Università Politecnica delle Marche
Scuola di Dottorato di Ricerca in Scienze dell'Ingegneria
Curriculum in "Environmental heritage and Sustainable changes", 15 ciclo nouvo serie (XXIX)

HERITAGE AND CLIMATE CHANGE: URBAN AND ARCHITECTURAL PERSPECTIVE FOR "FLOODSCAPE" IN QUANG TRI PROVINCE

Ph.D. Dissertation of:

Nguyen Huu Long Phung

Advisor:

Prof. Arch. Antonello Alici

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Dipartimento di Architettura Rilievo Disegno Urbanistica Storia
Via Brecce Bianche — 60131 - Ancona, Italy

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Abstract

Vietnam is one of the five countries likely to be most affected by climate change.
According to the report of EM-DAT (the Emergency Events Database), an estimated damage of $2,600 billion was caused by natural disasters damaged in the last twenty years (1994-2013). Flood alone accounted for 47% of all weather disasters, affecting 2.3 billion people (the majority of whom (95%) live in Asia). In Vietnam, about 649 natural disasters occurred in the last ten years (2005-2014), including flood, flash flood, hail, storm, cyclone and landslide. Total damage was estimated at approximately 1.5% GDP per year. There were 160 floods and flash floods occurred at that time and accounted for 58% of the total damage. In the future, climate change has increased the average surface temperature, changing the average rainfall, increasing frequency of extreme weather events and especially the rising of sea level that will increase flood risks and negative impacts of flooding to people and properties.
Meanwhile, heritage is the quintessence of a long process of development by humans. The heritages that characterize the values of culture and history of each nation, country or region; but it does not have the ability to adapt to changes in the weather or disasters of climate change. The changes in the weather and disasters happen every year and they directly affect the heritage. Consequences have been cumulative and results are that some of heritages have been corroded, several heritages have been destroyed a part and a few heritages have been totally damaged. Facing that situation, if there are no adaptive solutions to adapt to the disasters of climate change, the heritages will be gradually lost. Although Vietnam does not have more disasters such as earthquakes, volcanoes, country has influenced heavily by disasters related to water factors, such as flood, tsunami, hurricane or drought. This research is the study of the relationship between climate change and heritage, impacts of flooding on heritage and building the map of flood risk for heritage system in Quang Tri Province. The map showed that 87.5% of the heritages are located in flood risk area (189 in 216 heritages) and 4.2% of the heritages are located in high and very high-risk level. Solutions to response and adaptation to climate change for the heritages have been studied and proposed. Characteristic of flooding is usually happening on a large scale and keeping in 2 or 3 days. Therefore, to reduce flood risks for heritage, the solutions were developed based on spatial planning, urban planning, urban design and architecture design for heritage, corresponding to three steps: direction, storage and absorption. Although the solutions are not mostly complete, the adaptation requires time to application and filter in order to select the most effective solutions for practical application. In addition, the research is not only a basis for conservation but also a long-term orientation for design and urban planning toward sustainable development.

Sommario

Il Vietnam è tra i cinque paesi principalmente interessati dal cambiamento climatico.
Secondo il report EM-DAT (the Emergency Events Database), si deve a disastri naturali un danno pari a $2,600 billion nell'ultimo ventennio (1994-2013). Alle sole alluvioni si imputa il 47% dei suddetti danni a scapito di una popolazione di 2.3 billion, la maggior parte della quale asiatica, il 95%. In Vietnam, sono stati circa 649 gli eventi calamitosi tra il 2005 e il 2014: alluvioni, inondazioni, grandinate, tempeste, cicloni e frane. Il danno totale è stimato approssimativamente all'1.5% GDP all'anno. 160 alluvioni e inondazioni si sono susseguite causando il 58% dei danni totali.
In futuro il cambiamento climatico causerà l'aumento delle temperature della superficie terrestre, il regime di caduta delle pioggie con la crescita di eventi meteorologici estremi, con l'aumnto del livello del mare, il rischio di alluvioni e i relativi impatti sulla popolazione e sui territori.
Parallelamente a ciò il patrimonio culturale materiale e immateriale frutto di un lungo processo di sviluppo umano, rappresenta i valori culturali e storici del paese ma non è sufficientemente resiliente per adattarsi alle conseguenze del cambiamento climatico, che ogni anno colpiscono il patrimonio.
Le conseguenze di ciò si sono sovrapposte, danneggiando e distruggendo parzialmente e, in taluni casi totalmente, il patrimonio.
Affrontare questo quadro ambientale e climatico senza soluzioni di adattamento, porterà alla perdita di detto patrimonio e sebbene il Vietnam non sia soggetto a terremoti o eruzioni vulcaniche, esso è ampiamente soggetto a disastri dovuti a fattori climatici, quali alluvioni, tsunami, uragani e siccità.
La presente ricerca studia la relazione tra il cambiamento climatico e il patrimonio, l'impatto delle alluvioni sui monumenti e intende proporre una carta del rischio per il sistema del patrimonio di Quang Tri Province.
La mappa ha mostrato che l'87,5% dei monumenti si trovano in aree a rischio (189 siti su 216) e il 4,2% dei patrimoni si trovano in aree ad alto rischio.
Soluzioni per contrastare e adeguarsi al cambiamento climatico sono state studiate e proposte, al fine di contenere il rischio alla scala della pianificazione territoriale, urbana e nella progettazione architettonica. In particolare il metodo di lavoro prevede tre fasi riferibili a momenti diversi alluvionali: direction, storage and absorption.
Sebbene queste non siano definitive ed uniche, l'adattamento richiede tempi di sperimentazione e selezione per individuare le migliori scelte per applicazioni pratiche; inoltre, la ricerca non pone solo le basi per la conservazione del patrimonio, ma anche indirizzi a lungo termine per la progettazione urbana ed architettonica secondo le direttive dello sviluppo sostenibile.

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Chapter 1.
Introduction

1.1. Background

Each country has its own peculiar characteristics of the natural conditions which decided to cultural, economic - social those countries. Quang Tri Province located on the 17th parallel in central of Vietnam, is one of the provinces severely affected by extreme consequences of weather and war. Even though resources of Quang Tri are plentiful and diverse, there is gradually lost or modified by negative impacts of climate change and consequences of weather change. The system of cultural heritage in Quang Tri that represents characterizes of culture, history and local people, is one of those.

The change of climate is seen as the direct cause of natural disasters, such as drought, extreme heat, hail, hurricane and tropical storm, landslide, tsunami, etc and the indirect causes of man-made disasters. With the increase in the number and level of danger, flooding is a natural disaster and impacting almost all of human activities. Meanwhile, in contrast to the modern buildings with new construction methods, new materials and high technology can respond to the flooding, the response of heritage buildings are usually "weak". Flooding is also an urgent matter affecting the existence of some historic cities, such as Venice (Italy), the city of London (England) or the historic centers of Cesky Krumlov and Prague (Czech Republic)), and other world heritage sites.

Assessing the impact of the flood risk on heritage is essential to establish an appropriate plan for the conservation and preservation. There are many methods to assessment. In which, building layers map that combined on flood risk map and the heritage map will determine a heritage situated in risk area or not? How is the risk level of it? And what are the factors?,etc. That will be the basis for proposing the most effective solutions for each heritage or region that ensures the planning of the national policy.

1.2. Overview of research issues

1.2.1. Climate change

According to United Nations framework convention on climate change, “Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Definition of climate change by IPCC (Intergovernmental Panel on Climate Change), “Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability as result of human

activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods".
In the research, climate change is seen as a change in the typical or average weather that includes patterns of temperature, precipitation (rain or snow), humidity, wind and seasons of a region or city in long-term, typically decades or longer.

1.2.2. Disasters of climate change

Disaster is defined as "an overwhelming ecological disruption occurring on a scale sufficient to require outside assistance" (PAHO 1980) or "Disaster are exceptional events which suddenly kill or injure large number of people" (Red Cross/Red Crescent).
However, the word disaster usually implies a sudden, overpowering and unpredicted event. It is necessary to differ between disaster and annual natural flood phenomenon. Disasters of climate change are cataclysms caused the change of climate. There are two various types of disasters, natural and man-made or technological, each of which can take many different forms, the duration can range from an hourly disruption to days or weeks of ongoing destruction and it could result in a financial damage, social, environmental and human depend on the level.

Table 1. Natural and man-made disasters

Natural types of disasters	Man-made and technological types of disasters
- Agricultural diseases & pests	- Hazardous materials
- Damaging Winds	- Power service disruption & blackout
- Drought and water shortage	- Nuclear power plant and nuclear blast
- Earthquakes	- Radiological emergencies
- Emergency diseases (pandemic influenza)	- Chemical threat and biological weapons
- Extreme heat	- Cyber attacks
- Floods and flash floods	- Explosion
- Hail	- Civil unrest
- Hurricanes and tropical storms	
- Landslides & debris flow	
- Thunderstorms and lightning	
- Tornadoes	
- Tsunamis	
- Wildfire	
- Winter and ice storms	
- Sinkholes	

Source: Author

1.2.3. Flood and flooding

A flood is an overflow of water that submerges land which is usually dry. The European Union defines a flood as a covering by water of land not normally covered by water (Directive 2007/60/EC Chapter 1 Article2).
A flood occurs and it may cause flooding. Flooding can be viewed as a natural disaster or a man-made disaster, such as flooding from a river, lake, stream, or ocean, in which the water overtops or breaking of man-made buildings (e.g., dike, hydropower plants), resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an heavy rain or extreme rain.

1.2.4. Floodscape

Landscape architecture is a multi-disciplinary design. It includes analysis, planning, design, management, environments that designed and developed on the land as presented in a book "Design on the Land: The Development of Landscape Architecture" (Norman T.Newton, Belknap Press of Harvard University Press). Floodscape has similar work with the landscape but it is seen as a smaller category and focuses primarily on flooded areas.

1.2.5. Climate change scenario

Climate change scenario is assumptions have scientific bases and reliability based on the relationship of economic, social, greenhouse gas emissions, climate change and its consequences.
Research data of climate change was based on the climate change scenarios which are developed and published by Ministry of Natural Resources and Environment in "Scenarios of climate change and sea level rise for Vietnam, 2012".

1.2.6. Heritage

The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) meeting in Paris from 17 October to 21 November 1972, at its seventeenth session.
Monuments are architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, art or science;
Groups of buildings are groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science;
Sites are works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view.

1.2.7. Limitations

- Research area: Although the plain area of Quang Tri Province accounts for 1/4 of the total area, but that's where frequent occurred and heavily affected by flooding. It also is a place where focuses largely residential, architectures and heritages. So, besides the overall assessment of the province's potential, research areas of the thesis is focused on low plains of Quang Tri Province (below 100 m elevation), excluding the dunes are close to the sea and islands.
- Architect's perspective: The issue of weather, climate change or flooding are extensive categories and be understood in many different meanings in different subjects. In the study, those issues are understood, acquired and developed to cater to the study on the subject of architecture.
- Material: Contrary to the climate change that already taking place for a long time, Quang Tri Province has been developing in recent years. Therefore, materials and technologies to measure and calculate the changes of climate are very limited. The study inherited the results of some research and used the collected data in a limited scope to research, evaluate and give proposals.
- Tangible heritage: The thesis focused research and assessment the impacts of flooding on tangible heritage.

1.3. Thesis structure

- Chapter 1: The first chapter is the beginning of the thesis to introduce the background of forming ideas, the recognition and relationship of the studied objects, methodology and logic in solving problems. Because an object can be acknowledged in many different ways and with different meanings depending on fields, scientific and technical level in places where the object exists, accessibility issues and in many other factors. In the thesis, the relationship among climate change, flooding and heritage to be considered from the perspective of an architect and based on the natural conditions, socioeconomic of Quang Tri Province, where has been converting from war remedial to socioeconomic development since 1975.
- Chapter 2: Each country has specific features of the geographical location, history, establishment and development process, etc, it makes a characteristic of that country. Similarly, each province or region in a country also has its own specific characteristics of natural conditions, culture, climate, socioeconomic, etc that create potentials as well as difficulties in that province or region. Quang Tri Province was located on the 17th parallel in central Vietnam, where frequent occurs climatic disasters such as floods, hurricanes, landslides, droughts. The history and development process of the province have left more than 600 heritages that were recognized by the Ministry of Culture, Sports and Tourism of Vietnam and People's Committee of Quang Tri Province, are an invaluable potential of Quang Tri Province. However, heritage potential exploration and heritage preservation and conservation are still many difficulties and limitations leading to heritages are gradually lost or negatively changed under the impact of climate and consequences of climate change.

Chapter 3: The change of climate is happening and changing every day, so climate change predictions should also be seen as temporary. Therefore, this chapter aims to summarize the evolution of the variability of weather factors on a global scale, in Vietnam and Quang Tri Province. It is a basis for evaluating the correlation between climate change and flood risk, and to prove that climate change is the cause both direct and indirect leading to flooding in Quang Tri. With an increase in the number and level of danger, floods had been affecting almost all activities of human life. Meanwhile, in contrast to modern buildings with high technology can respond to the flooding, ability to adapt and respond to floods of heritages normally is very weak, so heritage damaged or collapsed is inevitable.

- Chapter 4: Building a flood risk map for heritage by using overlay mapping method based on the flood risk map and the heritage map, is a useful tool for assessing the level of influence of floods on heritage. The flood risk map was inherited from the project "Natural disaster risk management project: Conducting field surveys and hydraulic modeling in the basin of Thach Han and Ben Hai River, Quang Tri Province", a study of Intellectual Vietnam Corporation and Hanoi University of Science (a member of Vietnam National University, Hanoi) while the heritage map was build from the administrative map of Quang Tri and surveys of current location of heritage. The map will show whether a heritage situated in risk area or not? How is the risk level of a heritage and why? That will be one of the grounds to propose the most effective solutions for each heritage, urban area or region.
- Chapter 5: Flood is a natural phenomenon, which seems to happen in the whole world. However, do not have a general solution for all the countries and heritages because of the differences of geography, culture, economic, social. There were many studies about the impacts of flooding in Quang Tri, but it mostly stopped in strategies, policies or general recommendations. In this chapter, proposals to response and adaptation to flooding for Quang Tri Province has been studied based on the conditions of the province. Those proposals were concretized in three steps: direction, storage and absorption (DSA). However, the adaptation to flooding is a process and it will be repeated several times to choose the most effective and suitable solutions to application and development.

In the case of Quang Tri Citadel, besides the proposals at an urban planning level, "wireframe" is a solution at a heritage level that was studied and proposed in order to preserve and conserve Quang Tri ancient citadel, one of the most important heritage of Quang Tri Province.

- Conclusion: From the given assumptions and was resolved through the chapters, research issues and objects were synthesized as well as oriented further.

Chapter 2.
Potentials of Quang Tri Province

2.1. Characteristics of natural and socioeconomic conditions of research area

2.1.1. Geographical location

Quang Tri is a province on the north central coast of Vietnam, 600 kilometers (km) north of Hanoi[1] and 1140 kilometers south of Ho Chi Minh[2]. The latitude and longitude of Quang tri is from 16°18' to 17°10' N and from 106°32' to 107°34' E. Quang tri Province is surrounded by Le Thuy District of Quang Binh Province in the north, A Luoi and Phong Dien District of Thua Thien Hue Province in the south, Salavan and Savannakhet Province of Laos in the southwest and west, and the East Sea in the east.

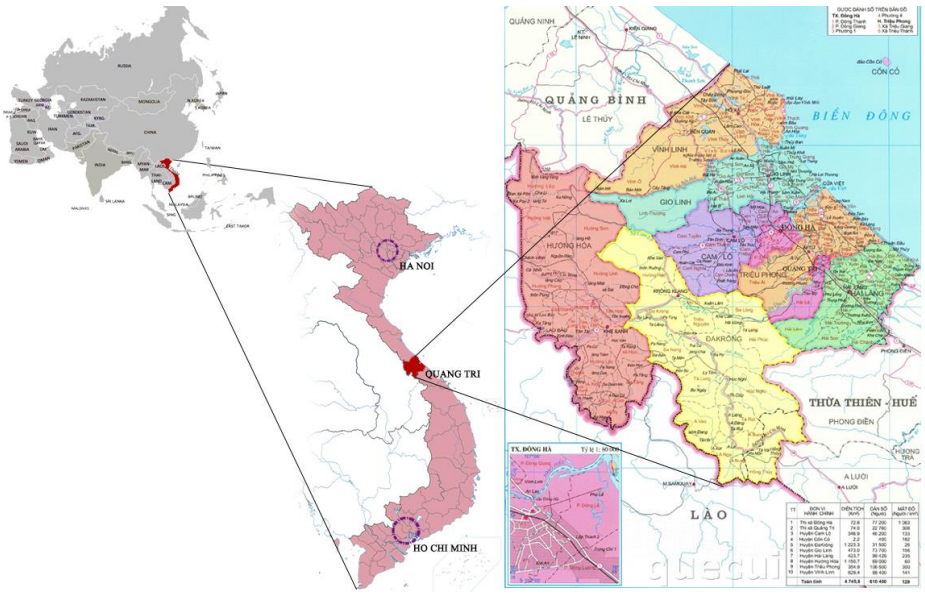


Figure 1. Geographical location map of Quang Tri Province
Source: Basemap: The electronic information page of Quang Tri Province (http://www.quang-tri.gov.vn), Edited by author.

[1] Hanoi is the capital of Vietnam and the country's second largest city
[2] Ho Chi Minh City formerly named and still also referred to as Saigon, is the largest city in Vietnam

It covers a total area of approximately 4,739.824 square kilometres (km2), Quang Tri is subdivided into 10 district-level subdivisions, including Dong Ha is the biggest city and the provincial capital of the Quang Tri Province, Quang Tri town and 8 districts are Vinh Linh, Gio Linh, Cam Lo, Trieu Phong, Hai Lang, Huong Hoa, Dakrong and Con Co's island.

2.1.2. Topography

Three-quarters of Quang Tri's territory consists of mountains and hills. Because of the topography of Truong Son Mountains[3], Quang Tri's terrain lowers from west to east and southeast and is divided into 4 types of terrain: highlands from the west of the Truong Son Mountains; hills and low mountains stretching along the province; midlands and narrow plains with silt deposits from rivers and sandbank areas with sand dunes along the coast.

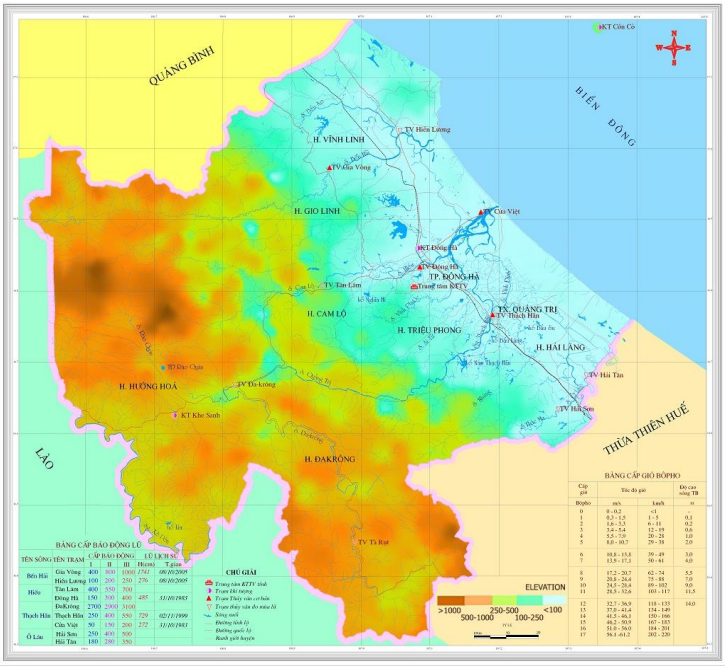


Figure 2. The map of topography and hydrometeorology station network of Quang Tri Province
Source: Meteorological and hydrological organization in Quang Tri, available at: http://quangtri.kttvttb.vn/vi/news/Ban-do/Ban-do-mang-luoi-tram-Khi-tuong-Thuy-van-tinh-Quang-Tri-581/.

[3] Truong Son Mountains is Vietnamese name of the Annamite Range or the Annamese Mountains, is a mountain range of eastern Indochina, which extends approximately 1,100 km through Laos, Vietnam, and a small area in northeast Cambodia

- Highland areas are distributed from the west of the Truong Son Mountains to the hill region, with elevations ranging 250-2,000 meter (m) and slopes ranging 20-30 degree (º). The highlands are characterized by steep slopes, sharp crests, and narrow valleys, are covered mainly by a dense broadleaf evergreen forest. The typical mountains are the Voi Mep, Sa Mui, Chau, Vang Cave. These areas are suitable for forestation, planting perennial crops, raising livestock and small hydropower exploitation, unsuitable for traffic, construction of infrastructure and organizing economic and social life.
- Hill and low mountain areas are the transitions between the highlands and flat plains, stretching along the province. The elevation is between 50-250 m, but some rise above 500 m. The elevation of the hilly areas in Cam Lo and Gio Linh is approximately 100-250 m while in Vinh Linh is about 50-100m. This type of topography is suitable for planning industrial crops such as rubber, pepper and perennial fruit.
- Midland and narrow plain are the areas where deposited by silt from river systems, with relatively flat terrain and elevation of 25-30 m. It includes Ben Hai River delta and Trieu Phong delta deposited by alluvial of Ben Hai River and Thach Han River. These are key areas of food productions, especially rice production in the districts of Hai Lang, Trieu Phong, Gio Linh, Vinh Linh.
- Sandbank areas are the dunes that distributed along the coast with flat terrain, suitable for organizing economic and social life. However, some areas with low-lying terrain are prone to flooding in heavy rains or some other areas are just dry sand dunes, unsuitable for agricultural production, thus people's life is not stable.

2.1.3. Climate

Quang Tri province is located in the tropical monsoon climate with high temperatures and harsh climate, which affected by dry and hot winds blowing southwest. Quang Tri's climate has two distinguished seasons: the rainy season is from September to November and the dry season is from December to August of the following year. The hottest dry period is from March to September because the impact of southwest winds often causing drought. From October to February of the next year, under the influence of the northeast monsoon, accompanied by rain often causing floods. Quang Tri is situated in the area usually affected by storms, especially in September and November, causing extreme rains and serious inundations, therefore affected infrastructure architecture, agricultural production and residents' life.
-Temperature: the annual average temperature is about 24°-25º celsius (C) in the flat plains, 22º-23º C at an altitude above 500 m. The cold season has 3 months (December and January, February of the next year), the temperature of this period lowers, the coldest month is below 22° C in plain, under 20º C at areas above 500 m. The hot season has 4 months (from May to August) with the average temperature of 28° C, the hottest months are June and July with temperature up to 40°-42º C.
-Precipitation: The rainfall of Quang Tri Province is distributed unevenly depending on geographic and topographic factors. The annual average rainfall is between 2,000-2,800 millimeters (mm) per year. The rainfall of 3 months of the rainy season accounted for 68-70 % of the annual average rainfall. The rainfall in the dry season of 9 months accounted for only 30% of the total. In the period from December to April of the dry season, it usually has showers each of 7-8 days with rainfall of 20-30 mm. Between two the dry periods, May and

June are the period with many downpours, called “Grain Buds flood” season. It can supply water to the network of rivers, as well as can cause flooding. The rainy season begins from September to November, sometimes the rainy season lasts until December. This is the time of storms and tropical low pressures not only in Quang Tri Province but also in the other central provinces. Due to the complex topography, the rainfall during the rainy season is also unevenly in the whole province. According to statistics the average rainfall for many years, the average monthly rainfall of stations was shown in the following table:

Table 2. Average monthly rainfall in years

Point/ month	Vinh Linh	Gia Vong	Dong Ha	Thach Han	Cua Viet	Huong Hoa	Khe Sanh	Ba Long
I	129.9	60.1	48.2	84.3	57.6	83.6	16.7	99.8
II	83.3	47.9	34.1	60.7	48.6	61.7	19.2	90.1
III	48.6	35.4	30.8	48.9	33.1	47.8	29.7	51.0
IV	51.9	64.1	60.7	63.0	50.8	97.8	89.8	71.7
V	100.5	143.6	119.3	135.0	102.6	191.5	158.9	156.6
VI	97.8	101.4	83.0	105.7	63.4	171.7	210.8	156.8
VII	94.3	78.7	65.7	82.9	68.1	148.9	187.8	74.2
VIII	125.3	155.0	163.2	135.3	150.3	219.1	295.9	173.1
IX	420.2	509.7	388.9	476.4	398.6	585.8	376.7	473.4
X	766.0	695.9	683.9	710.6	574.3	778.0	455.0	762.0
XI	462.3	456.4	429.0	438.6	415.7	415.7	227.7	175.8
XII	227.0	188.0	175.2	240.7	219.6	95.7	64.7	227.8
Ave. year	2614.1	2536.3	2291.8	2627.3	2187.8	2779.9	2118.6	2794.3

Source: T. S. Nguyen. Survey and assessment the quality of water in rural area in Quang Tri Province (Điều tra và đánh giá chất lượng nước sinh hoạt ở nông thôn tỉnh Quảng Trị). Ha Noi, 2009.

- Humidity: The average relative humidity in Quang Tri Province is around 83-88%[4]. The humidity has been changed over time between the east and west of Truong Son Mountains. The lowest humidity month is April with the humidity down to 22%. During the rainy season, the average relative humidity is often above 85%, sometimes up to 88-90%.
- Wind: The plains in Quang Tri are affected by two main wind direction, southwest monsoon and northeast monsoon. The hot dry southwest monsoon is a very typical phenomenon in Quang tri and considered as an intense phenomenon in Vietnam. From September to November is the time of the southwest monsoon wind, with the average wind speed of 2.0-2.2 meter per second (m/s) and the temperatures can be up to 40°-42ºC. The time of northeast monsoon is from December to March of the next year, with the average wind speed of 1.7-1.9 m/s.

[4] The ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature.

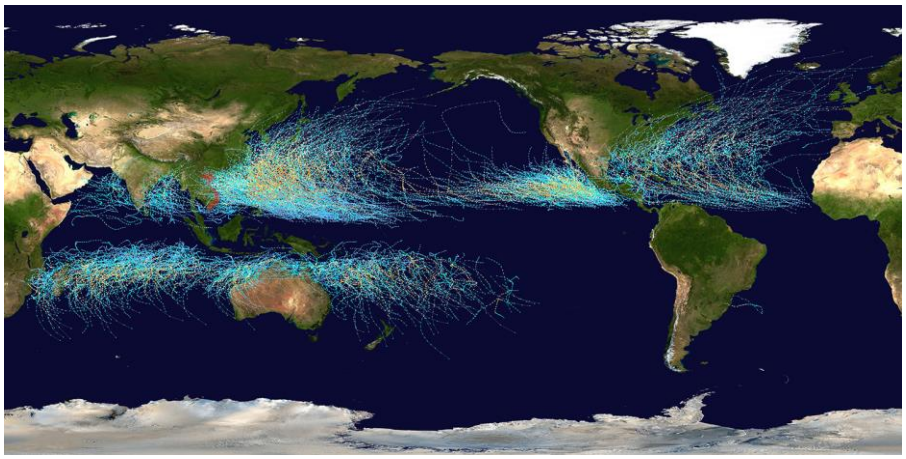


Figure 3. Map of the cumulative tracks of all tropical cyclones during the 1985–2005 time period
Source: https://en.wikipedia.org

2.1.4. Water surface system

The river density in Quang Tri is quite dense with the average density of 0.8-1 kilometer per square kilometer (0.8-1 km/km2). The general characteristics of river systems are short and steep because of Quang Tri's topography with narrow width and Truong Son Mountains in the west. The whole river is divided into 7 major river systems, including Thach Han, Ben Hai, O Lau (My Chanh), Hieu, Ben Da, Xe-Pon, Se-Pang-Hieng River system. In that, Ben Hai and Thach Han River are two main river systems that flow directly to the sea through Cua Tung and Cua Viet estuary. The total catchment area of the river systems is about 4,160 km2, including:

- Ben Hai River system originates from Chau cave region with 1,257 m high and 65 km length. The average annual flow is about 43.4 cubic meter per second (m3/s). The catchment area is about 809 km2. Ben Hai River empties into the sea at Cua Tung's estuary.
- Thach Han river system with 155 km length is the largest basin in Quang Tri's territory with a total area of 2,660 km2. The main tributaries of Thach Han river system originate from major mountain ranges, such as Sa Mui cave, Voi Mep cave (Rao Quan's branch), Ba Le cave, Dang cave (Dakrong's branch). Thach Han River empties into the sea at Cua Viet’s estuary.
- O Lau River system (or My Chanh River) was incorporated by two major tributaries are O Lau River in the south and My Chanh River in the north with a total length of 66 km. The total catchment area of two tributaries is approximately 900 km2 (belong to two provinces, Quang Tri and Thua Thien Hue) and empties into the sea at Tam Giang Lagoon, which belongs to Thua Thien Hue Province. The rest areas belong to Hieu, Ben Da River system and the branches of Mekong River that flow to the west, as Se-Pon River system in Lao Bao border gate passage, Se-Pang-Hieng in Cu Bai border posts (Huong Lap village, Huong Hoa district).

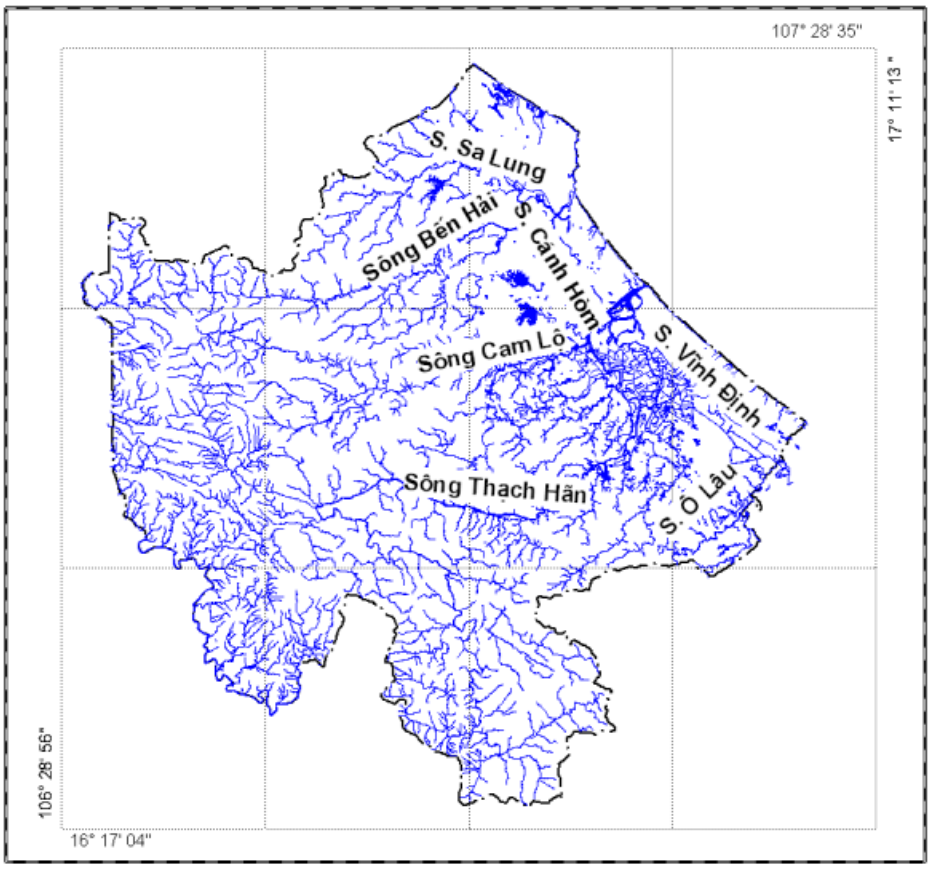


Figure 4. River and stream systems in Quang Tri Province
Source: T. N. Nguyen and P. N. Nguyen. Surface water resources of Quang Tri Province (Tài nguyên nước mặt tỉnh Quảng Trị). Vietnam National University's Journal of Science, vol. 25, no. 3s, pp. 472-483, 2009. Edited by author.

Besides the river system, the stream system and physical factors of the sea have also an important role for the water system in Quang Tri Province. The stream system is distributed densely in upstream with narrow width and steep slopes. Flows are classified into two seasons, flood season and dry season. The flood season appears as late as and sustains over a period of 4 months but the flow concentration is quite large, accounts for 62.5-80% of the total annual flow while the dry season lasts for 8 months and accounts only for 20-37.5%. The physical factors of the sea include waves, tide, flows that vary in different cycles combined with the topography characteristics to creating particular nature of the sea in coastal areas of Quang Tri Province. Ocean waves is an exogenous factor, which directly affects coastal areas and estuaries. Meanwhile, the change of tide and flow not only affects coastal areas but also dominates the hydrological regime in the downstream of the rivers,

especially during the dry season. It is also an important factor in the process of saltwater intrusion in the rivers and fields in downstream areas.

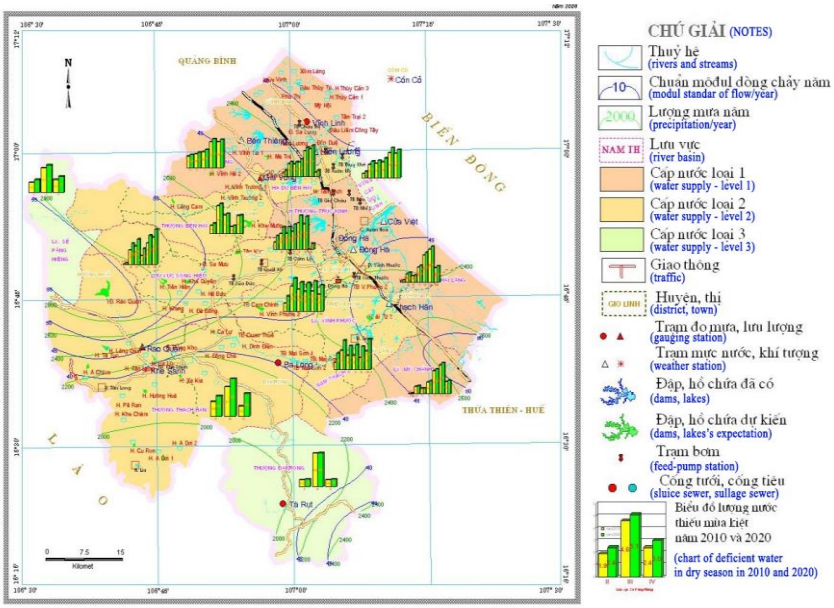


Figure 5. Water surface system and some information
Source: T. N. Nguyen and P. N. Nguyen. Surface water resources of Quang Tri Province (Tài nguyên nước mặt tỉnh Quảng Trị). Vietnam National University's Journal of Science, vol. 25, no. 3s, pp. 472-483, 2009. Edited by author.

2.2. Economic and social

2.2.1. Economy

Quang Tri is the first point of the economic corridor East - West, linking Vietnam, Laos, Thailand and Myanmar via Lao Bao international border gate. This is the very favorable condition to Quang Tri expand economic cooperation in the region, development of trade, international transportation, service and tourism development.

Table 3. The economic growth rates of Quang Tri Province by sectors

Sector / year	2005	2010	2011	2012	2013
GDP growth /year	10.4	10.6	9.5	7.1	6.9
Industry, construction	24.5	17.9	14.3	6.9	7.9
Agriculture, forestry and fishery	4.6	3.6	3.2	5.3	3.3
Service	8.0	9.1	9.3	8.4	8.3

Unit:%
Source: Quang Tri Statistical Yearbook 2013.

The economic development of Quang tri Province reached an average level and maintained stability in the past decades. In the period 2010 - 2014, the economic growth tended to decrease relatively large, from 10.6% in 2010 to 9.5% in 2011, 7.1% in 2012, 6.8% in 2013 and 6.7% in 2014. In 2014, the agriculture, forestry and fisheries achieved growth rates of 3.4%, the industry, construction reached 7.3% and the services increased with the growth of 8.1%[5]. However, the economic growth rates have been improved in recent years.

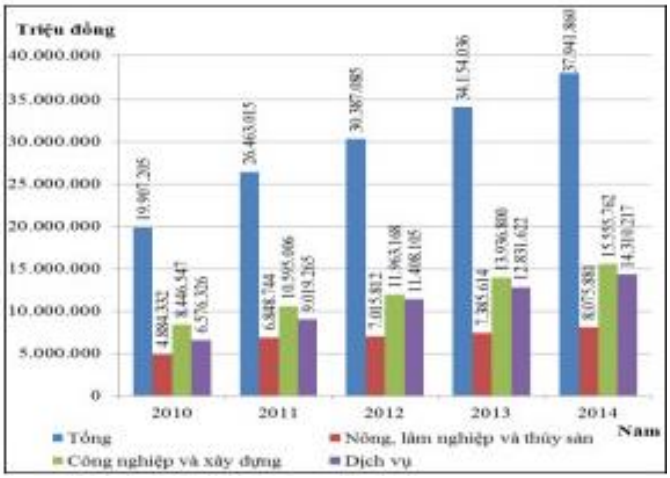


Figure 6. Provincial gross domestic product with current prices in each economic sector
Source: The electronic information page of Quang Tri Province (http://www.quang-tri.gov.vn)

The economic structure is being shifted towards increasing the proportion of industry, construction, services while reducing the proportion of agriculture, forestry and fisheries. The industry and construction have a role more and more important and the increasing the contribution of the economic structure. Provincial gross domestic product with current prices in each economic sector (*Figure 6*) showed that the industry and construction sector increased continuously since 2010 (35.5%) to 2014 (37.7%), the service sector increased from 34.7% (2011) to 38.7% (2014) whereas the agriculture, forestry and fisheries dropped from 28.9% (2010) to 23.5% (2014).

2.2.2. Population

The population of the province is 613,655 people[6], including 155,320 households (average of 3.92 persons/household) with 3 ethnic groups of Kinh, Van Kieu and Pa Co-Ta Oi, Kinh is the most populous. Urban population with 177,919 people accounted for 28.99%. The

[5] Quang Tri Statistical Yearbook 2014 of Quang Tri Statistics Office
[6] Quang Tri Statistical Yearbook 2013 of Quang Tri Statistics Office

rate of natural population growth decreased to 1.05% in 2007 and 1.12% in 2010; the mechanical population has not increased significantly. The annual average population increase about 5,000-6,000 people. The average population density is 129 people/km2, which is lowė compared to other provinces. The population is not evenly distributed among the regions. They have concentrated in big cities, towns, districts and vice versa in the mountain areas, such as Quang Tri Town: 308 people/km2, Dong Ha City: 1,157 people / km2, whereas Dakrong District: 29 people/km2 or Huong Hoa District: 64 people/km2.

Table 4. Average population by sex and region

Year	Population	Sex		Region	
		Male	Female	City	Countryside
2005	590276	291951	298325	152485	437791
2006	591869	292619	299250	155454	436415
2007	594101	293722	300379	158651	435450
2008	596712	295969	300743	162014	434698
2009	598568	295412	303156	167599	430969
2010	601665	297287	304378	170873	430792
2011	604671	299122	305549	174179	430492
2012	608172	301361	306811	176633	431539
2013	631655	303385	310270	177919	435736

Source: Quang Tri Statistical Yearbook 2013.

In the population structure by sex, women accounted for 50.5% with 310,270 people, men accounted for 49.5% with 303,385 people. The working-age population accounted for 54.62% with 345,000 people. Labor distribution accounted for 52.06% in agriculture - forestry, 3.94% in fisheries and 14.93% in construction - industry.

Table 5. The labor structure of occupations

Target / year	2007	2008	2009	2010	2011	2012	2013
Total labor	281.937	289.232	317.466	313.686	302.650	315.392	318.477
Agriculture and Forestry	169.208	164.266	173.465	162.623	167.795	165.787	165.800
Seafood	11.535	15.400	16.262	12.569	12.969	12.764	12.562
Mining industry	1.955	1.962	2.662	1.755	2.321	2.665	2.760
Processing industry	13.339	13.178	20.234	17.656	17.697	21.835	21.941
Build	13.514	13.801	22.053	21.877	21.307	22.070	22.860
Service	31.013	38.230	36.624	41.579	29.274	32.894	33.962
Hotel, restaurant	5.075	7.690	7.639	10.477	6.938	8.551	8.750
Transportation, warehousing	9.044	8.777	7.202	9.229	9.773	11.188	11.220
Finance and credit	2.666	2.235	1.333	1.407	1.223	1.316	1.416
Other labor	24.588	23.693	29.992	34.514	33.353	36.322	37.206

Source: Quang Tri Statistical Yearbook 2013.

The workforce was trained and had professional qualifications accounted for 39.4% of the total. Although population and workforce of Quang Tri Province are abundant, there are limitations, such as the uneven distribution of populated in the territory, the disparity of educational level between the plain areas and remote areas, the shortage of professional labor and qualified experts.

2.2.3. Education and cultural

Compared with the national education, the general educational level of Quang Tri is average and it is lower in remote areas. The communes in the plain areas are trying to perform well the task of eradicating illiteracy. In which, 60% of the labor force in rural areas reached secondary school level and 20% reached high school level. In mountainous areas, the dropout situation is still common. The proportion of illiterates and re-illiterate are still high.

Therefore, the aware ability of residents about climate change or heritage conservation and more is still very limited. To cope with the disaster and conservation, they are mainly based on experience, traditional tools, traditional solutions and it is not enough to respond and adapt to the impact of climate change and others.

2.2.4. Infrastructure

In recent years, infrastructure has been invested and constructed in a synchronous way and promoted many positive results.

The whole province has 13 urban areas, including 1 city of type III urban; 1 city of type IV urban and 11 cities of type V urban. The province will develop more 6 urban up to 2020, Bo Ban, Nam Cua Viet, Ta Rut, Huong Phung, A Tuc and My Thuy. Some urban will be adjusted function at the same time to create an inter-regional urban system and effective develop the specific characteristics of those urban. Dong Ha City, Quang Tri, Lao Bao and Khe Sanh town are seen as the centers of political, cultural and socioeconomic of the province, while the remaining towns serve as the centers of regions or districts.

The main traffics in Quang Tri province are roads, railways and waterway. Compared with the other central provinces, the transport systems are still being developing and upgrading. The traffic system between the plain areas and mountain areas have clear differences. The whole province has three major highways: national highway No.1A (from north to south connects Quang Binh, Quang Tri, Thua Thien Hue Province), route No.9 (from Dong Ha city to Laos) and route No.14 (from Dakrong bridge to Huong River upstream). The railway runs from north to south with the main station in Dong Ha city, where transshipment of people and goods. Waterway runs from the sea to the mainland based on Ben Hai, Hieu and Thach Han River system, but this waterway is for vessels with a tonnage less than 10 tons.

Health network in the plain areas has been widely popular, especially in urban areas and communities. Each district has a hospital with 80 patient beds, in addition, it also has medical centers and clinic stations to ensure the examination and treatment. However, the health system is still inadequate in mountainous areas. Each commune has a clinic station but the distance between residential areas and the clinic is pretty far so the examination and

treatment are still difficult. And because of superstition, so the cure by immolating still exists in some localities.

2.3. Heritage system and its potential

2.3.1. Tangible heritage

Quang Tri history has experienced many different cultures as Son Vi, Hoa Binh, Bac Son, Champa. Besides, it also is an evidence of the heroic struggle period to against invaders. According to Quang Tri Monument Conservation Center, on May 9.2014, the whole province has 602 monuments (complex of monuments) of historical, cultural and natural. In that, 479 monuments were recognized as the heritage of Quang Tri province, 33 monuments were recognized as the nation's heritage (Appendix A, the tangible heritage table in research area).

From prehistoric and protohistoric, Quang Tri today is said to belong to the kingdom of Van Lang and Au Lac. In the early Han Dynasty (from 179 BC to 192 AD), Quang Tri land belonged to Nhat Nam District. At the end of the second century, Lam Ap's kingdom was founded and lasted until the seventh century. This kingdom is considered the starting phase of the Kingdom of Champa. The surmised territory of Lam Ap's kingdom was the land stretching from Hai Van Pass to Ngang Pass today, which already included Quang Tri territory. Until the late 19th century, through many dynasties, from Ho Dynasty (1400-1407) to Ming Dynasty (1407-1427), Le Dynasty (1428-1788), Tay Son Dynasty (1788-1802) and finally, Nguyen Dynasty (1802-1884), Quang Tri gradually become an integral part of Dai Viet[7]. Some outstanding works for this development process are Champa ancient well systems and Quang Tri ancient citadel. The system of Champa ancient wells are assumed by scientists and archaeologists that it was built in the period between 9th and 11th century and Quang Tri Citadel was built the first time in 1802 at Tien Kien Ward (Trieu Thanh -Trieu Phong today) then moved to Thach Han commune in 1809 (Ward 2, Quang Tri town today). Moreover, although Tan So citadel left only ruins currently, many researchers suggest that it was built around the 1880s to fight the invasion of the French colonial. The citadel was covered by soldiers and villagers with soil and bamboo to create a strong defense system. Or the ruins of Cham towers are the evidence that demonstrated the process of living and development of Champa people on Quang Tri territory.

From 1884 to 1989, Quang Tri is the place of many fierce wars, especially the war against the French colonialists and US imperialists. In 602 monuments of the province, there are 442 monuments of historic with about 375 monuments of historical revolution. It shows the importance of historic revolution monuments in the life and development of Quang Tri province. Some prominent monuments are Ho Chi Minh Trail, Lao Bao prison, Truong Son Martyr's Cemetery, Vinh Moc tunnels, Complex of relics on Hien Luong banks.

Quang Tri since 1989, after the restoration of war consequences, conservation and promotion of heritage have been many positive changes. Province not only has many

[7] Dai Viet is the name of Vietnam in the periods from 1054 to 1400 and 1428 to 1804

policies of conservation and assessment of heritage, but also cooperate with foreign countries to study and promote the values of heritage to develop tourism by creating new and attractive tours, such as DMZ tours, spiritual tours, visiting old battlefields tour, tours for people who participated in the wars, etc.

An integral part of heritage potential of Quang Tri Province is religious and belief works. Quang Tri is an important point of connecting the South and North, thus Quang Tri can easy exchange with surrounding regions and countries. It is also favorable conditions for the penetration and development of foreign cultures, thoughts and religions. Therefore, Quang Tri has 2 religious groups both in the East and the West. These religions have originated from the East including Buddhism, Taoism, Confucianism and from the West including Catholic and Protestantism. They were introduced very early, then spread and rapidly developed. Buddhist and Christian are two main religions currently; they have an important position and left much uniqueness through the system of religious architectural works.

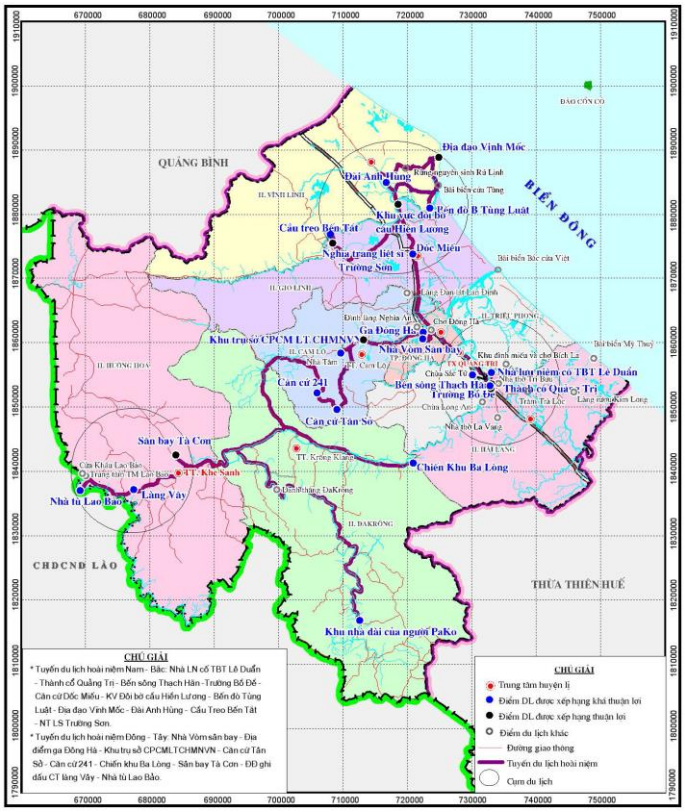


Figure 7. Planning map for tourist in Quang Tri based on the cultural historical relics
Source: T. T. Bui and M. C. Vu. The orientations of exploiting the cultural historical relics in Quang Tri Province for tourism (Định hướng khai thác các di tích lịch sử-văn hóa tỉnh quảng trị cho mục đích du lịch). Hue University's Journal of Science, vol. 72, no. 3, 2013.

According to many researchers and documentation[8], it can assert that Buddhism had been spreading and flourishing before Quang Tri was merged into Dai Viet territory. At the beginning, people just built small buildings with the simple functions for worship. To adapt to the development and needs of society, those buildings were expanded in both size and function, called the temples. Nowadays, temples are not only the places of religious activities, monasteries of monks but also the centers for community activities and it also is the repository of historical and cultural values of the nation. Quang Tri today has around 207 temples for the worship of Buddhist, such as Cam Lo, Dien Tho, Chau Quang, Tinh Quang, etc. Meanwhile, Christianity (Catholic and Protestantism) was conveyed to Quang Tri territory later, more than 300 years ago. Some Documents notes that missionaries arrived in Dang Trong[9] in the late 15th century. The penetration and development of Christianity have encountered many obstacles and difficulties because it was a religion of the West. Until 1954, Ngo Dinh Diem, a catholic, after becoming the president of South Vietnam, he created favorable conditions for the development of Catholic. Thus, Catholic in Quang Tri had an opportunity to develop. The number of parishioners and churches increased markedly. Currently, Quang Tri has about 18 Catholic churches, in that La Vang Holy Land (La Vang Church) is the place where hundreds of thousands people visit each year.

Figure 8. Cam Lo temple
Source: http://www.chuacamlo.com

[8] Nam hai ki quy noi phap's story (the first book) by Monk Nghia Tinh (635-713). On a trip to visit the countries in Southeast Asia and India (the period 671 to 691), he recalled that: "Towards the south is to Champa (Lam Ap). This country has many Chinh Luong and less Huu Bo". Chinh Luong and Huu Bo are Tuyet Nhat Thiet Huu Bo that belongs to Buddhism.

[9] Dang Trong was an southern land of Dai Viet controlled by Lord Nguyen during the 17th century, Trinh-Nguyen War

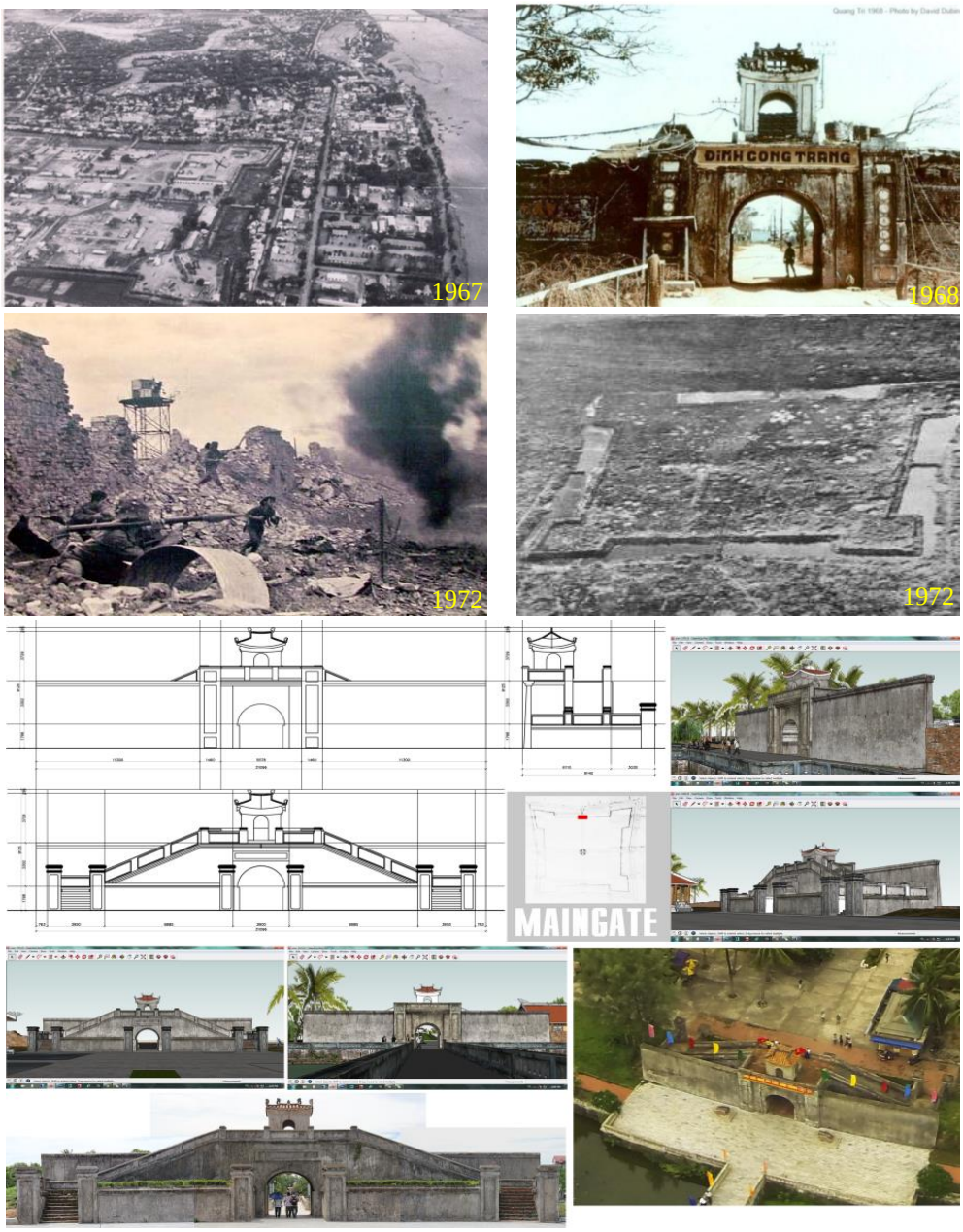


Figure 9. Quang Tri citadel in 1967, 1968, 1972 and nowadays
Source: Internet – Edited by author.

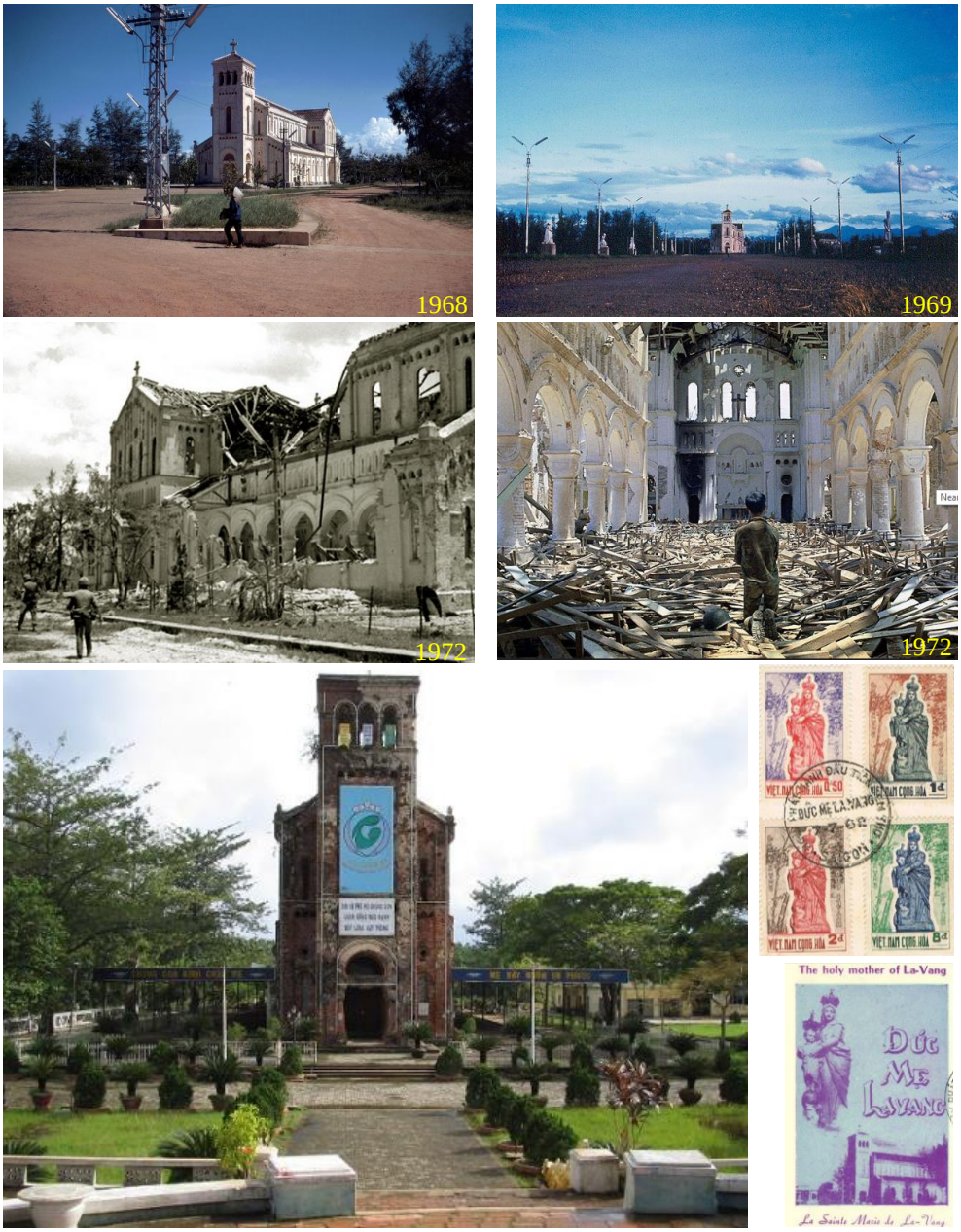


Figure 10. LaVang church in 1968, 1969, 1972 and today. It was also printed on some stamps in 1968
Source: Internet – Edited by author.

2.3.2. Intangible heritage

Besides the tangible heritage, Intangible heritage system in Quang Tri is also very rich and varied, including folk festivals formed from ancient or traditional festivals (usually be associated with traditional activities and handicraft village) and the newly formed festivals such as revolutionary festivals or religious festivals. The intangible heritage system clearly reflected in multi-regional factors, including mountain, plain and sea region. Time of festival depends on the characteristics of each festival. Most of the festivities take place in the spring as temple festivals or village festivals. One of the traditional festivals with the largest scale and earliest organized festival is Bich La temple festival in Trieu Dong commune, Trieu Phong district that takes place from 2nd to 3rd January of Lunar calendar; Gio Linh festival happens on 4th January of Lunar calendar; Cheo Can festival in Vinh Linh-Gio Linh area, Boat Race festival is from 2nd to 8th January of Lunar calendar in Hieu, Ben Hai, Thach Han and O Lau River. Meanwhile, the traditional festivals of ethnic minorities are usually held in the Spring and Autumn. These include the festivals such as New Crop festival (lễ hội Mừng Lúa Mới), Puc Po festival (lễ hội Cầu Mùa) of Van Kieu and Pa Co people in Huong Hoa and Dakrong; Arieu Ping festival (lễ hội Ariêu Ping) of Pa Co people.

Figure 11. A traditional handicraft village: Lan Dinh basketry
Source: Internet – Edited by author.

In recent years, the Department of Culture, Sports and Tourism in cooperation with local authorities to organize reconstruction of traditional festivals of ethnic minorities after years of being forgotten. Immediately, these festivals have regained its place in the cultural and spiritual life of the local people as the festival Arieu Ping festival, Puc Ro festival, Culture

and Sports festivals of ethnic groups in Dakrong district. Although the festivals of different ethnic groups with different organizational methods and different languages, they have a general purpose is to pray for good weather, abundant harvest, a prosperous new year, good health. It also was an opportunity to exchange culture of ethnic minorities before entering a new year. On the other hand, through these traditional festivals, many unique cultures and folk games characterized by ethnic groups such as gongs (cồng chiêng), khèn bè, olifant (tù và), etc be also stored and preserved for next generations.

2.3.3. Tourism potential

In general, the natural conditions of Quang Tri Province is a pretty basic advantage. The variety of topography has created climate zones suitable for the development of agriculture with animals and plants from tropical and subtropical. The temperate climate zone on the top of Truong Son Mountain opposed to the harsh climate in the plain area is one of the potentials for the development of sports activities, festivals, service and tourism, especially in summer.

Figure 12. Festival of lights on Thach Han River
Source: Internet – Edited by author.

Quang tri is the intersection of North-South traffic routes (North-South Railway, National Highway No. 1A, Ho Chi Minh trail) with East- West Economic Corridor through route No.9 and Lao Bao international border gate, which is a very favorable condition for cultural exchange and economic development. The river systems are evenly distributed throughout with two main river system Ben Hai and Thach Han. With 75 km of coast has shaped many beautiful, clean and fresh beaches such as Cua Tung, Cua Viet, Con Co Island, My Thuy,

Trieu Lang, Vinh Kim, Vinh Thai, etc. Ecological tourism with natural forests, Dakrong natural conservation area and Klu hot mineral water stream, Khe Gio, Ru Linh forest, Tra Loc pool, etc are the perfect venues for relaxation or healing. Furthermore, Quang Tri Province is planning to build Quang Tri airport, it will be one of the most favorable conditions affecting the development of the whole province.

One of the indispensable potentials is the tangible and intangible heritage system. However, a survey based on the tour of Quang Tri cultural, tourism and sports department, the travel companies of Quang Tri, Thua Thien Hue, Quang Binh and Hanoi showed that the exploitation of heritage for tourism development is not commensurate with the potential and strengths of the province. Specifically, there are more than 600 heritages in Quang Tri but only 18 heritages have been exploited in tours, including Ho Chi Minh trail, Quang Tri ancient citadel, Truong Son cemetery, Mieu slope, Vinh Moc tunnel, 241 hill, Rockpile hill, Ta Con airport, Lao Bao prison, Revolutionary Government of South Vietnam Republic's heritage site, General Secretary Le Duan's memorial house, Hien Luong bridge, Ben Hai River, Thach Han River, Gio An ancient wells system, the village of Bru - Van Kieu ethnic, Tinh Quang pagoda, La Vang church. The traditional festivals of Quang Tri have been restoring, preserving and promoting values, so the number of visitors coming for the traditional festivals has grown in recent years. However, it should be combined simultaneous two elements tangible and intangible heritage to create its characteristics in the development of tourism.

However, besides these favorable factors, Quang Tri also exists some difficulties and challenges. Quang Tri (as well as other central provinces) with a harsh climate is the place where usually occur droughts in the dry season and floods in the rainy season that causes damage to harvest, infrastructure, and the heritage system. Therefore, to response and adaptation to disasters under the impact of climate change has important implications that need to be done as soon as possible. Besides, the uneven distribution of the population in regions, the migration of workforce, the low awareness of indigenous peoples have been affecting not only on the planning and development of province but also the conservation and promotion of heritage values.

Chapter 3.
Climate change and flood risks

3.1. The evolution of global climate change

Assessment report of the 5th of Intergovernmental Panel on Climate Change(IPCC) showed that global warming is clear and since the 1950s climate changes have many changes unprecedented in comparison with last decades or last millennia. The warming of atmosphere and oceans have made the snow and ice melt, resulting in the rising of sea level as clearly evidence for the change of climate.
The IPCC said that greenhouse gas emissions, due to the activities of human, is the main reason caused of global warming and climate change. Greenhouse gas emissions have increased since pre-industrial times, mainly due to economic growth, population growth, higher than ever at present. CO2, CH4 and N2O in the atmospheric concentrations have reached an unprecedented high level and increased steadily since the 1750s, respectively 40%, 150% and 20%. The total of greenhouse gasses emitted by human activities in the period 2000-2010 was the highest in the history of mankind and reached 49 (± 4.5) GtCO2eq/year in 2010.

3.1.1. Temperature

Observations and measurements from all over the world showed that surface temperature is rising much more in the northernmost latitudes. In 100 years (1906-2005), the average temperature has increased about 0,74°C, the increase in temperature in the last 50 years nearly doubled compared with the previous 50 years. In the nearest three decades, Earth's surface temperature is hotter than all the previous decades since 1850. The period 1983-2012 seems to be the 30 warmest years in the past 800 years in the northern hemisphere. In the fifteen years since 2001, the average temperature was 0.5 ºC higher than the period 1961-1990, the highest ever recorded for every 10-year period since the start climate observation by instrumentation (Michel Jarraud, 2011). According to data from NOAA (USA), June 2010 was recorded as the hottest month worldwide since 1880, when the meteorological observations have made relatively system.
In the Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC), the average surface temperature for the period 2015- 2035 is similar for the four RCPs[10] (The

[10] The Representative Concentration Pathways (RCPs) used for making projections based on these factors, describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5). Scenarios without additional efforts to constrain emissions (’baseline scenarios’) lead to pathways ranging between RCP6.0 and RCP8.5 (Figure SPM.5a). RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperature.

Representative Concentration Pathways) will increase more than the period 1986- 2055 from 0.3°C to 7°C and. Predictions were given in cases there will be no major volcanic eruptions or unexpected changes in total solar irradiance or changes in some natural sources (e.g., CO2, CH4 and N2O). In the end of the 21st century (2081–2100), the increase in global mean surface temperature relative to 1986–2005 is likely to be 0.3°C to 1.7°C for RCP2.6, 1.1°C to 2.6°C for RCP4.5, 1.4°C to 3.1°C for RCP6.0 and 2.6°C to 4.8°C for RCP8.59.

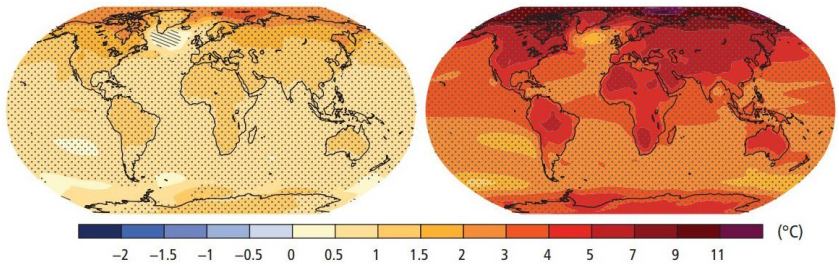


Figure 13. Change of average surface temperature (1986-2005 to 2081-2100)
Source: IPCC (Intergovernmental Panel on Climate Change). Climate Change 2014: Synthesis Report. IPCC, Geneva, 2014.

However, the changes of climate will depend on committed warming caused by past anthropogenic emissions, as well as anthropogenic emissions and natural climate variability in the future.

3.1.2. Precipitation

According to the synthesis report of the IPCC (2007), increased rainfall in the northern regions in period 1901-2005 and decreased in the tropic regions since 1970. In the tropics, precipitation decreases in South Asia and West Africa for the period 1901-2005. In subtropical and temperate, the precipitation increased significantly in central North America, Eastern North America, northern Europe, northern Asia and Central Asia. The frequency of heavy rain increased in many areas, including those where the rainfall tends to decrease.

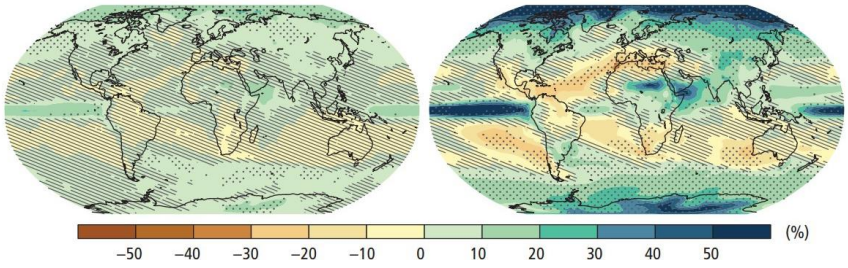


Figure 14. Change of average precipitation (1986-2005 to 2081-2100)
Source: IPCC (Intergovernmental Panel on Climate Change). Climate Change 2014: Synthesis Report. IPCC, Geneva, 2014.

In the most recent synthesis report (2014), IPCC said that the change of precipitation was not uniform at the present. The annual mean precipitation is likely to experience an increase in the high latitudes and the equatorial Pacific (under the RCP8.5 scenario). It will likely decrease in many mid-latitude and subtropical dry regions (under the RCP8.5 scenario). Extreme precipitation events over wet tropical regions and over most of the mid-latitude land masses can become more intense and more frequent.

3.1.3. The rising of sea level

The sea level worldwide rose about 1.8±0.5 mm/year in the period 1961-2003, of which, the contribution due to thermal expansion was about 0.42±0,12mm/year and the melting of ice was about 0.70±0,50mm/year. In the research of Chuch and White, they said that "the speed of sea level rise of global average is about 1.8mm/year" (Chuch and White, 2009). However, the changes of sea level are not uniform in the whole ocean. The speed of the rise in some areas may rise several times the global average, while the sea level in some other areas can lower, such as in the east coast of South America, the southern coast of Alaska, the northeastern coast of Canada or the coast of Scandinavian.

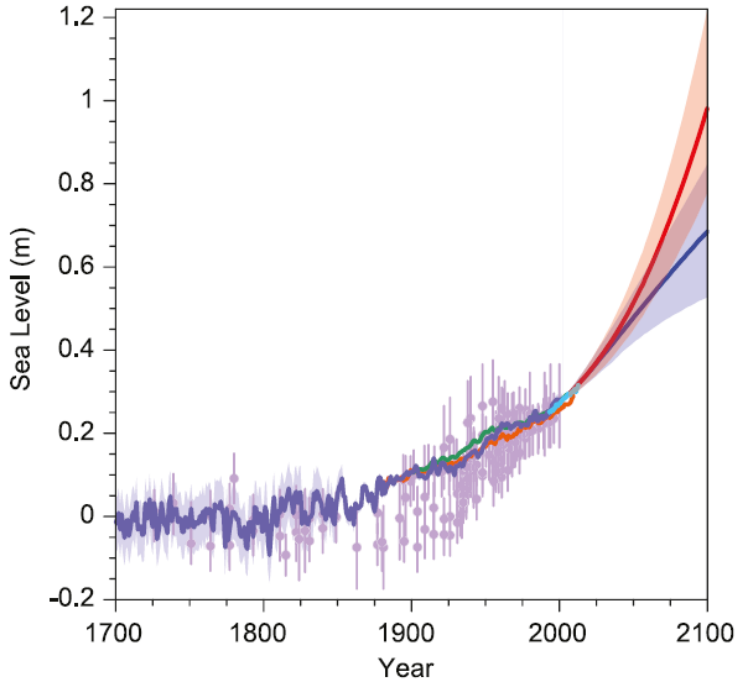


Figure 15. The past and future sea-level rise
Note: For the past, light purple (proxy data) and blue (tide tide gauge data). For the future, red (very high emissions) and blue (very low emissions)
Source: IPCC (Intergovernmental Panel on Climate Change). Climate Change 2014: Synthesis Report. IPCC, Geneva, 2014.

3.1.4. Others

The changes of climate have caused negative impacts on natural and man-made systems, and human in the whole world. The change weather elements, such as temperature, precipitation, humidity, has affected water resources, land resources that have reduced production of agriculture, industrial and broken the balance of economic - social. The rising of sea level threaten to inundate the island, lowlands, altering the entire life and activities of the human. The increase of extreme weather phenomena, such as El Nino, La Nina, Enso, etc, also cause great damage to many countries. According to estimates by the biology scientists, if the average temperature of the earth rises from 1.5°C to 2.5°C that will make about 20% - 30% of the organisms on the brink of extinction. If the average temperature increases more than 4°C will be only very few ecosystems capable of adapting, over 40% of ecosystems will be changed, disappear or destroyed on a global scale. Besides, if sea level rises up about 1 meter, millions of people can be lost their homes and thousands of hectares of farmland can be flooded, causing damage to hundreds of billions of dollars. Many island nations have less than 3m above sea level, such as Kiribati, Tuvalu, Madivale will be lost most of landward and a few other countries will be disappeared.

3.2. Climate change in Vietnam

Climate change has manifested clearly in Vietnam in 50 last years, as follows:
-The annual average temperature increased about 0.5ºC. The temperature of winter rose faster than summer and the temperature of landward rose faster than coastal and islands.
- The precipitation tends to decrease in the north and increase in the south. The maximum precipitation increases in the most of the regions. Especially in recent years, the number of extreme rain also increases correspondingly, more volatility occurs in the central region.
- The sea level has risen about 20cm.
- The frequency of occurrence of strong storms tends to increase. Hurricane season ends later and storms tend to move to the south in recent years.
- Flood events occur more frequently in all regions. The central of Vietnam is the largest suffered by flood and other events.
- Flooding due tidal flooding increase in both area and deep level, such as Can Tho, Ho Chi Minh, Ca Mau, Hai Phong, Vinh Long, etc.
- Landslides occur more in the provinces because of heavy rain, waves, tides, sea level rise and ocean currents.
- Drought tends to increase, but the level is not uniform.
Under the impacts of climate change, in Vietnam, the rainfall distribution and precipitation have many changes, the extreme weathers increase in frequency, severity and scale to cause many negative effects on human activities, such as manufacturing activities, ecosystems, infrastructure, economic, cultural, social and environmental.
The increase in temperature has broken the natural balance of flora and fauna species, depleting biodiversity, some of the species may disappear or extinction. The temperature increases also directly impact fields such as energy, transport, industry, construction, tourism, trade, community health, etc. For example in agricultural production, plants, animals or crops may be changed in some areas, including the winter crop in the north can be reduced or even no winter crop; or in community health field, the rising of temperature

and high humidity increase the pressure of temperature on the human body, especially on oldster and children. It also increases the diseases, especially of the tropical diseases, infectious diseases through the development of bacterial species, the insects and infected hosts.

Figure 16. Consequences of climate change in Vietnam: Drought and marine environment pollution
Source: Internet – Cropped by author

Results of the report "Synthesis report of Vietnam on disaster risk management and extreme events to promote adaptation to climate change" of Institute of Meteorology, Hydrology and Environment (IMHEN, 2015) showed that, in the period 1996-2011 (15 years), natural disasters such as storms, floods, flash floods, landslides, floods, droughts, saltwater intrusion and others have done considerable damage to people and properties; more than 10.711 people dead and missing, the value of the damaged property was estimated about 1.5% of GDP. The impact of climate change on economic was estimated around 0.5% for fisheries; 0.2% for agriculture and 4.4% for labor productivity.
In "Scenarios of climate change, sea level rise announced in 2012 by the Ministry of Natural Resources and Environment", at the end of the 21st century, the climate in Vietnam will have changes as follows:

3.2.1. Temperature

- Under the low emissions scenario: in the end of the 21st century, the annual average temperature increased from 1.6°C to 2.2°C in the most of the northern area and below 1.6 °C in the southern area (from Da Nang to the south).
- Under the medium emissions scenario: in the end of the 21st century, the annual average temperature increased from 2°C to 3°C in the most of the territory. The average temperature from Ha Tinh to Quang Tri is likely to rise faster. The lowest of average temperature increase from 2.2°C to 3°C, the highest increases from 2°C to 3.2°C. The number of days with the highest temperature over 35°C increased from 15 to 30 days in the whole country.
- Under the high emissions scenario: in the end of the 21st century, the annual average temperature increased common from 2.5°C to 3.7°C in the most areas.

3.2.2. Precipitation

- Under the low emissions scenario: in the end of the 21st century, the annual rainfall increases common over 6%, the increase has less growth about under 2% in the highland areas.
- Under the medium emissions scenario: in the end of the 21st century, the annual rainfall increases common from 2% to 7% in the most of the territory. The increase in the highland and southern central areas is less than 3%. The general trend is the rainfall will be decreased in the dry season and increased in the rainy season, which means that the dry season will appear more drought and rainy season will have more flood or more flood risks. The largest daily rainfall increases more than the period 1980-1999 in the north and southern central, decreases in the highland areas and southern central. However, the extreme rainy may appear in many areas with the rainfall that can be twice the current record.
- Under the high emissions scenario: in the end of the 21st century, the annual rainfall increases from 2% to 10% in the most of the territory, particularly in the highlands, the increase has less growth between 1%to 4%.

3.2.3. The rising of sea level

- Under the low emissions scenario: in the end of the 21st century, the highest sea level increases likely in the range of 54-72cm in areas from Ca Mau to Kien Giang; the lowest is between 42-57cm in the areas from Mong Cai to Hon Dau. The average sea level of Vietnam rises likely in the range of 49-64cm.
- Under the medium emissions scenario: in the end of the 21st century, the highest sea level is in areas from Ca Mau to Kien Giang, increases likely in the range of 62-82cm; the lowest is in the areas from Mong Cai to Hon Dau, between 49-64cm. The average sea level of Vietnam rises likely in the range of 57-73cm.
- Under the high emissions scenario: in the end of the 21st century, the highest sea level increases likely in the range of 85-105cm in areas from Ca Mau to Kien Giang; the lowest is between 66-85cm in the areas from Mong Cai to Hon Dau. The average sea level of Vietnam rises likely in the range of 78-95cm.

If the sea level rises over 1 meter, about 39% of the area in Mekong delta, more than 10% of the area in Hong's river delta and Quang Ninh's river delta, more than 2.5% of the area of the central coastal provinces (including Quang Tri) and more than 20% of the area of Ho Chi Minh are in danger of being flooded. Nearly 35% of the population of the provinces in Mekong delta, more than 9% of the population in Hong's river delta and Quang Ninh's river delta, nearly 9% of the population of the central coastal provinces and about 7% of the population of Ho Chi Minh will be directly affected. More than 4% of the railway system and more than 9% of highway system will be likely under water.

3.2.4. Climate change in Quang Tri Province

The evolution of climate in Quang Tri was results of research based on data from observation and measurement station systems during the period 1994-2013. The standard period used to compare is the period 1974-2013 and divided into 4 smaller periods, each period corresponding to a time of 10 years. There are the first period 1974-1983 (I), the

second period 1984-1993 (II), the third period 1994-2003 (III) and the last period 2004-2013 (IV). The analysis was focused on two elements of climate: temperature and precipitation.

- Temperature

Synthetic data showed that, the last period was the period that has the highest average temperature with 24.5°C (24.473°C), 0.003°C higher than the third period, 0.153°C higher than the second period, 0.183°C higher than the first period, 0.1°C higher than the average temperature of standard period.

Table 6. The average temperature in the periods

Period	I	II	III	IV	1974-2013
Average Temperature (°C)	24.3 (24.290)	24.3 (24.320)	24.5 (24.470)	24.5 (24.473)	24.4 (24.388)

Source: The data was calculated based on data of measuring stations in many years

The average temperature in the last period had 6 years higher than the standard period, namely 0.1°C higher than 2013, 0.2°C higher than 2007, 0.3°C higher than 2009, 0.4°C higher than 2006 and the highest average temperature was 2010 with 25.1 °C (0.7°C higher).

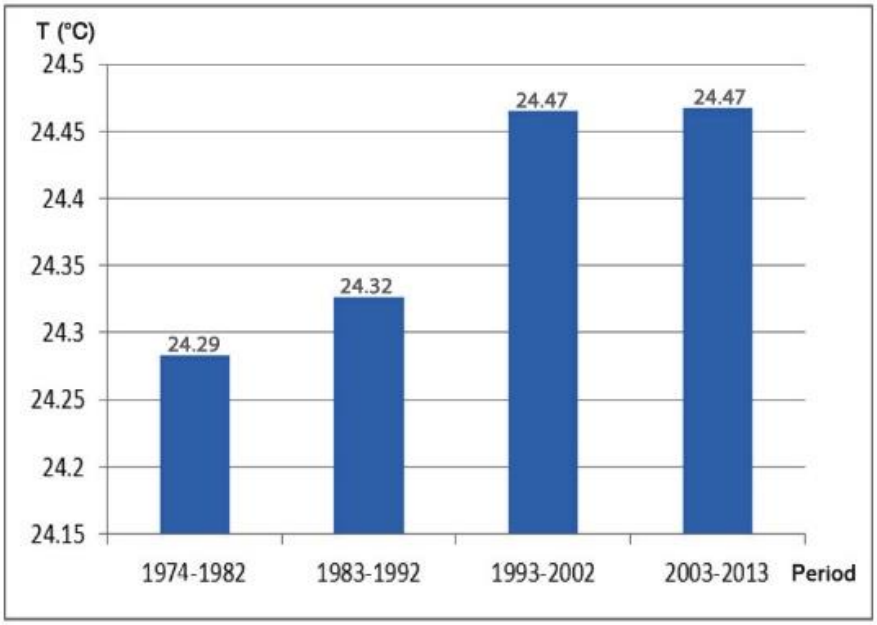


Figure 17. The chart of average temperature in the periods.

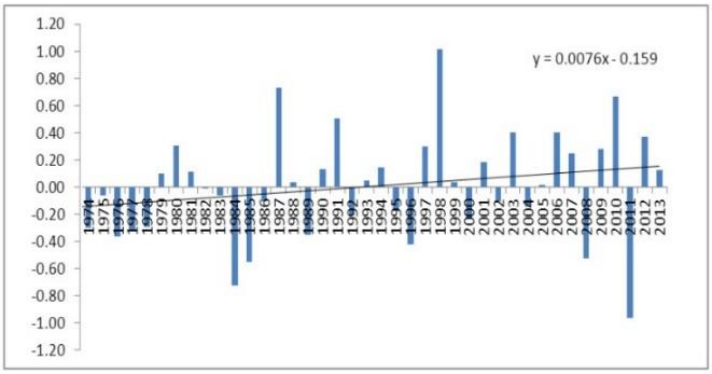


Figure 18. Average temperature anomalies in Quang Tri from 1974 to 2013

The charts above noticed that there were 3 months with the temperature higher than the average temperature of the standard period, it increased to 5 months and 6 months in the third period and the last period. It means that the temperature tends to rise over time.

- Precipitation

Because of geographic characteristics, rainfall distribution in stations was different, the lowest rainfall with 2118.6mm was measured at Khe Sanh station (Huong Hoa district) while the highest rainfall was in Ba Long station (Da Krong district) with 2794.3mm.

Table 7. The table of average precipitation of the third period and last period

Period	III(1994-2003)	IV (2004-2013)	1973-2013
Average precipitation (mm)	2339	2400	2325

Source: Result was calculated based on database of measuring stations in many years

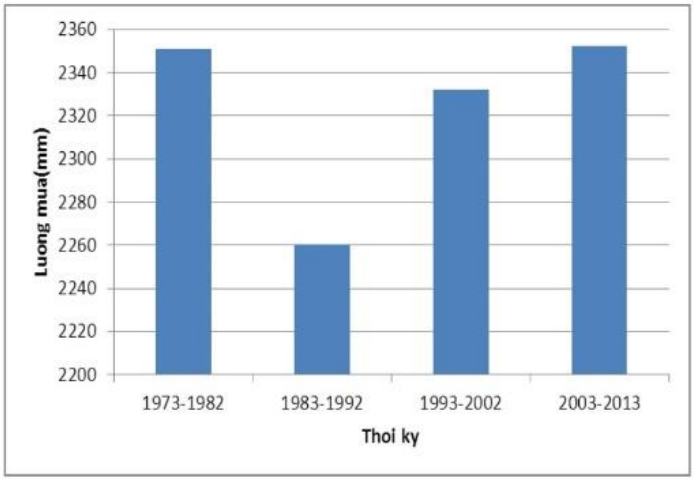


Figure 19. The chart of average precipitation of the periods

Due to the heterogeneity of rainfall data in the first period and second period, so database used below was derived from a research of Nguyen Thanh Loi[11].

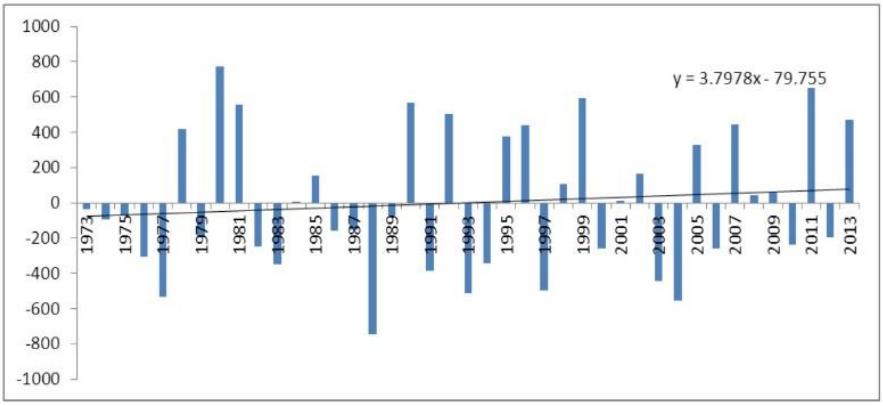


Figure 20. The average temperature anomalies in Quang Tri from 1974 to 2013.
Source: Studying the evolution of climate and hydrological in Quang Tri in the 1993 - 2013 period under the impact of climate change for developing the socio-economic, Nguyen Thanh Loi, 2015.

Comparing to the previous periods, the average rainfall in the last period was higher than the first period about 1mm, the second period nearly 92mm, the third period from roughly 20mm. There were 12 years with the rainfall higher than the average rainfall, including 1995, 1996, 1998, 1999, 2001, 2002, 2005, 2007, 2008, 2009, 2011 and 2013.
The first and second period had 3 years with the average rainfall higher than the standard period, it increased 5 years in the third period and 6 years in the last period. The above results showed that the precipitation had many changes in each period, and the biggest change was in the last period (from 2004 to 2013).
The change of weather elements led to the change of climate that directly impacts and causes extreme effects and disasters. Therefore, if those changes are predicted and combined with the timely response measures, it will reduce the consequences of climate change. The change of climate elements under climate change in period 2015-2035 was predicted as follows:
- Temperature
The average temperature for the period 2015-2035 is likely to rise in a range of 1°C compared to the standard period (from 1974 to 2013). There are 20 years with the higher temperature than the standard temperature (from 24.4°C to 27.1°C) and only one year with

[11] T. L. Nguyen. Studying the evolution of climate and hydrological in Quang Tri in the 1993 - 2013 period under the impact of climate change for developing the socio-economic (Nghiên cứu diễn biến khí hậu, thủy văn tỉnh Quảng Trị giai đoạn 1993 – 2013 dưới tác động của biến đổi khí hậu phục vụ phát triển kinh tế - xã hội trên địa bàn tỉnh). Quang Tri's Department of Science & Technology, Quang Tri, 2015.

the lower temperature than the standard average temperature (2018 - 23.7°C). The temperature in mountainous regions is predicted to increase higher than plain regions.

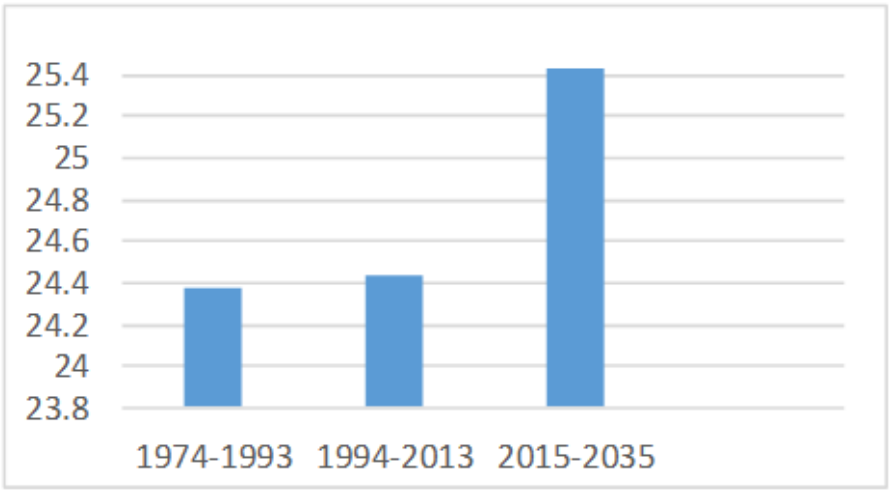


Figure 21. The chart of average temperature change in the period 2015-2035
Source: Author

There are ten years with abnormal high temperature (average monthly temperature higher than 30°C), 2015, 2017, 2020, 2025 to 2030 and 2035. There are fifteen years with unusual low temperature (average monthly temperature lower than 20°C), 2016 to 2024 and 2030 to 2035. The abnormal changes of temperature will be the causes of disasters such as drought, storm and flood. Table 8 shows the average temperature of Quang Tri from 2015 to 2035.

Table 8. The table of average temperature in Quang Tri from 2015 to 2035

Month /year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Ave.
2015	23.3	25.6	28.3	31.3	33.1	30.6	29.5	28.4	28.0	24.3	20.8	20.8	27.1
2016	17.9	21.6	27.6	25.6	26.5	27.1	28.0	28.3	26.0	23.8	21.6	22.0	24.6
2017	20.8	22.5	26.4	30.1	29.1	27.7	28.6	28.6	26.5	24.5	21.6	19.4	25.5
2018	17.7	20.3	22.1	24.6	26.0	26.9	28.6	28.3	26.1	24.1	20.2	20.0	23.7
2019	17.6	20.8	25.9	26.4	26.5	28.0	28.2	28.3	26.2	24.1	22.2	19.1	24.4
2020	18.6	24.2	26.1	33.2	34.1	27.4	27.8	28.1	26.5	24.6	23.0	21.5	26.3
2021	19.1	24.0	26.7	28.7	27.5	29.4	28.7	28.4	25.7	23.3	21.6	20.7	25.3
2022	21.2	22.5	27.5	26.2	26.6	29.3	29.2	28.2	25.7	23.2	21.6	18.6	25.0
2023	20.9	19.6	23.7	25.3	26.8	29.1	29.0	29.3	26.5	23.3	20.5	19.1	24.4
2024	19.4	20.6	28.0	29.0	28.1	27.5	27.9	27.9	26.4	23.0	21.8	22.1	25.1
2025	22.5	22.6	27.9	31.3	29.9	28.9	28.7	27.3	26.0	24.2	23.2	23.8	26.4
2026	22.9	23.3	25.8	30.8	30.3	28.3	29.2	27.7	27.0	25.1	23.0	20.7	26.2
2027	20.4	21.4	26.4	30.8	29.9	30.2	29.0	27.6	26.6	24.2	23.8	23.2	26.1
2028	20.8	22.5	27.7	32.3	33.2	30.6	29.0	28.0	27.2	24.2	23.5	22.4	26.8
2029	21.6	21.3	26.2	31.8	32.7	31.4	29.0	27.8	27.3	24.6	23.6	24.2	26.8

2030	22.6	21.3	28.8	30.3	29.5	28.8	29.7	29.4	27.1	23.3	22.3	19.1	26.0
2031	19.6	19.9	24.3	26.9	27.9	28.8	29.2	28.0	26.5	24.1	21.5	20.1	24.7
2032	18.4	21.7	28.8	24.6	26.0	28.5	29.6	29.0	26.2	24.4	22.3	20.1	24.8
2033	18.2	20.4	24.6	24.5	28.7	29.7	28.1	30.5	26.6	24.8	20.8	19.4	24.7
2034	19.4	21.7	21.2	26.4	27.2	29.4	30.2	28.9	26.5	24.4	21.8	18.5	24.6
2035	19.2	24.0	26.4	30.1	28.3	28.2	28.8	28.1	27.5	24.5	23.0	21.5	25.8

**Unit:ºC*

- Precipitation

The general rainfall tends to increase in the rainy season and decrease in the dry season that was described in *Table 9*. The rainy season rainfall (from September to next January) in mountainous areas has been predicted up to 221mm in the period 2015-2035, almost the same with the standard period (224mm). However, the monthly precipitation fluctuates very differently. The rainfall of September significantly reduced, while November, December, next January tends to increase. The dry season rainfall (from February to August) will decrease appreciably, from 143mm to 74mm.

Table 9. Precipitation of the rainy and dry season projected in Dong Ha and Khe Sanh station.

Station	Period			
	1973-2013		2015-2035	
	Rainy season	Dry season	Rainy season	Dry season
Dong Ha	353.9	83.8	232.6	70.1
Khe Sanh	224.4	143.1	220.8	73.6

**Unit: mm*

3.3. Sources of flooding

In the document "Designed for Flood risk" of RIBA (Royal Institute of British Architects), the sources of flood risk were divided into 6 sections, including tidal flooding, fluvial flooding, ground water flooding, fluvial flooding, flooding from sewers and flooding from man-made infrastructure. Or in the research "classification of floods" of A.F Mandych (Department of Physical Geography and Land-use, Institute of Geography, Moscow, Russia), there are three factors causing flood, including river floods, inundation of seacoasts, floods of inland seas and lakes. However, after surveying the current situation in Quang Tri, the sources of flood risk were divided into 3 main sources, including flooding from upstream and fluvial system, pluvial flooding and tidal flooding. Sometimes flood occurs due to a combination of 2 or 3 factors above.

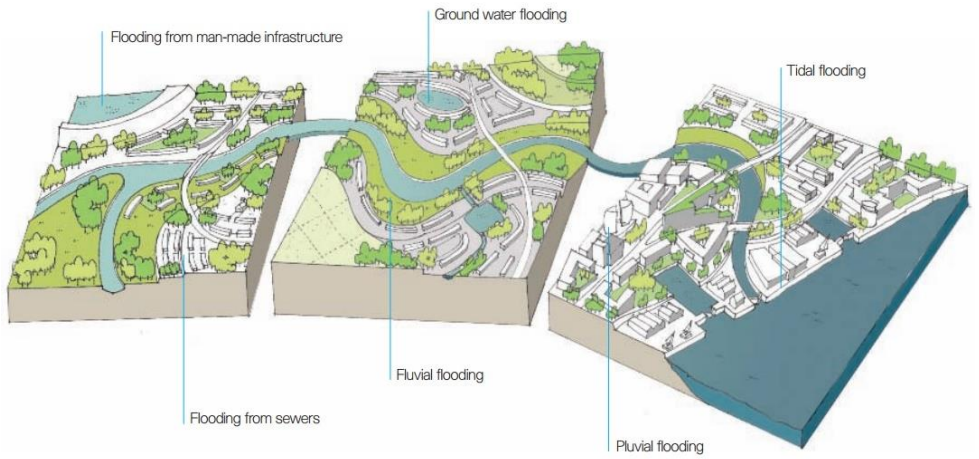


Figure 22. The sources of flood
Source: B. Gething and K. Puckett. Designing for Flood Risk. Climate Change Toolkit, London, RIBA (Royal Institute of British Architects), 2013.

3.3.1. Flooding from upstream and fluvial system

Upstream area of Quang Tri's river system are hills and high mountains, areas in between are valleys with slots, streams and small river system. That is also the drainage to deliver water from upstream to downstream. However, because of the geology and topographic characteristics, this drainage is very steep and been gradually narrowed. So when there is a heavy rain or extreme rain in a short time, the water will flow from the upstream to downstream with high velocity and volume. If the river and lake systems in downstream have not enough space for storage or delivery to the ocean, it will cause flooding in the plains. Flood risk from upstream and fluvial systems is very difficult to predict. It usually occurs in Quang Tri territory and causes large damages.

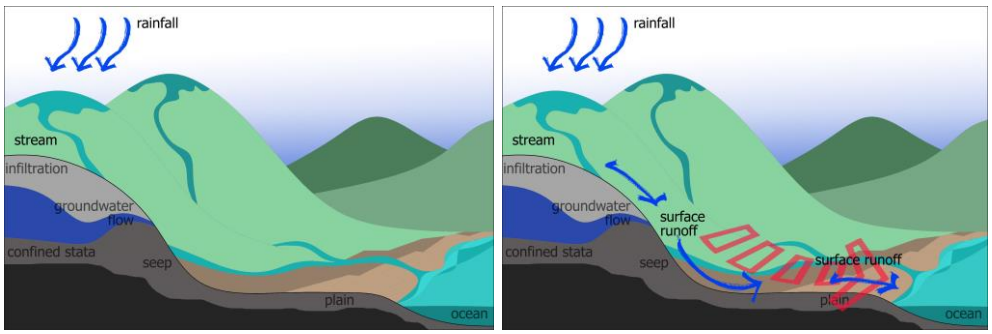


Figure 23. Illustration of flooding from upstream and fluvial system
Source: Author

In addition, the industrial constructions were also built in this area, such as hydropower plants or pumping stations, leading to affect the natural drainage. And if there is any incident that occurs can also cause downstream flooding damage can not be anticipated.

3.3.2. Pluvial flooding (urban flooding)

When the drainage system (natural and artificial) that can not store or transport a heavy rainfall will cause flooding, called pluvial flooding or urban flooding. The risk of flooding from pluvial flooding in urban or residential areas is usually higher than in countryside areas, because of the urban development has increased impervious surface area, affecting the natural water absorption. Besides, the urban structure or urban planning does not meet the drainage problems, combined with intense rainfall can also increase the flood risks.

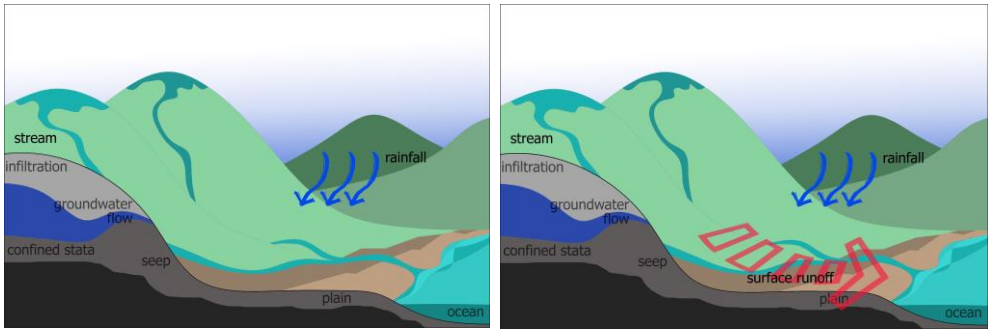


Figure 24. Illustration of pluvial flooding
Source: Author

However, this risk can be predicted based on the rainfall and urban drainage systems. It also occurs in the same areas depend on the level of the ground, so if it is to accurately predict the risk can be reduced. The flood risk can be reduced if it is predicted correctly.

3.3.3. Tidal flooding

The ebb phenomenon of tide (the sea level rises every 6 hours and it goes down again in the next 6 hours) is a normal nature phenomenon and as a rule, it is usually repeated monthly. Besides, in Vietnam, the highest tide level in the year is in October, November, December and next January. There are four main reasons leading to the tide ebb. Firstly, it is caused by the gravity of the Earth and the Moon. Secondly, it is caused by the flow of the atmosphere and wind. Thirdly, it is impacted by the random phenomenon, such as storm, earthquake, etc. For example, when the tide is rising and a storm comes from the sea at the same time, it will contribute to rising quickly of the tide level . Or earthquakes happen in the ocean but it will cause tsunamis, leading to rising suddenly of the tide level. Fourthly, climate change causes the rising of tide level every year.

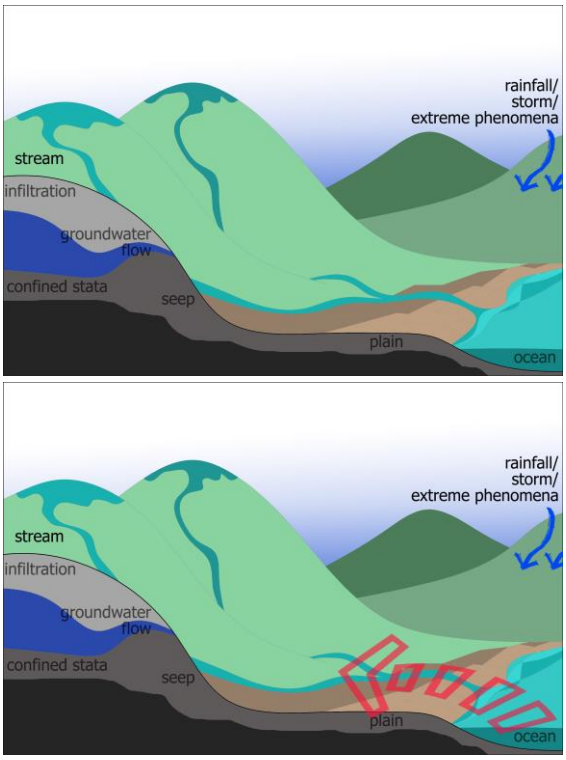


Figure 25. Illustration of tidal flooding
Source: Author

Although the tide ebb has certain rules but sometimes it is combined with other effects causes abnormal changes that it is difficult to control.

3.4. Climate change has increased the flood risks and extreme consequences

3.4.1. Climate change and flood risks

Based on the changes of the climate elements and the sources of the flood risk were studied above, it can be confirmed that climate change is one of the indirect cause to increasing the flood risk in both the volume and damage.
Although there was difference between EM-DAT (range 35-213 floods) and DFO (42-235 floods) in the number of events reported annually, an average of 135 floods (range 35-235 floods) occurred and affected human populations annually and 82% of them occurred during or after the 1990s. The frequency of flood events raised gradually over time and impacts on human activities varied greatly between years and were often happened around large events (*Figure 26 and Figure 27*).

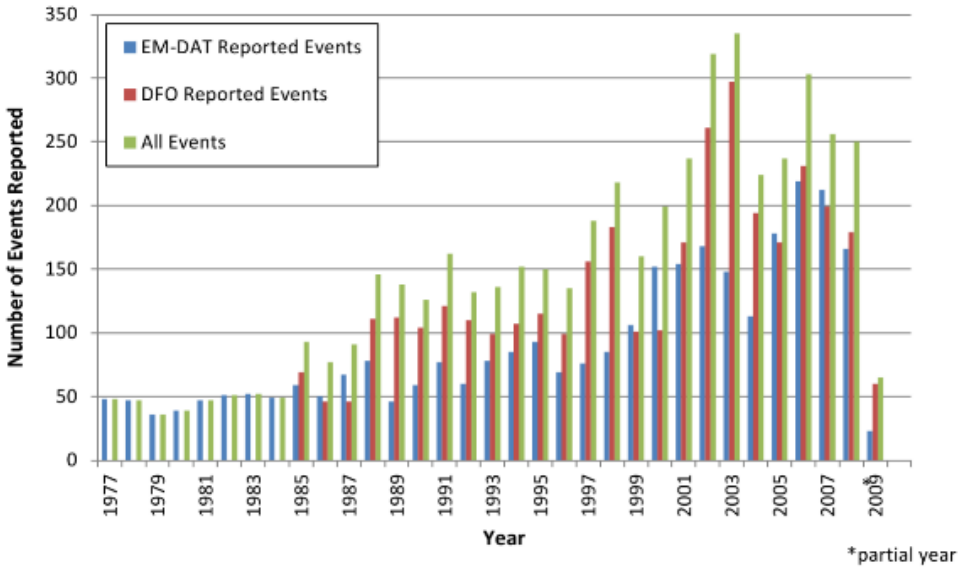


Figure 26. Statistics of flood events by EM-DAT and DFO
Source: S. Doocy, A. Daniels, S. Dooling et al. The human impact of volcanoes: a historical review of events 1900-2009 and systematic literature review. PLoS currents, vol. 5, 2013.

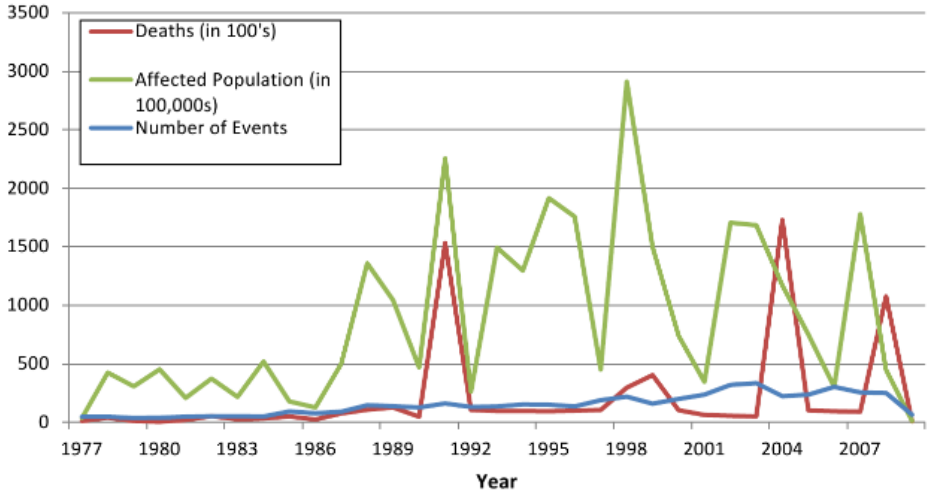


Figure 27. Number of flood events and effects on population
Source: S. Doocy, A. Daniels, S. Dooling et al. The human impact of volcanoes: a historical review of events 1900-2009 and systematic literature review. PLoS currents, vol. 5, 2013.

For example:
- 1991: The storm on 30 April in Bangladesh killed at least 131.000 people.
- 1992: The Andrew's storm in Florida (U.S) killed 65 people, destroyed 25.000 houses and damaged 20 billion USD.
- 1993: The muddy flood in Honduras killed 400 people and destroyed over 1000 houses in three days, from 31 October to second November.
- 1998: This year can be considered as the biggest natural disasters in the 20th century, such as the tornado appeared in Florida on 23 February, killed at least 42 people, more than 260 people were injured and hundreds of houses were damaged; the muddy flood in May occurred in Sarno city, killed at least 135 people and more than 2.000 people were lost houses; The unusual heat wave killed more than 2.500 Indians from May to early June; The flood in two months (from July to August) in Yangtze River killed 3.656 people and affected 230 million people; The tsunami happened in Papua New Guinea on 17 July killed at least 2,500 people;
- 1999: Flood and flash mud killed at least 10.000 people in Venezuela in December. The Government of Venezuela declared that it was the worst hazard for years.
- 2002: European borne the large flood that damaged 20 billion Euro and killed over 200 people in August.

Climate change is happening and the flood is also increasing in both quantity and danger, so how is the relationship between them?

For example, the case of tidal flooding, climate change raises the global average temperature leading to thermal expansion of the ocean, melting of ice in Greenland and Antarctic or the reducing of evaporation capability in landward, are the causes to rising the sea level. In which, the thermal expansion phenomenon of the ocean was been considered a key factor leading to the rising of sea level. However, a new database of the melting of ice in Greenland and Antarctic showed that it has more influence. The sea level is rising while the ground level has no change. The first, it will cause flooding in the lowlands and then it will affect the dam system that was built to prevent the sea level before and the result is a large area will be flooded.

Or the case of flooding from upstream and fluvial system, climate change alters the number of sunshine hours, precipitation, evaporation, wind direction and speed will affect precipitation in upstream as well as in plain. If these changes are predicted incorrect or no solutions for prevention, the inundation is inevitable.

3.4.2. Impacts of climate change on world heritage sites

The World Heritage Committee at its 29th session in 2005 recognized that the impacts of climate change are affecting many World Heritage properties and are likely to affect much more, both natural and cultural, in the years ahead[12].

The impacts of climate change have been destroying nearly all of the heritage sites in the world. The melting of sea ice increases not only flooding the lowlands where maybe

[12] A. Colette. Case studies on climate change and World Heritage. Paris, UNESCO World Heritage Centre, 2009.

contains the world heritage, but also affect the surrounding ecosystem, such as Sagarmatha National Park (Nepal) , Huascaran National Park (Peru), Ilulissat Icefjord (Denmark), Kilimanjaro National Park (United Republic of Tanzania) Jungfrau-Aletsch-Bietschhorn or (Switzerland). The rising of the sea level is also the cause of the shrinking and intersection of Sundarbans mangrove forests wich is the largest of such forests in the world (more than 10,000 km2 of land and water, more than half in India, the rest in Bangladesh), placed in the delta of the Ganges, Brahmaputra and Meghna Rivers, on the Bay of Bengal.
Archaeological evidence have preserved under the ground until now because they have attained a balance by the biological, chemical and hydrological biological processes of the soil. Climate change will be accompanied by a number of changes in environmental elements that may threaten buried evidence by exacerbating decomposition at archaeological sites, such as Chan Chan Archaeological Zone (Peru), Ivvavik/ Vuntut/ Herschel Island (Canada), Chavín Archaeological Site (Peru) or Golden Mountains of Altai (Russian).

3.4.3. In the case of Venice and its lagoon, Italy

Founded in the 5th century includes over 118 small islands, Venice was a major maritime power in the 10th century. The whole city is an architectural masterpiece in which even The most idyllic building contains works by some of the world's greatest artists such as Giorgione, Titian, Tintoretto, Veronese. It was directly associated with living activities and events of local people, with ideas, beliefs, events, festivals and literary works of outstanding universal significance. Therefore, it was recognized a heritage of the world in 1987 with six cultural criteria. There are Venice is a unique artistic achievement; The influence of Venice on the development of architecture and monumental arts is considerable; With the unusualness of an archaeological site which still breathes life, Venice bears testimony unto itself; Venice possesses an incomparable series of architectural ensembles illustrating the high of the Republic’s splendour; In the Mediterranean area, the lagoon of Venice represents an outstanding example of a semi-lacustral habitat which has become vulnerable as a result of irreversible natural and climate changes. In this coherent ecosystem where the muddy shelves (alternately above and below water level) are as important as the islands, pile-dwellings, fishing villages and rice fields need to be protected no less than the palazzi and churches; Venice symbolizes the people’s victorious struggle against the elements as they managed to master a hostile nature. The city is also directly and tangibly associated with the history of humankind.
The first ten years of the 20th century, St. Mark's Square flooded less than ten times per year. Flooding was considered the highest on record occurred on 16 November 2002 with the flood level was 147cm, 67cm higher than the surface of St. Mark's. It was 144 cm in flood event occurred on 06 November 2000 and was one of the ten most severe events since the 1900s, with 93% area of the city under water. Flooding was occurring 40 times per year in the 1980s and over 60 flood events per year have been recorded since September 2000. Within the 20th century, the IPCC reports that the global average sea level rose between 0.1 m and 0.2 m, adding to the natural subsidence of the Venice lagoon of 1 - 1.5 mm per year. It means that flooding situations of Venice and its lagoon will be increasingly worse.

Figure 28. St. Mark's Square flooded in 2012 and reach the sixth highest tide level in 150 years
Author: Larisa Brown, available at: http://www.dailymail.co.uk/news/article-2231342/Tourists-swim-Venices-iconic-St-Marks-Square-Floating-City-flooded-high-tides.html.

The reduction and adaptation solutions for flooding problems in Venice were the subjects of many meetings and discussions. The mobility management solutions that harness natural processes to cope with sea level rise rather than hard defenses should be applied? The Italian Government finally decided for the implementation of mobile barriers (the so-called MOSE system, Experimental Electromechanical Module or Modulo Sperimentale Elettromeccanico) to protect the City of Venice and its lagoon from high waters. They've been applied for the protection of St Mark's Square and for the construction of breakwaters at the Malamocco inlet.

3.4.4. In the case of Historic City of Ayutthaya, Thailand

Thailand is a country at the central of the Indochinese peninsula in Southeast Asia and known as a country with amazing history, cultural, landscapes through archaeological sites, museums, temples, festivals, sandy beaches, hill tribe, wildlife, tropical islands and several heritages. In the heritage system of Thailand, there are five heritages recognized by Unesco as the World Heritage Sites, including Ban Chiang Archaeological Site (designated in 1992), Historic City of Ayutthaya (designated in 1991), Sukhothai and Associated Historic Towns (designated in 1991), Dong Phayayen Khao Yai Forest Complex (designated in

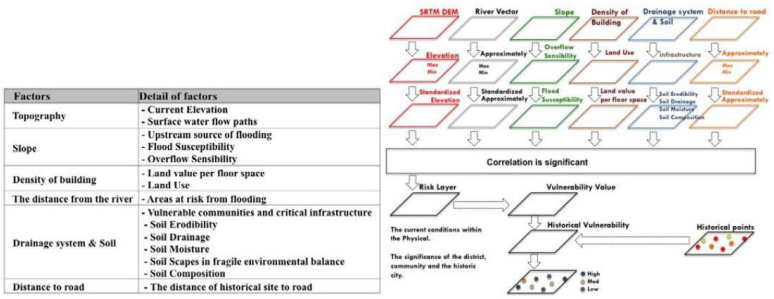
2005), Thungyai Huai Kha Khaeng Wildlife Sanctuaries (designated in 1991)[13]. In which, Ayutthaya (historic city of Ayutthaya) has been seriously affecting by the annual flooding.

Figure 29. Historic City of Ayutthaya (Thailand)
Note: (a) The tourist map of Ayutthaya historic city. (b) Overview of Wat Chaiwatthanaram Buddhist temple in the city of Ayutthaya Historical Park. (c) A View of Ayutthaya.
Source: (b) Author: Tuul & Bruno Morandi, available at: http://brunomorandi.photoshelter.com/image/I0000Dek.DSGVPXI. (c) Author: Patricia Alberth, available at: whc.unesco.org/en/documents/122793.

The Historic City of Ayutthaya was formed in 1351 by King Uthong (or Ramathibodi I) and became second capital of the Kingdom of Siam (after Sukhothaiuntil). It was located on an island surrounded by three rivers (Chao Phraya, Lopburi and Pa Sak River) connecting the city to the sea and above the tidal bore of the Gulf of Siam as it existed at that time. Thus, the city escaped attacks by the sea-going warships of other nations. The location also helped to protect the city from seasonal flooding[14]. It grew to be one of the world's largest and most cosmopolitan urban areas and a center of global diplomacy and commerce during the time from the 14th to the 18th century. The city was attacked and destroyed by the Burmese army in 1767. Ayutthaya is now an archaeological ruin, characterized by the remains of tall prang (reliquary towers) and Buddhist monasteries of monumental proportions, which give an idea of the city's past size and the splendor of its

[13] UNESCO. Properties inscribed on the World Heritage List. http://whc.unesco.org/en/statesparties/th/.
[14] UNESCO. Historic City of Ayutthaya. http://whc.unesco.org/en/list/576.

architecture. The Fine Art Department began the renovation on the ruins in 1969 with the site being declared historic park in1976. In 1991, part of the Historic City of Ayutthaya was listed as UNESCO World Heritage Site. The listed part of the site covers the central and the southwestern part of Ayutthaya Island including Wat Mahathat, Wat Phra Ram, Wat Ratchaburana, and Wihan Phra MongKhon[15].



Factors	Detail of factors
Topography	- Current Elevation - Surface water flow paths
Slope	- Upstream source of flooding - Flood Susceptibility - Overflow Sensibility
Density of building	- Land value per floor space - Land Use
The distance from the river	- Areas at risk from flooding
Drainage system & Soil	- Vulnerable communities and critical infrastructure - Soil Erodibility - Soil Drainage - Soil Moisture - Soil Scapes in fragile environmental balance - Soil Composition
Distance to road	- The distance of historical site to road

Figure 30. Disaster vulnerability factors
Source: W. Daungthima and H. Kazunori. Assessing the flood impacts and the cultural properties vulnerabilities in Ayutthaya, Thailand. Procedia Environmental Sciences, vol. 17, pp. 739-748, 2013.

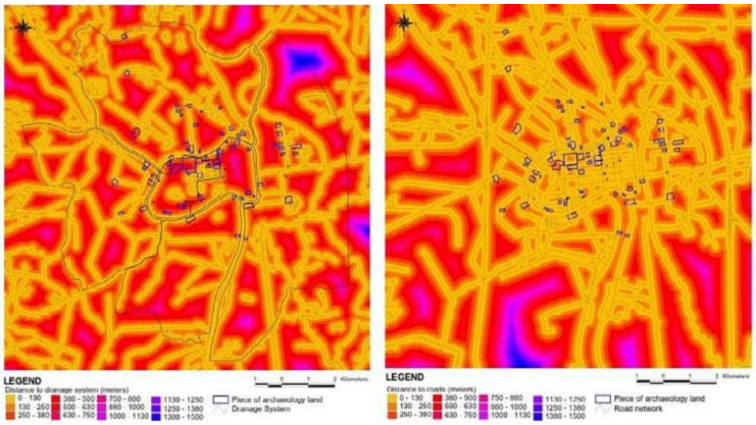


Figure 31. The drainage system of Ayutthaya historical sites and the distance from road of Ayutthaya historical site
Source: W. Daungthima and H. Kazunori. Assessing the flood impacts and the cultural properties vulnerabilities in Ayutthaya, Thailand. Procedia Environmental Sciences, vol. 17, pp. 739-748, 2013.

[15] WorldAtlas. UNESCO World Heritage Sites in Thailand. http://www.worldatlas.com/art-icles/unesco-world-heritage-sites-in-thailand.html.

Flooding is an important natural risk in Thailand. It usually occurs every year and the river basins are places being the most affected. It is similar to Ayutthaya's river basin area. Ayutthaya's river flooding problems occur for such a long time ago. In the past, the local people solved this problem by digging canals we still can find today many canals and water gates today at most of the rivers around and inside the Ayutthaya Island[16]. However, those canals are not appropriate in the current situation under the changes of social, economic, urban development, climate and environment. Many flood events happened and negatively affected the heritage system. In that, a flood in 2011 affected and damaged seriously to many important historic monuments of Ayutthaya.

Figure 32. Flooding in Ayutthaya Province in 2011
Source: NASA (National Aeronautics and Space Administration).

For example, the reclining Buddha at Wat Lokayasutharam carved by cement with dimensions of 37 meters long and 8 meters high. The sculpture is located inside the historic area of Ayutthaya city. This place is regarded as a sacred place for offerings and praying of local people and visitors. This Buddha, whose head rests on a lotus flower and it is usually dressed in yellow tunic so characteristic of Ayutthaya. However, it has been damaging by natural disasters, human impacts and environment.

[16] W. Daungthima and H. Kazunori. Assessing the flood impacts and the cultural properties vulnerabilities in Ayutthaya, Thailand. Procedia Environmental Sciences, vol. 17, pp. 739-748, 2013.

Figure 33. Wat Chaiwatthanaram Buddhist temple before and after flooding in 2011
Note: (a) The image was taken from video Aerial shot: Wat Chaiwatthanaram Buddhist temple in the city of Ayutthaya historical park, Thailand footage from drones, shows Wat Chaiwatthanaram Buddhist temple and surrounding landscape in the normal state. (b) The aerial picture shows the flooded World Heritage site Chaiwattanaram Temple on 11 October 2011.
Source: (a) Author: Thana Thanawong, available at: http://www.shutterstock.com/fr/video/clip-12804683-stock-footage-aerial-shot-wat-chaiwatthanaram-buddhist-temple-in-the-city-of-ayutthaya-historical-park.html?src=rel/14617711:9/gg. (b) Author: Christophe Archamba-ult/Afp/Getty Images, available at: http://climateadaptation.tumblr.com/post/1132-6573721/nationalpost-photos-of-the-day-this-aerial.

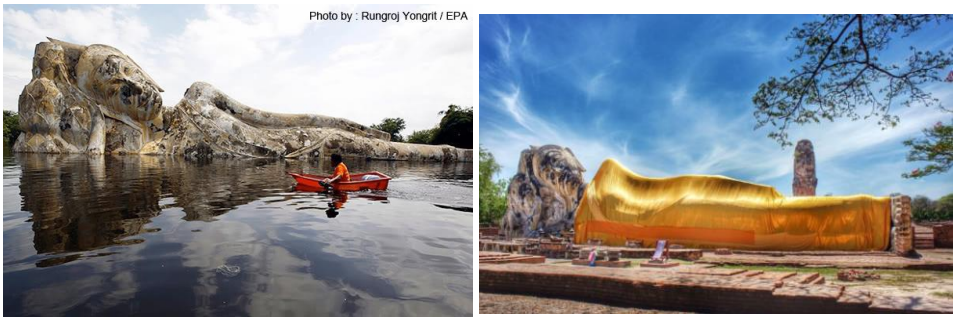


Figure 34. Reclining Buddha image at Wat Lokayasutharam after and before flooding in October 2011
Source: (a) Author: Rungroj Yongrit/ EPA, available at: http://explorelah.blogspot.it/2011/11/10/bangkok-ayutthaya.html. (b) Author: Nayika C, availabel at: https://commons.wikimedia.org/wiki/File:Wat_Lokayasutharam_(Temple)_Ayuthaya,_Thailand.jpg.

The expressions of the negative impact on the reclining Buddha were shown in the Figure 35, such as the colour of sculpture has been changing; the sculpture surface has been corroding and appearing many cracks; the base has been compromising by moss and weeds.

Figure 35. Expressions of the negative impact on the reclining Buddha.
Author: Vietnamitas en Madrid, edited by author, availabel at: http://en.vietnamitas-enmadrid.com/thailand/ayutthaya-historical-park.html.

Chapter 4.
Assessment of flood risk to heritage system in Quang Tri Province

4.1. Assessment methods

Flood risks for heritage were assessed based on the map that was a combination of the flood risk map and the heritage map by using overlay mapping method, called the heritage risk map. On the heritage risk map, a heritage can be determined whether it is in risk areas or not, the flood risk for heritage is high or low, or which solutions are necessary for heritage and surrounding spaces to response in flood events and more.

4.2. Flood risk mapping of research area

4.2.1. Overview of flood risk map

Flood maps are maps that show flood hazards, flood areas and related spatial informations, such as the map of flood depth, the maps of flood real-time, the map of flood velocity, that are indispensable components for an effective approach to manage flood risks. The flood situation occurred recently in the developing countries have called for flood risk assessments in urban and rural. This is particularly important when discussing spatial issues like land-use planning in the framework of flood management (WMO, 2008b).
"Flood risk is the combination of the probability of a flood event and of the potential adverse consequences to human health, the environment and economic activity associated with a flood event" source: European Flood Directive. Therefore, the flood risk map is not only the map shows flooded areas, but also a combination based on database of flood depth map, flood real-time map, flood velocity map, the momentum map of flood (the product of the water level and velocity of flood), elements in the flood (sediment, salt, chemicals, waste, soil, etc). In which, the database of flood depth, flood velocity and flood time has important role in determining the risks of flood. The integration between flood depth and flood velocity shows the ability to destroy objects in areas where floodwater flow through, such as human, ecosystems, houses or public buildings. Meanwhile the real-time of flooding will indirectly affect the destruction of the objects above, especially on heritages that are very weak to adapt to changes of environment.

The overall aims of flood maps is to provide informations in the past, the potential of floods and their impacts. Therefore, the flood risk map is not only scientific basis for urban planning to prevent flooding but also a basic document for the selection of building design solutions. It will provide the informations needed to inform people about the risk of flooding in where they are living and safety areas where they can evacuate in case of flood event.

There are many methods to develop flood maps, and fully depend on the condition of each individual, group or country. Nowadays, with the development of science and technology, the softwares are used to building flood maps have developed and applied commonly, such as GIS, Mike Flood, Nam.

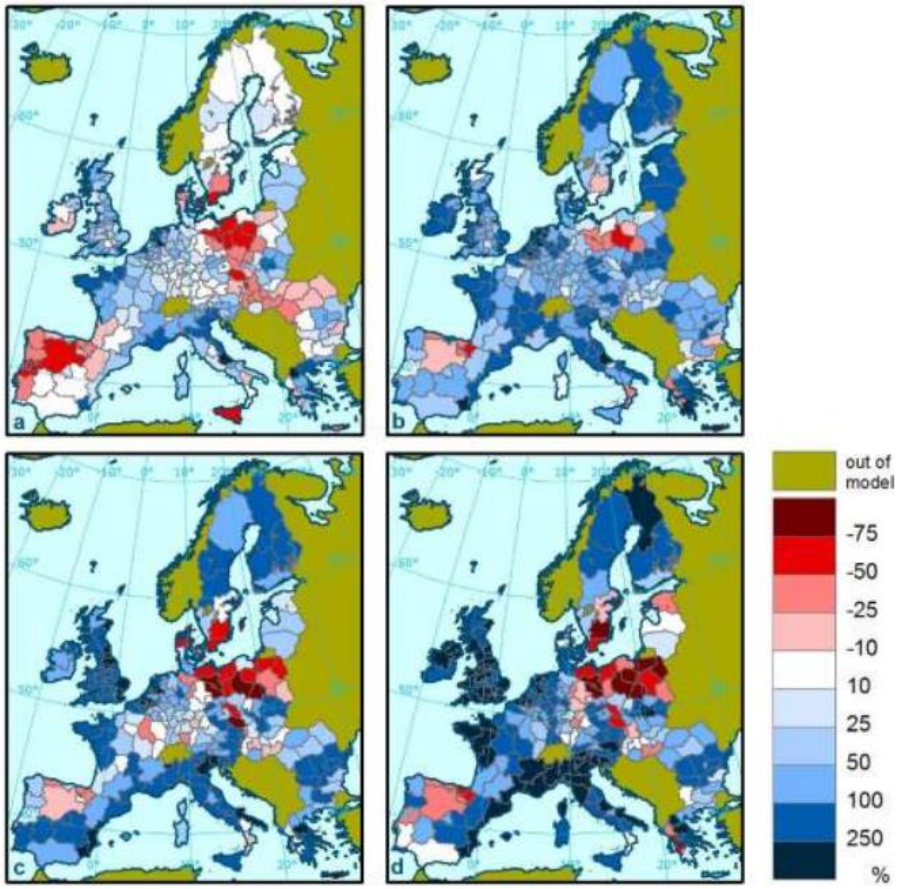


Figure 36. Change in expected annual damages
Note: Change in expected annual damages (averaged over administrative level NUTS2) from floods compared to the baseline period (1961-1990) for the 2000s (a), 2020s (b), 2050s (c) and 2080s (d), all for the A1B scenario. Ensemble average results based on LISF.
Source: JRC scientific and policy reports: Overview of disaster risks that the EU faces.

In November 2002, after the dramatic floods in Europe (among others Austria, Czech Republic, Germany), the Water Directors of the European Union (Norway, Switzerland and then Candidate Countries) agreed to take the initiative for severe actions in the prediction, prevention and mitigation of flooding. The flood maps are indispensable tools to provide informations about hazards, vulnerabilities and risks, and to implement the necessary prevention and preparedness solutions.

4.2.2. Introducing project "Natural disaster risk management project: Conducting field surveys and hydraulic modeling in the basin of Thach Han and Ben Hai River, Quang Tri Province"

"Conducting field surveys and hydraulic modeling in the basin of Thach han and Ben Hai River, Quang Tri Province" is one of the operations of section 4 (WB4) belong to natural disaster risk management project (NDRMP) , for the purpose of building flood maps of the basins and coastal floodplains in Thanh Hoa, Quang Tri and Quang Nam Province. The project was supported by loans from the World Bank (WB) through the International development Association (IDA). The project has four main components, investment to mitigate and disaster prevention; risk management based on community; reconstruction after disasters; enhancement for project management capacity.

The project objective is to build and deploy the hydraulic and hydrology model to support for urban planning and flood management in low areas in Quang Tri Province. The main objectives are as follows:

- To evaluate available data and collect more data for building hydraulic modeling and GIS database of flooding in Thach Han and Ben Hai River basin, Quang Tri Province.
- To develop and calibrate one-way models for river network (including hydrological model and hydraulic model) and two-way model for floodplains in Thach Han and Ben Hai River basin, Quang Tri Province.
- Applying the models to the current flood situations and combine some of flood management scenarios.
- Development and integration the flood maps based on GIS for managing and responding to floods.
- Completion and transfer of the technology of forecasting and warning flood to Quang Tri Province;
- Organise training for local officials to ensure the sustainability of the project results.

There are many approaches to mapping the design flood corresponding to different frequency, but within the project framework, flood calculation method was developed from design rain corresponding to design frequency based on assumption of the flood and rain phenomena that have the same frequency at the basins, and combined with the correction of calculated data at stations in research area. The steps in the process of design flood modeling are as follows:

- Step 1: Calculation of design flood flow at the sub-basin for hydraulic model with the design frequency of 1%, 2%, 5%, 10% and 20% by applying Mike-NAM hydrological model with the respective design rain.
- Step 2: Run the hydraulic model with the boundaries of flow simulated above.
- Step 3: Calculate the design flood water levels at the hydrological stations in Thach Han and Dong Ha River.
- Step 4: Comparison the simulation results of hydraulic model with the design flood parameters in step 3 and adjusting until the values are nearly equal.
- Step 5: Conducting design flood simulation, exporting the informations about flood water level, flood depth level, flood velocity, flood risk level, etc for the development of flood maps corresponding to the frequency.

Some of illustrations for design flood simulation process:

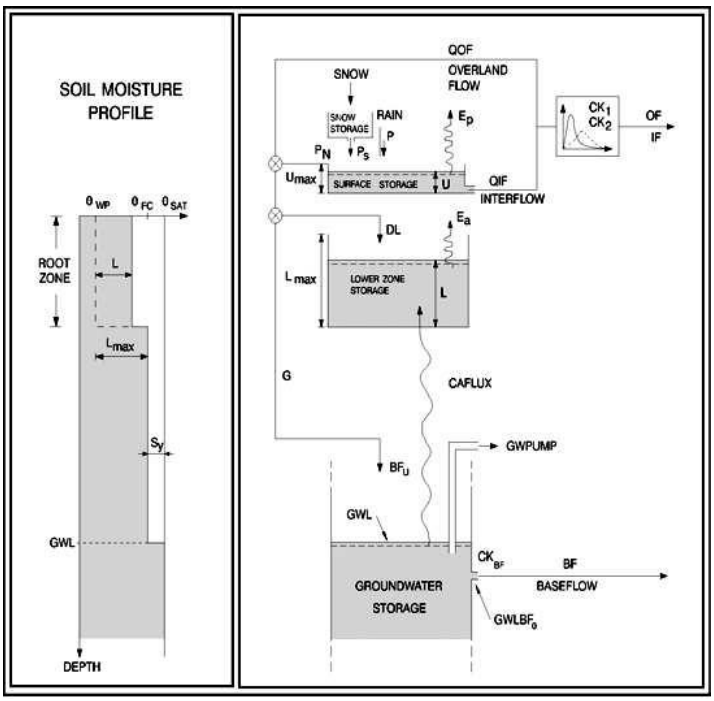


Figure 37. Vertical structure of Nam model.

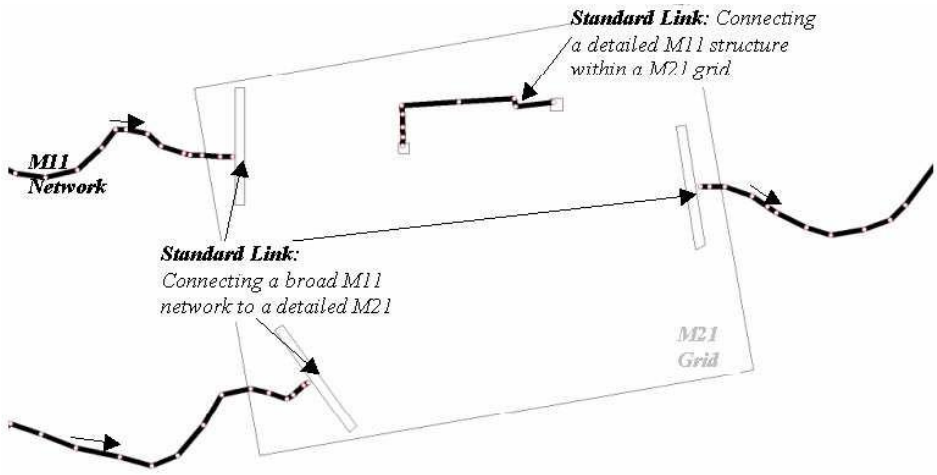


Figure 38. Standard link between Mike 11 and Mike 21 in Mikeflood

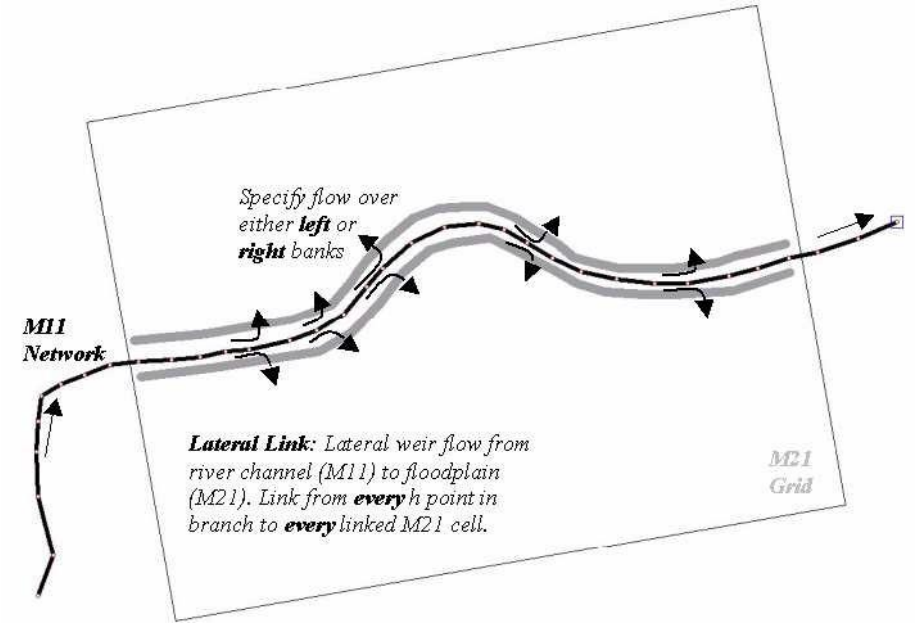


Figure 39. Lateral links between Mike 11 and Mike 21 in Mikeflood

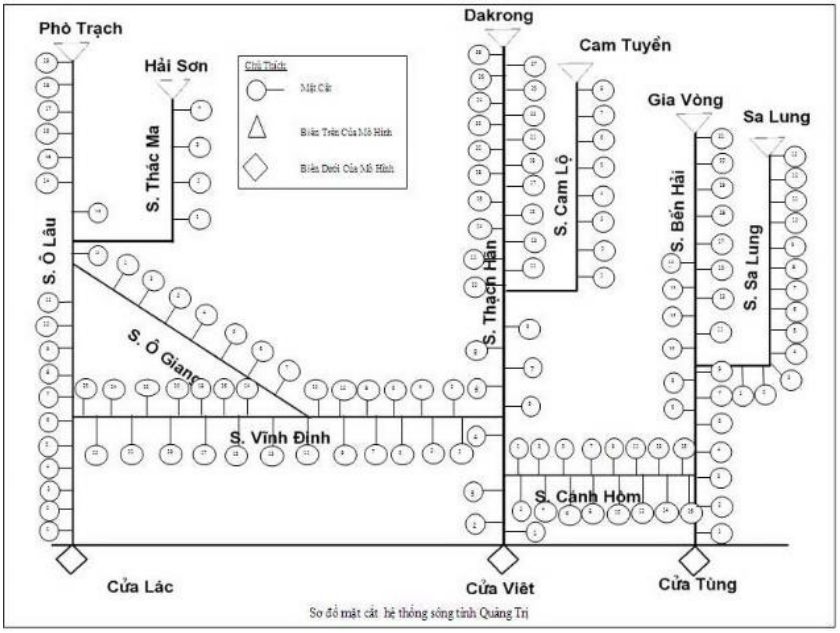


Figure 40. Diagram of hydraulic division in O Lau, Thach Han and Ben Hai River basin

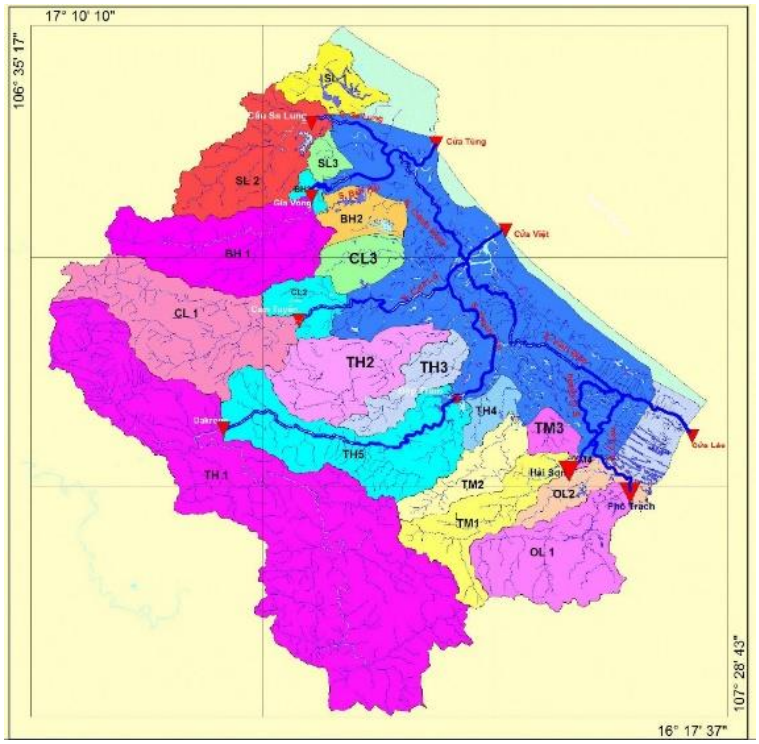


Figure 41. Division of the basins in O Lau, Thach Han and Ben Hai River.

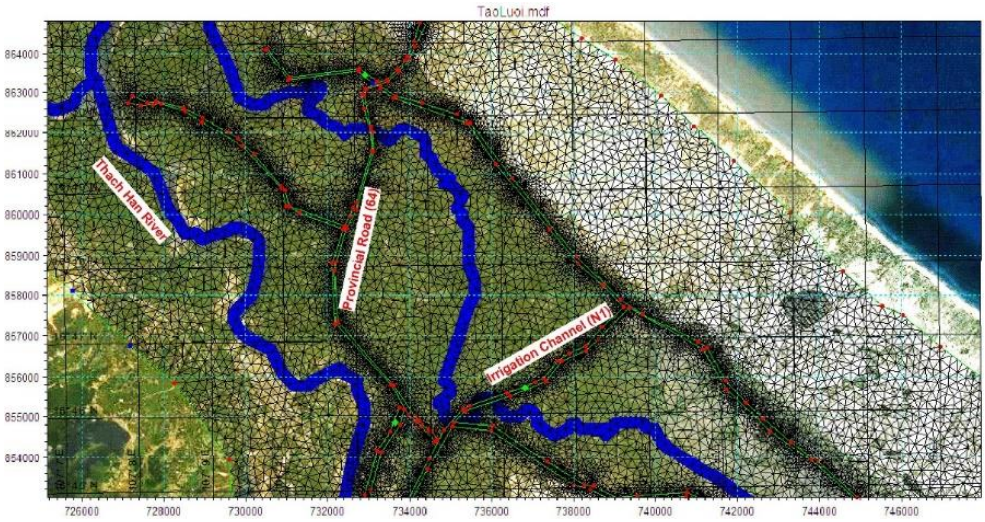


Figure 42. Limitation of calculated area

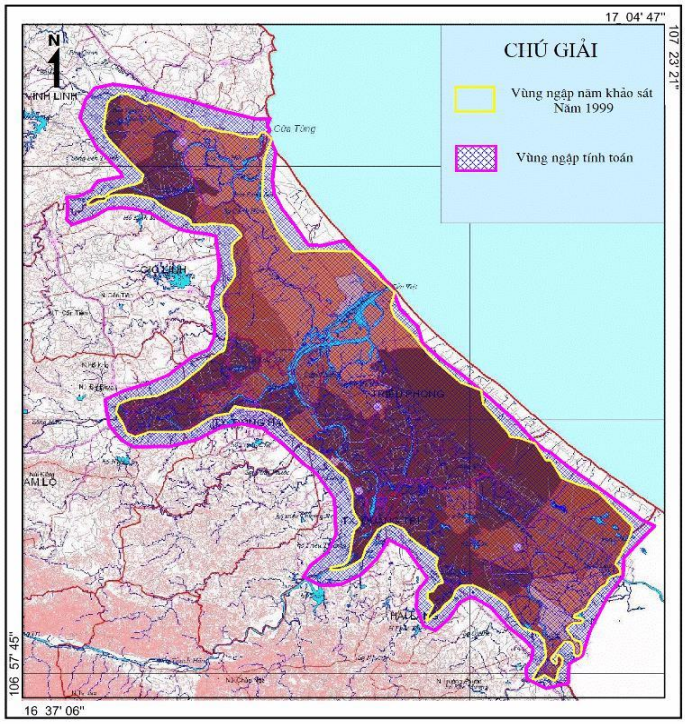


Figure 43. Mesh divisions in the research area.

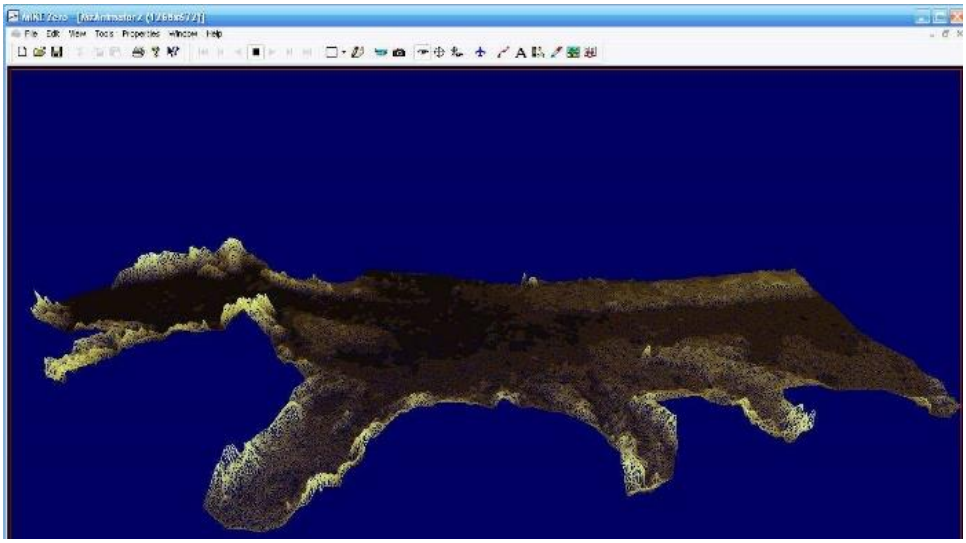


Figure 44. Illustration of finite element mesh used in the research area.

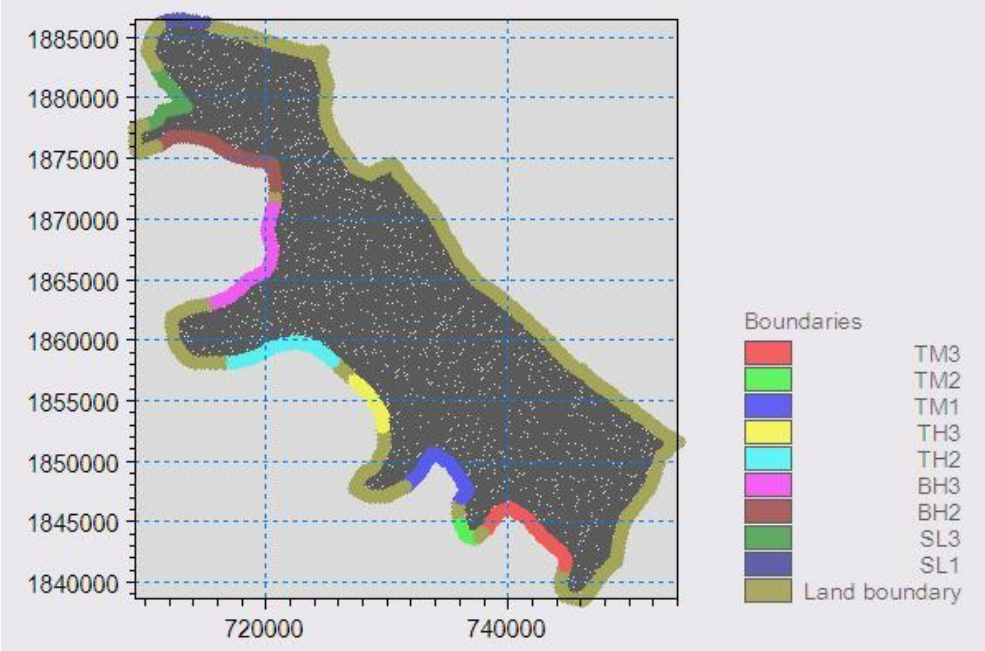


Figure 45. Relative positions of boundaries in two-way model

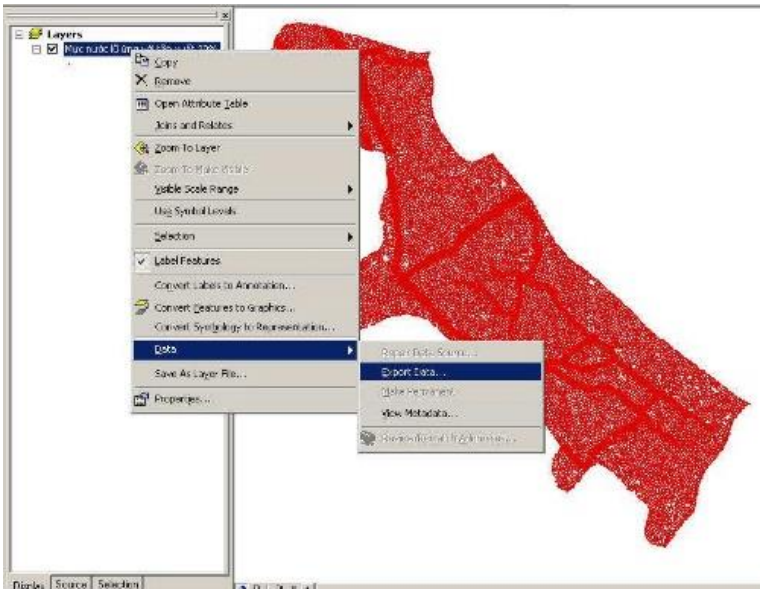


Figure 46. Converting data into ArcGIS

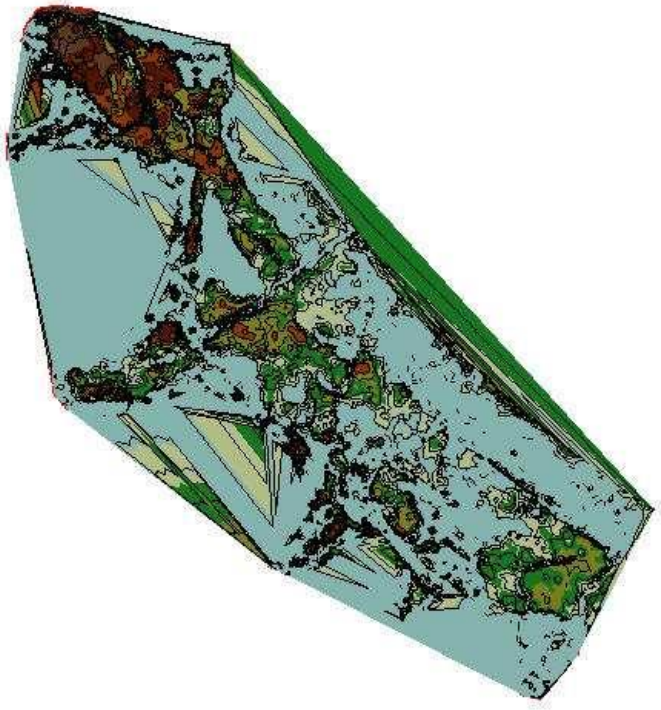


Figure 47. Preliminary results interpolated from the TIN model

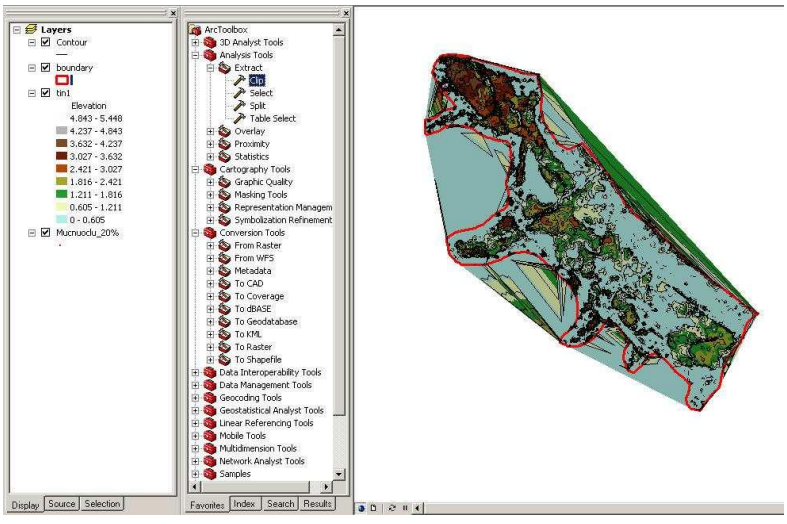


Figure 48. Results compared with the research area

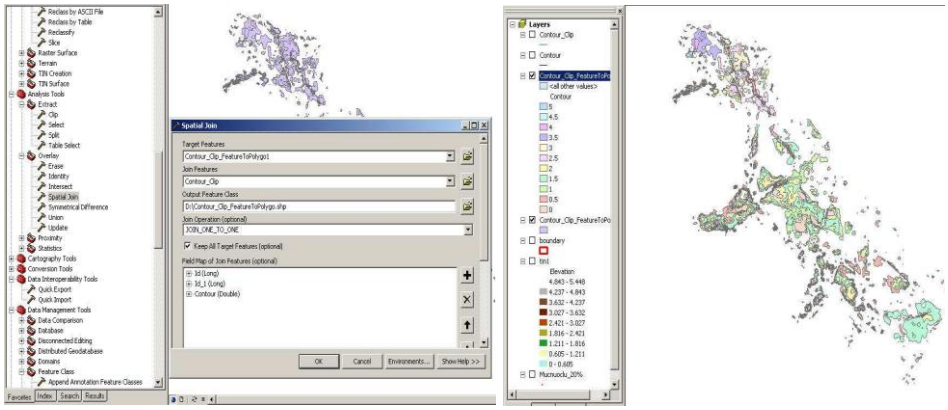


Figure 49. Connecting data with interpolated results and the flood map results shown on ArcGIS

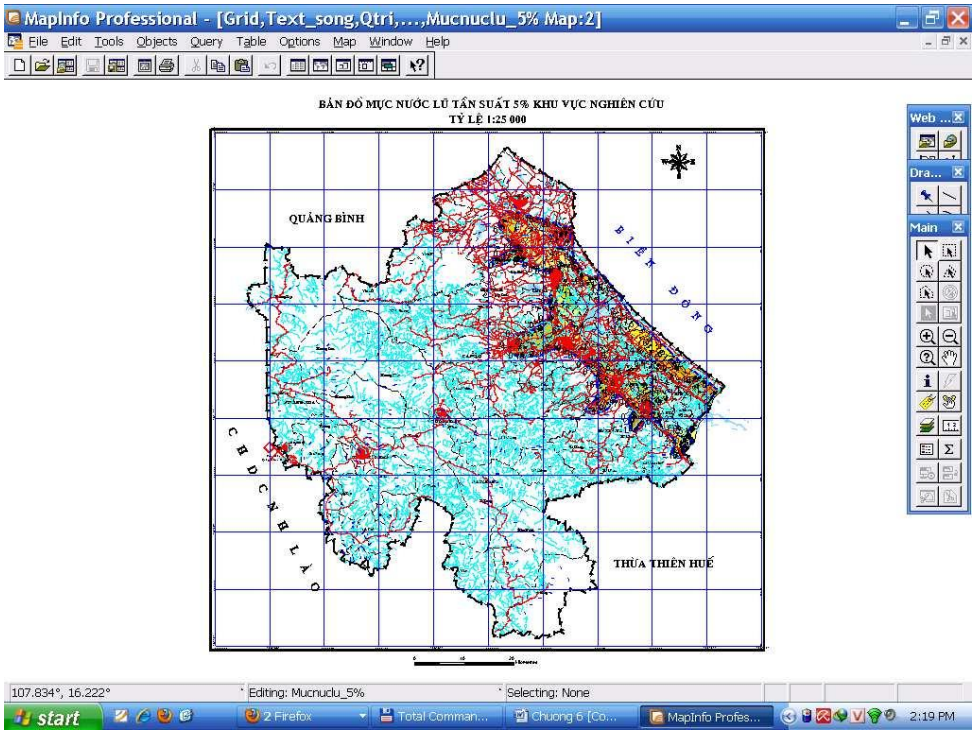


Figure 50. The map of floodplains simulated on MapInfo

4.2.3. The map of flood risk in research area

After comparing and testing the result of several projects and studies, such as "Assessment of flood vulnerability of in basins Thạch Hãn and Bến Hải", "Flood inundation mapping for downstream region of Thach Han and Ben Hai River, Quang Tri Province", the base maps of flood in research area were inherited from the result of the project "Natural disaster risk management project: Conducting field surveys and hydraulic modeling in the basin of Thach Han and Ben Hai River, Quang Tri Province" studied by Intellectual Vietnam Corporation and Hanoi University of Science (a member of Vietnam National University, Hanoi). In which, the flood risk map was developed based on the flood depth map and the flood velocity map. However, it should be incorporate more the flood real-time map, because of the depth, velocity and real-time of flood which are very important factors to impact flood risks and risk level for heritage.

Researchers have calculated and provided flood risk maps with five design floods 1%, 2%, 5%, 10% and 20% corresponding to repetition frequency are in 100 years, 50 years, 20 years, 10 years and 5 years. The repetition frequency of 1% means that for every one hundred years will appear a flood which has magnitude is tantamount to design flood. Similarly, the repetition frequency of 2% means that for every one hundred years will appear two floods or every fifty years will appear a flood which has magnitude equivalent to design flood. The repetition frequency of 5%, 10% and 20% mean that for every twenty years, ten years and five years will appear a flood that has magnitude equivalent to design flood.

However, in this study, the flood risks for heritage are evaluated based on flood risk map with the frequency of 1% (P=1%), because this frequency is most likely to happen than the remaining cases.

The level in the flood risk map has divided into 5 levels: very low, low, moderate, high and very high level. The map showed that the risk situation appeared most of basin area of Ben Hai and Thach Han River. The moderate level of flood risk accounts for most of area while the high level and very high level concentrated nearby the rivers, such as Trung Giang, Gio My, Gio Viet, Trieu Do, Trieu Hoa, Hai Hoa, Hai Duong commune, because those areas have large flood velocity and long real-time flood. Therefore, those are the areas with the greatest risk level and directly destroyed to heritage.

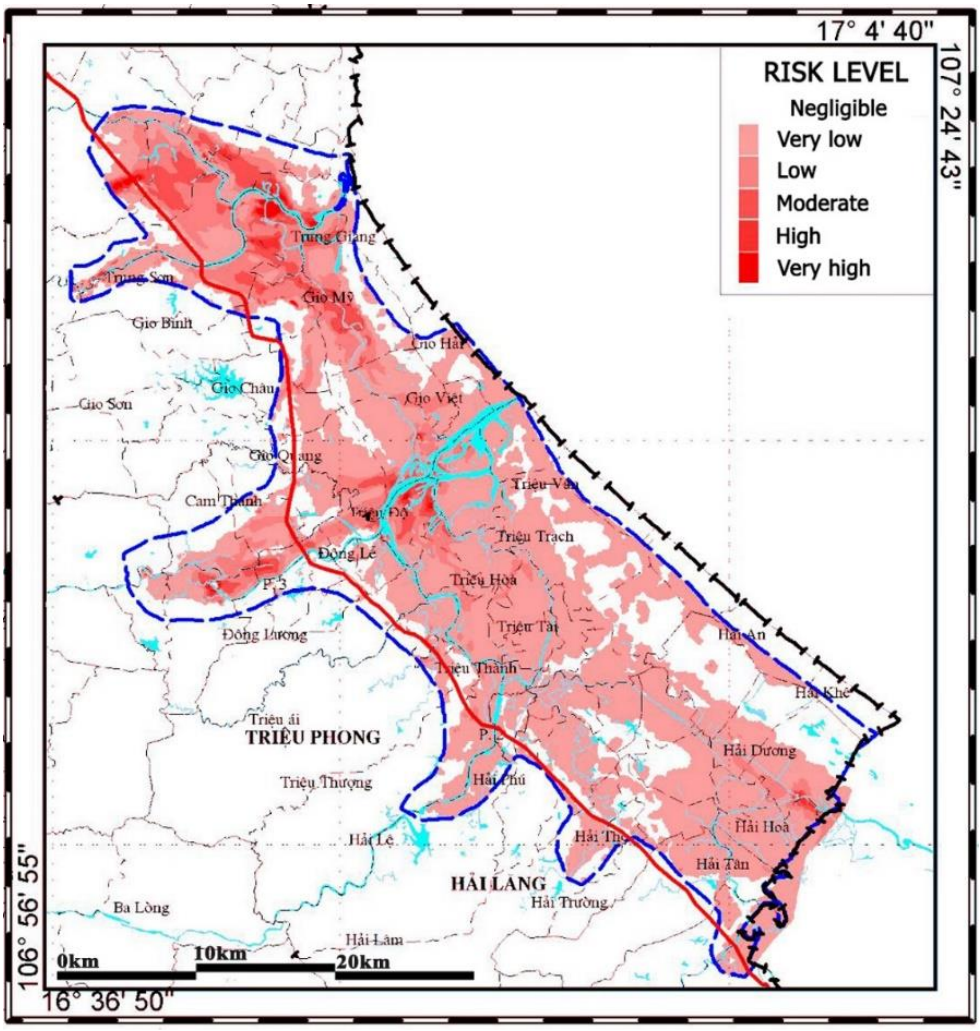


Figure 51. Flood risk map of research area (P=1%)
Source: Intellectual Vietnam Corporation and Hanoi University of Science. Conducting field surveys and hydraulic modeling in the basin of Thach han and Ben Hai River, Quang Tri Province (Tiến hành khảo sát thực địa và lập mô hình thủy lực lưu vực sông thạch hãn và bến hải, tỉnh Quảng Trị). Ha Noi, 2010.

4.3. The map of heritage system in Quang Tri Province

Quang Tri Province has 602 heritages but there are 216 heritages in the research area. Thus the map of heritage in Quang Tri was studied and established based on 216 those heritages (Figure 42). The heritages are varied in shape, size and scale so it is difficult to develop the

map which shows the whole features of the heritages. After simplifying the plan of heritages, combined with the geographical location, the decentralization and classification of heritage, the heritages in the plain of Quang Tri are divided into four groups with characterized as follows:

4.3.1. Historical and cultural monuments

Cultural and historical monuments include bulidings; sites and relics, antiques and museum piece belong its sites; sites have outstanding historical, cultural and scientific value. The cultural and historic heritages must have one of the criterias, as follows :
- Buildings or sites that have had typical historical events during the development and defence of the country.
- Buildings or sites associated with national heroes or notables.
- Buildings or sites that have had typical historical event during the period of revolutionary resistance.
Mapping based on the location of monuments (*Figure 53*).

4.3.2. Archaeological monuments

Archaeological monuments are highlight valuable archaeological places where marked the stages of development of culture.
Mapping based on the location of monuments (*Figure 54*).

4.3.3. Artistic and architectural monuments

Artistic and architectural monuments include art architectural works, building or group buildings, urbans that have had typical value in the stage development of art architectural or history.
Mapping based on the location of monuments (*Figure 55*).

4.3.4. Natural heritage

Natural heritages are natural landscapes or sites wich combined of natural landscape with works or buildings of outstanding universal value from the aesthetic, historical, scientific point of view. Natural heritages must have one of the criteria as follows:
- Natural landscapes or sites wich combined of natural landscape with aesthetic value works.
- Natural areas where have the value of geology, geography, geomorphology, biodiversity, specific ecosystem or natural areas contain traces of the stage development of the Earth.
Mapping based on the location of monuments (*Figure 56*).

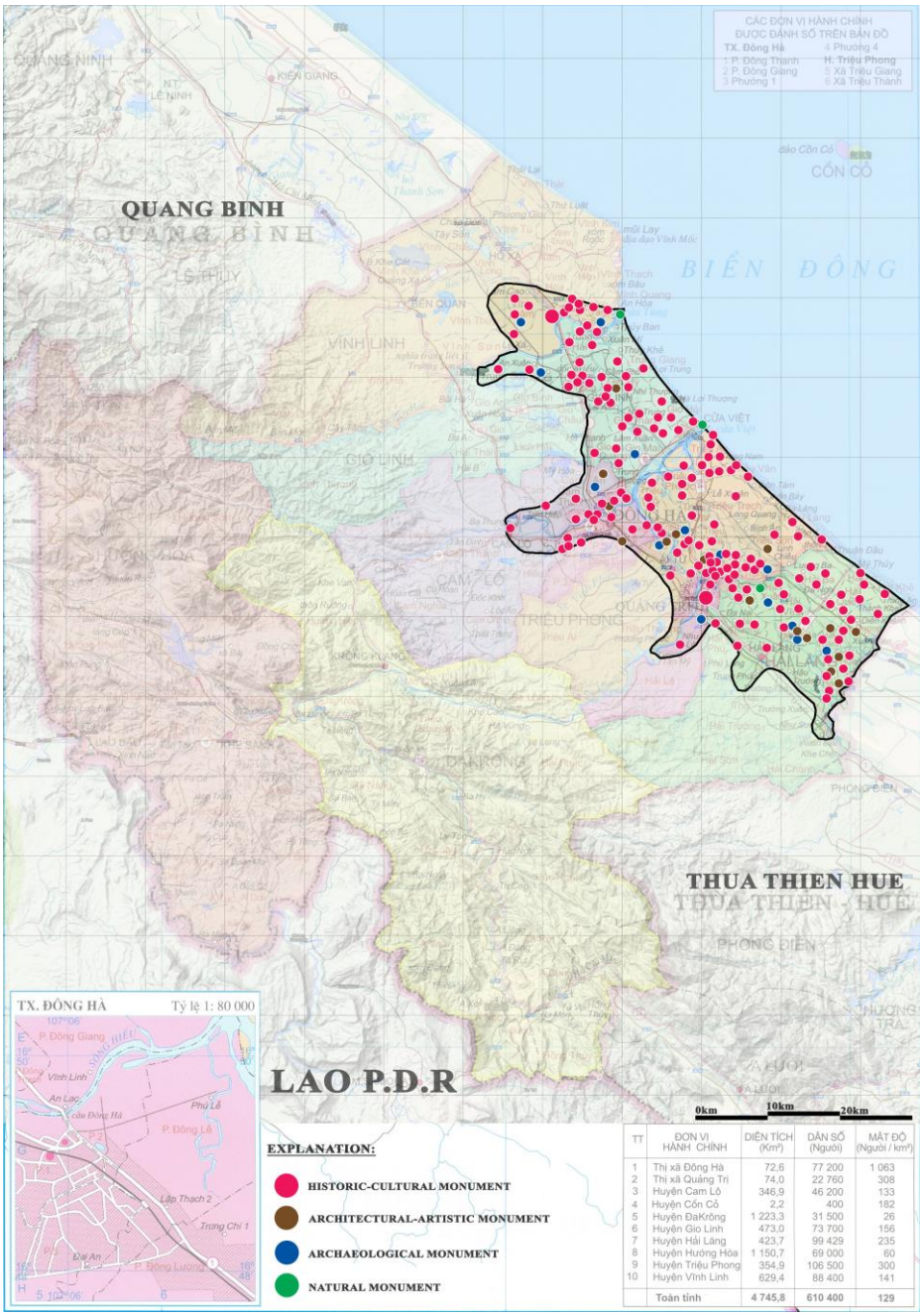


Figure 52. Heritage map in Quang Tri Province
Source: Author

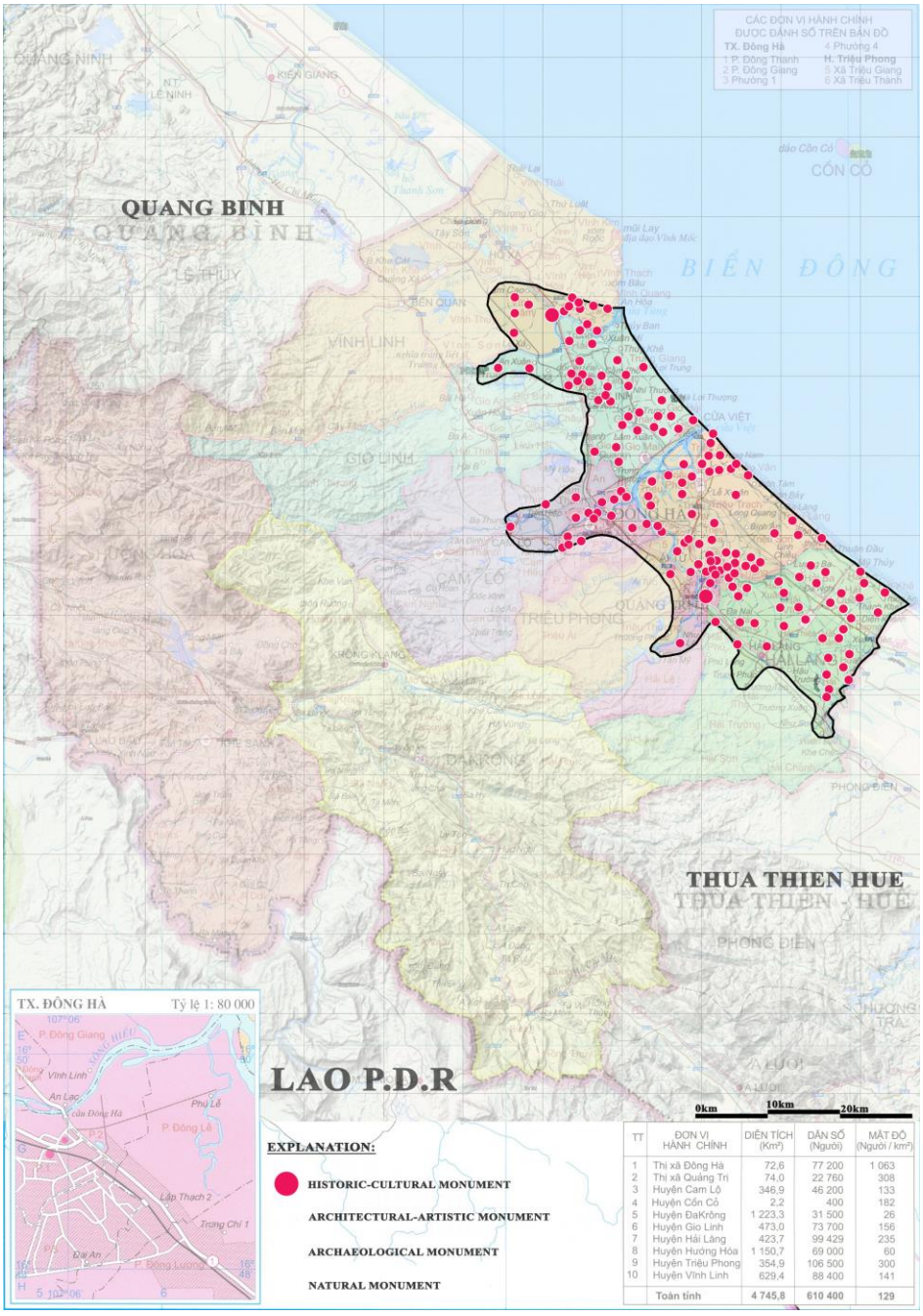


Figure 53. The map of the historical and cultural monuments
Source: Author

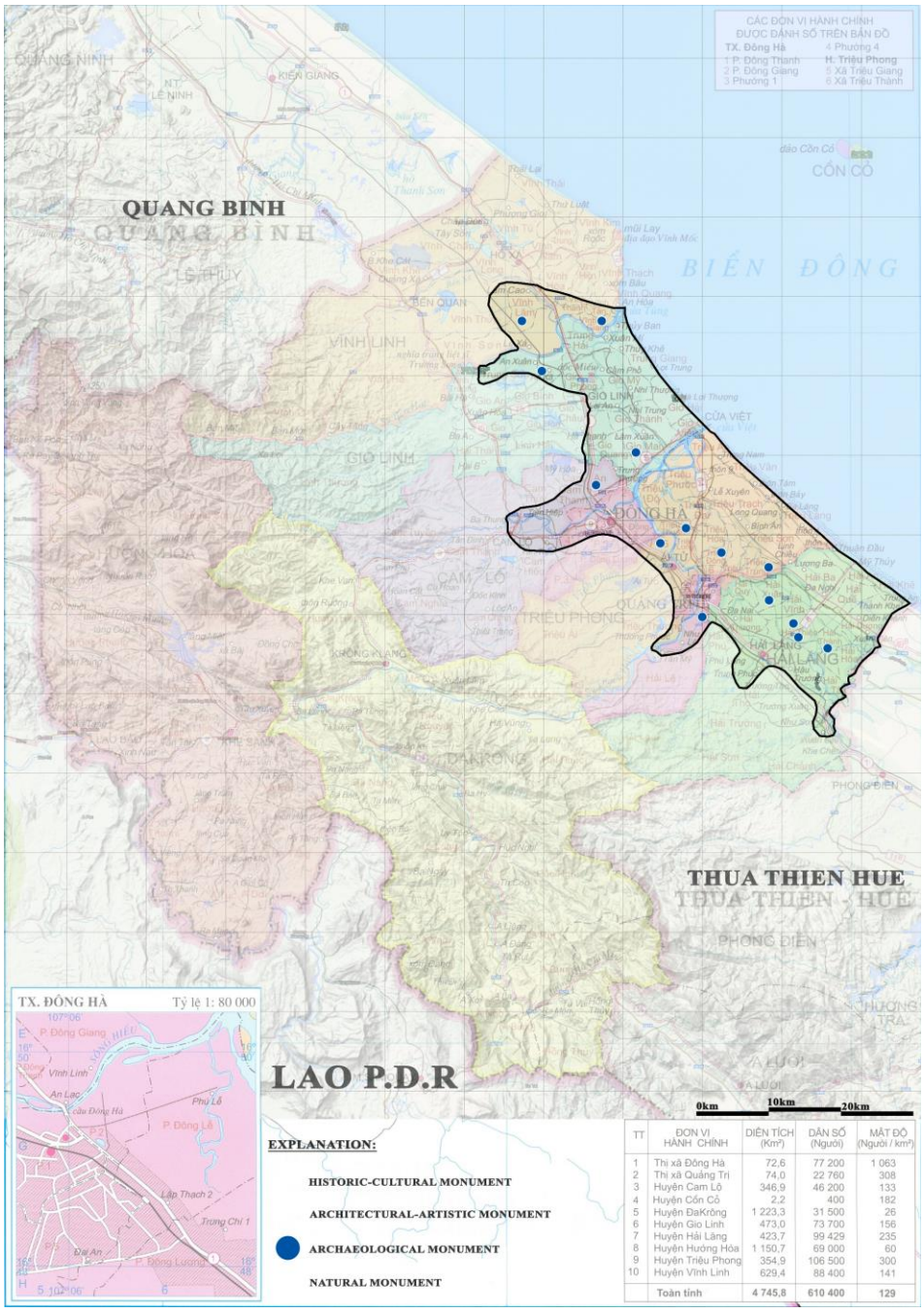


Figure 54. The map of the archaeological monuments
Source: Author

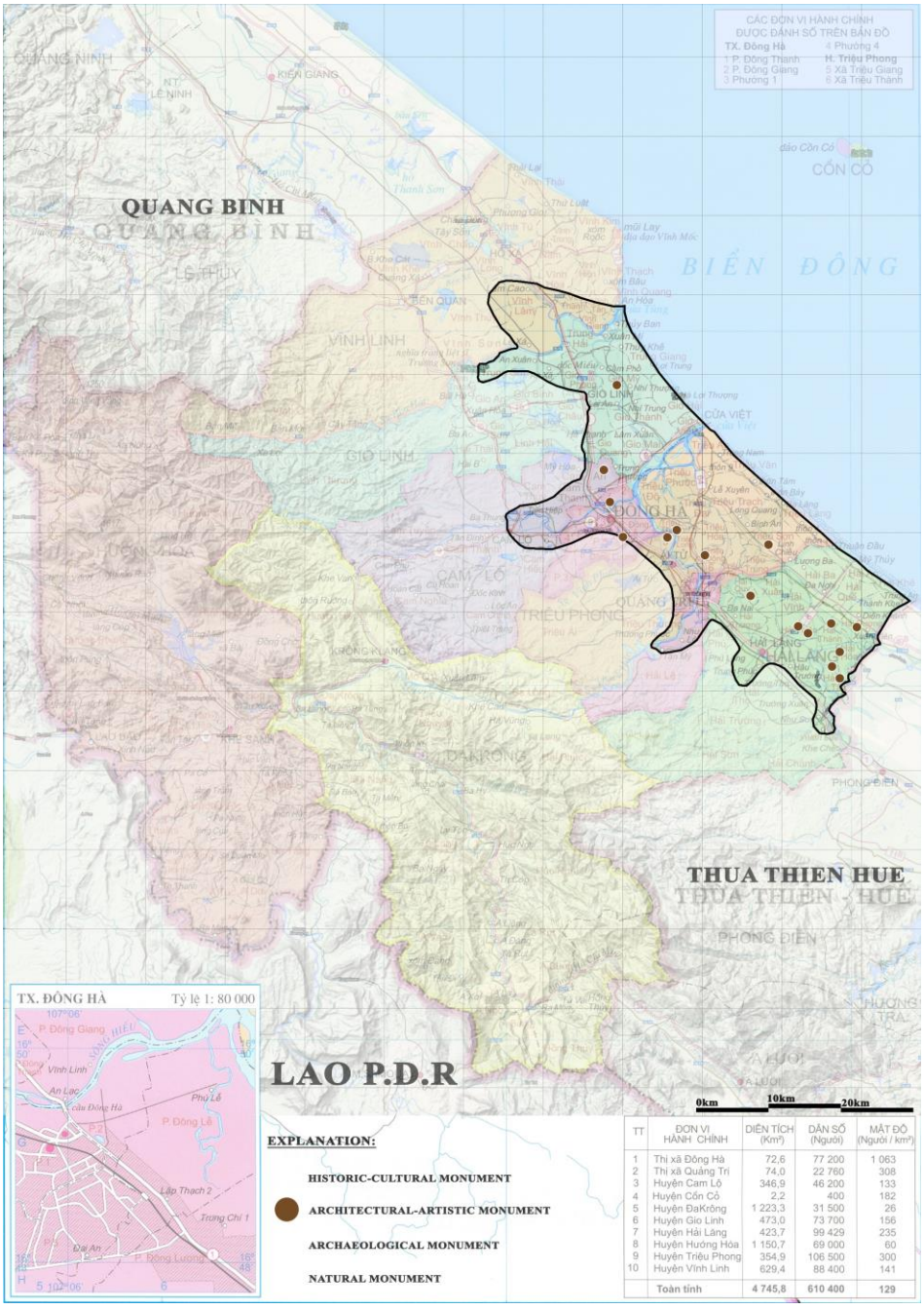
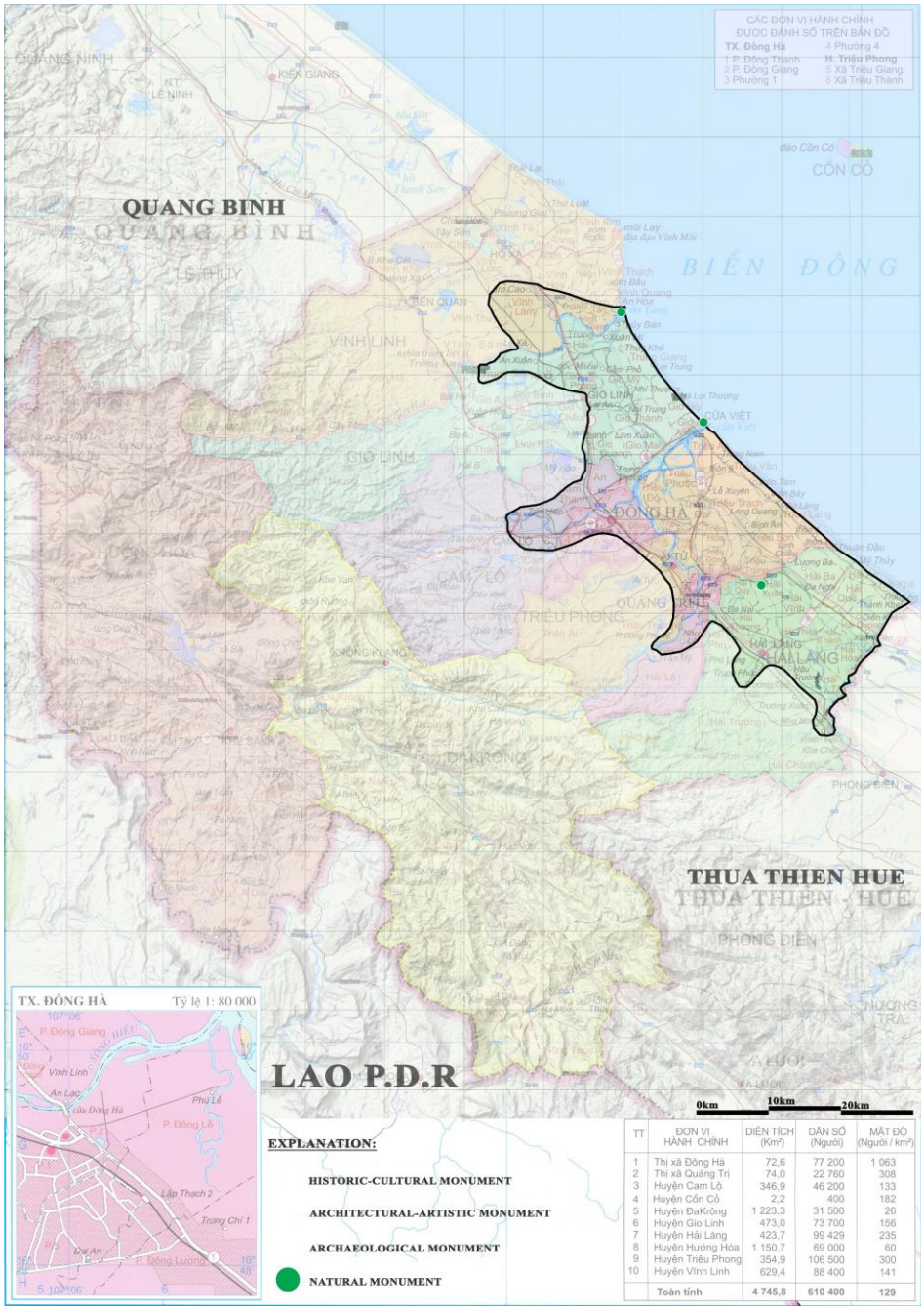


Figure 55. The map of the artistic and architectural monuments
Source: Author



TT	ĐƠN VỊ HÀNH CHÍNH	DIỆN TÍCH (Km²)	DÂN SỐ (Người)	MẬT ĐỘ (Người / km²)
1	Thị xã Đông Hà	72,6	77 200	1 063
2	Thị xã Quảng Trị	74,0	22 760	308
3	Huyện Cam Lộ	346,9	46 200	133
4	Huyện Cồn Cỏ	2,2	400	182
5	Huyện ĐaKrông	1 223,3	31 500	26
6	Huyện Gio Linh	473,0	73 700	156
7	Huyện Hải Lăng	423,7	99 429	235
8	Huyện Hướng Hóa	1 150,7	69 000	60
9	Huyện Triệu Phong	354,9	106 500	300
10	Huyện Vĩnh Linh	629,4	88 400	141
	Toàn tỉnh	4 745,8	610 400	129

Figure 56. The map of the natural heritage
Source: Author

4.4. Assessment

The map of flood risk for heritage was established base on the flood risk map and the heritage map as follows:

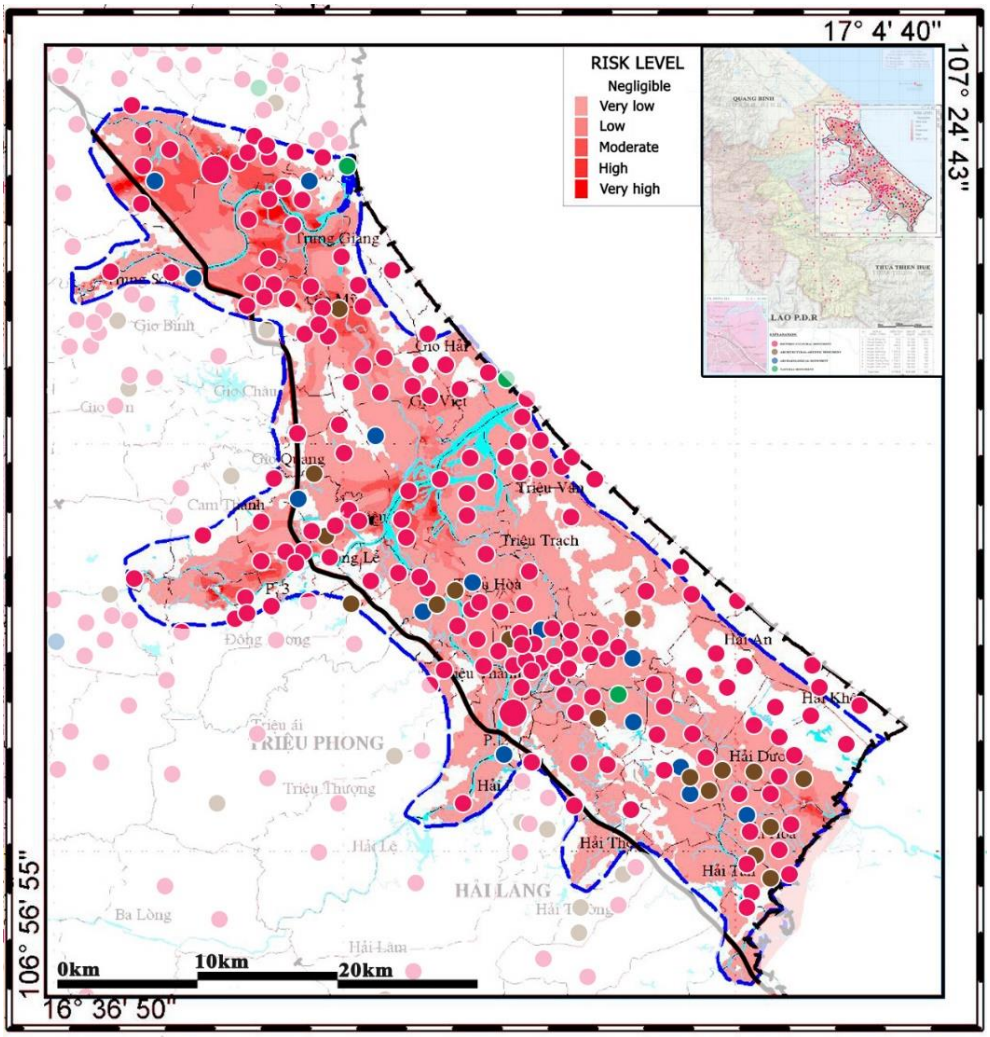


Figure 57. The map of flood risk for heritage in Quang Tri plain
Source: Author

The map showed that nearly all of the heritages in plain of Quang Tri Province are located in flood risk area (189 in 216 heritages, accounting for 87.5%). The heritages are located in areas with high and very high level are less because the flood risk area from high to very high flood is not large (9 in 216 heritages, accounting for 4.2%).

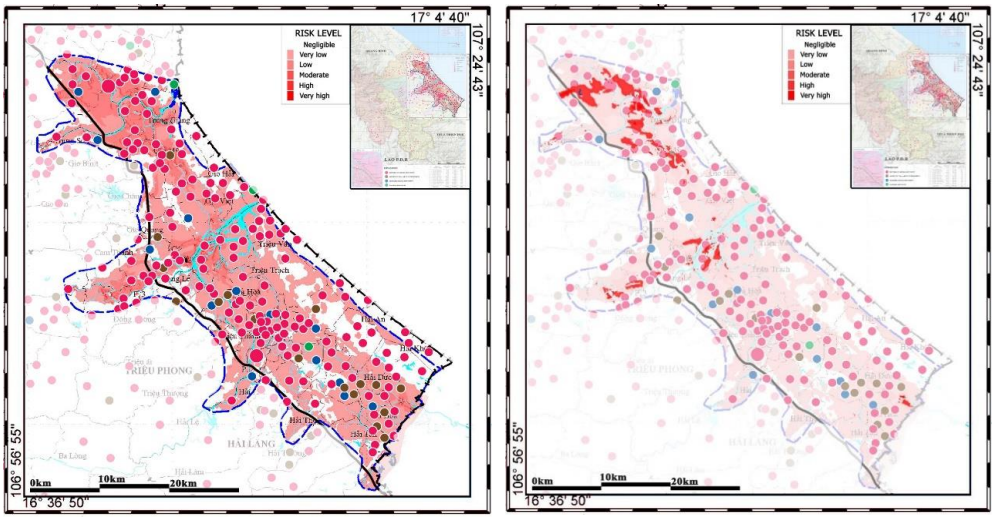


Figure 58. The map of heritage flood risk in case of moderate level and over moderate level (high and very high level)
Source: Author

The heritages are located in high and very high level of flood risk listed as follows:
- The cultural and historical monuments: khu vực đôi bờ Hiền Lương, bến đò Tùng Luật, bãi cát thôn 3, địa đạo tân lý, địa điểm ấp chiến lược Lễ Môn.
- The archaeological monument: di chỉ đá nổi,
- The artistic and architectural monuments: bia quán Vĩnh Định Hà thập nhị vận và Vĩnh định Hà cảm tác, đình làng Điếu Ngao.
- The natural heritage: khu danh thắng cửa Tùng (Cua Tung beach).

Chapter 5.
Proposal to response and adaptation to flooding for Quang Tri Province.

5.1. Background to building proposals: Heritage, urban and urban development

Before the term “urban” appeared in Vietnam, an urban had been called “a village”.
After learning how to cultivate wet-rice, the ancient Vietnamese transformed from shifting cultivation of wandering hill-tribe to agglomeration in certain locations. Those places usually were concentrated in areas close to river or lake to get water easily for living activities, irrigation, moving and barter. Hamlets, thorps, farms and villages were gradually formed at these concentrated places, more and more bigger and synchronous. Finally, it established a methodical administrative unit with a rapid development of economy and culture, making the Vietnamese village style to be longstanding culture and sustainable future. According to many historians, the Vietnamese village originated from Van Lang’s period (2524–258 BC). It was strong expanded in Ly’s period (1009–1225). The structure of a typical village in Vietnam includes a village-gate at the main entrance; field-gates on the ways to field; hamlet-gate in each hamlet; green bamboo fence and moat wrap around the village to decay and defense. In the village center are located temples, communal houses, shrines, “Thanh Hoang” or blessed symbols for descendants worship forever. Communal temples are also places for meeting of council, civil commune and festival venues. In front of communal temples, there is wide village-gate, several villages have lotus pond reached build an open space and sacred. This space is connected to the main road of village toward to village-road and there are many traffic lanes toward to each alley. Beginning of village is often a place where both sublime and miraculous to build temples, pagodas. Each house of inhabitants has taken direction of communal temples to locate their house. Direction of communal temples is determined according to fengshui principles. The village has conventions to appoint how to astringent organize community’s life from rites, learning and production activities, rank, to recompense as standards of living. Each village worship a distinct “Thanh Hoang” (Angel or God) and has specific unique culture, so each village has unique cohousing and completely different. The remaining heritages of today were formed from there.
According to the time, when the people’s lives changed, the buildings in the village were also changed. Depending on the circumstance of each family whose house can have 1 compartment 2 lean-tos or 3 compartments 2 lean-tos, etc. The village’s public buildings were also expanded with more durable materials (e.g., stone, brick, wood, etc). Architectural, environment and landscape have a remarkable change. Architectural and culture of agricultural area and handicraft have many different changes. The village handicraft in the village was created, the rural market was combined with shops, boutiques.
The transformation from the village to the urban increased more and more clearly. The ancient villages have left for today many valuable buildings that expressed the culture, folk

experience in choosing locations for construction and construction methods to mitigate the natural disasters. However, the rapid development of socio–economic and the urbanization have many negative impacts on heritages. In additionally, the war caused destruction to many valuable heritages but also formed many constructions associated with important benchmarks history of Quang Tri Province.

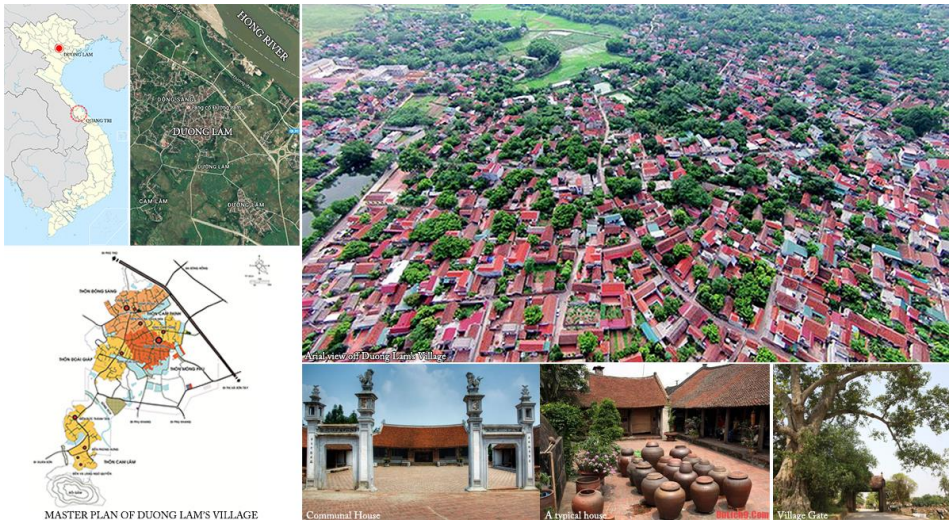


Figure 59. A typical village in the north Vietnam
Note: Duong Lam village with approximately 1000 years of history is a typical ancient village in Vietnam that was recognized as a national heritage in 2006
Source: Internet, edited by author

After 1954, when Vietnam won independence, the numerous of cultural constructions such as temples, pagodas degraded or changed usage purposes in this period. The urban planning of Quang Tri Province transformed from overcoming consequences of war to economic rehabilitation and development. At this time, the demand for socio-economic development became the foundation for urban planning and ignoring other factors such as natural conditions, traditional culture, environment, heritage. Several urban planning impossible kept up with the development of social, the change of environment and climate. Or the urban planning was heaped up together was accidentally put on the heritage into the risks: flood and flood, landslide, uncultivated heritage, etc.
Because flooding usually happens in a large area, so to response and adaptation to flooding for Quang Tri Province, proposals should be considered and studied on a proportional scale, such as regional planning, spatial planning, urban planning, urban design and the architecture design and detailed design. The proposals were concretized based on three steps: direction, storage and absorption (DSA).

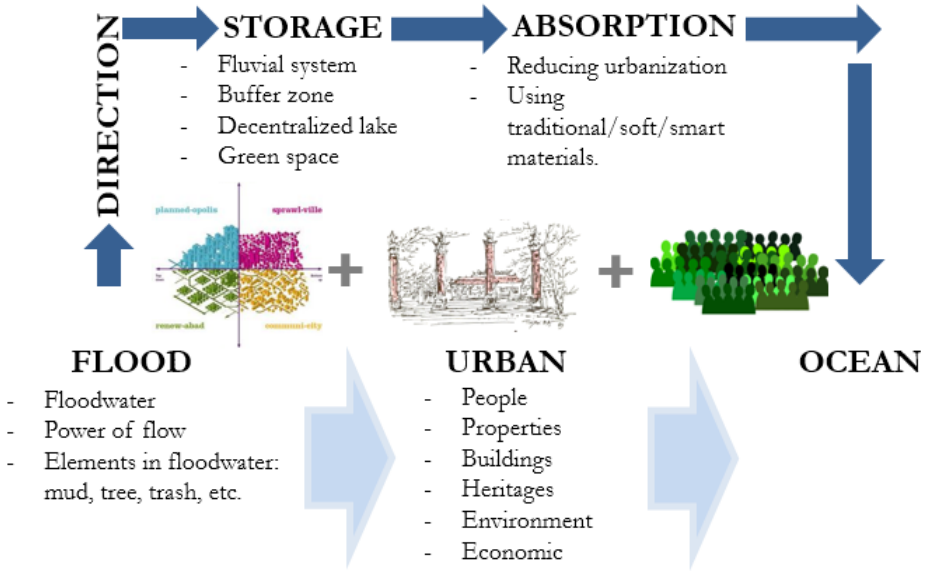


Figure 60. Illustration of DSA's idea (direction, storage and absorption) and natural flood escape
Note: Dark blue arrows symbolize the process of new drainage while light blue arrows symbolize the process of natural flood escape.
Source: Author

5.2. Direction

The formation and development of urban in Quang Tri Province have accidentally put urban today at flood risk area. Direction means identifying flood escape direction to move or disperse the flooded risk from this region to others, where are established for flooding (storage space). In the sources of flooding in Quang Tri Province[17], although in different backgrounds, it has the same cause. The flood escape direction or drainage system is inappropriate. For example, in the case of flooding from upstream and fluvial system, flood escape direction has been based on natural conditions without planning or direction, so floodwater flows from upstream to the sea on principle water flows from upland to lowland areas, and as a result, everything is swept away by the flow. In the case of pluvial flooding (urban flooding), the drainage system of rainwater and floodwater is integrated with the system of urban sewage disposal. In normal conditions, the urban drainage system works well, but in the event of heavy rain or flood, it cannot drain off the water and causing urban flooding.

[17] Introduced in "Sources of flooding", page 35.

The direction to prevent flooding is seen as a first priority in the process of responding and adapting to flood for Quang Tri Province. However, this issue not only related to architectural planning, but also the role of other disciplines, such as hydrology, geography, geology or even ecology. The conditions of topography, hydrology, dyke systems, residential, flood situation of each particular region will be the basis for proposing a reasonable flood escape direction of its urban.

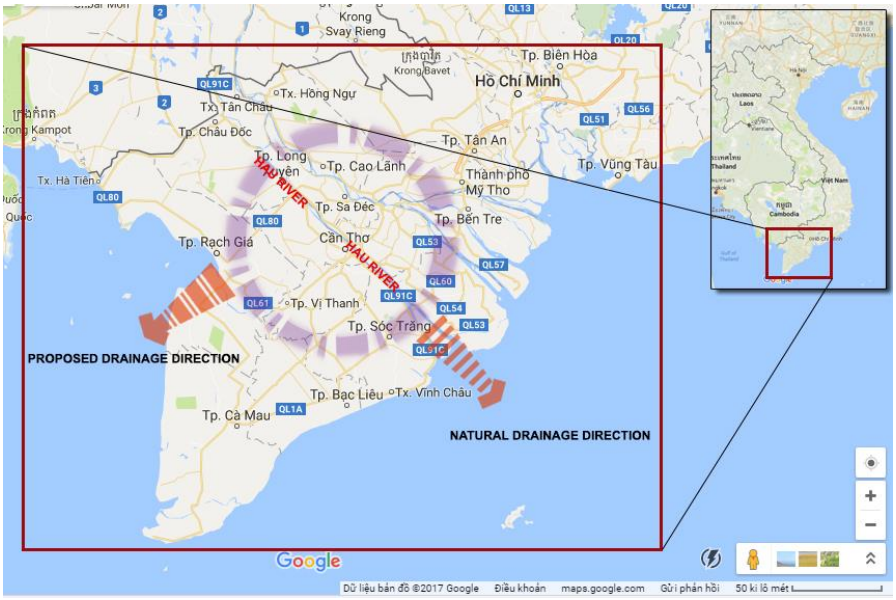


Figure 61. Illustration of idea "Draining floodwater to the Western sea"
Source: Author illustrated based on google map.

A typical project: the project "Draining floodwater to the western sea" was completely written in 1997 by Professor Nguyen Sinh Huy (1932-2012) and colleagues. The project was applied in practice, including the renovation of available drainage works and building a number of other works, both reducing water pressure to the Long Xuyen quadrangle and using floodwater to alkaline soil improvement in Ha Tien quadrangle. So far, the drainage system has been showing many benefits in controlling and reducing floods.

5.2.1. Flood escape space and urban development direction

Ben Hai River and Thach Han River are two main flood escape directions of the Quang Tri Province. Under the impacts of climate change, changes of land-use structure and urban structure have changed the circulation of flow. Especially, under the changes of convection currents and wave direction have changed the nature and location of Cua Tung estuary (Ben Hai River) and Cua Viet estuary (Thach Han River). That limits the natural flow and causes flooding in the abnormal disaster phenomenon. On the other hand, in spatial planning or urban planning without drainage planning accidentally pushes projects, residential areas and industrial zones to works that prevent drainage direction, including natural drainage

and floodwater drainage. Based on the flood risk map, natural conditions of the province, in addition to two main drainage spaces (Ben Hai River and Thach Han River), it is necessary to set up additional flood escape directions rely on the branches of the rivers. In that, Canh Hom River and Vinh Dinh River are the rivers that have several advantages should be exploited in order to support the main drainage system and protect two main cities of Quang Tri Province (Dong Ha city and Quang Tri town) at the same time.

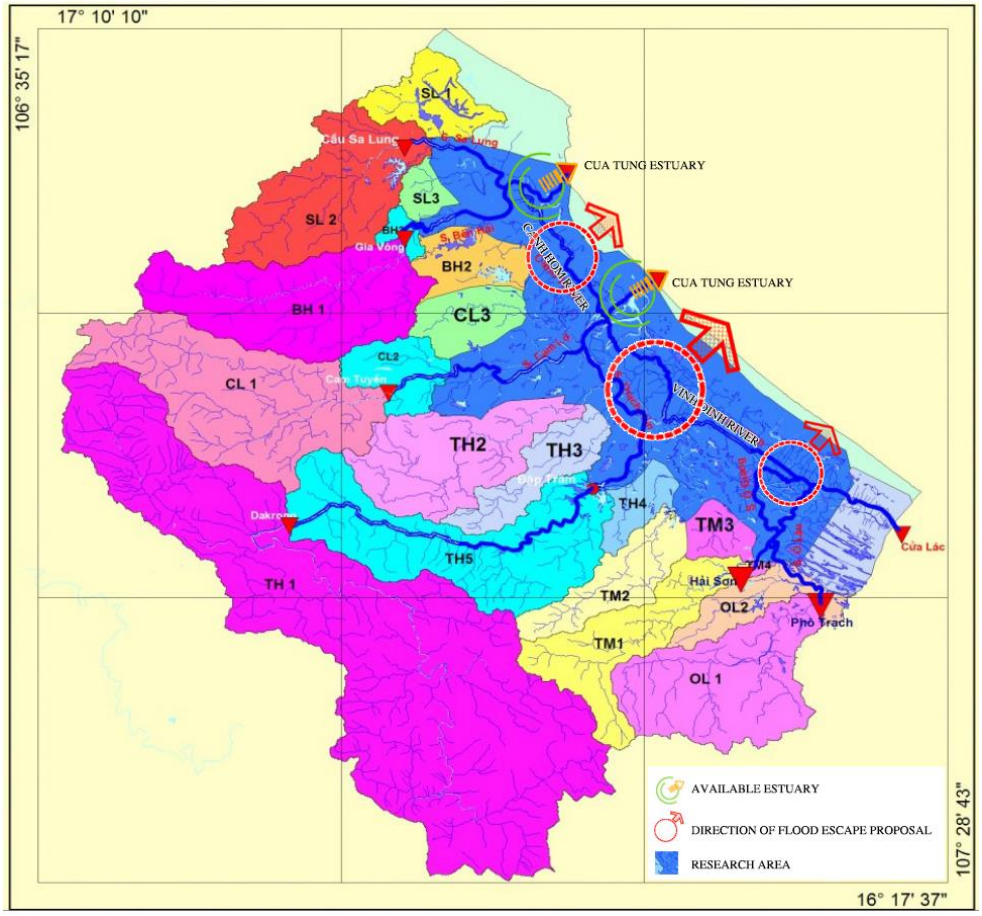


Figure 62. Directions of flood escape proposal
Author: Basemap: Project "Conducting field surveys and hydraulic modeling in the basin of Thach han and Ben Hai River, Quang Tri Province". Edited by author.

On the other hand, spaces are not used for drainage, will be seen as the ideal areas for urban development, the safety zones to protect people, properties and heritage. Therefore, if the direction for drainage is planned and rational exploitation not only reduces flooding but also facilitate the sustainable development of human and urban.

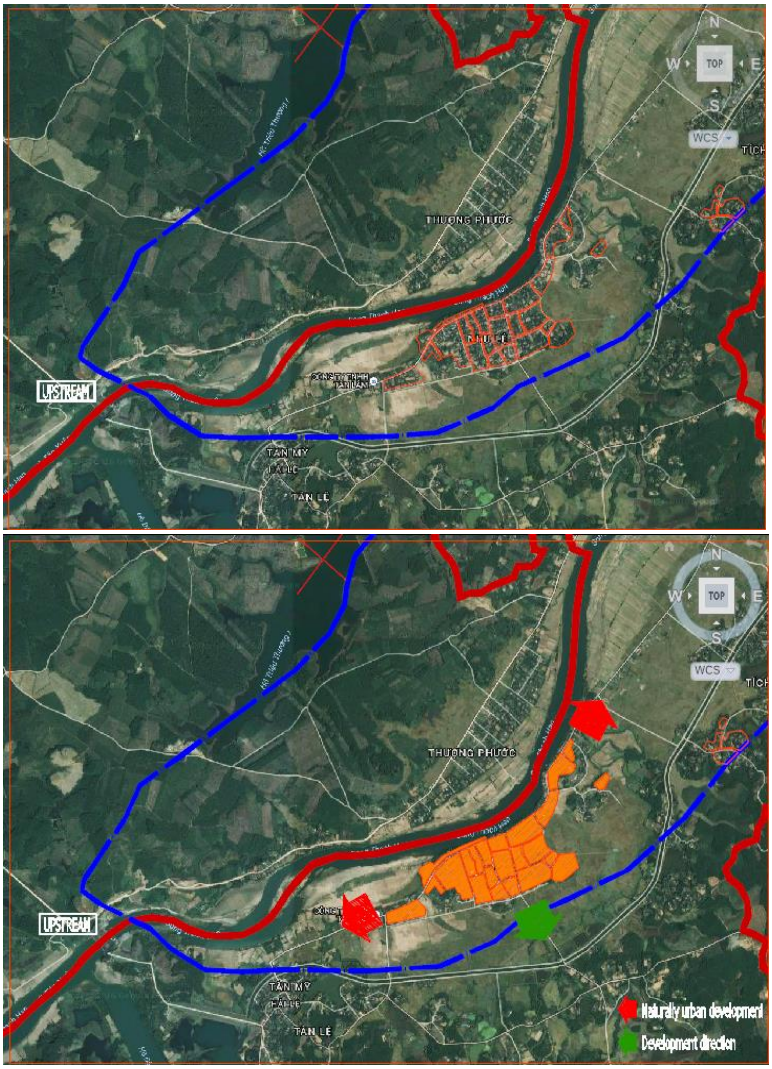


Figure 63. An example of development direction of a residential area (Nhu Le hamlet, Quang Tri town, Quang Tri Province)
Source: Author

Under the unpredictable effects of climate change, naturally urban development of urban will inadvertently put urban into flood risk areas. That is one of the objective causes that increases the damage caused by flooding. For existing urban areas, it needs to apply measures to minimize the damage, such as relocation of buildings, creating "buffer zones" or "flexible spaces". In the future, it is necessary to establish an appropriate planning direction for sustainable urban development.

5.2.2. Safety zone, safety point

Safety zone or safety point is area or building without flood risk where local people can migrate to during flood events to protect their lives and properties. Through many sources from local, there is no integrated study about the issues above until now. In flood events or other disasters, the local people migrate to other places in a natural way or experience, but sometimes it was moved from this risk area to other risk areas. Thus, the establishment of safety zone map is needed to cope with floods. Because of the limitations of the research, the safety zone, in this case, was studied in flood event and in the plain of Quang Tri Province.

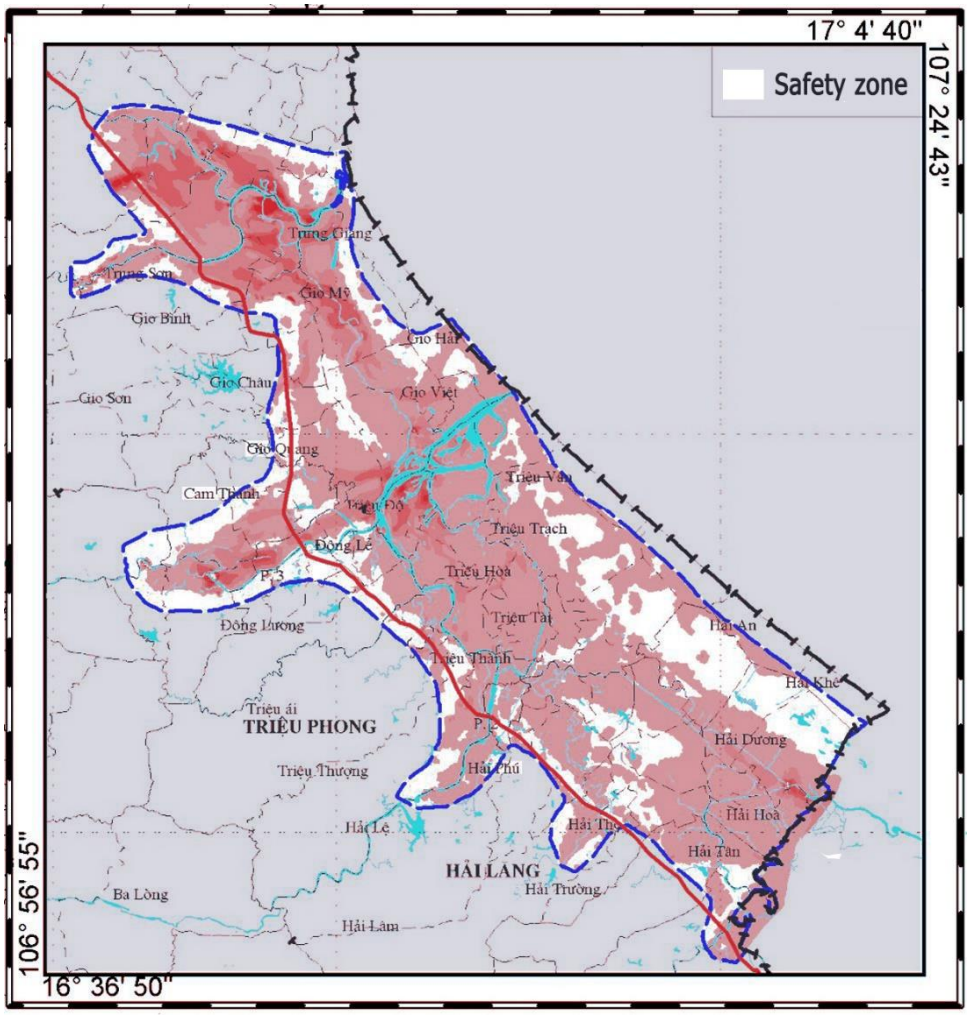
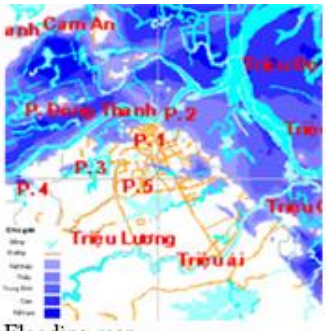


Figure 64. The map of safety zones in research area
Source: Author.

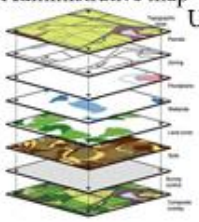
LEGEND:

1- tỉnh uỷ tỉnh quảng trị
2- ubnd tỉnh quảng trị
3- hđnd tỉnh
4- công an tỉnh
5-thanh tra tỉnh
6- hải quan tỉnh
7- kho bạc tỉnh
8- ldld tỉnh
9- tỉnh đội tỉnh quảng trị
10- toà án nhân dân tỉnh
11- bệnh viện tỉnh
12- cục thuế tỉnh quảng trị
13- thư viện tỉnh
14- bảo tàng tỉnh
15- sở xây dựng
16- sở tư pháp
17- mặt trận tổ quốc
18- ban tổ chức chính quyền
19- ban dân tộc miền núi
20- sở văn hoá
21- sở giáo dục - đào tạo
22- sở thuỷ sản
23- chi cục di dân pt vùng kt mới
24- Trung tâm y tế thị xã đông hà
25- sở công nghiệp-tcn
26- báo quảng trị
27- sở điện lực
28- bđ thị xã (tt bc-vt đông hà)
29- chi cục kiểm lâm
30- chợ đông hà
31- sở thương mại
32- ubnd thị
33- rạp chiếu phim
34- công ty bảo việt
35- ngân hàng nhà nước
36- chi cục thống kê
37- sở khcn - môi trường
38- ngân hàng đt & pt
39- khu văn hoá trung tâm
40- sở tdtt - sân vận động
41- trường ptth
42- trường dạy nghề
43- nhà thi đấu
44- sở giao thông - vận tải
45- trường cao đẳng sư phạm
46- công an thị xã
47- xn tân lâm
48- xn tơ tằm
49- phòng cháy chữa cháy
50- xn bưu điện
51- trường y tế
52- xn xây dựng 55-4
53- nhà Bảo tàng tỉnh quảng trị
54- nhà hàng hùng vương
55- khách sạn
56- sở tài nguyên môi trường
57- xn xây lắp
58- ubnd phường
59- chi nhánh nh csxh quảng trị
60- bến xe ô tô đông hà
61- chi cục thuế đông hà
62- ngân hàng nn & ptnt
63- ngân hàng đt & pt (cn tỉnh quảng trị)
64- tt bảo vệ sức khoẻ bà mẹ trẻ em
65- cn ngân hàng công thương
66- bệnh xá công an tỉnh quảng trị
67- cty xăng dầu quảng trị
68- phòng xuất nhập cảnh
69- công ty in
70- cty đt - pt csht
71- ub dân số gia đình trẻ em
72- ga đông hà
73- trường ptcs
74- xn quân đội 334
75- nghĩa trang đường 9
76- xn vlxd - phân bón - xm
77- Công ty lâm nghiệp đ'eang 9
78- trung tâm đại học huế
79- xn cơ khí ô tô
80- công ty công trình đô thị
81- cơ quan ct công cộng
82- chợ phường
83- cty tư vấn xây dựng
84- trường đảng tỉnh quảng trị
85- uỷ ban y tế việt nam hà lan
86- nhà khách tỉnh uỷ
87- nghĩa trang
88- phân viện đại học huế
89- trung tâm phục hồi chức năng
90- trung tâm thương mại
91- nhà văn hoá thiếu nhi



Flooding map


Administrative map


Using overlay mapping method to identify safety point in flood events

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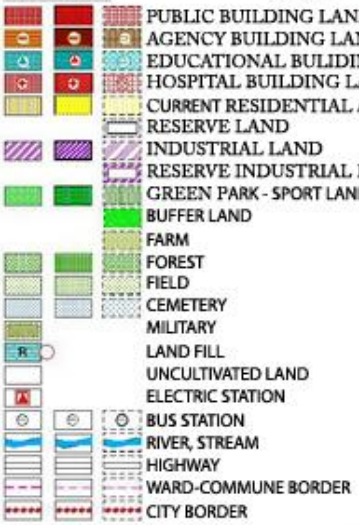


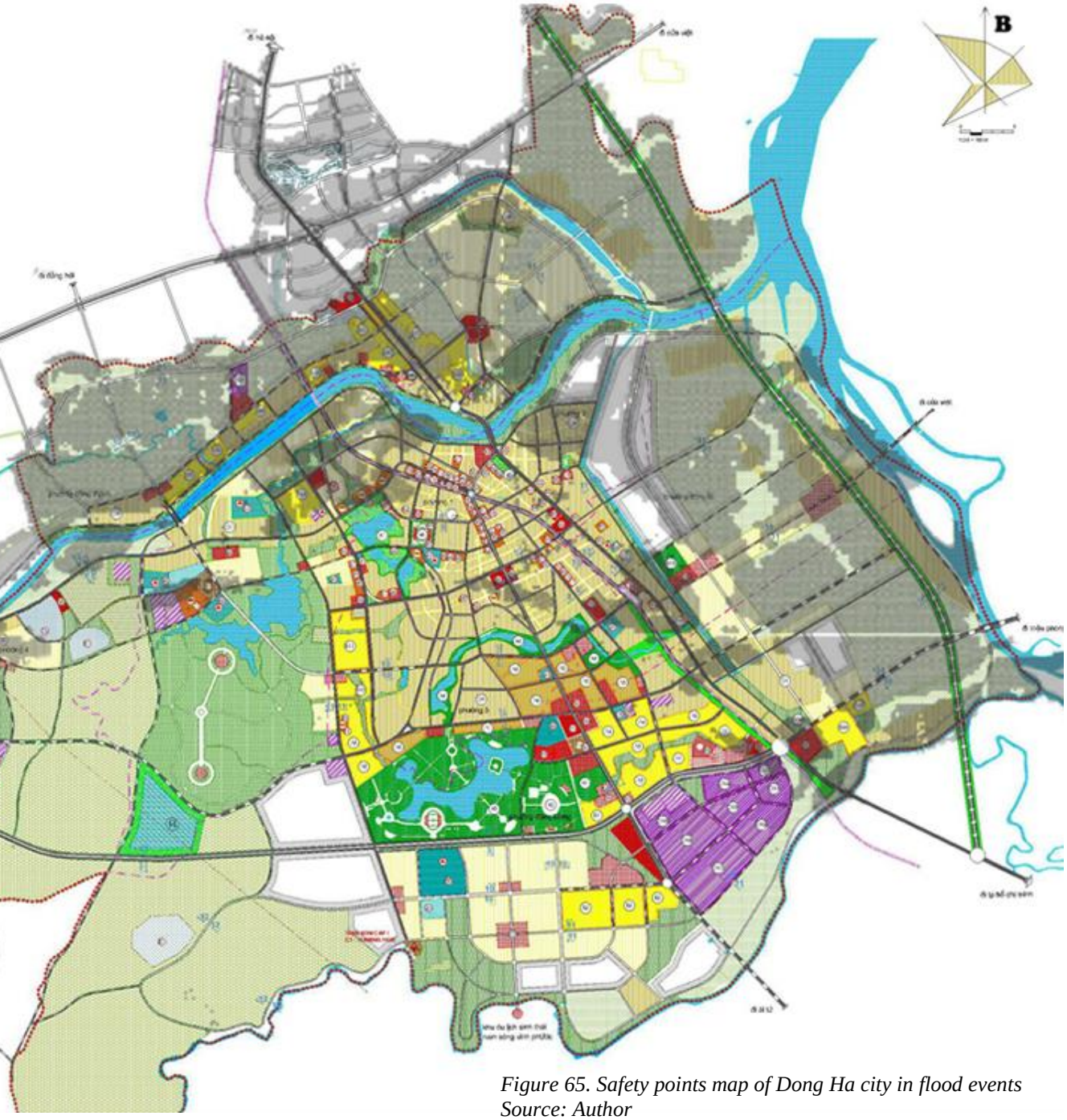


Figure 65. Safety points map of Dong Ha city in flood events
Source: Author

5.3. Storage

Storage is the method of keeping floodwater in storage spaces in order to avoid damage to urban areas and reducing flood level during flood events. The storage space is the space adjacent to rivers, flood escape directions, regularly flooded places. In fact, it could be the fields, floodplains, wetlands, etc. These spaces will provide more space for rivers, channels to expand during flooding and reduce flood peak. That means it will help control and reduce the flood risk in downstream by a natural way. In addition, the storage space is also seen as a buffer ecosystem to regulate the microclimate, reduce pollution and provide habitat for flora and fauna.

However, the increase in demand for residential land and urban development has narrowed these natural spaces. Wetlands have been filled. The water surface system has been fragmented and disconnected. Spaces next to the river have occupied to serve personal purposes. Thus, the storage spaces gradually lost while no spaces are reimbursed, which is the cause to create new flood zones (difficult to control) and floods occur faster (no enough time to implement response actions) and flooded time lasts longer (increasing damage).

5.3.1. Expanding drainage and storage space

The traditional method to solve the problem of flooding is the enhancement of drainage capability by "expanding" drainage system. Expanding means that, expanding the available drainage system and establishing new drainage systems, such as new sewer systems, canals, channels and lakes. However, the establishment of a new drainage system requires a large investment and high operating costs, long construction period, which are not consistent with the socio-economic condition of Quang Tri Province. Thus, if the available drainage and storage system are planned and expanded rationally will solve a part of flooding in the present time.

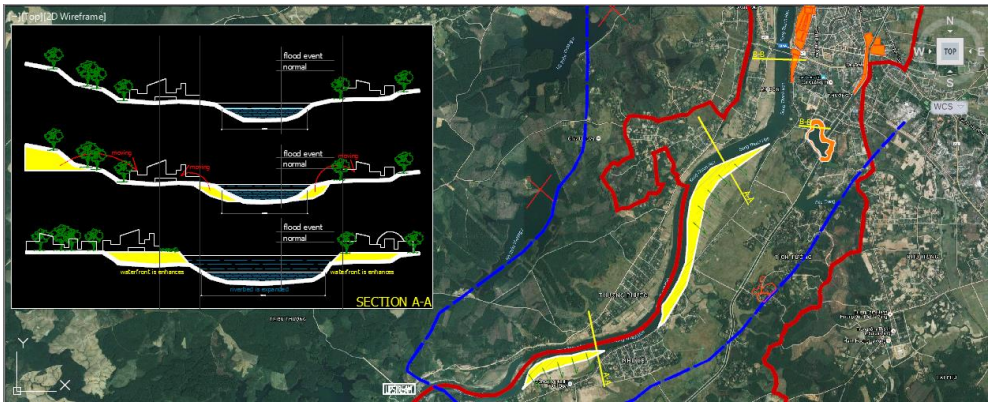


Figure 66. Expanding steadily drainage spaces from upstream to sea
Source: Author

In the future, under the impacts of climate change, population growth combined with the demand of residential land will be the challenges for the available natural drainage system. It will require a different approach to creating a drainage system more flexible, which can adapt to changes in the future. In some other countries, as they face regularly with floods, many new approaches have started to appear. The idea of the new approach is to reduce the pressure of draining on the existing drainage systems by integrating with urban infrastructures, such as green spaces, parks, even the facades of buildings. It will help improve the quality of urban dwellers life, the quality of potable water and reduce heat island effect in urban areas. Water can be collected and stored in tanks under buildings and used for other purposes, such as watering plant, cleaning or recycled to serve other purposes. The role of "floodscape" design and "floodscape" planning will be more apparent, specific solutions will be studied, applied and chosen.

5.3.2. Conservation buffer zone

The buffer is a transitional space between two or more different space. The concept of buffer zone was also mentioned in the criteria in Article 4, the Seville strategy and the statutory framework of the world network adopted at the General Conference of UNESCO in Nov. 1995, “a buffer zone or zones clearly identified and surrounding or contiguous to the core area or areas, where only activities compatible with the conservation objectives can take place” or in the guide Conservation buffers: design guidelines for buffers, corridors, and greenways, Gary Bentrup 2008, “Buffers are strips of vegetation placed in the landscape to influence ecological processes and provide a variety of goods and services to us”,. There are many names of the buffer, such as greenway, wildlife corridor, windbreak or filter strip. The name of the buffer depends on the main function of it because each of buffer usually has more than one function even if it designed with only one function.

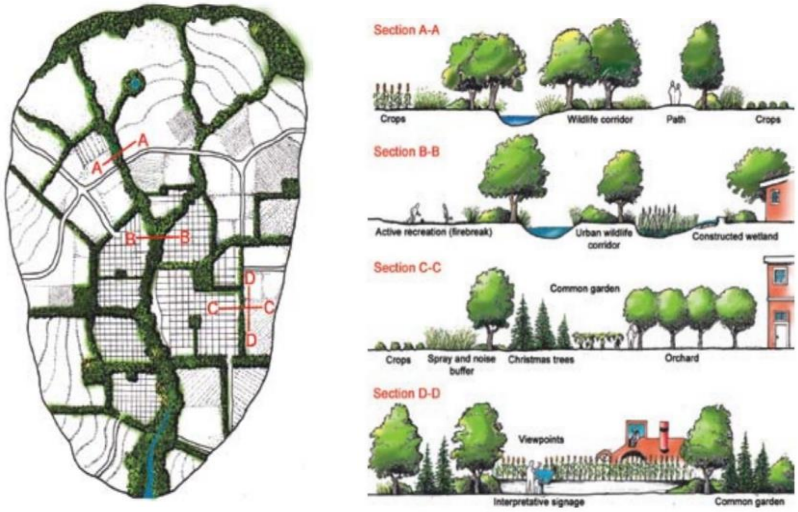


Figure 67. Conceptual plan and sections illustrating several types of conservation buffers in a watershed. Each buffer accomplishes different sets of functions and objectives

Note: Section A-A: a buffer designed to filter agricultural runoff to reduce a community's drinking water treatment costs. This buffer provides habitat and a conduit for wildlife while offering a public recreational trail. Section B-B: a buffer in a more urbanized area. A constructed wetland in the buffer treats runoff before it flows into the stream. An active recreation area in the buffer provides a firebreak to protect homes. Wildlife still benefits from this buffer, but this objective plays a less significant role than in Section A-A due to the buffer location. Section C-C: a buffer between an agricultural field and a residential area. This buffer serves as a common garden for both rural and urban residents. Noise control and protection from agricultural spray are also provided by the buffer. Products such as fruits, nuts, and Christmas trees can be harvested from the buffer. Section D-D: a buffer illustrating how the buffer in Section C-C provides aesthetic views at selected locations. Other aesthetic considerations are incorporated in the design to encourage human use. Signage informs residents about conservation measures being used to protect natural resources.
Source: G. Bentrup. Conservation Buffers: Design guidelines for buffers, corridors, and greenways. Asheville, 2008.

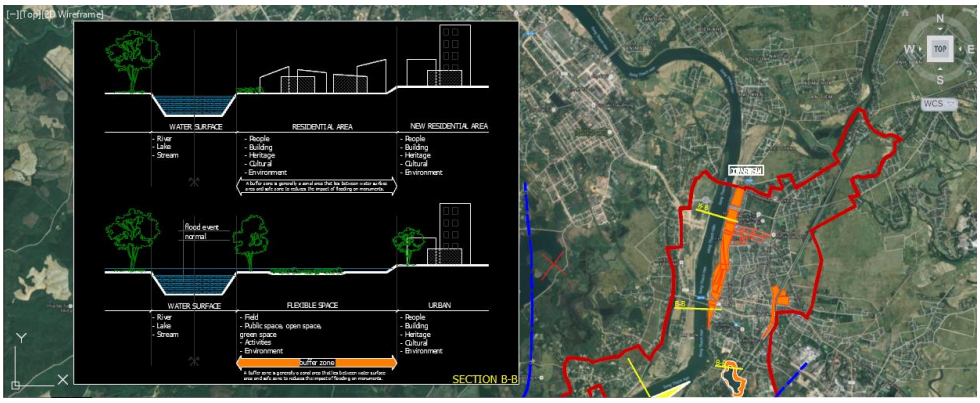


Figure 68. A buffer within urban area (section B-B)
Note: Buffer spaces within urban areas are the spaces that located between flood risk areas (rivers, canals) and important areas (residence area, heritage, trade center area, national security and defense areas). It functions to minimize the risk and impact of flooding on those important areas and used as a "flexible space" in urban areas.
Source: Author

5.3.3. Decentralized regulatory space

When rivers and canals are not enough water storage capacity, water will overtop the banks and led to flooding. Decentralized regulatory spaces are spaces where receive partial floodwater from rivers and canals during flooding, and slowly filtered and flows back out drainage network after flooding. The more decentralised regulatory spaces are allocated the more the flood risk will be reduced. Quang Tri Province has 101 reservoirs with a capacity of 1 million cubic meters (m3) to over 10 million cubic meters (m3). The total water reserves in the reservoirs in Quang Tri Province is about 221 million m3. This is the

favorable conditions to exploiting and using as decentralized regulatory spaces for flood control and economic exploitation, such as hydroelectricity combines sightseeing, tourism.

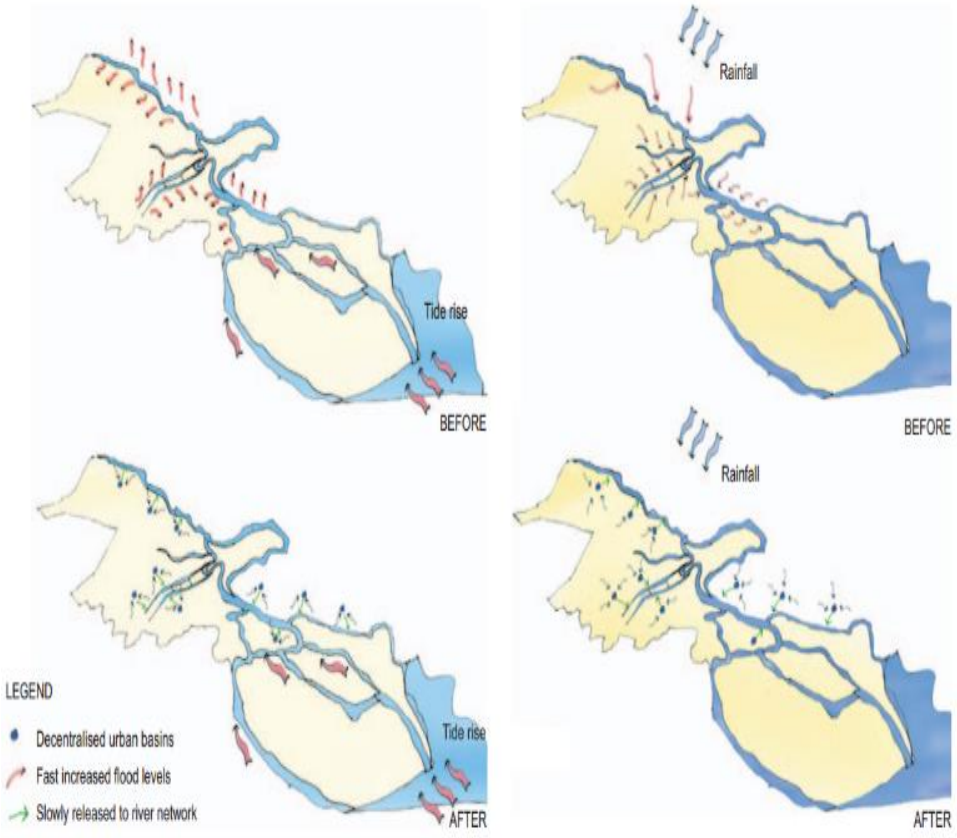


Figure 69. Before and after applying decentralized detention basin during tide rise and rainfall events
Source: L. H. C. Huynh, R. Eckert, M. Maikämper et al. Adapt-HCMC: Handbook on Climate Change Adapted Urban Planning & Design for Ho Chi Minh City, Vietnam. Germany, Brandenburg University of Technology Cottbus, 2013.

5.3.4. Flexible space

Flexible space is the space which has similar functions to decentralized regulatory spaces, but at a smaller scale. It is usually located within the urban area, with direct regulatory functions for individual projects and for itself urban. Due to the limitations of urban land resources, the regulatory space in the urban is usually associated with multiple functions and other activities, such as sports, farming, parks, climate regulation, it is called flexible space.

Figure 70. A flexible space sample - 1
Note: Playing fields or playgrounds as multifunctional areas: for recreational purposes and for temporary water during flooding and rainfall events.
Source: L. H. C. Huynh, R. Eckert, M. Maikämper et al. Adapt-HCMC: Handbook on Climate Change Adapted Urban Planning & Design for Ho Chi Minh City, Vietnam. Germany, Brandenburg University of Technology Cottbus, 2013.

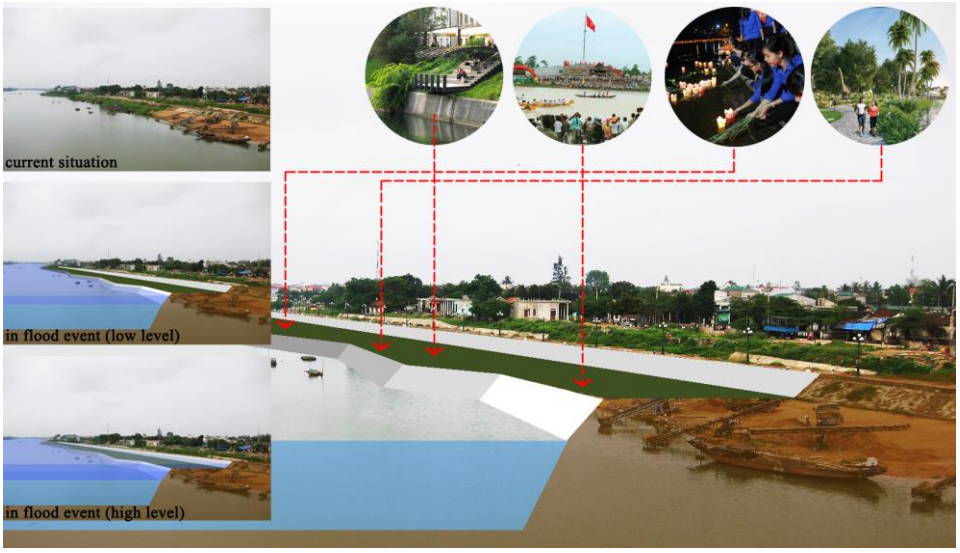


Figure 71. A flexible space sample - 2
Note: Based on natural and socioeconomic features to create flexible spaces adapt to floods: Thach Han and Ben Hai riverbanks should be renovated and used as a place for activities, traditional festivals, public space in normal status.
Source: Author

5.4. Absorption

"The severity of a flood depends not only on the amount of water that accumulates in a period of time but also on the land's ability to deal with this water. As we have seen, one element of this is the size of rivers and streams in an area. But an equally important factor is the land's absorbency. When it rains, soil acts as a sort of sponge. When the land is saturated -- that is, has soaked up all the water it can - any more water that accumulates must flow as runoff"[18].

Material and absorption have intimate relationships with each other, in other words, the level of absorption depends on the nature of materials. For example, the soil in the middle of the forest is an excellent sponge while rock is almost not so absorbent and clay falls somewhere in between. One of the least absorbent material is concrete. However, concrete is considered as the most popular materials for construction in Vietnam as well as in Quang Tri at present. The appearance of concrete and urban development, human being have changed the surface of the ground in a variety of ways. One of the most noticeable changes has been covering the ground by asphalt and concrete or other similar materials. Some more developed cities where the ground covering is more common (e.g., Ho Chi Minh City, Ha Noi or Hue), it may not take much rain to cause significant flooding.

5.4.1. Keeping the balance between urbanization and natural environment

Population growth, migration from rural to urban and urban expansion are specific factors for urbanization. The factors will constantly change and develop in the future. Although the urbanization rate in QuangTri Province is not too fast but it has been going on and affecting the urban ecological environment. Such as the increase of urban construction density is to meet demands for residential land and other living activities of urban dwellers. The urban construction density is being increased, it means the natural area in urban is being reduced. Whereas, the average permeability of water into the soil of urban land to land is about 1/5 (one over five) compared to natural greenery land. The transformation of the urban land and natural land is too fast, is one of the reasons leading to urban flooding.

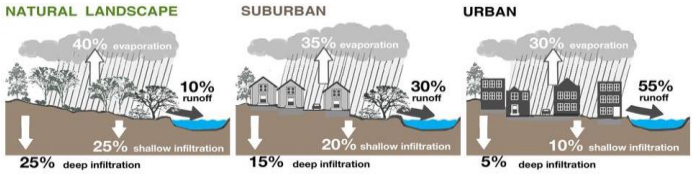


Figure 72. Water balance and watershed resilience to flooding can be correlated to the percent of porous versus impervious cover
Source: D. Watson and M. Adams. Design for Flooding: architecture, landscape, and urban design for resilience to climate change. New Jersey, John wiley & sons, 2010.

[18] T. Harris. How Floods Work. http://science.howstuffworks.com/nature/natural-disasters/flood.htm/printable.

Realizing the importance of the balance between urbanization and natural environment, many countries in the world have multiple solutions and policies in urban design and urban planning. For example, regulation on the gaps between building and sidewalk, regulation on materials used in urban design (in The United States of America (USA), Australia, Thailand, etc), regulation on the minimum percentage of natural greenery land compared with total area in the new planning area or regulation on green area per capita in urban areas, etc. These regulations should also be applied seriously to young urban cities in Quang Tri Province, such as Dong Ha city and Quang Tri town (the biggest city and town) in order to these urban develop more harmonious and sustainable in the future.

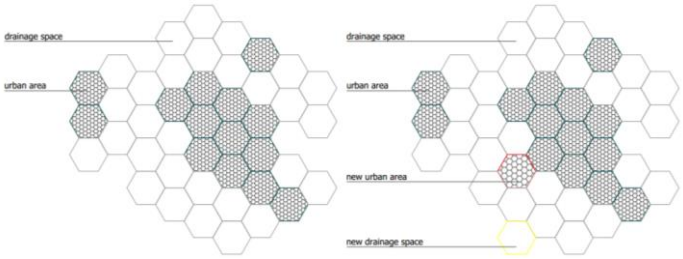


Figure 73. "Plus and minus" principle: each of new urban unit is used, the need to establish a new drainage unit
Source: Author

5.5. In the case of Quang Tri ancient citadel

5.5.1. Quang Tri ancient citadel in the past and nowadays

Quang Tri citadel is one of the most important heritage in the heritage system of Quang Tri Province. In this research, the architecture history of Quang Tri citadel was divided into three periods.

- Quang Tri citadel in the period of Nguyen Dynasty (1802-1885)

Quang Tri citadel was built the first time in 1802 during the reign of the first king of Nguyen Dynasty, King Gia Long (1802-1820). At this time, it was embanked simple by earth in Tien Kien, Dang Xuong district (Trieu Giang commune, Trieu Phong district today) with the rectangular shape. It was moved to Thạch Hãn commune, Hai Lang district (Quang Tri town today) in 1809[19]. Then, the citadel was expanded in 1833 and rebuilt by brick in 1837 during the reign of the second king of Nguyen Dynasty, King Minh Mang (1820 – 1841). It was based on European military techniques with four angled bastions at four corners that protrude from the citadel walls to protect one another. The walls had the perimeter of 2,080 square meters (m2), two layers (one by brick and one by soil) with about 4.25m height, 12.75m thickness at the base and 0.72m at the top of brick walls. Outside, the

[19] Quoc su quan trieu Nguyen. Dai Nam Comprehensive Encyclopedia (Dai Nam Nhat Thong Chi). Hue, Thuan Hoa publishing house, 2006.

citadel was surrounding by a ditch with depth 2,13m and with 34,85m. In each side of citadel had a gate in the midpoint (called Tien, Hau, Ta, Huu gate for the front, back, left, right sides), which had been constructed with the main archway. The second floor was a small traditional gazebo, roofed by curved tiles and in front of each gate had a curved bridge[20].

Quang Tri was used as an administrative center rather than a military defense work. More than 160 years under the monarchy, the citadel was the headquarters of the local government that represented Hue court to manage and operate the political, economic, cultural and social activities in the whole district. Therefore, many buildings were built inside the walls for staying and working of agencies of the administrative apparatus of Quang Tri Province. One of the most important building was Royal step-over place. This place was the Emperor's resting in his inspection missions and for monthly ceremonies and annual events. Behind this place is Tuan Phu, An Sat, Lanh Binh, Doc Hoc, soldier's camp, kitchen, storage, prison, etc. These works were built by Ruong house's architectural style of the Nguyen Dynasty with wooden frame structure, tiled roof, brick or wood planks wall.

- Quang Tri citadel in the period of French colony and the revolution against French Colonialism and American Empire (1885-1975)

Because of the importance location of Quang Tri Province, the French established a political center in the Quang Tri town with the administrative apparatus includes both the French government and Nguyen Dynasty. After 1885, Dong Hoi citadel and Quang Tri citadel were seen as important outposts of the military system of the French army between Hue and Vinh city. During this period, the architecture inside the citadel had many changes. To serve the administration and troops of the French army, the buildings of Nguyen dynasty were used or changed its functions. The Commander of the French army had resided in the palace of Emperor before he had to build a new building in 1887 as in an objection treaties of Nguyen's dynasty. Some buildings in the North area of Citadel were converted into the offices and residences for officers, European Marines, European non-commissioned officer, etc. Some buildings were constructed newly, such as post office, infirmary, kitchen, bakery, toms of French soldiers and other auxiliary buildings. In the early of 20th century, French army expanded the available prison towards the Northeast corner of the citadel (right side of 3rd battalion Chase force's camps), with an area up to over 15,000 m2 to imprison the communist and political prisoners. The new prison was described as follows: “The wall of the prison had height of 4m, perimeter of about 500m and broken glass pieces on the top of walls. Inside the prison area, there were two large opposite prisons in the West and the East side, which constructed with thick wall, tiled roof, iron windows and iron door. In the south of area was a large building, which was divided into many rooms for the chief of prison, jailer and guards. Beside those buildings, there were many smaller buildings inside prison area such as guard’s residence, handicraft product building, watchtowers, wells, toilets, etc”[21]. A new detention area was constructed inside this prison area in 1939 and completed in 1941 to imprison the most dangerous

[20, 21] V. T. T. Nguyen. Vietnam citadel system under the Nguyễn dynasty and the case of Quảng Tri citadel. Construction, Civil Engineering and Architecture, Marche Polytechnic University, Ancona, 2016.

communists. It was built by laterite and brick with a rectangular shape. In the middle of prison was a narrow corridor stretching from the beginning to the end of the prison with about 18.5m height and 0.95m width, enough space for a prisoner. There were seven cells of each side along the corridor with 1.15m width, 2.05m length and 1.80m height for each. The cell seemed to be sealed except for the main iron door and a small slit to get light. When French tried to attack Quang Tri again after losing the right to rule in Vietnam in 1945, the buildings inside were completely destroyed but the citadel and prison area were only damaged partially.

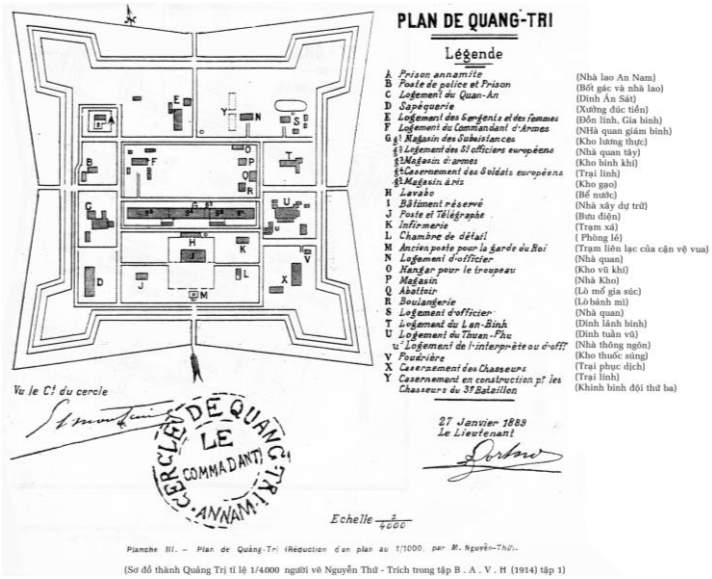


Figure 74. Plan of Quang Tri citadel in 1889 (drew by Nguyen Thu)
Source: L. Cadière. Bulletin des Amis du Vieux Huế (Những người bạn Cố Đô Huế). Thuan Hoa publishing house, Association des Amis du vieux Huế, 1914.

After the Geneva Agreements (or Geneva Accords) signed at the Geneva Conference in July 1954, Quang Tri citadel became a military base of Republic of Vietnam's Military Forces that supported by America. In this time, many buildings were rebuilt for military purposes at the same position as before, such as camps, residences, gun emplacement, etc. Many battles were launched in Quang Tri Province as well as Quang Tri citadel area but it did not affect much to the buildings until 1972. The battle in 1972 is the most fierce battle in Vietnam. About 328,000 tons of bombs and 690,000 artillery shells dropped down in this area from 28/6 to 16/9/1972 (81 days and nights) by American aircraft[21]. Everything was almost destroyed completely. Quang Tri citadel and the surrounding area were almost flattened.

[21] The battle in 1972 is also called "81 days and nights battle"

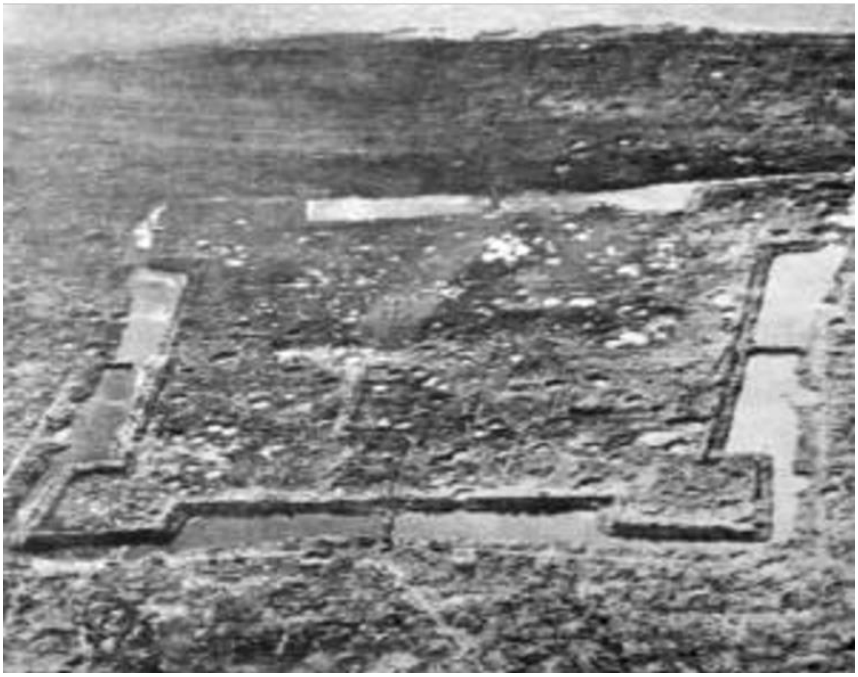


Figure 75. Overview of Quang Tri citadel after the "81 days and nights" battle
Source: Internet, available at: http://ongvove.wordpress.com/2009/09/02/cổ-thành-quảng-trị-bức-tường-thanh-oan-trai/.

Figure 76. A part of Quang Tri citadel wall after the 1972 war
Author: Sóng Thần

Quang Tri citadel is a monument that overcame many important historical landmarks. In 1986, Quang Tri citadel and the monuments mark the 81 days and nights battle recognized as a national monument by Decision no. 235/VH-QD on 12 Dec 1986. In 1992, Ministry of Culture and Information invested to embellishing and building this place into a memorial park, including a memorial in the center, restoration of the main gate, moat system and landscape. Quang Tri citadel's museum was built inside the citadel in 2002 to display the history of 81 days and nights battle. The Prime Minister issued Decision No. 2383 / QD-TT on 12 Sep 2013, recognized Quang Tri citadel and the monuments mark 81 days and nights battle in 1972 is a national special monument. In 2014, the sub-project of upgrading the reception and memorial has been completed[22].

- Quang Tri citadel nowadays

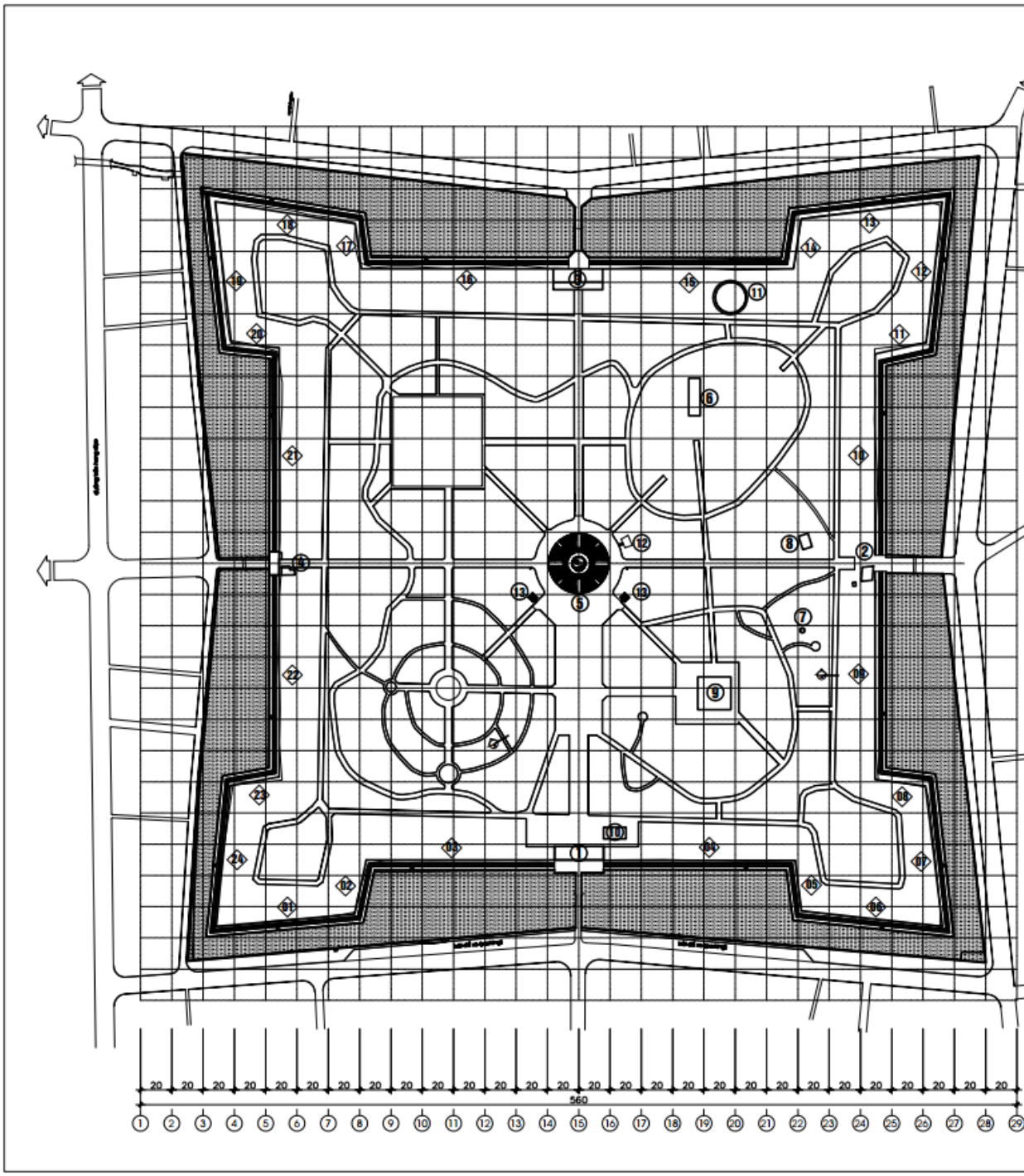
Quang Tri citadel is located in the central of Quang Tri town, about 2km from national highway No. 1° to the southwest, about 500 meters from Thach Han River to the west. Three sides of the citadel are residential areas and the west side is separated by Thach Han River.

Figure 77. Current situation of Quang Tri citadel
Source: Google map, edited by author.

[22] The sub-projects is a part of the project: The conservation and restoration of Quang Tri citadel's historical and revolutionary site.

Figure 78. An aerial view of Quang Tri citadel and surrounding area
Author: (a) Nguyen Quang Huy (2014). (b) Basemap:google earth, edited by author.

To assess the current situation, Quang Tri citadel was divided into 24 parts and 4 gates, as follows (*Figure 79*):
- The wall system was severely damaged by wars and human. The cracks, subsidence and tilting have occurred throughout the length of the wall. The development of vegetation also affects the aesthetic as well as the existence of the brick wall layers.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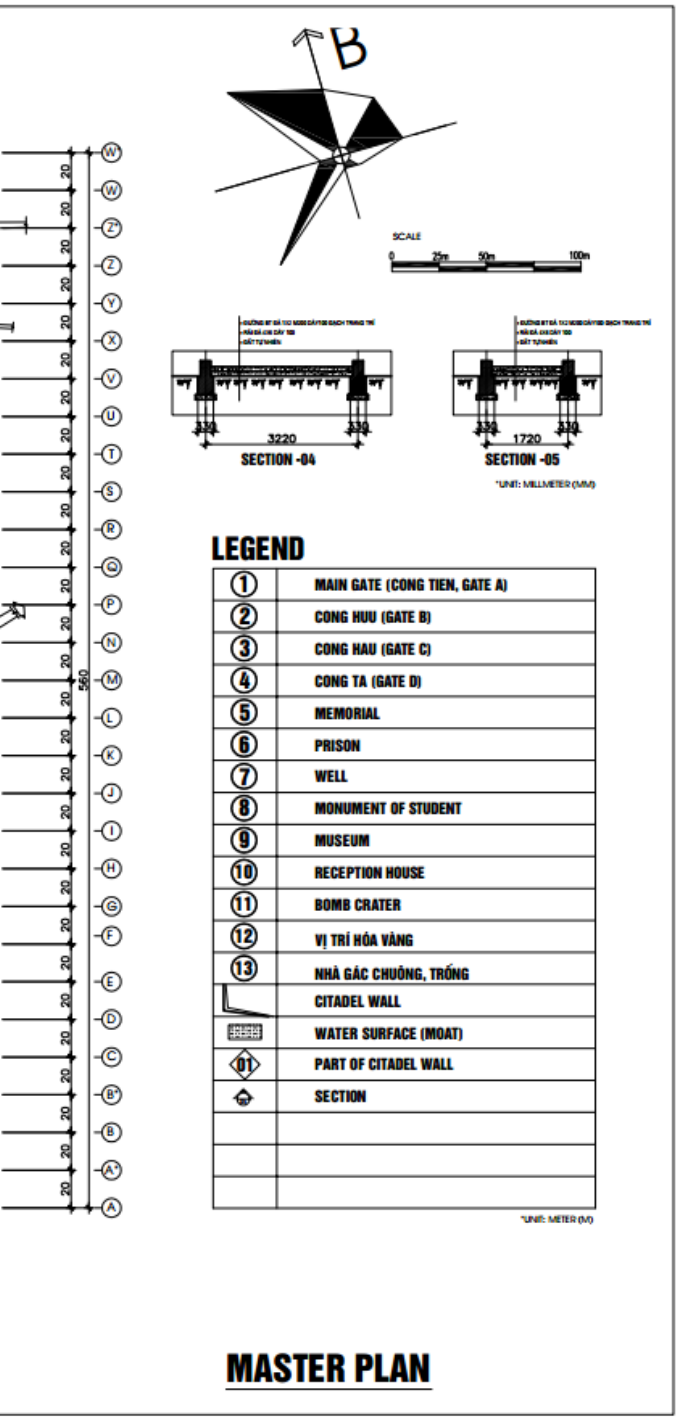

Figure 79.Master plan of Quang Tri citadel (2013)and parts of citadel wall (2014)
Source: Master plan of Quang Tri citadel: Quang Tri construction consulting joint stock company, edited by author. The parts of citadel wall: "Projecting landscape heritage: A requalification project as an instrument for the re-birth of Quang Tri old citadel in Vietnam", done by Polytechnic University of Marche, edited by author.

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- Gate A (main gate or “cong Tien”) was destroyed by war and rebuilt in 1992 with two main materials, brick and mortar. The gate has two floors. The first floor is the entrance which has arch door shape with two thick iron wood doors. The second floor is the gazebo with square floor, negative positive overlap roof, decorations on the top and top-edge of the roof.

Figure 80. Gate A (main gate or “cong Tien”)
Source: Author.

Gate B or “cong Huu” was almost completely destroyed, leaving the only vestige of a brick block on the left side of the gate. A temporary fence was erected by two concrete pillars and steel pipes to separate inside and outside.

Figure 81. Gate B or “cong Huu”
Source: Nguyen Quang Huy, 2014

Gate C or “cong Hau” has not been yet fully collapsed, but it was severely damaged by the war. Currently, this gate has only the first floor with the entrance arch. The second floor was completely lost. The mortar covering has been almost peeled off. The brick surface layer has altered and disturbed. Depending on the season, the vegetation layer has covered almost all of the gate surface.

Figure 82. Gate C or “cong Hau”
Source: Author.

Gate D or “cong Ta” was almost completely destroyed, leaving only vestiges of brick blocks on two sides of the gate. A temporary fence was erected by three concrete pillars and steel door to separate inside and outside.

Figure 83. Gate D or “cong Ta”
Source: Author.

- The current bridges are works that restored almost the same with originals in 1993. There are four bridges corresponding to four gates. It was built by brick, stone and mortar so it is more strong than before.

Figure 84. The main gate, bridge and a part of moat
Source: Internet – Edited by author.

- The moat system, the original moat embankment was built by basalt boulders. In 2011, the railing systems were built by cement and concrete. Moat-bed (river-bed) was dredged, the water landscape was planned and regenerated to serve tourists.

Figure 85. A part of moat and citadel wall
Author: Nguyen Quang Huy, 2014.

- The prison located in the northeast corner of the citadel. After the war, the prison was severely damaged, only remaining stability cell system from the French colonial period. Brick, stone and mortar are the main materials used to build this work. However, under the impacts of weather and vegetation, the mortar layers have been weathered leads to cracking and peeling other materials.

Figure 86. Perspectives of the prison
Author: Nguyen Quang Huy, 2014.

- The memorial was built in the center of the citadel in 1997. It has a cone shape that symbolizes a common grave of the soldiers who died in the wars. The grave was designed with the concept of yin and yang philosophy, which means to sublimity for the souls. Excepting the surrounding grass layer of the memorial, this area used mostly industrial materials that are not friendly with environment, increasing heat absorption and reducing natural permeability.

Figure 87. Perspectives of the memorial
Author: Quang Duc, available at: http://mekongtourdmz.com.vn/vi/news/cam-nang-du-lich-15/huyen-thoai-thanh-co-quang-tri-32.html.

- The museum was built in the southeast corner of the citadel in 2002. This is a place where displays artifacts and reappears the history of the citadel from the beginning until the reunification. Especially, the farewell letters of soldiers sent to their families during the battle in 1972 were still kept in this place.

Figure 88. Interior and exterior perspective of the museum
Author: VOV, available at: http://soha.vn/quan-su/thanh-co-quang-tri-ky-uc-hao-hung-mot-thoi-hoa-lua-2013091617221625.html.

- The reception house is located on the right side of the main gate. This building was built and completed in 2014 in the style of Ruong's house but concrete was used to replace wood, which is a traditional material in Ruong's house. The reception house and museum are two new buildings located inside the citadel area..

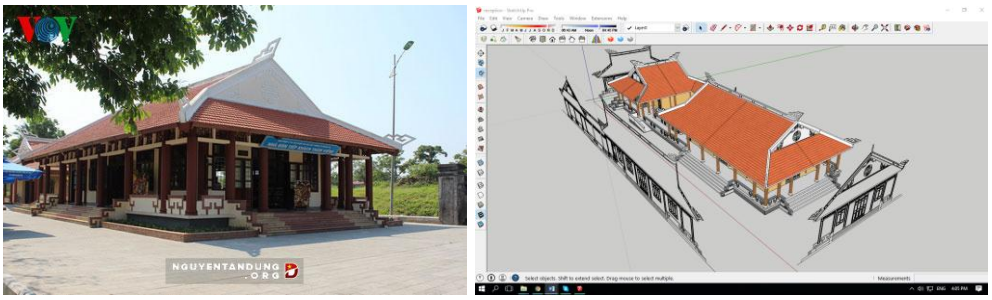


Figure 89. The reception house and 3D model was modeled by author
Author: VOV, available at: http://vov.vn/xa-hoi/thanh-co-quang-tri-hoi-sinh-tu-tro-tan-396827.vov.

Besides, there are many other works inside the citadel wall, such as a feat monument of student in Quang Tri that was built in 2002; a well near the prison that was a supply of water for life activities inside the citadel; a green park system includes trees, shrubs and greenswards; many traces of bomb craters and bullets that are still remain on the walls, the gates and on the ground, in which the biggest bomb crater is located in the north of citadel with area of 24 square meters and 2.5 meters deep.

5.5.2. The risks of QuangTri ancient citadel in flood event

a. Risks from the environment and unbridled development of vegetation covers
The process of flooding is divided into 3 phases: before flooding, during flooding and after flooding. In the first phase (before flooding), heritage site, environment and vegetation are balanced in a natural way. Although this balance is sometimes broken by the weather, human, or other natural disasters, but in one way or another, people still try to maintain that balance.

Figure 90. The changes of vegetarian in the moat system around the citadel
Note: (a) The the southeast corner was taken in August 2011, author: Mai Linh, available at: http://vanthientungqtlh.blogspot.it/2011/08/thanh-pho-quang-tri-nam-xua.html. (b) The the southeast corner was taken in July 2012. (c) Gate C (cong Hau) was taken in August 2012 from inside.
Source: (a) and (b) Author: doson.ha, available at: http://www.dosonha.nghesi.vn/2012/0-8/ve-quang-tri-tri-ong-oi-phan-7_2.html. (c) and (d) Author: Vvova, available at: http://www.phuot.vn/archive/index.php/t-51870.html). (d) Gate C (cong Hau) was taken in October 2008 from inside, author: Dang Huy, (available at: http://timeoutvietnam.vn/huyen-thoai-thanh-co-quang-tri-9208.html.

In flood event, the floodwater also brings many benefits for the environment and vegetation around the citadel. There are nutrients in the alluvium and mud that is carried along when the floodwaters flows from upstream to downstream. When the floodwater flow on the ground surface, it also helps washout of toxic substances and regeneration of soil fertility. However, besides alluvium and mud, it also brings much waste, solid waste, corpses of

animal and plant, toxic chemicals from upstream and where the floodwater flows through. Combined with the other pollution sources in urban, such as feces, household waste, sewage from sewer systems, manure and waste from livestock pens to cause severe pollution to the environment and ecosystem. If the flooding lasts longer than 3 days, a part of components in floodwater will be decomposed during flooding, another part will continue to be decomposed after floodwater recedes (after flooding phase). If the flooding lasts longer than 5 days, trees and crops may be died because of being soaked in water for a long time, affecting the landscape of heritage and urban.

Figure 91. Remedial actions after flooding
Note: (a) and (b) The soldiers of Regiment 19, Division 968 help people in Cam Lo district to clean up after flooding in November 2016. (c) and (d) People and volunteer force in Cam Lo district positive overcome consequences of flooding.
Source: (a) and (b) Author: Hung Thoa, available at: http://lao-dong.com.vn/thoi-su-xa-hoi/quang-tri-beo-luc-binh-khung-tran-ve-sau-lu-quan-doi-ve-giup-dan-lam-sach-ruong-607582.bld. (c) and (d) Author: Le Chung, available at: http://giadinh.net.vn/xa-hoi/nguoi-dan-mien-trung-gong-minh-khac-phuc-hau-qua-sau-lu-lon-20161102114837-333.htm.

After flooding is the time of increasing the environmental pollution and the effects of floodwater on vegetation continue to take place. Water in rivers, lakes is very muddy. Garbage, trees and objects drift on the water surface. The streets are full of mud and rotten smell from dead animals, insects, and decomposed plant. Floodwater also carries the harmful seeds of plants and animals from other places to this area. They will develop very quickly and deeply rooted in the architectural constructions when they get favorable conditions, such as temperature, humid, nutrients, etc. There are the risks that direct impact heritage and landscape through the surrounding environment. Meanwhile, the response and

remediation action of flood consequences are usually very slow and passive. Soldiers, volunteers and local people are the main forces that directly do those things to protecting environment, urban as well as heritage after flooding without any professional team or group. Because these forces have not done a basic training yet as well as the limited understanding of conservation work, so it is seen as one of the risks that impact Quang Tri citadel in the process of remedial after flooding.

In addition, numerous studies have confirmed that microorganisms have been threatening to buildings and world heritage in the whole world. Vietnam is a tropical country so the occurrence and extent of damage are more serious, not only in Quang Tri ancient citadel but also in most other heritages. The microorganism is always present in the natural environment and in itself of the tangible heritages. Impacts still occur daily, but when they get favorable conditions, it happens faster, stronger and more serious. These favorable conditions include weather elements, the traditional materials of Vietnam architecture (wood, bamboo, brick, and stone), environmental condition, or even the knowledge of local people. However, there has been no research on this issue to assess the degree of influence in the citadel until now. Eric Doehne, a scientist at the Getty Conservation Institute, said that "One of the recent discoveries that is of concern is that increased air pollution can sometimes increase biodeterioration. Some bacteria feed on chemicals found in pollutants, excreting an acid that eats away at stone, metal and paint"[23].

In the article "World monuments suffer under a microscopic menace" was published on the website of The New York Times by Bina Venkataraman on 24 June 2008, has mentioned some of the harmful effects of microorganisms on the heritage sites. According to Thomas Warscheid, a geomicrobiologist based in Germany, who has studied Angkor Wat for more than a decade, said in an interview that "These bacteria (Gloeocapsa) not only stain the stone black, they also increase the water absorbed by the shale in morning monsoon rains and the heat absorbed when the sun comes out. These impacts had broken away parts of celestial dancer sculptures on the temple walls. It is getting worse, up to 60 or 70 percent of the temple have got black until now". Sophia Papida, a conservator of the Acropolis Restoration Service, said that "Microbes pose a serious risk to the monuments at the Acropolis in Athens, including the golden-proportioned Parthenon and the Temple of Athena Nike. Bacteria penetrate the veins of the marble, attract water and expand, cracking the monuments' faces and pillars. Lichens burrow circular holes in the marble, a phenomenon known as honeycomb weathering, and exfoliate sculptural friezes that tell the stories of gods and goddesses. Acropolis stones can crumble into thousands of pieces by the attack of microbes. They had to removed the microorganisms and then put it back together.

b. Collapsed risk of citadel walls

There are two reasons that can lead to the collapse of citadel walls, the self-decomposition of materials (subjective reasons) and the impacts of external (objective reasons).

Quang Tri citadel wall includes 24 parts as introduced above. There are the parts that have the greatest influential risk and even capable of collapsing in the flood event. It were built with two main materials, brick and mortar. A survey in 2014 showed that the surface of

[23] B. Venkataraman. World monuments suffer under a microscopic menace. The New York Times, 2008.

brick and mortar in some places has been appearing decayed condition and the mortar joints have been losing cohesion.

To explain this phenomenon, there were many assumptions being given, for example, due to the location, shape and survival time of heritage sites, methods and techniques of construction, the composition of raw materials which used for construction buldings (soil, clay, sand, cement, etc), the acidity of the natural environment (the presence of ions Cl^-, NO_3^-), etc[24]. This phenomenon will make the brick layers gradually lose available connectivity, leading to the decay of bricks and as a result, the wall parts will be collapsed. The collapse will occur more quickly under the impacts of external or in disaster events, such as floods or storms. This is a natural phenomenon and it is not only occur in Quang Tri citadel but also in many other heritages (both ancient/old and new buildings).

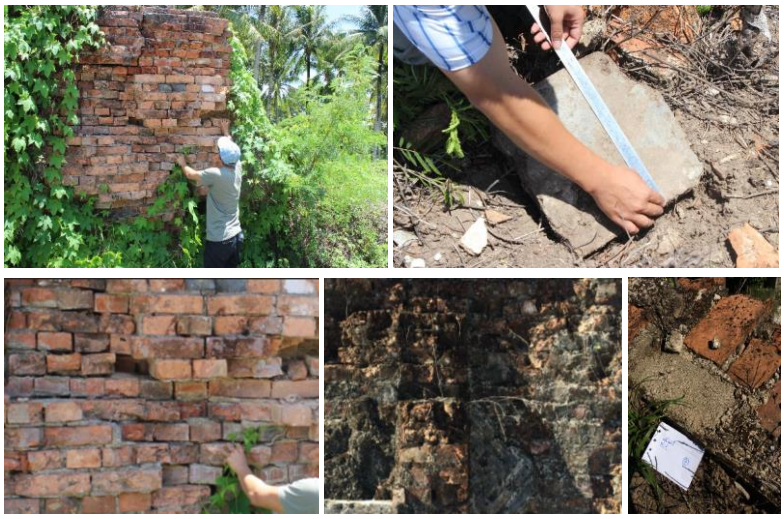


Figure 92. The mortar joints have been losing cohesion causes the decay of bricks. It is the cause of the collapse of the citadel walls
Source: Author.

[24] In a study of Dr. Tran Minh Duc, he gave two reasons for decaying of brick are: (a) Due to the acidic environment, namely the presence of ions Cl- and NO_3- are the factors that can cause chemical reactions with minerals in brick and creating products less durable than before. The reaction rate is not high when corrosives in solid form. Conversely, under the presence of water, the corrosives become solutions (liquids) and its destruction increases many times. (b) Due to the soluble salts in brick, the most typical is $CaSO_4$ (gypsum) or Na_2SO_4 (Anhydrous sodium sulfate). The salt combined with water to form hydrated crystals and volume will increases several times (calcium sulphate) or a few dozen times (sodium sulphate). Salt crystals fill pore spaces. When it rises excessively, it break the wall of pores and brick will be decayed. In particular, it shows the role of water: water increases the reaction rate in group A and it is like a catalysts for the crystallization of salts in group B. Water is one of agents of spreading damage from place to place in brick buildings, especially in the case of capillary corrosion.

The impacts of external or objective reasons are the chan`ge of geological led to the subsidence of the walls, the vibration caused by motor vehicles in modern times, urban planning and heritage buffer planning. Or because of the effects of the wars so the remaining walls are quite fragmented and it can be collapsed at any time.

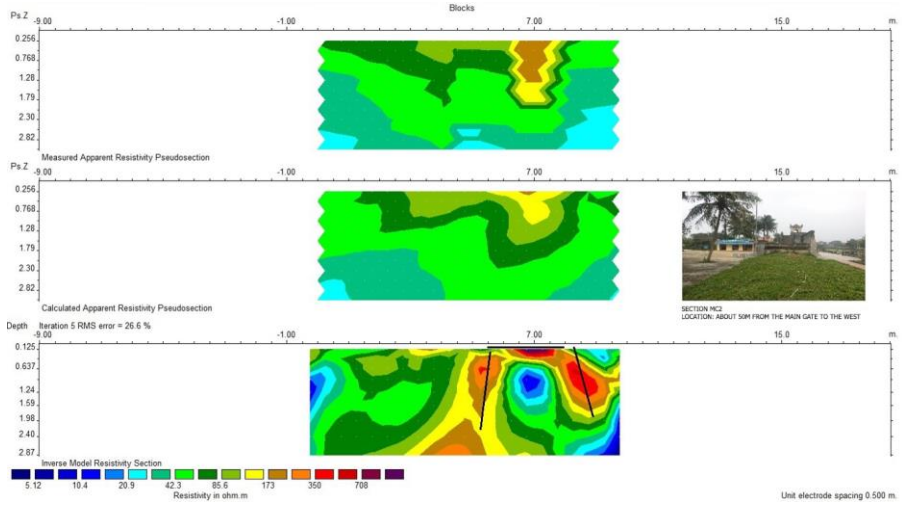


Figure 93. A section of inverse model resistivity
Source: Tran Huu Tuyen, 2014

Based on the intensity of resistivity, the inverse model resistivity sections shows the structure of the soil beneath the walls by colors. Blue corresponds to weak soil layer (groundwater, mud, sand, etc) while purple represents hard soil layer (rock, stone, rubble or a less-weathered regolith, etc). In the case of flooding, the soil structure will be affected and indirect impact on the citadel walls. Consequently, it will be subsided, dilapidated or even collapsed.

Figure 94. The citadel walls can be collapsed under the impacts of external
Source: Author.

However, facing with those risks, beside periodically vegetation trimming, there is no specific solution to minimize the risk of collapse of the walls. And of course, in flood event, the collapsed risk will increase by pouring water absorption of the materials, the abnormal increase of water level (floodwater), the power of floodwater flow and elements in the floodwater (e.g., garbage, mud, tree trunks, chemical, etc).

Figure 95. A segment of parapet wall of Quang Tri citadel collapsed after raining on the morning 18 Sep 2013
Source: Quốc Nam, available at: http://tuoitre.vn/tin/chinh-tri-xa-hoi/201309-18/mien-trung-tay-nguyen-cang-nguoi-phong-chong-bao-so-8/569692.html.

5.5.3. Proposals for Quang Tri ancient citadel

To reduce the risks that were analyzed above,beside the proposals at urban planning level, under the perspective of an architect, there are some proposals for Quang Tri ancient citadel, as follows:
- Regular maintenance, repair and upgrade of the drainage system inside and outside Quang Tri citadel to cope with pluvial flooding (urban flooding) or in cases of extreme rain or other natural disasters. The drainage system works stability will ensure the flow of water, rainwater or floodwater from inner citadel and surrounding areas to river system. Restricting the flood risks also means limiting the impacts of flooding on the landscape (vegetation covers) and heritage (foundation of citadel wall, buildings, materials).

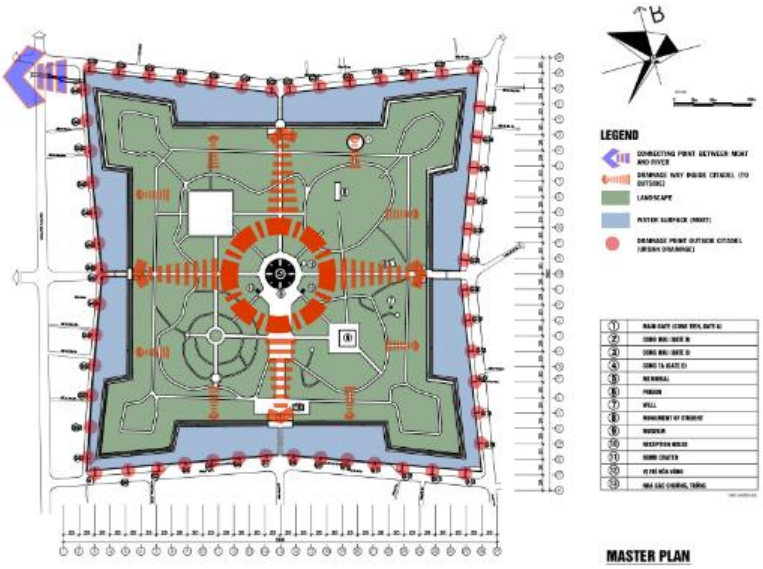


Figure 96. Drainage system map of the area around Quang Tri citadel
Source: Author

- Keeping the natural balance between surface water and underground water (storage and absorption) by reasonable using permeable (lawns, vacant land areas) and impermeable area (footpaths, yards, squares).

Figure 97. Entrance to the memorial
Source: (a) Author: Coi to, available at: http://www.phuot.vn/threads/3133-Xuyên-Việt-2009-tường-thuật-trực-tiếp-của-bạn-Còi-To/page3. (b) Author: Nguyen Thi Trang, available at: http://lienketviet.net/blog/1511/thanh-co-quang-tri-81-ngay-dem/.

The main entrance leading to the memorial was expanded and changed materials in 2014. Images were taken in 2009 (a) and 2015 (b). It means that permeable area has been replaced by impermeable area through increasing area and using “hard” materials, environmental unfriendly materials, impermeable materials.
In addition to planning and reasonable spatial transformation, the using of selected materials (permeable materials, environmental friendly materials or material of biological origin) not only contributes to stable that balance but also reduces the changes of climate, by reducing absorbed and emitted heat, the amount of carbon released into the environment during the production of materials.

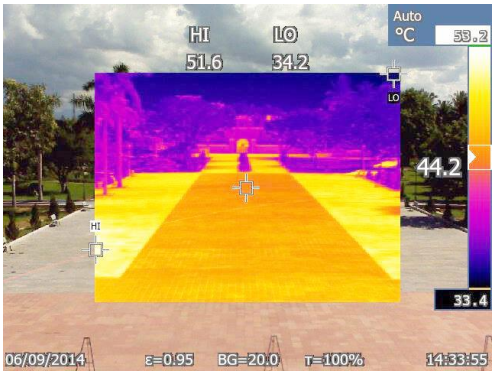


Figure 98. Thermal image around the memorial
Source: Author. The image was taken by Fluke TiRx Thermal Imaging Camera in 2014.

- “Wireframe” solution
"Wireframe" is a combination of conservation and minimizing the collapsed risks of the citadel walls. The idea came from the history of the Quang Tri Citadel (the formation, completion and breakdown) and the simplification of architectural shapes (point, line, face and shape). A "line-citadel" will be erected in order to simulate the originality of Quang tri citadel under Nguyen Dynasty (before collapsing by the wars). the originality will be reflected in the original architectural style, dimensions and scale that helps people to reminiscent of the original and integrity citadel.

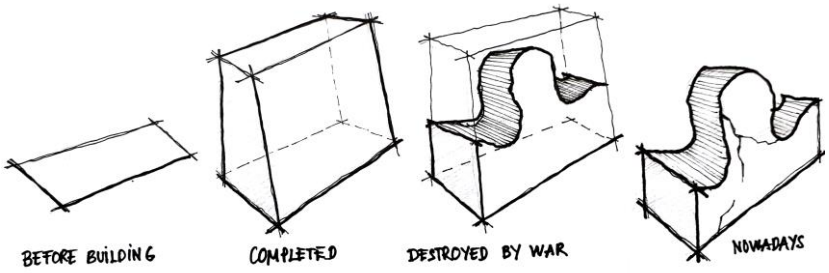


Figure 99. History of the Quang Tri Citadel (the formation, completion and breakdown)
Source: Author

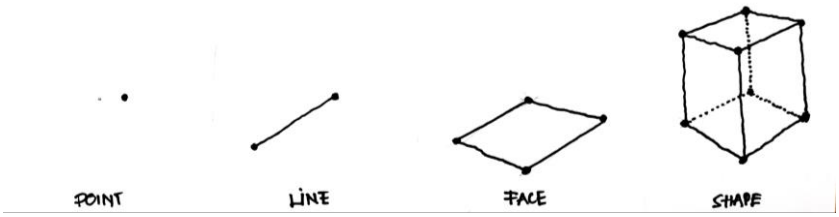


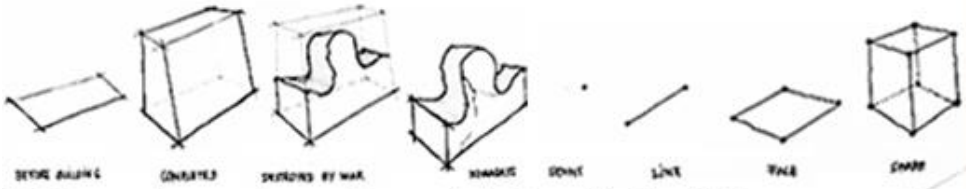
Figure 100. The simplification of architectural shapes (point, line, face and shape)
Source: Author

Besides, although the citadel walls are facing the risk of collapse[25] at any time, it has had no any supported solutions until now. In this case, the wireframe will be flexibly processed to form fulcrums. The fulcrums will support and fixed those walls. It means that the collapsed risk of the citadel walls will be reduced in the flood events or in other natural disasters (hurricanes, extreme rain, etc) or under the outside influences.

Figure 101. Perspectives of "Wireframe" and flexible fulcrums
Source: Author

[25] Introduced in " The risks of QuangTri ancient citadel in flood event", page 105.

WIREFRAME

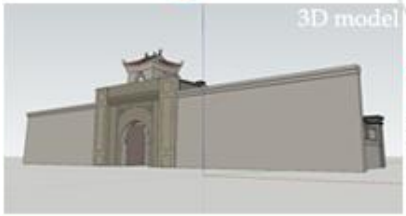


IDEA: a combination between history of the Quang Tri Citadel (formation, completion and breakdown) and the simplification of architectural shapes (point, line, face and shape)

Current image

compared with historical documents

Ioriginal architecture of Quang Tri ancient citadel

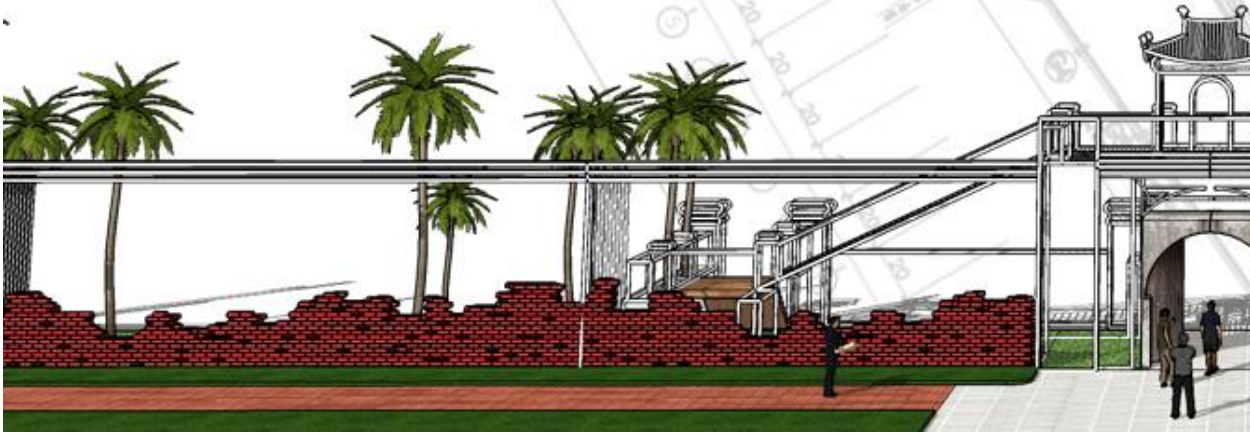


3D model
Wireframe

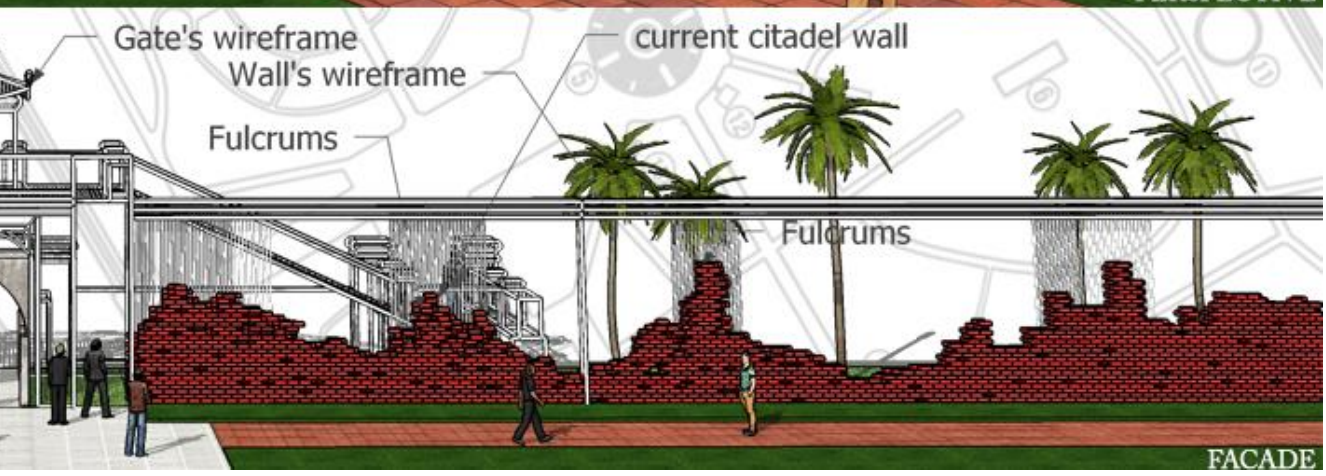
PROCESS OF CREATING

Quang Tri's wireframe

simplify part by part




Gate's wireframe
Wall's wireframe
current citadel wall
Fulcrums
Fulcrums
PERSPECTIVE


Gate's wireframe
Wall's wireframe
current citadel wall
Fulcrums
Fulcrums
FACADE

Conclusion

The heritage system is a valuable potential of Quang Tri Province. This type of asset is non-renewable and irreplaceable, but very easy to be deformed by the impact of external factors (environment, climate change, people, war, etc). The impacts of flooding on heritage are very clearly, so the conservation and preservation of heritage are very necessary and urgent. To reducing those impacts, there are two problems that need to be solved: (1) flood adaptation and (2) heritage conservation and preservation.

1. Flood adaptation

Flooding is a natural phenomenon of weather that occurs every year and it is impossible to avoid or prevent. Adaptation is almost the most effective solution to respond and mitigate the impacts of flooding. The adaptation to flood is a process, including prevention, protection and mitigation. In that, people will reduce adverse impacts and bring into play the opportunities that flood brings about. It will be repeated several times to choose the most effective solutions to application and development.

The above research proposals can not resolve completely the flood problem, but that is the basis for urban planning and heritage conservation to adapt to flooding and climate change in the future. Based on the flood risk map for heritage and the heritage map can formulate strategies for heritage conservation not only in flood event but also other disasters.

2. Heritage conservation and preservation

The cultural heritages are products of historical conditions, culture, socioeconomic, political through many historical periods. Thus, the relationship of heritage with historical period when they were created is the important information that researcher and conservationists need to cautious, including the two most important factors like originality and authenticity of historical monuments. The originality attached to the constituent parts of monuments that were created at the beginning. And the authenticity of history associated with the creative imprint formed during the existence of monuments (architectural elements, materials, construction techniques, methods and traditional functions of monuments, etc). So, the originality and authenticity of history factors will determine the value of monument.

Under the impact of climate change, the heritage system in Quang Tri Province has been affecting and destroying by flooding (and many other disasters) before conservation. Therefore, the research, evaluation and giving timely solutions (conservation and preservation) will preserve the whole value of heritage. However, the conservation and preservation of heritage do not mean to put heritage in a separate environment to avoiding negative impacts on heritage, the cultural heritage should be linked to people, local communities and the urban development. And it should not be applied as an available formula or model and for all cases. Strategies, models, principles theoretical must be applied flexibly depending on historical conditions, characteristics, the typical value of heritage, current situation and damage level, and based on criterions of the Department of Cultural Heritage of Vietnam, as follows:

- Protecting and promoting the typical value of monuments is the first priority (the value of history, culture, science and traditional function as well as the new features of the monument).
- Using all possible measures for the conservation and restoration to store and preserve the originality and authenticity of historical for the next generation (the next generation will have the physical condition and technique are certainly better than us and they can give a better conservation plan).
- The conservation and restoration must also maintain the traditional functions of the monument.

3. Further

This thesis just focused to research in the low plain area (downstream area) of Quang Tri Province and the proposals were given at the basic level. For a more overview of the impacts of flooding on the whole heritage as well as the flooded risk for heritage system in Quang Tri territory, the research needs to be expanded in the high plain (upstream area) and mountain area. In these areas, the nature and characteristics of flooding will be different from the low plain area, such as the real-time of flooding, flow velocity, components in floodwaters, etc. Similarly, it is also different between the heritage in low plain area and higher areas, such as material, foundation structure, shape, etc.

The proposals in this research were seen under the perspective of an architect. However, to conserving and preserving the heritage sites really effectively, those proposals need to be considered under other areas, such as chemistry, biology, archaeology, studies of materials and more. In further research, the proposals should be concretized into solutions accordance with the criterias, policies and requirements of each specific area.

References

[1] A core group led by the Netherlands and France. "*Best Practices on flood prevention, protection and mitigation*" in Water Directors meeting, Athens, 2003.

[2] Associated Programme on Flood Management. *Flood mapping*. Urban Flood Management in a Changing Climate, Associated Programme on Flood Management, 2013.

[3] Associated Programme on Flood Management. *Urban flood management in a changing climate*. Flood Management Tools Series, Associated Programme on Flood Management, 2012.

[4] Associated programme on flood management. *Urban flood risk management*. Flood Management Tools Series, Associated programme on flood management, 2008.

[5] G. Bentrup. *Conservation Buffers: Design guidelines for buffers, corridors, and greenways.* Asheville, 2008.

[6] E. J. Blakely. *Urban planning for climate change*. Lincoln Institute of Land Policy, pp. 1-25, 2007.

[7] J. Blanksby and S. Moore. *Structural surface water management measures.* UK, 2012.

[8] T. T. Bui, D. T. Truong, T. V. H. Do et al. *Assessment of resources to design the tourist routes in Quang Tri province (Đánh giá tài nguyên phục vụ việc thiết kế tuyến du lịch tỉnh Quảng Trị)*. Ho Chi Minh city University of Education's Journal of science, no. 35, pp. 136-144, 2012.

[9] T. T. Bui and M. C. Vu. *The orientations of exploiting the cultural historical relics in quang tri province for tourism (Định hướng khai thác các di tích lịch sử-văn hóa tỉnh quảng trị cho mục đích du lịch)*. Hue University's Journal of Science, vol. 72, no. 3, 2013.

[10] L. Cadière. *Bulletin des Amis du Vieux Huế (Những người bạn Cố Đô Huế).* Thuan Hoa publishing house, Association des Amis du vieux Huế, 1914.

[11] T. V. Can, T. S. Nguyen, C. T. Ngo et al. *Establish tools assessment of flood vulnerability suitable for river basins in central Vietnam (Xây dựng bộ công cụ đánh giá tính dễ bị tổn thương do lũ lụt phù hợp cho các lưu vực sông ở miền Trung, Việt Nam)*. Vietnam National University's (VNU) Journal of Science, vol. 31, no. 3S, pp. 277-285, 2015.

[12] A. Cherry, K. Curtis, A. Day et al. *Living with water: visions of a flooded future.* UK, Building Futures, 2007.

[13] A. Colette. *Case studies on climate change and World Heritage.* Paris, UNESCO World Heritage Centre, 2009.

[14] A. Dale, B. Hankin, N. Hunter et al. *Framework and tools for local flood risk assessment* Bristol, Environment Agency, 2014.

[15] D. K. Dang. *Nghiên cứu tính dễ tổn thương do lũ lụt hạ lưu sông Thạch Hãn, tỉnh Quảng Trị*. Vietnam National University, Hanoi, 2011.

[16] T. K. N. Dang. *Dự án rà soát, bổ sung quy hoạch phòng chống lũ các tỉnh miền Trung từ Quảng Bình đến Bình Thuận*. Institute of Water Resources Planning, 2011.

[17] W. Daungthima and H. Kazunori. *Assessing the flood impacts and the cultural properties vulnerabilities in Ayutthaya, Thailand*. Procedia Environmental Sciences, vol. 17, pp. 739-748, 2013.

[18] P. David. *Flooding and historic buildings.* England, Historic England, 2015.

[19] H. Do. *Urban planning adapt to climate change (Quy hoạch đô thị thích ứng với biến đổi khí hậu)*. Vietnam Urban Planning and Development Association, Ha Noi, 2015.
[20] M. K. Doan. *Vietnam's vernacular architecture in contemporary world (Kiến trúc bản địa Việt Nam trong thế giới đương đại)*. Journal of Science and Technology in Civil Engineering, no. 19, pp. 10-15, 2014.
[21] S. Doocy, A. Daniels, S. Dooling et al. *The human impact of volcanoes: a historical review of events 1900-2009 and systematic literature review*. PLoS currents, vol. 5, 2013.
[22] J. Edwards, M. Gustafsson, B. Näslund et al. *Handbook for Vulnerability Mapping.* Swedish, Swedish Rescue Services Agency, 2007.
[23] J. Eleutério. *Flood risk analysis: Impact of uncertainty in hazard modelling and vulnerability assessments on damage estimations*. National school of Water and Environmental Engineering Department, Université de Strasbourg, France, 2012.
[24] B. Gething and K. Puckett. *Designing for Flood Risk*. Climate Change Toolkit, London, RIBA (Royal Institute of British Architects), 2013.
[25] E. Gospodinov and G. Burnham. *Disaster definitions*. The Johns Hopkins and International Federation of Red Cross and Red Crescent Societies Public Health Guide for Emergencies, pp. 24-43, Geneva, The John Hopkins and the International Federation of Red Cross and Red Crescent Societies, 2008.
[26] Government of Ireland. *The Planning System and Flood Risk Management: Guidelines for Planning Authorities.* Dublin, The stationery office, 2009.
[27] V. H. Ha, D. T. Truong and V. L. Nguyen. *Analyse the cause, the extent of damage by the natural disasters at Huong Hoa district, Quang Tri province and proposed mitigation solution (Phân tích nguyên nhân, mức độ thiệt hại do thiên tai ở huyện Hướng Hóa, tỉnh Quảng Trị và đề xuất giải pháp giảm thiểu)*. Hue University of Science's Journal of Science and Technology, vol. 1, no. 1, pp. 71-82, 2014.
[28] S. Hallegatte. *Strategies to adapt to an uncertain climate change*. Global Environmental Change, vol. 19, no. 2, pp. 240-247, 2009.
[29] M. Haraguchi and U. Lall. *Flood risks and impacts future research questions and implication to private investment decision-making for supply chain networks*. Background Paper prepared for the Global Assessment Report on Disaster Risk Reduction 2013, Geneva, 2013.
[30] T. Harris. *How Floods Work*. http://science.howstuffworks.com/nature/natural-disasters/flood.htm/printable.
[31] L. H. C. Huynh, R. Eckert, M. Maikämper et al. *Adapt-HCMC: Handbook on Climate Change Adapted Urban Planning & Design for Ho Chi Minh City, Vietnam.* Germany, Brandenburg University of Technology Cottbus, 2013.
[32] IMHEN and UNDP. *Viet Nam special report on managing the risks of extreme events and disasters to advance climate change adaptation (Báo cáo đặc biệt của Việt Nam về quản lý rủi ro thiên tai và hiện tượng cực đoan nhằm thúc đẩy thích ứng với biến đổi khí hậu).* Ha Noi, Viet Nam Publishing House of Natural Resources, Environment and Cartography, 2015.
[33] Intellectual Vietnam Corporation and Hanoi University of Science. *Conducting field surveys and hydraulic modeling in the basin of Thach han and Ben Hai river, Quang Tri province (Tiến hành khảo sát thực địa và lập mô hình thủy lực lưu vực sông thạch hãn và bến hải, tỉnh Quảng Trị)*. Ha Noi, 2010.

[34] IPCC (Intergovernmental Panel on Climate Change). *Climate Change 2014: Synthesis Report*. IPCC, Geneva, 2014.
[35] J. Jokilehto. *Definition of cultural heritage: References to documents in history*. ICCROM Working Group 'Heritage and Society', pp. 4-8, 2005.
[36] Kyoto Protocol. *Kyoto Protocol*. United Nations framework convention on climate change, 1997.
[37] K. J. Macks. *Guideline housing construction techniques in flood and storm zone (Hướng dẫn kỹ thuật xây dựng nhà vùng bão lụt).* Construction Publishing House, Vu Quoc Chinh, 1997.
[38] A. F. Mandych. *Classification of Floods. Water Interaction with Energy, Environment*. Food and Agriculture, vol. 2, pp. 1-9, 2012.
[39] Ministry of Natural Resources and Environment (Vietnam). *Climate change and sea level rise scenarios for Vietnam (Kịch bản biến đổi khí hậu, nước biển dâng cho Việt Nam).* Ha Noi, Ministry of Natural Resources and Environment, 2012.
[40] Ministry of Natural Resources and Environment (Vietnam). *National target program to respond to climate change (Chương trình mục tiêu quốc gia ứng phó với biến đổi khí hậu).* Ha Noi, Ministry of Natural Resources and Environment, 2008.
[41] H. Nasiri, M. J. M. Yusof and T. A. M. Ali. *An overview to flood vulnerability assessment methods*. Sustainable Water Resources Management, pp. 1-6, 2016.
[42] C. T. Ngo, L. P. Pham, V. T. Le et al. *Climate evolution in Quảng Trị during the 1993 - 2013 and the 2015-2035 periods under the impact of climate Change (Diễn biến khí hậu tỉnh Quảng Trị thời kỳ 1993 - 2013 và thời kỳ chịu tác động của biến đổi khí hậu 2015-2035)*. Vietnam National University's Journal of Science, vol. 31, no. 1S, pp. 85-92, 2015.
[43] D. A. Nguyen. *The impact of climate change on the development and planning of urban (Tác động của biến đổi khí hậu đến quy hoạch phát triển đô thị)*. Hoa phong e&c development and investment joint stock company, Ha Noi, 2013.
[44] P. B. Nguyen, T. T. H. Nguyen, L. N. Nguyen et al. *Assessing the situation of storm and flood in Vietnam (Đánh giá tình hình bão lụt ở Việt Nam)*. Hue University of Medicine and Pharmacy, Hue, 2015.
[45] Q. H. Nguyen, T. S. Nguyen and N. A. Tran. *Assessement of Flood Vulnerability of in basins Thach Han and Ben Hai (Đánh giá tính dễ bị tổn thương lũ lụt các lưu vực sông Thạch Hãn và Bến Hải)*. Vietnam National University's Journal of Science, vol. 31, no. 1S, pp. 48-55, 2015.
[46] T. Nguyen, H. S. Nguyen and D. D. Nguyen. *Examining damages caused by landslides and flash floods in Quang Tri province (Nghiên cứu tình hình thiệt hại do trượt lở và lũ quét gây ra ở tỉnh Quảng Trị)*. Ho Chi Minh city University of Education's Journal of science, no. 40, pp. 140-148, 2013.
[47] T. L. Nguyen. *Studying the evolution of climate and hydrological in Quang Tri in the 1993 - 2013 period under the impact of climate change for developing the socio-economic (Nghiên cứu diễn biến khí hậu, thủy văn tỉnh Quảng Trị giai đoạn 1993 – 2013 dưới tác động của biến đổi khí hậu phục vụ phát triển kinh tế - xã hội trên địa bàn tỉnh)*. Quang Tri's Department of Science & Technology, Quang Tri, 2015.
[48] T. N. Nguyen and P. N. Nguyen. *Surface water resources of Quang Tri province (Tài nguyên nước mặt tỉnh Quảng Trị)*. Vietnam National University's Journal of Science, vol. 25, no. 3s, pp. 472-483, 2009.

[49] T. S. Nguyen. *Survey and assessment the quality of water in rural area in Quang Tri province (Điều tra và đánh giá chất lượng nước sinh hoạt ở nông thôn tỉnh Quảng Trị)*. Ha Noi, 2009.
[50] T. S. Nguyen. *Vietnam Natural resources estimation (Đánh giá tài nguyên nước Việt Nam).* Viet Nam Education Publishing House, Nguyen Thanh Son, 2005.
[51] V. T. Nguyen, T. H. Nguyen, T. Tran et al. *Climate change and impacts in Vietnam (Biến đổi khí hậu và tác động ở Việt Nam).* Ha Noi, Pham Van Dien, 2010.
[52] V. T. T. Nguyen. *Vietnam citadel system under the Nguyễn dynasty and the case of Quảng Tri citadel*. Construction, Civil Engineering and Architecture, Marche Polytechnic University, Ancona, 2016.
[53] L. P. Pham. *Studying the evolution of climate and hydrological in Quang Tri in the 1973 - 2013 period under the impact of climate change (Nghiên cứu diễn biến khí hậu, thủy văn tỉnh Quảng Trị giai đoạn 1973-2013 trong bối cảnh biến đổi khí hậu)*. Hydrographic Faculty Vietnam National University, Ha Noi, 2015.
[54] A. Pistrika and G. Tsakiris. *Flood risk assessment: A methodological framework*. Water Resources Management: New Approaches and Technologies. European Water Resources Association, Chania, Crete-Greece, 2007.
[55] Quang Tri Statistics Office. *Quang Tri Statistical Yearbook 2013.* Ha Noi, Statistical Publishing House, 2014.
[56] Quang Tri Statistics Office. *Quang Tri Statistical Yearbook 2014.* Ha Noi, Statistical Publishing House, 2015.
[57] Quoc su quan trieu Nguyen. *Dai Nam Comprehensive Encyclopedia (Dai Nam Nhat Thong Chi).* Hue, Thuan Hoa publishing house, 2006.
[58] K. Rao, M. Cassar, C. Young et al. *Climate change and world heritage: report on predicting and managing the impacts of climate change on world heritage, and strategy to assist states parties to implement appropriate management responses.* Paris, UNESCO World Heritage Centre, 2007.
[59] D. Satterthwaite. "*Climate change and urbanization: Effects and implications for urban governance*" in United Nations Expert Group meeting on population distribution, urbanization, internal migration and development, pp. 21-23, 2008.
[60] Scottish Advisory and Implementation Forum for Flooding. *Flood Risk Management (Scotland) Act 2009: Surface Water Management Planning Guidance.* Scotland, Scottish Government, 2013.
[61] J. B. Smith, J. M. Vogel and J. E. C. III. *An architecture for government action on adaptation to climate change. An editorial comment*. Climatic Change, vol. 95, no. 1-2, pp. 53-61, 2009.
[62] Technology development and resources investigation center. *Environmental protection planning of Quang Tri province in the period 2006 - 2010, vision 2020 (Quy hoạch bảo vệ môi trường tỉnh quảng trị giai đoạn 2006 – 2010, tầm nhìn 2020)*. Technology development and resources investigation center, 2014.
[63] N. T. Tong and D. D. Bui. *Đề xuất mô hình quản lý rủi ro ngập lụt đô thị thích ứng với biến đổi khí hậu*. Journa of Natural Resources and Environment (Ministry of Natural Resources and Environment), vol. 1, pp. 31-32, 2014.
[64] N. A. Tran. *Flood inundation mapping for downstream region of Thach Han and Ben Hai river, Quang Tri province (Xây dựng bản đồ ngập lụt hạ lưu các sông Bến Hải và*

Thạch Hãn, tỉnh Quảng Trị). Vietnam National University's Journal of Science, vol. 27, no. 1S, pp. 1-8, 2011.
[65] UNESCO. *Historic City of Ayutthaya*. http://whc.unesco.org/en/list/576.
[66] UNESCO. *Properties inscribed on the World Heritage List*. http://whc.unesco.org/en/statesparties/th/.
[67] B. Venkataraman. *World monuments suffer under a microscopic menace*. The New York Times, 2008.
[68] D. L. Vu, N. A. Tran, T. B. Hoang et al. *An introduction to flood forecast technology in Ben Hai and Thach Han river systems using MIKE 11 model (Giới thiệu công nghệ dự báo lũ hệ thống sông Bến Hải và Thạch Hãn sử dụng mô hình MIKE 11)*. Vietnam National University's (VNU) Journal of Science, vol. 26, no. 3S, pp. 397-404, 2010.
[69] T. H. Vu. *Assessment of vulnerable by flooding to the economic and social in the basins of Ben Hai and Thach Han river in the context of climate change (Đánh giá tính dễ bị tổn thương do lũ đến kinh tế - xã hội lưu vực sông Bến Hải – Thạch Hãn trong bối cảnh biến đổi khí hậu)*. Hydrology Department, College of Natural Science - Vietnam National University, Hanoi, 2013.
[70] D. Watson and M. Adams. *Design for Flooding: architecture, landscape, and urban design for resilience to climate change.* New Jersey, John wiley & sons, 2010.
[71] WorldAtlas. *UNESCO World Heritage Sites In Thailand*. http://www.worldatlas.com/articles/unesco-world-heritage-sites-in-thailand.html.
[72] M. J. Zakour. *Social work and disasters*. Disciplines, disasters and emergency management. The convergence and divergence of concepts, issues, and trends from the research literature, pp. 124-141, 2007.

Website:
- http://www.quangtri.gov.vn
- http://quangtri.kttvttb.vn
- https://en.wikipedia.org
- http://www.chuacamlo.com
- www.unesco.org
- http://www.dailymail.co.uk
- http://brunomorandi.photoshelter.com
- https://www.nasa.gov
- http://www.shutterstock.com
- http://climateadaptation.tumblr.com
- http://explorelah.blogspot.it
- http://en.vietnamitasenmadrid.com
- http://science.howstuffworks.com
- http://ongvove.wordpress.com
- http://mekongtourdmz.com.vn
- http://soha.vn
- http://vov.vn
- http://www.dosonha.nghesi.vn
- http://www.phuot.vn
- http://timeoutvietnam.vn
- http://laodong.com.vn

- http://giadinh.net.vn
- https://www.nytimes.com
- http://tuoitre.vn
- http://lienketviet.net
- http://www.worldatlas.com

Appendix
The table of tangible heritage in research area

A.1. Heritage system and its potential

No	DECENTRALIZATION	NAME	LOCATION	**RECOGNIZED**	**TYPE**
1	Quốc gia đặc biệt (di tích có giá trị đặc biệt tiêu biểu của quốc gia_Luật di sản)	Khu vực đôi bờ Hiền Lương - Bến hải	Cụm di tích này nằm ở điểm giao nhau giữa Quốc lộ 1A và sông Bến Hải; phía Bắc thuộc thôn Hiền Lương, xã Vĩnh Thành, huyện Vĩnh Linh; phía Nam thuộc thôn Xuân Hòa, xã Trung Hải, huyện Gio Linh	Ngày 09/12/2013, Thủ tướng Chính phủ đã có Quyết định số 2383/QĐ-TTg xếp hạng di tích lịch sử Đôi bờ Hiền Lương - Bến Hải (huyện Vĩnh Linh và huyện Gio Linh, tỉnh Quảng Trị) là di tích quốc gia đặc biệt.	Historical and cultural monument

2		Thành Cổ Quảng Trị và các di tích ghi dấu 81 ngày đêm	phường 2, khu phố 4, thị xã Quảng Trị	Di tích đã được Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 235/QĐ-VH ngày 12/12/1986. Ngày 09/12/2013, Thủ tướng Chính phủ đã có Quyết định số 2383/QĐ-TTg xếp hạng di tích lịch sử Thành Cổ Quảng Trị và những địa điểm lưu niệm sự kiện 81 ngày đêm năm 1972 (thị xã Quảng Trị, huyện Hải Lăng và huyện Triệu Phong, tỉnh Quảng Trị) là di tích quốc gia đặc biệt.	
3		Di tích lịch sử Địa đạo Vịnh Mốc và hệ thống làng hầm Vĩnh Linh	xã Vĩnh Thạch, huyện Vĩnh Linh	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 09/VH-QĐ ngày 21/5/1975. Ngày 31/12/2014, Thủ tướng Chính phủ đã ban hành Quyết định số 2408/QĐ-TTg xếp hạng di tích "Địa đạo Vịnh Mốc và Hệ thống làng hầm Vĩnh Linh" là di tích cấp Quốc gia đặc biệt.	

4	Quốc gia (di tích có giá trị tiêu biểu của quốc gia_Luật di sản)	Bến đò Tùng Luật	thôn Tùng Luật, xã Vĩnh Giang, huyện Vĩnh Linh	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 2410/QĐ-VH ngày 02/9/1996	Historical and cultural monument
5		Cảng quân sự Đông Hà	thôn Điếu Ngao thuộc phường II, thành phố Đông Hà	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 236/QĐ-VH ngày 12/12/1986	
6		Căn cứ Dốc Miếu - Cồn Tiên	thôn Gia Môn, xã Gio Phong, huyện Gio Linh	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 236/QĐ-VH ngày 12/12/1986	
7		Đình làng Hà Thượng	làng Hà Thượng, thị trấn Gio Linh, huyện GIo Linh	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 154/QĐ-BVHTT ngày 25/01/1991	
8		Vụ thảm sát làng Tân Minh năm 1947	xã Gio Thành, huyện Gio Linh	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng quốc gia theo Quyết định số 65QĐ-VH ngày 15/11/1991	

9		Vụ thảm sát làng Mỹ Thủy năm 1948	xã Hải An, huyện Hải Lăng	Bộ Văn hóa Thông tin (nay là Bộ Văn hóa, Thể thao và Du lịch) xếp hạng di tích quốc gia theo Quyết định số 38-2001/QĐ-BVHTT ngày 12/7/2001	
10	Cấp Tỉnh (di tích có giá trị tiêu biểu của địa phương_ Luật di sản)	Di chỉ Đá Nổi	làng Mai Xá, xã Gio Mai, huyện Gio Linh		Archaeological monument
11		Di chỉ Lòi Rú-Bàu Đông	làng Câu Hoan, xã Hải Thiện, thị trấn Hải Lăng		
12		Khu đền tháp Chăm Câu Hoan	làng Câu Hoan, xã Hải Thiện, huyện Hải Lăng		
13		Khu đền tháp Chăm Dương Lệ	làng Dương Lệ Đông, xã Triệu Thuận, huyện Triệu Phong		
14		Khu đền tháp Chăm Trung Đơn	làng Trung Đơn, xã Hải Thành, huyện Hải Lăng		
15		Tháp Chăm An Xá	làng An Xá, xã Trung Sơn, huyện Gio Linh		

16		Tháp Chăm Bích La	làng Bích La Trung, xã Triệu Đông, huyện Triệu Phong		
17		Tháp Chăm Duy Viên	thôn Duy Viên, xã Vĩnh Lâm, huyện Vĩnh Linh		
18		Tháp Chăm Kim Đâu	làng Kim Đâu, xã Cam An, (Cam Giang cũ), huyện Cam Lộ		
19		Tháp Chăm Ngô Xá	làng Ngô Xá Tây, xã Triệu Trung, huyện Triệu Phong		
20		Tháp Chăm Thạch Hãn	phường 1, thị xã Quảng Trị		
21		Tháp Chăm Trà Liên	làng Trà Liên, xã Triệu Giang, huyện Triệu Phong		
22		Tháp Chăm Trà Lộc	làng Trà Lộc, xã Hải Xuân, huyện Hải Lăng		
23		Khu vực thành Cổ Lũy	làng Phước Mỹ, xã Vĩnh Giang, huyện Vĩnh Linh		

24		Bia "Qúa Vĩnh Định Hà thập nhị vận" và "Vĩnh Định Hà cảm tác"	làng Câu Hoan, xã Hải Thiện, huyện Hải Lăng		Artistic and architectural monument
25		Chùa Trung Đơn	làng Trung Đơn, xã Hải Thành, huyện Hải Lăng		
26		Địa điểm lỵ sở dinh chúa Nguyễn (1558-1626)	xã Triệu Giang, huyện Triệu Phong		
27		Đình làng Câu Hoan	làng Câu Hoan, xã Hải Thiện, huyện Hải Lăng		
28		Đình làng Diên Khánh	làng Diên Khánh, xã Hải Dương, huyện Hải Lăng		
29		Đình làng Lập Thạch	làng Lập Thạch, phường Đông Lễ, thành phố Đông Hà		
30		Đình làng Văn Trị	xã Hải Tân, huyện Hải Lăng		
31		Đình làng Trâm Lý	làng Trâm Lý thuộc xã Hải Quy, huyện Hải Lăng		

32		Hệ thống công trình khai thác nước cổ An Mỹ	làng An Mỹ, xã Gio Mỹ, huyện Gio Linh		
33		Khu đình, miếu và chợ Bích La	làng Bích La, xã Triệu Đông, huyện Triệu Phong		
34		Khu chợ Thuận và Thành Thuận Châu	nằm trên khu đất tiếp giáp của ba làng Vệ Nghĩa (Triệu Long), Đại Hào và Phúc Lộc (Triệu Thuận)		
35		Miếu bà Chúa Ngọc	làng Kim Đâu, xã Cam An, huyện Cam Lộ		
36		Miếu Nghè Phương Sơn	xã Triệu Sơn, huyện Triệu Phong		
37		Bãi cát thôn 3	xã Triệu Lăng, huyện Triệu Phong		Historical and cultural monument
38		Bãi cát thôn 8	xã Triệu Vân, huyện Triệu Phong		
39		Bãi cát Gia Độ	xã Triệu Độ, huyện Triệu Phong		
40		Bãi sông An Đôn	làng An Đôn, xã Triệu Thượng, huyện Triệu Phong		

41		Bến đò Dương Xuân	làng Dương Xuân, xã Triệu Phước, huyện Triệu Phong		
42		Bến đò Mai Xá	thôn Mai Xá, xã Gio Mai, huyện Gio Linh		
43		Bến đò Phú Liêu	xã Triệu Tài, huyện Triệu Phong		
44		Bến lội Giàng Phao	làng Giàng Phao, xã Trung Sơn, huyện Gio Linh		
45		Bến phà Phúc Lâm	Nằm ở bờ Bắc sông Sa Lung, thuộc địa phận thôn Phúc Lâm, xã Vĩnh Long, huyện Vĩnh Linh		
46		Bến suối Tà Long	xã Hải Phúc, huyện Đakrông		
47		Bia công tích làng An Khê	Bia nằm trong khuôn viên đình làng An Khê, xã Gio Sơn, huyện Gio Linh		
48		Bình độ 100	Di tích thuộc làng Hảo Sơn, xã Gio An, huyện Gio Linh		

49		Các địa điểm thuộc bến đò Thượng Đông, Phan Hiền, Dục Đức, Tiên An	thôn Phan Hiền, thôn Dục Đức và thôn Tiên An, thuộc xã Vĩnh Sơn, huyện Vĩnh Linh		
50		Cao điểm 28	thôn Cẩm Phổ, xã Gio Mỹ, huyện Gio Linh		
51		Cao điểm 31	xã Gio Mỹ, huyện Gio Linh		
52		Cao điểm Ka Tăng và Tà Phúc	xã Hướng Tân, huyện Hướng Hóa		
53		Cao điểm Phu Nhoi	nằm ở ranh giới của 2 xã Húc và Pa Tầng, huyện Hướng Hóa		
54		Căn cứ Khe Mương	Khe Mương, Cồn Tàu, Tân Điền, Trấm ở phía Tây xã Hải Sơn, huyện Hải Lăng		
55		Căn cứ La Vang	làng Phú Hưng (làng La Vang ngày xưa), thuộc xã Hải Phú, huyện Hải Lăng		
56		Căn cứ Quán Ngang	làng Trúc Lâm, xã Gio Quang, huyện Gio Linh		

57		Cầu sắt Đông Hà	Cầu bắc qua sông Hiếu, nối phường 3 với phường Đông Thanh, thuộc thành phố Đông Hà		
58		Chiến khu Ba Cầu	làng Diên Sanh, xã Hải Thọ, huyện Hải Lăng		
59		Chiến khu Thủy Ba	thôn Thủy Ba, xã Vĩnh Thủy, huyện Vĩnh Linh		
60		Chợ An Nha	làng An Nha, thuộc xã Gio An, huyện Gio Linh		
61		Chợ Cam Thủy	làng Tam Hiệp, xã Cam Thủy, huyện Cam Lộ		
62		Chợ Định cư	thôn I, xã Triệu Lăng, huyện Triệu Phong		
63		Chợ Hà Tây	xã Triệu An, huyện Triệu Phong		
64		Chợ Hôm	nằm trên bờ sông Thạch Hãn, thuộc làng Lập Thạch, phường Đông Lễ, thành phố Đông Hà		

65		Chợ Kênh	thôn Võ Xá, xã Trung Sơn, huyện Gio Linh		
66		Chợ Lùm Lòi	làng Văn Vận, xã Hải Quy, huyện Hải Lăng		
67		Chợ Sãi	xóm Bành và xóm Hà, thôn Cổ Thành, xã Triệu Thành, huyện Triệu Phong		
68		Chùa An Thái	nằm bên hữu ngạn sông Cam Lộ		
69		Chùa Hải Chữ	thôn Hải Chữ, xã Trung Giang, huyện Gio Linh		
70		Chùa Kim Long	thuộc làng Kim Long, xã Hải Quế, huyện Hải Lăng		
71		Chùa Ngô Xá	thôn Ngô Xá, xã Triệu Trung, huyện Triệu Phong		
72		Chùa Phước Điền	xóm Đại Phước, thôn Phước Điền, xã Hải Thành, huyện Hải Lăng		
73		Cồn Hàng	làng Văn Phong, xã Triệu Sơn, huyện Triệu Phong		

74		Cồn Lăng	xóm Cồn, làng Trung Đơn, xã Hải Thành, huyện Hải Lăng		
75		Cồn Muồng	xóm Cộ, thuộc thôn Lưỡng Kim, xã Triệu Phước, huyện Triệu Phong		
76		Cồn Mụ Bạt	thôn Dương Lệ Đông, xã Triệu Thuận, huyện Triệu Phong		
77		Đài tưởng niệm anh hùng Kiều Ngọc Luân	xã Triệu Đông, huyện Triệu Phong		
78		Đàn âm hồn	xóm Bàu, thôn Đạo Đầu, xã Triệu Trung, huyện Triệu Phong		
79		Địa đạo Hiền Dũng	thôn Hiền Dũng, xã Vĩnh Hòa, huyện Vĩnh Linh		
80		Địa đạo Tân Lý	xóm Cửa, thôn An Đức, xã Vĩnh Quang, huyện Vĩnh Linh		
81		Địa đạo Tân Mỹ	thôn Tân Mỹ, xã Vĩnh Giang (giáp sông Bến Hải), huyện Vĩnh Linh		

82		Địa điểm Ba Dốc	làng Lan Đình, xã Gio Phong, huyện Gio Linh		
83		Địa điểm bờ Bắc ngã ba Gia Độ	phường Đông Giang, thành phố Đông Hà		
84		Địa điểm chiến thắng thôn An Du Đông	thôn An Du Đông 1, xã Vĩnh Tân, thuộc huyện Vĩnh Linh		
85		Địa điểm chiến thắng An Thơ	làng An Thơ, xã Hải Hòa, huyện Hải Lăng		
86		Địa điểm chiến thắng Cát Lài	thôn Lại An, xã Gio Mỹ, huyện Gio Linh		
87		Địa điểm chiến thắng Câu Nhi	xóm Chùa, làng Câu Nhi, xã Hải Tân, huyện Hải Lăng		
88		Địa điểm chiến thắng Đập Kình	xóm Tràỵ, làng Bạch Lộc, xã Trung Hải, huyện Gio Linh		
89		Địa điểm chiến thắng Hà Lỗ-Câu Nhi	xã Hải Tân, huyện Hải Lăng		

90		Địa điểm chiến thắng Tài Lương	xã Triệu Tài, huyện Triệu Phong		
91		Địa điểm chiến thắng Thuận Đầu năm 1972	thôn Thuận Đầu, xã Hải An, huyện Hải Lăng		
92		Địa điểm chiến thắng Xuân Long	xã Trung Hải, huyện Gio Linh		
93		Địa điểm đồn Bến Ngự	xã Gio Mỹ, huyện Gio Linh		
94		Địa điểm đồn Câu Hoan	xã Hải Thiện, huyện Hải Lăng		
95		Địa điểm đồn Câu Nhi	xã Hải Tân, huyện Hải Lăng		
96		Địa điểm đồn Nhĩ Hạ	xã Gio Thành, huyện Gio Linh		
97		Địa điểm ghi dấu chiến thắng Ba Du-Cỗ Lũy-Phương Lang	xã Hải Ba, huyện Hải Lăng		

98		Địa điểm ghi dấu chiến thắng "Bạch Đằng trên sông Hiếu"	thôn Vinh Quang Hạ, xã Gio Quang, huyện Gio Linh		
99		Địa điểm ghi dấu trận chống càn làng Phước Sa	xã Gio Quang, huyện Gio Linh		
100		Địa điểm ghi dấu trận chống càn rú Long Hà	thôn Long Hà, xã Gio Việt, huyện Gio Linh		
101		Địa điểm ghi dấu trận chống càn thôn Diêm Hà	xã Gio Hải, huyện Gio Linh		
102		Địa điểm ghi dấu trận chống càn thôn Hà La	thôn Hà La, xã Triệu Phước, huyện Triệu Phong		
103		Địa điểm ghi dấu trận đánh tàu xóm Vụng	thuộc thôn Tân Lợi, xã Gio Hải, huyện Gio Linh		
104		Địa điểm lô cốt và nhà ga Đông Hà	khu phố I, phường I, thành phố Đông Hà		

105		Địa điểm Pồng A Nang	bản A Dông, thôn La Lay, xã A Ngo, huyện Đakrông		
106		Địa điểm quận lỵ Triệu Phong	thôn Nạn Cửu, xã Triệu Đông, huyện Triệu Phong		
107		Địa điểm tòa Khâm sứ	phường 2, thị xã Quảng Trị		
108		Địa điểm trại tập trung Cửa Việt	thôn Tân Lợi, xã Gio việt, huyện Gio Linh		
109		Địa điểm trận địa Bàu Ngang	nằm trên ranh giới của hai xã Vĩnh Lâm, Vĩnh Sơn, huyện Vĩnh Linh		
110		Địa điểm trận địa phòng không Cồn Diễu	thôn Hải Chữ, xã Trung Hải, huyện Gio Linh		
111		Địa điểm trận địa phòng không 12 ly 7 Gia Lâm	thôn Gia Lâm, xã Vĩnh Long, huyện Vĩnh Linh		
112		Địa điểm trận địa phòng không 12 ly 7 Tân Thuận	thôn Tân Thuận, xã Vĩnh Thái, huyện Vĩnh Linh		

113		Địa điểm trận địa phòng không Ba Vòi	thôn Tân Hòa, xã Vĩnh Hiền, huyện Vĩnh Linh		
114		Địa điểm trận địa phòng không Tiên Mỹ	thôn Tiên Mỹ, xã Vĩnh Lâm, huyện Vĩnh Linh		
115		Địa điểm trận địa xóm Rú	xóm Rú, thôn Tân Trại, xã Vĩnh Thành, huyện Vĩnh Linh		
116		Địa điểm Trường cấp I, II Triệu Giang	làng Tiền Kiên, xã Triệu Giang, huyện Triệu Phong		
117		Địa điểm Trường cấp I, II Triệu Vân	thôn 8, xã Triệu Vân, huyện Triệu Phong		
118		Địa điểm Trường PTCS Vĩnh Tân	thôn An Du Đông 2, xã Vĩnh Tân, huyện Vĩnh Linh		
119		Địa điểm Trường tiểu học Thượng Xá	thôn Thượng Xá, xã Hải Thượng, huyện Hải Lăng		
120		Địa điểm xóm Khe	thị trấn Gio Linh, huyện Gio Linh		

121		Địa điểm xóm ngoài Bích La Nam	thôn Bích La Nam, xã Triệu Đông, huyện Triệu Phong		
122		Địa điểm xóm Nổ làng Trung Đơn	xóm Nổ, làng Trung Đơn, xã Hải Thành, huyện Hải Lăng		
123		Địa điểm xóm Tả làng Lam Thủy	xã Hải Vĩnh, huyện Hải Lăng		
124		Đình làng An Lợi	xã Triệu Độ, huyện Triệu Phong		
125		Đình làng Đan Quế	xã Hải Quế, huyện Hải Lăng		
126		Đình làng Nại Cửu	xã Triệu Đông, huyện Triệu Phong		
127		Đình làng Quảng Xá	thôn Quảng Xá, xã Vĩnh Lâm, huyện Vĩnh Linh		
128		Đình thôn II	thôn II, xã Triệu Lăng, huyện Triệu Phong		
129		Đồi cát thôn 9	thôn 9, xã Triệu Vân, huyện Triệu Phong		

130		Động muối Tường Vân	thôn Tường Vân, xã Triệu An, huyện Triệu Phong		
131		Động Bồ Chao	phường Đông Thanh, thành phố Đông Hà		
132		Động Mở	thôn Tường Vân, xã Triệu An, huyện Triệu Phong		
133		Động Ông Do	thôn 8, xã Triệu Vân, huyện Triệu Phong		
134		Động Quai Vạc	nằm giữa ranh giới phường 4, thành phố Đông Hà và thôn Vĩnh Đại, xã Cam Hiếu, huyện Cam Lộ		
135		Khe Đoàn Phương Lang	thôn Phương Lang, xã Hải Ba, huyện Hải Lăng		
136		Khe Làng An	bàn xã Triệu Nguyên, huyện Đakrông		
137		Khe Me	xã Vĩnh Trường, huyện Gio Linh		
138		Khe Nưa	bản II, xã Vĩnh Ô, huyện Vĩnh Linh		

139		Khe Ồ	thôn Xuân Lâm, xã Triệu Nguyên, huyện Đakrông		
140		Khe Tiên	xã Vĩnh Hà, huyện Vĩnh Linh		
141		Khe U Sau	thôn Tà Rụt, xã Tà Rụt, huyện Đakrong		
142		Khu Mã Chiềng An Hưng	thôn An Hưng, xã Triệu Tài, huyện Triệu Phong		
143		Khu xóm dưới Lạc Tân	thôn Lạc Tân, xã Gio Phong (nay là khu vực 3, thị trấn Gio Linh), huyện Gio Linh		
144		Lăng Đen	làng Thi Ông, xã Hải Vĩnh, huyện Hải Lăng		
145		Lòi Thị	thôn Tân Minh, xã Gio Thành, huyện Gio Linh		
146		Lùm Đình	làng Linh Yên, xã Triệu Trạch, huyện Triệu Phong		
147		Miếu Bà làng Trung An	làng Trung An, xã Hải Khê, huyện Hải Lăng		

148		Miếu Bà thôn Vệ Nghĩa	xã Triệu Long, huyện Triệu Phong		
149		Miếu Cao Sơn	làng Lan Đình, xã Gio Phong, huyện Gio Linh		
150		Miếu Lôi Chấn Cồn Khoai	làng Tường Vân, xã Triệu An, huyện Triệu Phong		
151		Miếu Mộc Bài	làng Nhĩ Trung, xã Gio Thành, huyện Gio Linh		
152		Miếu Thành Hoàng làng Thủy Trung	làng Thủy Trung, xã Vĩnh Trung, huyện Vĩnh Linh		
153		Mồ Doi Diên Sanh	làng Diên Sanh, xã Hải Thọ, huyện Hải Lăng		
154		Mộ Khóa Bảo-Nguyễn Hữu Đồng	xã Cam Thành, huyện Cam Lộ		
155		Mốc km4, km5 đường 9A	khu phố 5, phường 4, thành phố Đông Hà		
156		Mũi hói Kim Long	làng Kim Long, xã Hải Quế, huyện Hải Lăng		

157		Ngã ba Hiền Lương	thôn Hiền Lương, xã Vĩnh Thành, huyện Vĩnh Linh		
158		Ngã ba ông Quyền	làng Cổ Lũy, xã Hải Ba, huyện Hải Lăng		
159		Ngã tư Hội Yên	làng Hội Yên, xã Hải Quế, huyện Hải Lăng		
160		Nghè Thành Hoàng làng Phú Liêu	làng Phú Liêu, xã Triệu Tài, huyện Triệu Phong		
161		Ngõ nhà ông Phan Tường	xã Triệu Ái, huyện Triệu Phong		
162		Nhà bia tưởng niệm liệt sĩ	khóm 2, thị trấn Cam Lộ, huyện Cam Lộ		
163		Nhà lưu niệm Cố tổng Bí thư Lê Duẩn	làng Hậu Kiên, xã Triệu Thành, huyện Triệu Phong		
164		Nhà ông Dương Diễn	khóm I, thị trấn Gio Linh, huyện Gio Linh		
165		Nhà ông Khâm	xóm Biền, phường Đông Thanh, thành phố Đông Hà		

166		Nhà ông Lê Mậu Tương	thôn Tạc Tân, xã Gio Phong (nay là khu phố 3, thị trấn Gio Linh), huyện Gio Linh		
167		Nhà ông Lê Quang Xuân	thôn Duy Hòa, xã Triệu Hòa, huyện Triệu Phong		
168		Nhà ông Lê Táo	làng Mỹ Lộc, xã Triệu Hòa, huyện Triệu Phong		
169		Nhà ông Lương Khoan	xã Triệu Trung, huyện Triệu Phong		
170		Nhà ông Nguyễn Đình Đăng	xã Triệu Phước, huyện Triệu Phong		
171		Nhà ông Nguyễn Đức Úc	khu phố II, phường III, thành phố Đông Hà		
172		Nhà ông Nguyễn Ngọc Châu	thôn Đại Hào, xã Triệu Đại, huyện Triệu Phong		
173		Nhà ông Nguyễn Sỏ	thôn Vệ Nghĩa, xã Triệu Long, huyện Triệu Phong		
174		Nhà ông Nguyễn Thược	xã Vĩnh Thành, huyện Vĩnh Linh		

175		Nhà ông Nguyễn Xộc	xóm Cống, làng Xuân Viên, xã Hải Dương, huyện Hải Lăng		
176		Nhà ông Nhạn	thôn Liêm Công Đông, xã Vĩnh Thành, huyện Vĩnh Linh		
177		Nhà ông Tổng Trọng	làng Như Lệ, xã Hải Lệ, huyện Hải Lăng (nay là thị xã Quảng Trị)		
178		Nhà ông Trần Duy Bá	xóm Cống, làng Xuân Viên, xã Hải Dương, huyện Hải Lăng		
179		Nhà ông Trình	thôn Liêm Công Tây, xã Vĩnh Thành, huyện Vĩnh Linh		
180		Nhà thờ họ Đoàn	làng Gia Đăng, xã Triệu Lăng, huyện Triệu Phong		
181		Nhà thờ họ Hoàng	làng Điếu Ngao, nay là khu phố I, phường 2, thành phố Đông Hà		
182		Nhà thờ họ Lê Bá	làng Lưỡng Kim, xã Triệu Phước, huyện Triệu Phong		

183		Nhà thờ họ Lê làng An Lợi	làng An Lợi, xã Triệu Độ, huyện Triệu Phong		
184		Nhà thờ họ Lê thôn Hoàng Hà	thôn Hoàng Hà, xã Gio Thành, huyện Gio Linh		
185		Nhà thờ họ Nguyễn Công	làng An Thơ, xã Hải Hòa, huyện Hải Lăng		
186		Nhà thờ họ Nguyễn Khắc	thôn Lập thạch, phương Đông Lễ, thành phố Đông Hà		
187		Nhà thờ họ Võ Đâu Kênh	làng Đâu Kênh, xã Triệu Long, huyện Triệu Phong		
188		Nhà thờ Ngô Xá Đông	làng Ngô Xá Đông, xã Triệu Trung, huyện Triệu Phong		
189		Phường Sắn	xã Hải Phú, huyện Hải Lăng		
190		Quân cảng Cửa Việt	thôn Phú Hội, xã Triệu An, huyện Triệu Phong		
191		Rú Bời Lời	thôn Hà My, xã Triệu Hòa, huyện Triệu Phong		

192		Rú Hoàng Hà	thôn Hoàng Hà, xã Gio Thành, huyện Gio Linh		
193		Rú Hộp	thôn Thượng Xá, xã Hải Thượng, huyện Hải Lăng		
194		Rú Trạng Nhỏ	làng Trà Lộc, xã Hải Xuân, huyện Hải Lăng		
195		Sân bay Ái Tử	thị trấn Ái Tử, huyện Triệu Phong		
196		Vùng bàu Chùa Câu Hoan	làng Câu Hoan, xã Hải Thiện, huyện Hải Lăng		
197		Vụ thảm sát làng Kim Giao năm 1948	xã Hải Dương, huyện Hải Lăng		
198		Vụ thảm sát Quy Thiện năm 1947	xã Hải Quy, huyện Hải Lăng		
199		Vụ thảm sát Trung An - