Living with Inundation and Dehydration:

Comparison of the Adaptive Landscape in the Chao Phraya and the Bangpakong River Deltas

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Abstract

This paper compares the research outcomes regarding the two river deltas in the central part of Thailand: the Chao Phraya River – CPR and the Bangpakong River – BPR. The most common feature of the river deltas in this region is an ecosystem landscape that fluxuates throughout the year. These river dynamics are known as the pulse flow, which influences the way of life of riverfront communities and agriculture. The pulse differences are high and low in magnitude on the scale of a day, a lunar calendar month, annual seasons, a century, or even a longer period. The objectives of this study are to understand how people's lives are affected by water to understand the dynamics of nature when living under different circumstances, such as inundation or dehydration. Primary data from prior observations and field surveys of the two rivers are analyzed and the recent impacts from anthropocentrism, including using waterways as sewage channels for decades, are assessed to seek connections with nature and other forms of life. The conclusion leads to the understanding of the transboundary nature in multidisciplinary research and holistic approaches to integrate bioengineering and local wisdom into planning and design, which will offer the most efficient instruments for sustaining waterfront development and transition into the coming of a new epoch of ecological naturalism.

Keywords: *Chao Phraya River, Bangpakong River, Adaptive Landscape, River Delta, Cultural Landscape, Thailand*

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Introduction

Human Settlement and the Relationship to the Cultural Landscape

The river delta in Thailand has a long history of ancient settlements, empires and kingdoms. There is evidence of ancient settlements in U-Thong in 500 BC, the Dvaravati period in the first millennium AD, and especially during the Ayutthaya Period (1550-1767), the most significant period of the Ayutthaya kingdom, where the kingdom developed trade activities along the canals connected with the Chao Phraya River through the Gulf of Thailand. Later, in 1768, during the reign of King Taksin the Great, Thonburi, which is on the opposite side of the Chao Phraya River from present Bangkok, was chosen as the new capital after Ayutthaya was totally burnt by the enemy and could not be rehabilitated. Many studies stated that Thai people of the past were accustomed to river floods and developed a way of living in this vast floodplain, and during battles, the Thai or Siamese military wisely used the long inundation during flood times in the delta as a natural barrier against the enemy. Then, at the end of the eighteenth century, the capital was transferred to Rattanakosin and later named "Bangkok." The Thai people started the reclamation of the young delta, and agriculture gradually shifted to an export-oriented rice monoculture (Ishii, 1978, cited by Tuan & Molle, 2000). The settlements along the canal embankments and some older and cluster-type villages to the north of the delta showed the best characteristics of the cultural landscapes of the delta.

Traditional ways of living with water in the Thai cultural landscape have also been strongly related to the physical locations of rivers and deltas. In addition, there were canal excavations to provide short cuts between the river and canals to join the waterways to facilitate waterway traffic. Excavating laborers were typically drawn from the king's conscription. Land development in the periods of Thonburi and King Rama III (1768-1851) in the Rattanakosin era was similar to that of the Ayutthaya period, whereby canals were excavated to provide short cuts to the river and to join rivers together for the purpose of faster and convenient trade routes and city moats were dug as defensive barriers. During the reign of King Rama IV (1851-1868), the excavation of canals facilitated an increase in the area for paddy fields, as well as sugar transportation from the main sugar-cane belt, such as Nakhon Chaisri. The government carried out canal excavation with the aim of changing wild land into farmland. These canals were excavated for transportation and irrigation use on the western side of the Chao Phraya River. King Rama V (1868-1910) created "the Canal Department" to look after canal excavation along the Chao Phraya delta to enhance the importance of communication and transportation with foreign countries (Jarupongsakul & Kaida, 2000).

The history of the region also provides a sense of identity and traditional wisdom, both in the case of the Chao Phraya River watershed (20,298 sq. km) – CPR – and in the case of the Bangpakong River watershed (20,440 sq. km) – BPR. Especially in the CPR case, we found a paradigm shift and the invention of best practices for future generation flood protection using 'the meaning and spirit of cultural landscape' model. The cultural landscape and the waterfront landscape change and shift the Thai way of life, which may severely impact the country's sustainability and food security for future generations. The incorporation of information about

a river's natural resources and cultural history should also be conceptualized into the design of riverfront features. Finally, adopting local wisdom-based community participation should be encouraged to mitigate the future impacts of riverfront construction (Aruninta, Matsushima and Phukumchai, 2020).

