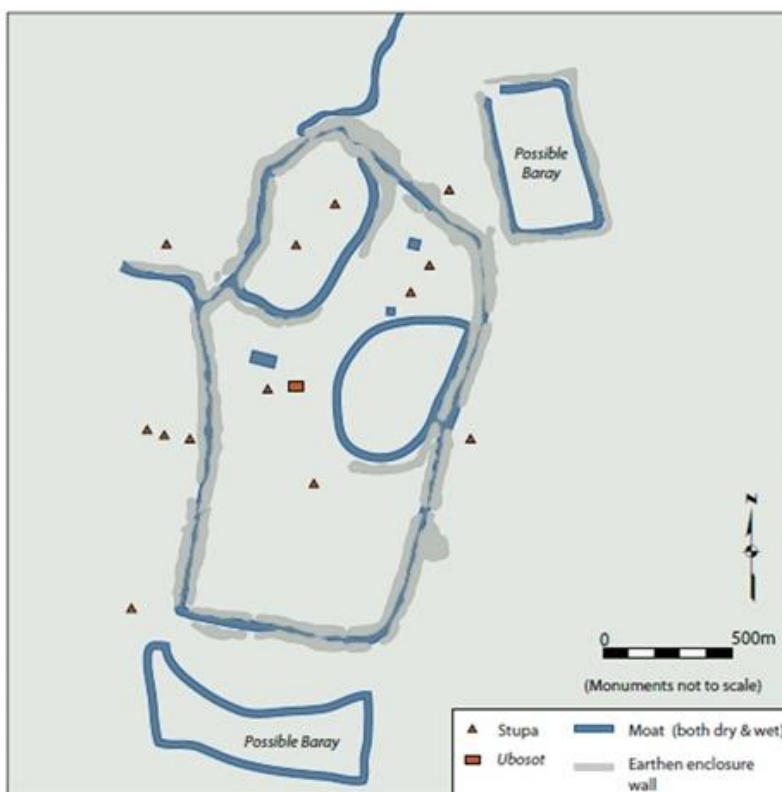


Figure 2: Muang Fah Daed Song Yang, an example of the moat settlements have developed in three stages in Northeast Thailand. Source: Gallon, Mathew D. (2013)

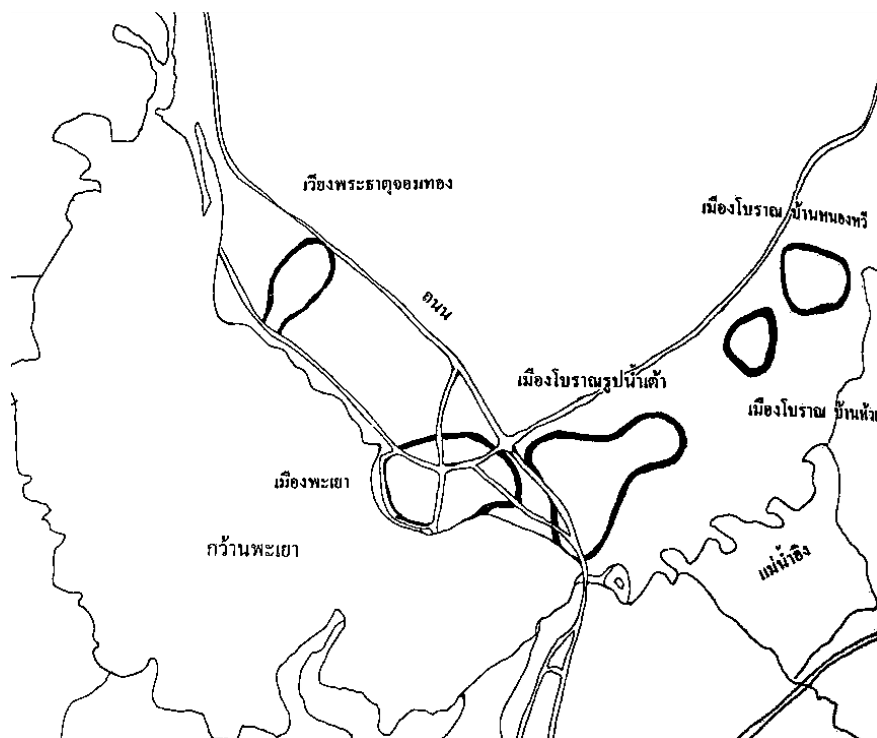


Figure 3: A group of moat settlements in the plain area near Phayao Lake.  
Source: Wongtes, S. (1984)



Figure 4: Google Earth (2018) representation of Phang Phra pond, a man-made pond in Srivijaya period



### 3. From 13<sup>th</sup> Century CE to the Present Days

After the 13<sup>th</sup> century CE, most of the independent communities had united and became a part of “state/kingdom,” that initiated a new economic stage in the evolution of society, in each region as complex society – a new social class “the urbanites.” However, still, the archaeological collections illustrated that the new level of after 13<sup>th</sup>- century societies applied and tried to improve the prior technology of water management continuously until the present day. This also illustrates how great human’s adaptive ability to live with distinctive water conditions both harmoniously and sustainably has been well evidenced and demonstrated.

In the Sukhothai Period (13<sup>th</sup> – 15<sup>th</sup> century CE), Sukhothai City – the capital city was situated on the northern part of Chao Phraya Delta surrounding with several mountains. According to the terrace deposit and the natural environment of Sukhothai, the soil characteristic had no capacity to hold water and underground water resources were too deep, the city was resulted in drought regularly (Sihamat, 2017a and 2017b). Sukhothai, as a center of management, had to manage to contain a good amount of water for agriculture and also for preventing damage caused from the annual floods. The water management in Sukhothai had been applied systematic water management concept that borrowed the idea of making a great rectangular or square city plan surrounded by ditches from ancient Khmer culture, and latter this system would have influenced the building of Chiang Mai city during the Lanna period (Chaowanapreecha, 1986).

Since water resources from the mountains in the west, which flows into the same valley, the dam was built to store water known as “Saritpong,” and then a canal leading to the lowlands, where the city located, was built. At the same time, they had managed to draw water into the city by storing water in the “ponds” for using in dry season through large channels and clay pipes for conveying water (Sihamat, 2017a, 2017b and Krabuansaeng, 1995). As the nature of water management system, there were many reservoirs as watercourse that connect together to create complex waterways for daily use, and agriculture with religious symbolic meanings (Chaowanapreecha 1986: 48-49; Krabuansaeng 1995: 160-164). Therefore, Sukhothai was capable of being a great center of management in this period (Figure 5).

Water management system in the Lanna Period (13<sup>th</sup> – 16<sup>th</sup> century CE) had developed and the foundation was derived from previous time. In this period, water management through moat and/or mound settlements were still in use along with,

simultaneously, weir water management system, as it had occurred in a recorded written (Surarerks, 2001). However, after the development of Chiang Mai City, the evidences indicated that many towns were built in a rectangular form with a single moat and/or mound. It is assumed that Chiang Mai was under the influence of ancient Khmer culture which was transferred from the contemporary state, Sukhothai (Srisuwan, 2014) (Figure 6). Since the Ayutthaya Period (15<sup>th</sup> – 18<sup>th</sup> century CE), the administrative center had transposed to the floodplain areas, the lower part of Chao Phraya Delta, which founded over the connecting area of old and young delta. This area filled with network of rivers and canals. According to the geographical facts, the hydrology of Ayutthaya had difference characteristics comparing with Sukhothai. The annual floods brought sediments from the northern mountains, and rivers kept the area the productive agriculture. Somehow, the amount of water was too much, and the city needed to be managed by several methods.

Water management system in this period were constantly evolving, especially digging canals inside the city seemed to be the top priority. Within the city, there are ditches and canals in both north-south and east-west axis (Chumsai na Ayudhaya, 1928). This structure could help to distribute the water source thoroughly as well as to prevent flood (Songserm, 2011). Also, canals were used for travelling as “bypass canal,” which the canals had been dug to shorten the long journey time from the crooked Chao Phraya River that could support better communication and transportation (Thai Encyclopedia for Juvenile 33). The result was Ayutthaya became a kingdom with a complex waterway network. Not only canal, but there were also “water gates,” connecting inner canals with outer rivers, to control water, “city walls” were applied for flood protection and protecting the city from the enemies concurrently (Palakawongse na Ayudhaya, 1985), and “pond,” scattering throughout the city, reservoirs were dug for collecting water for consumption in dry season (Ayutthaya Historical Park Project, 1980-1982). Ayutthaya was once a large island city wisely adapted to the water conditions by using it for multiples purposes (Figure 7).

In the Thonburi and Rattanakosin Period (18<sup>th</sup> century CE – Present), the cities were situated in the lower Chao Phraya basin over a young delta at the river mouth of Chao Phraya. The Cities were located about 50 kilometers inland off the Gulf of Thailand. According to geography, the geo-ecology of Thonburi and Rattanakosin were far more diverse than Ayutthaya and before.

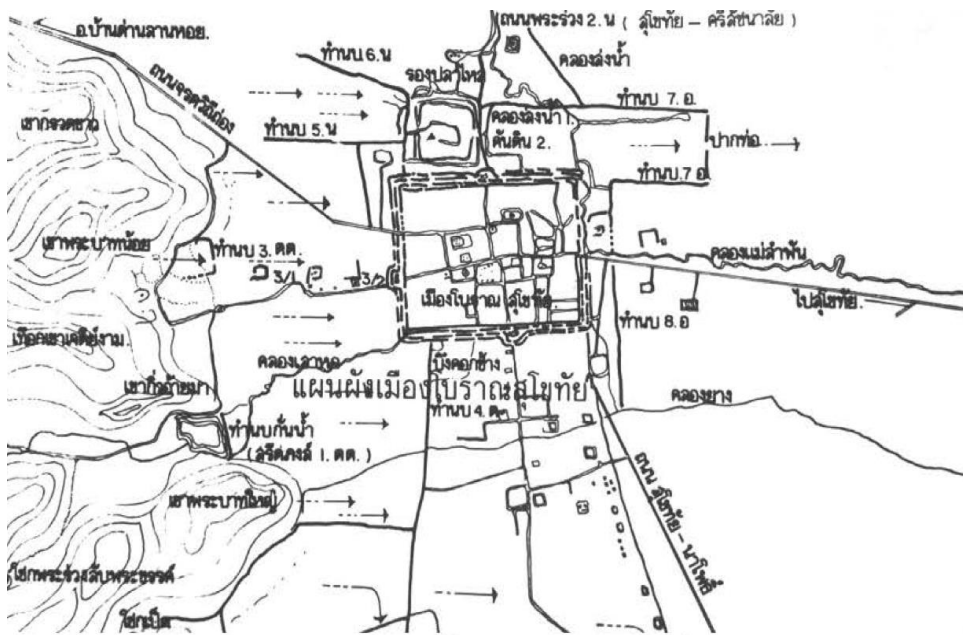


Figure 5: Sukhothai City's settlement pattern. Source: Unjaijin, K. (2016)

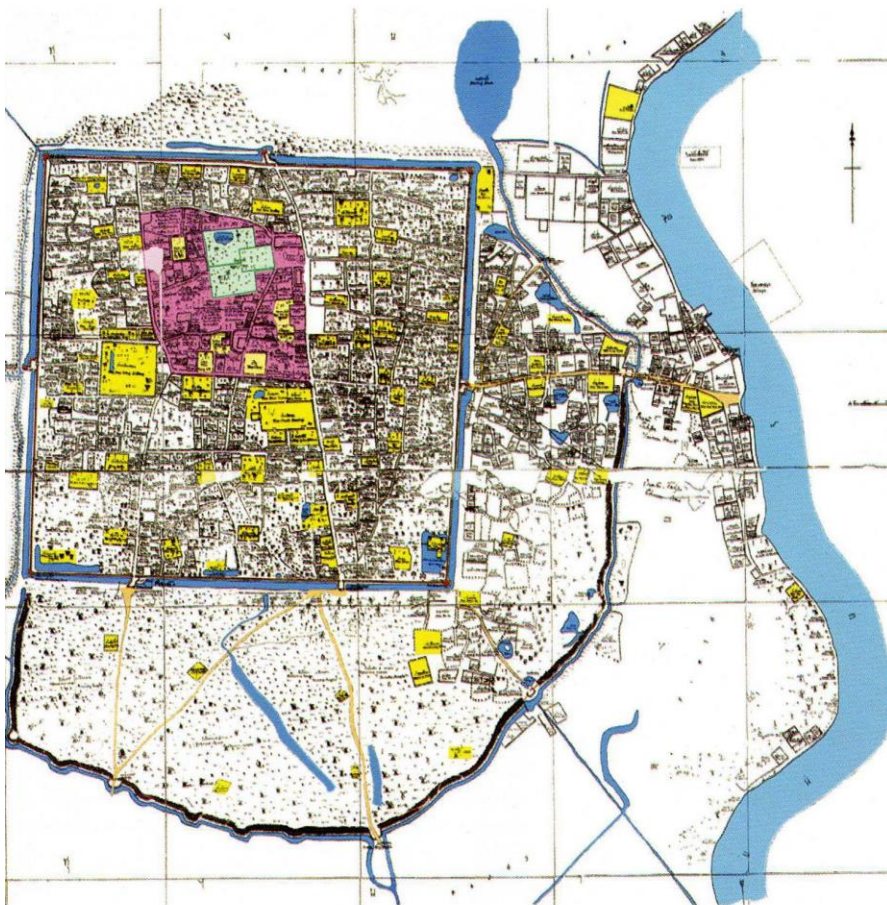


Figure 6: Map representation of Chiang Mai and Waterways nearby the City during King Rama V.  
Source: Unjaijin, K. (2016)



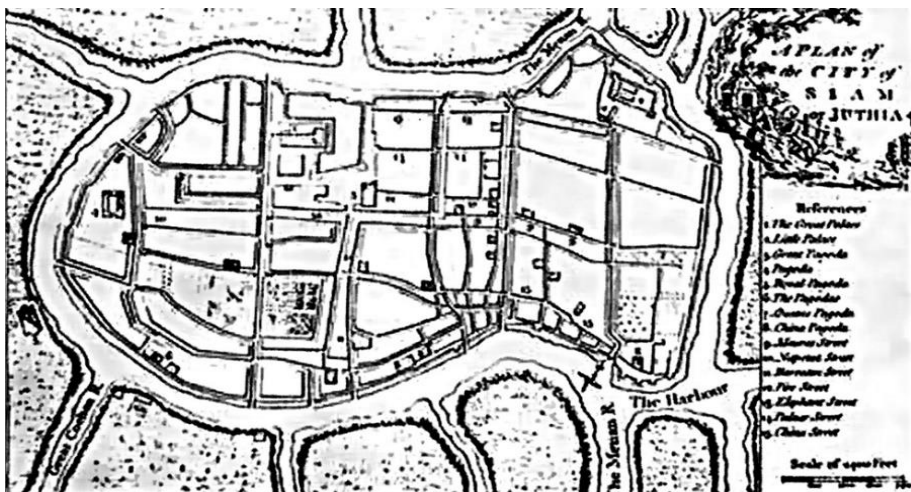


Figure 7: Ayutthaya city's settlement pattern. Source: Pattanaanek, W. (2000)

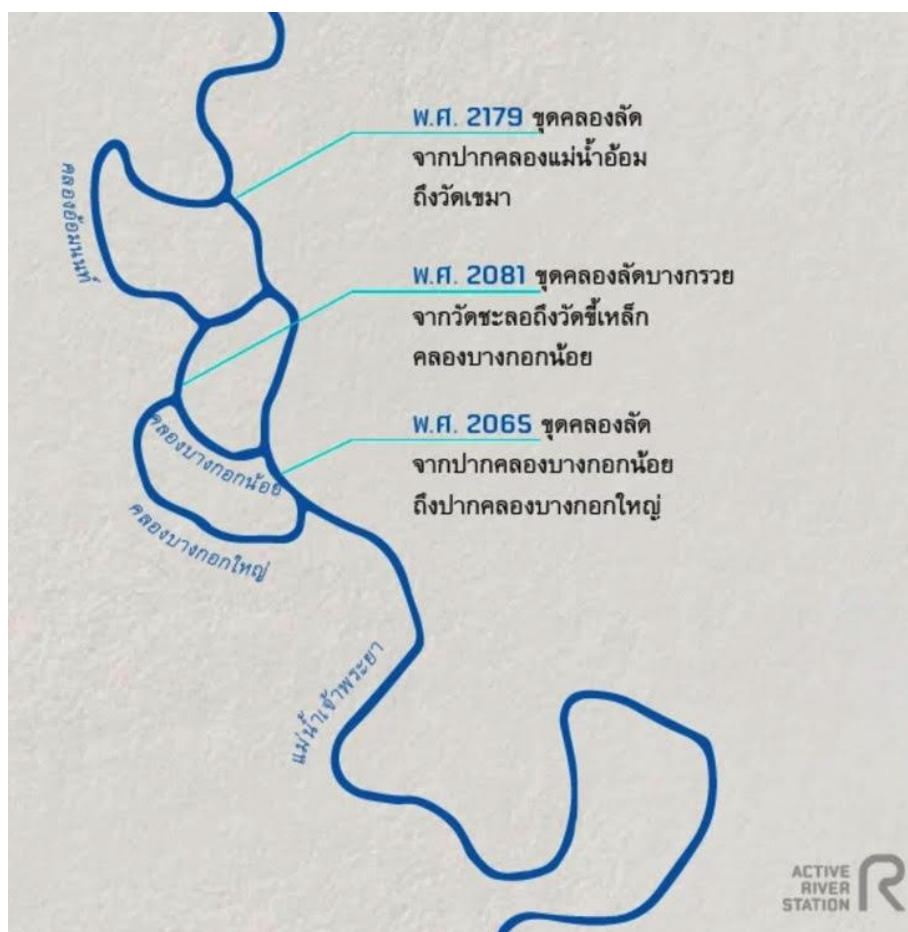


Figure 8: The sharp of canals (blue lines) and bypass canals (green lines) in Bangkok  
Source: Active River Station (2018)

The Thon Buri river basin area began to be important as the capital city of Thonburi in the Thonburi Period, in this period, the main strategy was to focus on the development of infrastructure:

dredging canals for using in both the consumer, agriculture, transportation and strategic advantage (Ayutthaya Historical Park Project, 1980-1982) (Figure 8). Later, in the Ratanakosin Period, the

capital city, Bangkok, had shifted to the east bank of the Chao Phraya River (Pattanaanek, 2000). Many canals, still, had been dredged as in the Thonburi Period. However, the number of dredging of canals had increased a lot more than before, which was probably caused by the continuously increasing population, especially during the reign of King Rama V (Pattanaanek, 2000). After that, during the edge of King Rama VI – IX. (in the present day), while the evolution of modern technologies has been developing continuously, the technology or strategy to manage water also have been improving to be more efficient (Surarerks, 2001).

#### 4. Application of Geo-informatics Utilizing Drone Mapping for Detail Study of Ancient Water Management System in Thailand

In order to conduct further study on the detail of different ancient water management systems mentioned. Geo-informatics can be utilized to understand how such systems were used, how the systems were abandoned, and how we can revitalize such systems again for the benefit of local people in the surround and nearby area. The first step is to detection of such systems utilizing the remote sensing data such as aerial photos and satellite images to detect manmade structures.

The next step is to integrate remote sensing data together with the ground survey data to extract Digital Elevation Model (DEM) or Digital Surface Model (DSM) to study the water flow direction, water holding capacity, as well as the location of settlements in the surrounding area. In this regard, we will need the multi-disciplinary approach to integrate the knowledge from archaeology, anthropology, history of the area with geo-informatics knowledge of the area to come up with knowledge of how the water management systems were operated at ancient time. We will illustrate from the case study below.

At present, Unmanned Aerial Vehicle (UAV) technology has been developed to the advanced level for aerial survey that used to be available by airplane or helicopter survey only. It is now possible to use UAV to conduct aerial survey that can product very high resolution aerial survey data that not possible to obtain before in the past. The researcher can obtain up to 1 cm. resolution aerial orthophoto mosaic and DSM with simple equipment and software (Figure 9) In order to illustrate the usefulness of UAV survey for the study of the ancient water management systems, we will use the case study at Prasat Sadok Kok Thom and the surrounding area in Thailand.

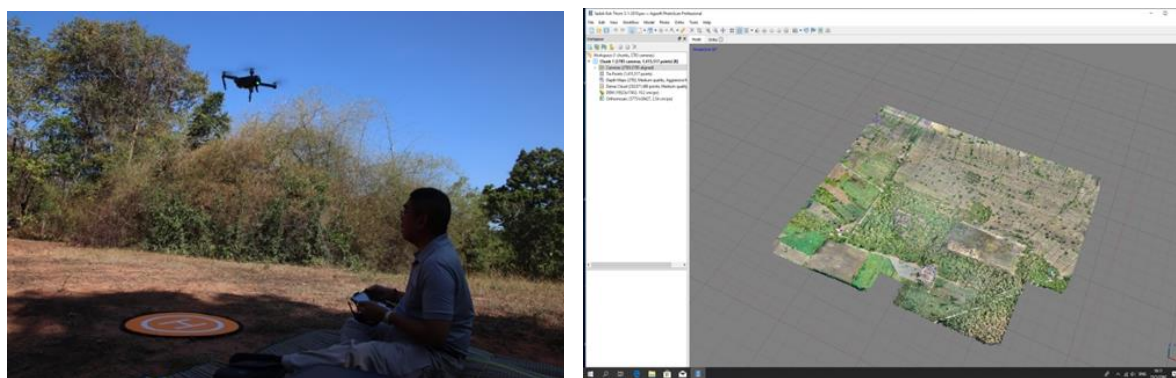


Figure 9: Sample equipment and software to produce orthophoto mosaic and DSM, Left: Commercial Drone (DJI MAVIC Pro), Right: Photoscan photogrammetry software



Figure 10: The current surrounding landscape of Prasat Sadok Kok Thom





Figure 11: The orthophoto mosaic of Prasat Sadok Kok Thom area

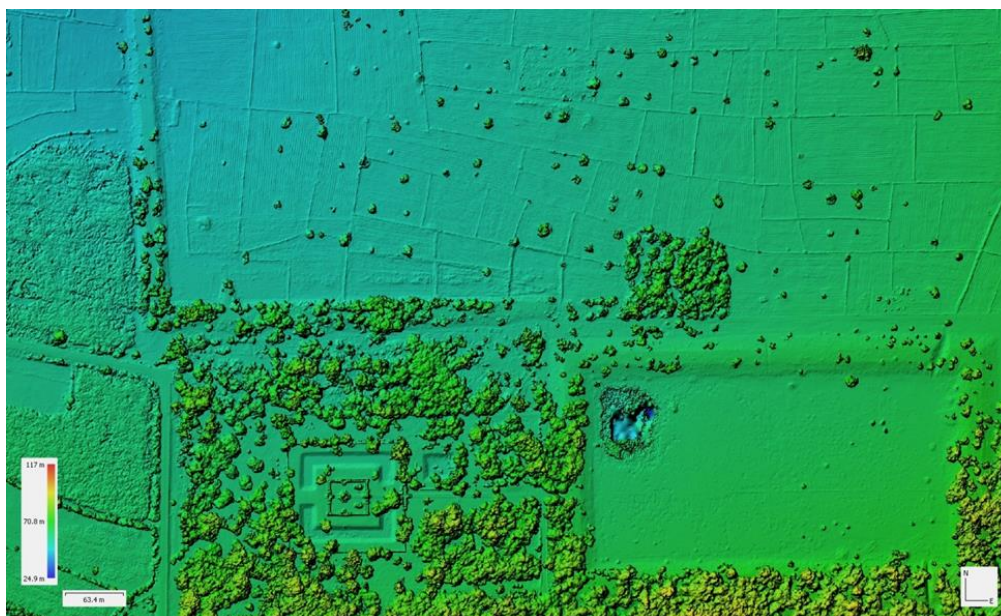
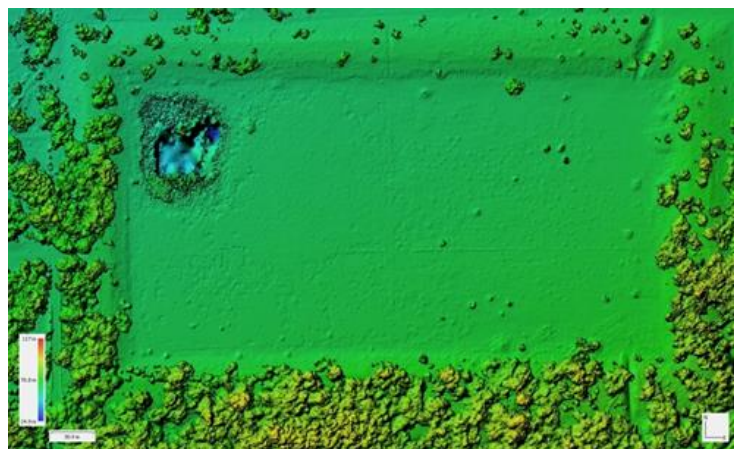


Figure 12: The DSM of Prasat Sadok Kok Thom area

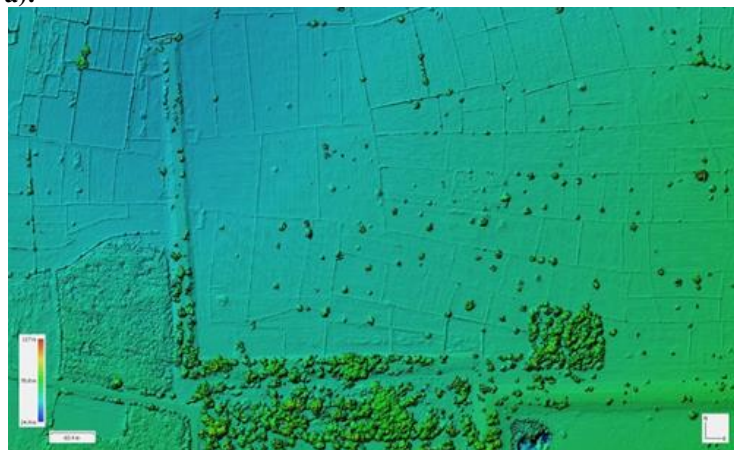
The site is located in eastern Thailand along the border between Thailand and Cambodia. Sdok Kok Thom is an 11<sup>th</sup> century Khmer temple, located about 1.5 km. of the Thai-Cambodia border. The temple was dedicated to the Hindu god Shiva and from the inscription, the temple was constructed by a prominent priestly family. Sdok Kok Thom is well

known for its most illuminating inscriptions left behind by the Khmer Empire. (Wikipedia 2019) The current surrounding landscape is illustrated from the Figure 10. By conducting UAV aerial survey, we had obtained 2785 aerial images of the area surveyed in approximately 3 hours on 2 December 2018.





a):



b):

Figure 13: a): Dry Baray on the eastern side and other water structure, b): Ancient Water Structure on the northern side of Sdok Kok Thom

We had processed these images with Photoscan photogrammetry software and obtained the DSM, orthophoto mosaic, as well as 3D model of the landscape. From the orthophoto mosaic, we can identify manmade structures with the L shape on the north side of the temple, and rectangle shape on the east side of the temple. From previous surveys by archaeologists, we already know that these two structures were used for water management, especially the rectangle structure is called “baray” in Khmer language. Baray was related to religion and believe as well as utilized as water reservoir. From the orthophoto mosaic, it can be observed that both of the ancient water structures are dried out and we can still observe the structures very clearly by DSM. In addition, if the DSM is observed closely, the low elevation and the slope of the water structures still can be observed after almost 1000 years of their existence. From this information, we can calculate that these 2 water structures can still hold the water, if the water can be arranged to flow into these water

structures as well as removing of the sediment on the top soil (Figure 11, 12, 13).

If we observe the DSM closely, we can notice that the elevation of the L shape structure is lower than the elevation of the baray. The average elevation of the L shape structure is 51.55 meters above the MSL, and the average elevation of the baray is 59.35 meters above the MSL. This may help to answer why the ancient people built up the L shape structure. The baray may be used mainly for religion and ritual believe because it cannot hold very large volume of water due to its elevation, but the L shape structure can hold up larger about of water due to its elevation. This is the physical proof of the reason why the ancient people built up both structures, not only the baray. We believe that this geo-informatics part of the study can help the local communities. We can also use the result of this research to educate the young generation for better future of the region. This will ultimately prevent flood and drought.

## 5. Conclusion

Given this survey of ancient water management in Thailand, the water management system in Thailand could be dated back to prehistoric times (during the Iron Age period), however, more archaeological collections – especially the features of settlement and man-made which were recorded through geoinformatics application, represented that the form of water management had appeared obviously in the early historical period. Along the presented information, “Water Resource” always plays a major role in the human’s way of life in every period and also “Water Management and/or Water management System” showed how well human understand of the environment surrounding them and learned to adapt to environment and also tried to defeat nature. Moreover, as the archeological research have shown, many civilizations could only flourish as a result of advanced methods of managing their water resource, no doubt in others, the beginning of society evolved from the struggle with the water element.

The study of ancient water management in Thailand demonstrates that the ancient people in the area had developed their water manage system according to the topography, their believe and religion, as well as the available knowledge and technology that were available to them. From the east to the west, from the north to the south, there were similarity in the water management system as well as the difference. By the available geoinformatics technology as well as the advancement on other field of studies, we can make progress on the detail study of ancient water management systems in Thailand as well as neighboring countries. The new knowledge will be able to answer the questions that may have no answer in the past relating to the water management system of many ancient sites in the region. But the most important issue is that the information will help to support the condition of the living of the local people in the area. In many areas of Cambodia, Myanmar, and Thailand, there still exists problems from the lack of water resource and management, especially in remote area of these countries. There are two main situations: too much water in the rainy season causing the flood, and not enough water in the dry season causing the drought. Such damage and influence as the disaster for local community varies in the three regions together with local topographical features and meteorological affects and differences. In order to solve the current problems on water resource and management, we can learn and utilize the ancient water resource and management in the area where ancient cities and sites are nearby but the ancient water resource and

management is now not used or unknown by the local people since only few ancient water resource and management systems are still in function now.

## References

- Active River Station, 2018, *Canals – Roads – Boats Arteries of Eastern Venice (in Thai)*, available from <https://www.activeriverstation.com/blog/>
- Ayutthaya Historical Park Project, 1980-1982, *The Excavation Report of the Ancient Palace 1980 – 1982 (in Thai)*, n.p. 32-43.
- Chaowanapreecha, P., 1986. *The Studies of the Relationship between Water Resources and the City of Sukhothai (in Thai)*. A Thesis Submitted for Partial Fulfillment for the Master’s Degree of Arts to the Department of Archaeology, Graduate School, Silpakorn University.1-7.
- Chumsai na Ayudhaya, S., 1982, Ayudhaya (in Thai). In *The Story of Cities*, Bangkok, Arun Kan Pim. 25.
- Dredged canals in Thailand (in Thai)*. In *Thai Encyclopedia for Juvenile* 33. Website: <http://kanchanapisek.or.th/kp6/sub/book/book.php?book=33&chap=3&page=t33-3-infodetail03-.html>
- Fine Arts Department, 2007, *Glossary of archaeological terms (in Thai)*, Bangkok, Division of Archaeology, Fine Arts Department. 86.
- Gallon, Mathew D., 2013, *Ideology, Identity and the Construction of Urban Communities: The Archaeology of Kamphaeng Saen, Central Thailand (c. Fifth to Ninth Century CE)*, A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Anthropology) in the University of Michigan.
- Inthrawut, P., 1993, *A Study on the Ancient Civilization in the Old Lumphun Town Prior to the Mid 13th Century, Based on the Archaeological Evidence (in Thai)*, Bangkok: Faculty of Archaeology, Silpakorn University. 92.
- Kijngam, A., Higham, C., and Viriyarom, W., 1981, *New perspective of Earthen Constructions in Northeast Thailand (in Thai)*. *Silpawattanatham* 25, 1 (March). 21-25.
- Krabuansaeng, S., 1995, *Triboon: the Water Management in Sukhothai City (in Thai)*. In the 3<sup>rd</sup> French-Thai Academic Conference “The Development of the States in Thailand from Archaeological Evidences”. Bangkok, Silpakorn University. 159-160.
- Mithen, S., 2012, *Thirst: Water and Power in the Ancient World*, London: Weidenfeld and Nicols.



- Moore, E., 1988, *Water Resources Management in Northeast Thailand (in Thai)*. In *Thailand from Early history to 15<sup>th</sup> Century CE: The First French-Thai International Conference*, Bangkok, Silpakorn University.
- Palakawongse na Ayudhaya, A., 1985, *The Study of Archaeological Geography from the Ancient Maps in Ayutthaya Period (in Thai)*, A Thesis, submitted for partial fulfillment for the master's degree of Arts to the Department of Archaeology, Graduate School, Silpakorn University. 70.
- Pattanaanek, W., 2000, *The Evolution of Communities and City Planning (in Thai)*, Pathumtani, Rangsit University Press. 23.
- Phiyakul, C., 1999, *Phang (man-made pond) in Sating Phra Peninsula (in Thai)*, in *Encyclopedia of Thai Culture (Southern Thailand)*, Bangkok, The foundation of Encyclopedia of Thai Culture, Siam Commercial Bank. 5342-5345.
- Praicharnjit, S., Dityadet, P. and Phomanot, S., 1996, *Cities and Communities in Lanna period (in Thai)*, Bangkok, The Secretariat of The Prime Minister.
- Sangwan, N., 1981, *The Studies of Ancient Cities in Northeast Thailand (in Thai)*. *Silpawattanatham* 25, 1 (March). 47-48.
- Saraya, T., 1994, *History of Thai people (in Thai)*, Second Edition, Bangkok, Siam. 78-79.
- Sdok Kok Thom (n.d.)*, Website:  
[https://en.wikipedia.org/wiki/Sdok\\_Kok\\_Thom](https://en.wikipedia.org/wiki/Sdok_Kok_Thom)
- Sihamat, A., 2017a, *Irrigation System and Water Control in Ancient city of Sukhothai Part I (in Thai)*. *Silpakorn journal* 60, 4 (July-August). 26-27.
- Sihamat, A., 2017b, *Irrigation System and Water Control in Ancient city of Sukhothai Part II (in Thai)*. *Silpakorn journal* 60, 5 (September-October).
- Songserm, P., 2011, *The Studies on Canals in Ayutthaya period (in Thai)*, A Thesis Submitted for Partial Fulfillment for The Bachelor's Degree of Arts to the Department of Archaeology, Silpakorn University. 71.
- Srisuwan, A., 2014, *Wiang Kum Kam. In Chiang Mai City: Architecture and Beliefs (in Thai)*, Chiang Mai, Faculty of Architecture, Chiang Mai University. 27-62.
- Steward, J. H., 1955, *Irrigation Civilizations: A Comparative Study*, Washington D.C., Pan American Union.
- Suksom, N., 2002, *Historical Archaeology in Surat Thani (in Thai)*, Bangkok, Nakhon Si Thammarat Archeology and National Museum Office 11. 67-68.
- Supajanya, T., 2001, *Canal Cities: the Wisdom, of City Establishing from the Past to Rattakosin period (in Thai)*. In *Geography and Thai Lifestyle*, Bangkok: Princess Maha Chakri Sirindhorn Anthropology Centre (Public Organisation). 313-315.
- Surarerks, V., 2001, *Geography and Thai Lifestyle: Hydraulic Society and the Spatial Analysis (in Thai)*. In *Geography and Thai Lifestyle*, Bangkok, Princess Maha Chakri Sirindhorn Anthropology Centre (Public Organisation). 44-46.
- Tanabe, S., 1975, *Irrigated Agriculture in the Thai Economic History (in Thai)*. *Thammasat University Journal (Bangkok)* 5, 2: 80-94.
- Walipodom, S., 1982, *The Development of Settlements in Southern Thailand in Srivijaya Period (in Thai)*. In *Archaeology in Srivijaya period conference report*, Bangkok: Phikaneth. 134-142.
- Wongtes, S., 1984, *Phayao Ancient City*, Bangkok: Matchon.
- Unjaijin, K., 2016, *Old and New Ping River and Water Management in Ancient City of Chiang Mai (in Thai)*, *Sipakorn Journal*. Vol. 59, 2 (March – April, 2016).