Another case on the BPR, the US$43 billion Eastern Economic Corridor - EEC mega-project, will be expanded into a very fragile wetland of the BPR Basin, Chachoengsao, Thailand, in the east of Bangkok. This large-scale economic development plan will affect the cultural landscape of the riparian area, where there are the following three different types of ecosystems according to the seasons in a year: 1) fresh, 2) brackish and 3) salt waters. The dynamic nature of the BPR has played a crucial role in the breeding and feeding of various aquatic vegetation and animals, especially those contributing to household food security. The environmental attractiveness of an area, as a valuable resource, can attract investment and jobs and enhance the value of property in the longer term, as in the following 4 proposed themes: 1) ecological service, 2) hybrid farming agriculture, 3) aquaculture, and 4) cultural landscape and resilient communities (Aruninta and Dhammasiri, 2021).

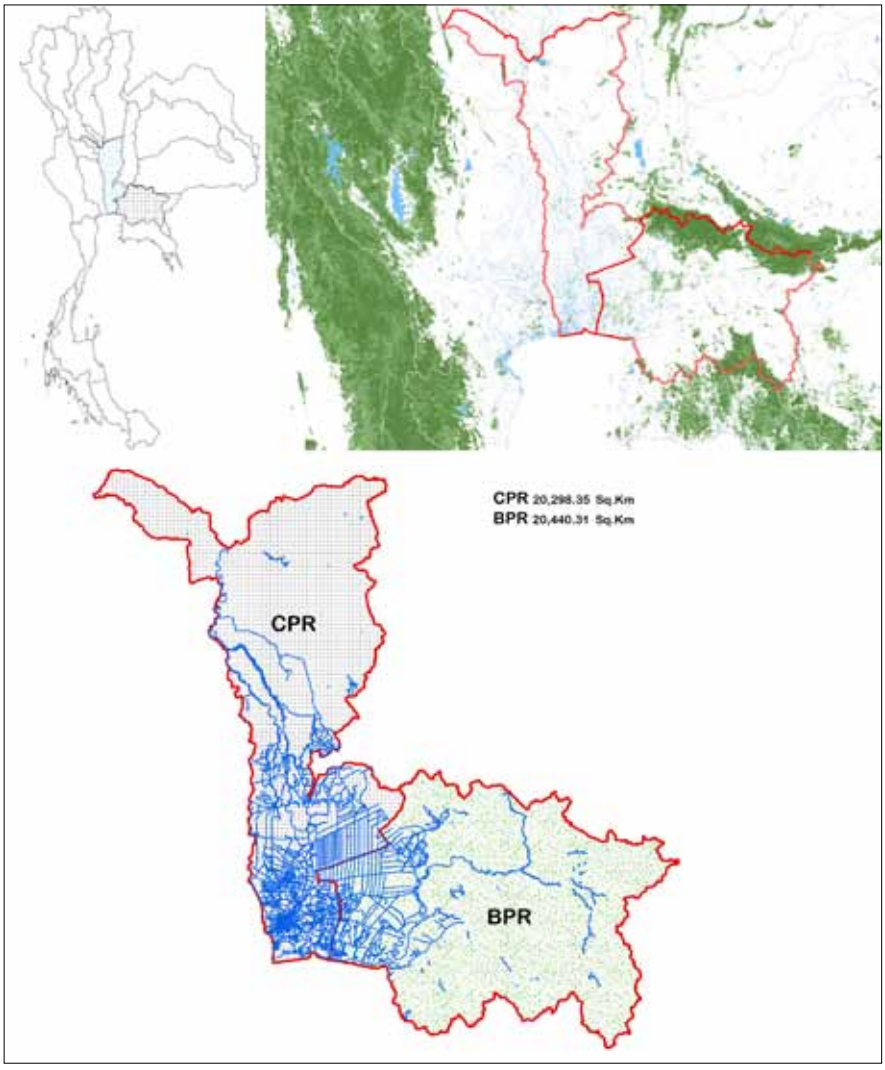

Figure 1. Research project location map on the Chao Phraya River (CPR) & the Bangpakong River (BPR).

Understanding the Dynamics and Consequences of Nature

As also mentioned in many studies, people living in the Tropical Zone, specifically Southeast Asia, seem to live with nature and their surrounding environment by developing various agrarian systems according to the ecological conditions of their environments (Kaida 1991, cited by Tuan & Molle, 2000 ibid). They have adaptive strategies to deal with the natural parameters (soil, relief, rainfall, flood, etc.) while gradually engaging in endeavors to modify these conditions through different engineering and technological innovations (dikes, canals, lifting devices, genetic crop improvement, etc.). However, the ecological conditions in flood-prone lowlands are unsuitable for any crop other than rice. Raised bed systems, with partial or full protection from the flood regime, are under development in southeast Asian deltas, including the CPR delta (F. Molle et al., 1999). A total of 300,000 ha in the CPR delta are still cropped with deepwater and floating rice varieties (Chompadist, Molle and Durongdet, 2000). They have also resorted to the raised bed technique to polderize this old tidal marsh and have built a huge canal network to ensure drainage and irrigation year round; thus, farmers in this area are able to grow a vast range of vegetables and fruits (Cheyroux, 2000).

The river basins in the central part of Thailand have a strong sense of identity and traditional wisdom regarding the amphibian nature of the delta area, where the traditional houses were built on stilts that let the high tides flow underneath the house. There are a number of Buddhist temples and monasteries in the area, and the front entrances are located toward the waterfront. In front of the temple gateways, there are always fish sanctuaries to welcome kindhearted Buddhists at the boat pier. In the past, the land behind waterfront houses was typically used for agriculture; paddy fields and vegetable farms were located in the upstream and midstream areas, and fruit orchards, flower groves, and vegetable gardens were located in the downstream areas.

In addition, Thai traditional ways of life also have a strong relationship with water, such as the Songkran 'Water' Festival, which is held from 13th – 15th April (Thai New Year's Day), where participants splash each other with water. In addition, on the day of the full moon in November, there is another water related festival called Loi Kratong, which is when Thai people pay respect to the river goddess by letting their suffering float away into the river in small flower pontoons. The riverfronts have offered them access to the water in everyday life and for those special events. Therefore, the tangible edge of the water and the intangible cultural landscape have met each other where the land, water, and people rely on the same river.

Most of the region is originally lower than the level at high tide. The tidal plain of the delta is the region where a direct impact from a rise in the sea-level may occur. Coastal erosion is already in progress, and there is a possibility that the region may become submerged if the sea level rises. The acceleration of bad drainage conditions is anticipated in the deltaic plain because the surface gradient of the region is very low and the relative drainage gradient will decrease as the sea level rises. As there is little relief in the deltaic plain region except for artificial re-

claimed land, the impact of a rise in sea level might be widespread. The land subsidence of the region also accelerates the effect of the sea level rise. In the deltaic floodplain, differences in flooding conditions can be observed in relation to the microscopic landforms. Natural levees and other higher places suffer little flooding or escape flooding. In contrast, swampy areas of a flood basin suffer severe flooding. Most floods develop in areas surrounded by natural levees. The flooding conditions may be accelerated due to future sea-level rising. (Umitsu, 2000). Hungspreug, Khao-uppatum & Thanopanuwat (2000) suggested that the causes of floods, in general, may come from the following two main sources: nature and human intervention.

Natural causes include 1) overbank flow, 2) heavy rainfall, and 3) tidal influences. Man-made causes include 1) deforestation, 2) uncoordinated development, 3) destruction of flood embankments, and 4) over abstraction of groundwater.
They also concluded that in addition to the natural causes, several human intervention activities, such as land use in flood risk areas, development of upstream areas, operation of flow control facilities such as dams, and coordination among agencies concerned with flood management, are associated with the increase in flood damage.

Although flood protection work in the lower part of the CPR basin was implemented by the government, annual flood disasters have continuously occurred with even more impacts. Aruninta (2018) categorized the ways to prevent floods as follows: 1) land treatment, 2) floods and floodplains, 3) dams and reservoirs along with baffles, 4) levees-walls, 5) channel alterations, 6) diversions, 7) detention-retention, and 8) landfills. Flood control facilities included grey infrastructure along the CPR banks to prevent overflow into the cultivating lands. A series of dikes on the eastern side of Bangkok and permanent pumping facilities were constructed to prevent water from flowing into residential areas and to drain rainwater into the river. Flooding of the city of Bangkok and the surrounding suburban areas occurred much more often during the last decade due to several reasons, such as heavy local rainfall and changes in land use from agriculture to industrial and residential areas (Jarupongsakul & Kaida, 2000 ibid).

Although efforts have been made to mitigate flood damage in many river basins through the construction of dams, reservoirs, dikes and pump stations, flooding problems still persist due to the increase in flood discharge as a result of deforestation, expansion of farmlands and urban areas, etc., in line with economic growth. The flood damage potential is increasing due to rapid urbanization and land development in downstream areas, particularly the Bangkok metropolitan area and other municipalities along the CPR. A disastrous flood occurred in October 1995, resulting in extensive damage to property and loss of human lives. Thailand's worst flood in 2011 demonstrated that not only people and their properties but also public facilities in the floodplains of the CPR basin were at risk. Similar to the 2011 flood in South Korea, which was the largest single-day rainfall in July since records began in 1907, experts and news media also attacked Seoul city authorities, accusing them of making the situation worse through an allegedly

reckless development of hills near residential areas in the south of the capital. Some residents living under Mount Umyeon in southern Seoul, where eight landslides occurred, believe the disaster was preventable (Agence France-Presse, 2011). In contrast, the characteristics of delta land and the network of canals make the area more suitable for agriculture rather than residential or industrial purposes, but for the past three decades, the country's development has been concentrated on promoting industry as a replacement for agriculture. Jarupongsakul & Kaida (2000 ibid) also discussed the water management issues in the CPR delta and argued that they would become much more complex and increasingly important in the near future, and this in turn would have a definite impact, both positively and negatively, on the future land and water development of the Rangsit area. As a result, there has been more investment in various areas, reflecting the rapid growth of the community and economy and the transformation of agricultural land to other land uses. Such rapid urbanization has caused unplanned development, especially in cities that have received economic policy support. Currently, since there is no effective control of land use planning, and the limited capabilities of the government sectors, poorly coordinated planning, and poor administration have resulted in more serious and complicated problems. Development and urbanization have created sprawl. The unplanned expansions along major infrastructure networks have resulted in inefficient land use. The developments created ribbon-shaped pieces of land that led to super blocks, blind land, urban voids and vacant spaces (Aruninta, 2009). Similarly, the construction of roads, buildings, facilities, cultural and service centers are considered problems of urbanization (Hnes & Cherevko, 2017); without effective control, unplanned sprawl and expansion switched the waterfront communities to their backs and made it difficult to construct systematic and interconnected infrastructure networks. sois (small lanes), walkways, sewer and storm drainage channels, etc. The river and canal systems occasionally become sewer drainage ditches, parts of which have been filled up for accessibility purposes, and heavy rainfall and high tidal action cause frequent flooding.

The energy issue seems to be another factor; the Thai energy generation system was based on hydroelectricity. Thus, this is a controversial issue, as the Electricity Generating Authority of Thailand - EGAT is often accused of using huge amounts of water for the sake of only energy generation, which depletes the water stocks available for agriculture, energy generation and dam management, and must be adapted to changing conditions (Molle et al., 2001). In addition to hydroelectricity, water has become a very significant resource, so large-scale development of irrigation has long been an attractive option for postwar development. Thailand has developed approximately four million hectares of irrigated land, and its northeastern region (Isaan)—both the driest and poorest part of the country—has been the target of many water management projects (Molle & Floch, 2008).

The natural phenomena of floods and droughts are the major routine disasters involving water management, especially from hydropower dams. Floods are a natural phenomenon, and while residents have adapted their lifestyles to deal with annual flood occurrences, they cause significant economic losses. The major causes

have been the decline in flood retention and the confinement of flood plains due to increasing development, the rapid urbanization around Bangkok, the growth of provincial cities and the intensification of agriculture (ONWRC, 2009). The CPR Delta suffered from severe flooding in 1980 and 1983 and, most recently, experienced the so-called "Worst Flood in Thailand's" in 2011, which submerged cities, industrial parks and ancient temples, and water management experts blamed human activity for turning an unusually heavy monsoon season into a disaster. According to the flood volume, flood mitigation cannot occur without having an effect. Therefore, the idea of His Majesty King Bhumibol Adulyadej was applied, known as the 'Monkey Cheek Principle' or flood retention pond, which uses lowlands for water retardation. The implementation involved using lowlands, which are located in the upper parts of the communities, as the retention ponds. At a specific duration, there are water-control buildings and equipment to control the in- and out-flow of water. For purpose is to control the water volume in the lowlands before the flooding season by using drainage or pumping water from the lowlands into the main river to the extent that the river can support the water; the main river can support the excess water from the lowland; therefore, floods will not affect the lower community.

The development of a flood retarding area is one of the measures for flood mitigation in the CPR Basin. It helps to decrease the flood volume or water volume in the rivers during their peak period. The method of diverting water into retarding areas within the determined time and criteria is specified. If the maximum volume of water is higher than the determined volume, the flood-retarding areas cannot support flood mitigation. The flood retarding area development therefore needs to be combined with heavy rain and high tide flood management to increase the drainage efficiency in the areas (UNESCAP, 2009).

These aforementioned problems resulted from continuous field visits over many years. The authors categorized the spaces and structures located on the waterfront and made it difficult to access the rivers as the communities did in the past. The observations found built structures that can be divided into the following two types: 1) flood walls and 2) flood terraces.

Recently, anthropocentrism has left behind waterways that were used as sewage channels for decades, canals that were replaced with roads and highways to mobilize cities, and the fear of seasonal inundation, so-called *'antlophobia.'* At the same time, in this dichotomous world, engineering technology under drought climate pressure and *'aridita*phobia,' that is, the fear of drought, has tried to introduce the construction of larger dams. Therefore, it is time to return to nature as in the former time and support the coming of a new epoch of ecological naturalism or der ökologische naturalismus (Oechsle, 1988), a subset of biophilia (Wilson, 1984), which is the idea that humans possess an innate tendency to seek connections with nature and other forms of life.

Methodology

The results from prior studies on the CPR (Aruninta, Matsushima & Phukumchai, 2020 ibid) raised the question of whether we should live our life to achieve economic development or turn back to our origins. The studies concluded that best practices in the design and planning of riverfronts should be emphasized and conceptualized into the design of riverfront features. Then, adopting local wisdom-based community participation should be encouraged to mitigate the future impacts of riverfront construction. In the BPR delta, we found 'Na Kha Wang' hybrid farmers (Figure 2), who cultivated rice during the rainy season and adapted the same piece of land to aquaculture (Aruninta and Dhammasiri, 2021 ibid), including crabs, shrimps, mussels, prawns, and shellfishes. Rice-aquaculture hybrid farming (Reddy and Kishori, 2018) usually uses fewer pesticides and are occasionally organic because the saline environment limits the weed and pest populations. This sequential/rice-aquaculture rotation/alternate farming begins annual rice production around September – October, and the harvesting season begins in December; then, the area is irrigated with sea water and the aquatic species (ASp) that come from outside through sea water or are cultivated within the land are grown.

Figure 2. Left, traditional Thai houses, which are usually raised on stilts and are flood resilient in the CPR delta. Right, 'Na Kha Wang' site preparation in the rainy season (September) for rice farming after aquaculture farming in the BPR delta.

Especially in the Tropical Zone, it is crucial to understand the natural processes of *flood pulse and flow* for floodplain restoration because inundation (wetting) and dehydration (drying) and input of river-derived nutrients result in high floodplain productivity, and natural river floodplains are highly productive and diverse ecosystems (Keizer et al., 2014). Thus, the authors will assess the primary data from the prior observations and field surveys of the two rivers and discuss them more specifically to discuss the influence of the built infrastructures on both river basins, theoretically comparing them with the natural flood pulse adaptations by the local communities.

Figure 3. Fruit orchard farmers adapt to high saline soils and seasonal pulse flows by digging ditches and adding earth mounds to form different types of plant beds..

Upstream	Midstream	Downstream
Sta1-CPR: Shrine/Rim Kheun 15°41'59.9"N+100°08'31.8"E	Sta6-CPR4: Wat Phanan Choeng, Ayutthaya 14°20'40.6"N+100°34'42.1"E	Sta10-CPR8: Koh Kred, Nonthaburi 13°54'46.2"N+100°29'30.1"E
Sta2-Nan1: Paknam Po Railway Station 15°42'17.1"N+100°09'11.9"E	Sta7-CPR5: Wat Chaiwattanaram 14°20'34.0"N+100°32'34.7"E	Sta11-CPR9: Lad Po, Samut Prakarn 13°39'49.9"N+100°32'20.4"E
Sta3-Ping1: Wat Thep Samakeetham 15°43'51.2"N+100°07'22.3"E	Sta8-CPR6: Bang Baln/Embankment 14°25'29.9"N+100°29'09.3"E	Sta12-CPR10: Butterfly Fort, Samut Prakarn 13°36'00.5"N+100°35'14.4"E
Sta4-CPR2: Chao Phraya Dam, Chainat 15°09'28.9"N+100°10'48.0"E	Sta9-CPR7: Silpacheep Bangsai 14°09'08.2"N+100°30'57.5"E	
Sta5-CPR3: Wat Pa Kwai Beach, Singhaburi 14°48'55.5"N+100°26'27.1"E		

Figure 4. Table of the locations of the CPR survey stations are divided into upstream (Sta1-5), mid-stream (Sta6-9), and downstream (Sta10-12) - March 2016.

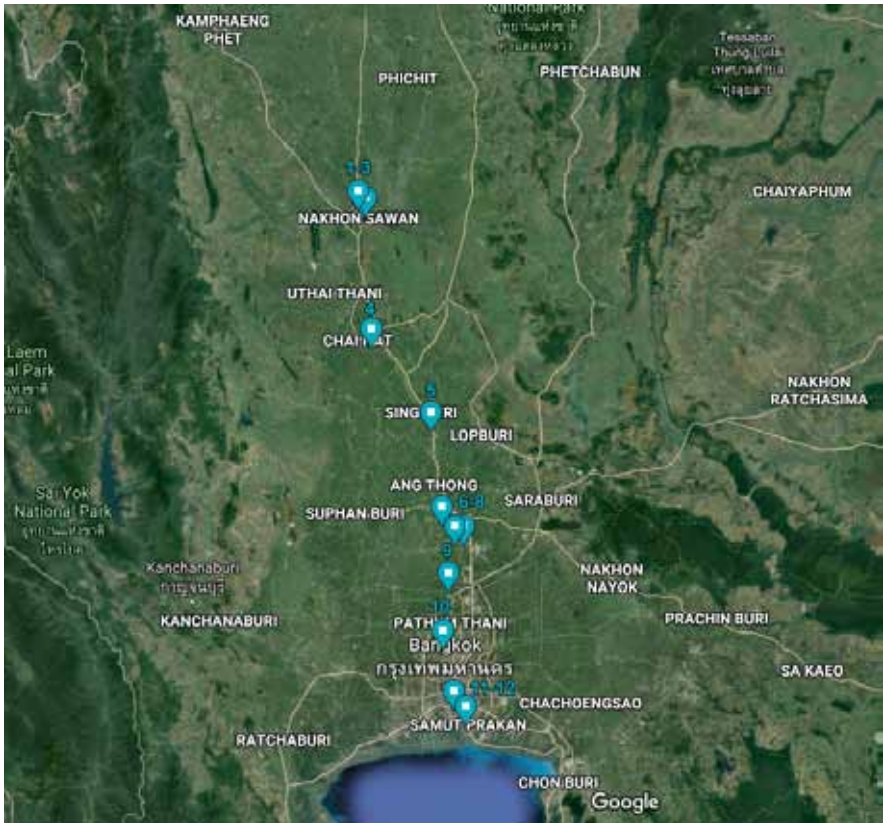

Figure 5. Location map of the CPR survey stations.

Station	Location	
Sta1 - Wat Bang Taen BPR+Nakhon Nayok	13° 54' 4.320" N	101° 10' 3.216" E
Sta2 - Integrated Orchard Ban Songsana	13° 49' 6.276" N	101° 10' 23.952" E
Sta3 - Phra Sathup Chedi (Paknam Jolo)	13° 44' 23.136" N	101° 12' 37.728" E
Sta4 - Irrigation canal	13° 44' 27.240" N	101° 7' 59.484" E
Sta5 - Ama Shrine	13° 40' 6.924" N	101° 3' 48.528" E
Sta6 - Wat Ban Pho	13° 34' 59.196" N	101° 4' 10.884" E
Sta7 - Khao Din (Na Kha Wang)	13° 32' 31.776" N	101° 2' 26.952" E
Sta8 - Klong Om Kaeo (Amata Industrial Estate)	13° 28' 49.044" N	101° 0' 28.548" E
Sta9 - Klong Tamru (Salt Farm)	13° 26' 8.628" N	100° 59' 50.856" E
Sta10 - Bang Pakong EGAT Training Center, Electricity Generating Authority of Thailand	13° 28' 27.048" N	100° 58' 51.384" E

Figure 6. Table of the locations of 10 BPR survey stations (Sta1-10) - February 2020.

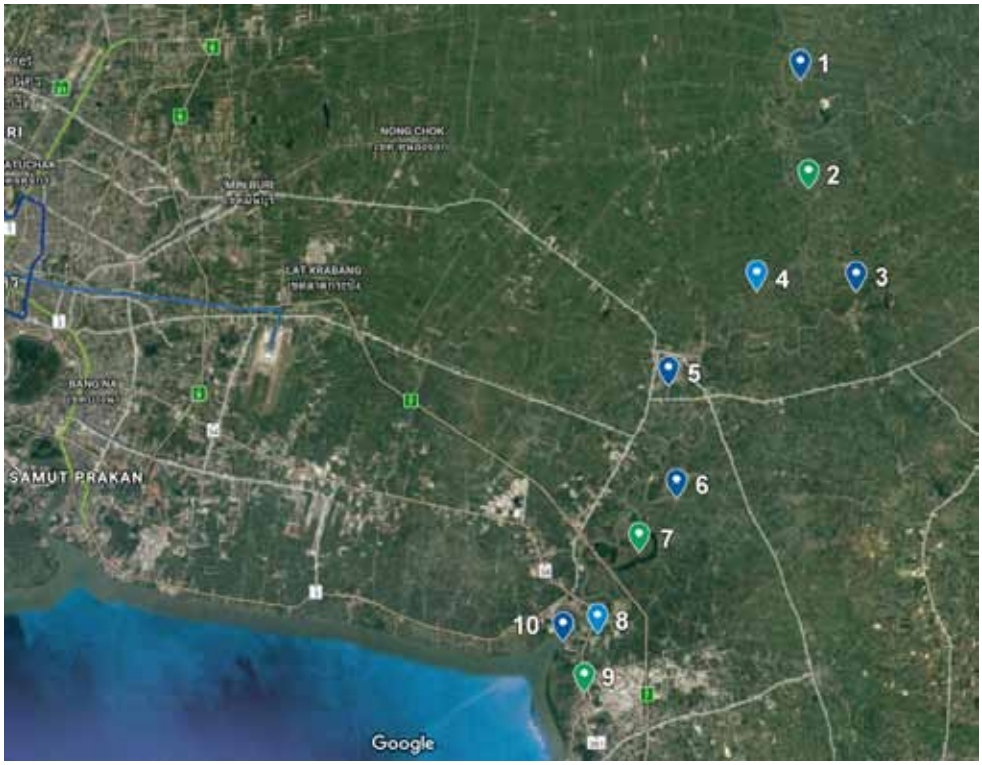

Figure 7. Map of the locations of the BPR survey stations.

Findings and Discussion

The original settlements along the canal embankments and some older and cluster-type villages of the areas show the best characteristics of the delta cultural landscapes. While urbanization is a threat and affects the transformation of agricultural land into modern urban life estates, there are a few places that still allow visitors to feel the tranquility of the old days. Some of them are the main attractions for canal cruise tourist routes that arrive by boat. The canals are commonly controlled by floodgates, so tourists usually come in small groups using long-tail motor boats to explore the communities and learn about living on the water. Agro-tourism and gastronomy tourism in this unique cultural landscape are attracted by the resilience of farmers to seasonal inundation and dehydration – the so-called flood pulse – and the ecological services that secure their food sustainably. The lifestyles of the old communities were simple and their lives are lived on the canals, e.g., taking baths, brushing teeth, washing, using canal water for drinking and cooking, and even defecation. There are a few store boats and postal service boats; in the mornings, monks from the Buddhist monastery along the canals will row their boats to obtain food from door fronts, and peddlers sell fresh vegetables, fruits, meat, flowers, old style brew coffee, and household goods.

During the past few decades, younger generations have tended to work in the city and commute to their offices by car, and backyard orchards have been transformed to garages and paved to form small access roads. Elderly people cannot engage in planting. Hence, orchards and gardens have been abandoned. Families usually owned large plots of land, including a traditional cluster house for extended family, such as grandparents, daughters/sons, and granddaughters/sons, which were later were divided into the more individual detached houses.

CPR Survey in March, 2016	BPR Survey in February 2020
 Shrine/Rim Kheun - 15° 42' 0.741" N 100° 8' 31.785" E	 Wat Khanak - 13° 52' 25.958" N 101° 8' 26.786" E
 Chao Phraya Dam - 15° 9' 31.101" N 100° 10' 48.274" E	 Bangpakong Barrage - 13° 42' 27.6" N 101° 08' 06.8" E
 Wat Pa Kwai Beach - 14° 48' 53.241" N 100° 26' 15.025" E	 Tha Sa An - 13° 32' 41.125" N 100° 59' 38.519" E
 Bang Baln flood wall - 14° 25' 30.642" N 100° 29' 9.120" E	 Klong Om Kaeo - 13° 28' 52.365" N 101° 0' 24.690" E

Figure 8. Concrete structures along the CPR & BPR banks for flood protection and irrigation purposes.

The significant findings on both rivers are the influences of the dynamic ecosystem landscape, especially the pulse flow, which has formulated the way of life of the riverfront communities and agriculture, and how people live with water to understand how the dynamics of nature affect life in different circumstances. When anthropocentrism approached, people tended to leave behind the waterway as their sewage channels. Even though the high and low pulse differences occur on the scale of a day, a lunar calendar month, annual seasons, a century, or even a longer period, the combination of the two fears of '*antlophobia*' and '*ariditaphobia*' throughout the year, therefore, has led to grey infrastructures and developments along the rivers and their watersheds. These separate structures were found to impact not only the waterfront landscape (Figure 6) but also the mindset of the communities and organizations involved.

Conclusion: Formulation of a Creative & Adaptive Landscape

A new epoch of '*ecological naturalism*' is coming, which is a subset of 'biophilia,' which is the idea that humans seek connections with nature and other forms of life. To integrate bioengineering and local wisdom into design and planning, people must understand the dynamics of nature and adapt themselves to mitigate and remediate to create more sustainable and resilient development. The conclusion leads to the understanding of the transboundary nature in the multidisciplinary research and holistic approaches to Earth science, environmental science, and human geography or anthropogeography and their relationships with communities, cultures, and economies and interactions with the environment across locations. The best management practices – BMPs – especially in stormwater management, green infrastructure and low impact development (LID) practices, which minimize impervious surfaces and avoid large grey infrastructure and land disturbance by using bioengineering and maximizing the retention of native vegetation and soils, should be introduced as an approach to land development (or redevelopment) that addresses nature resiliency, similar to how the local wisdoms were applied in former times.

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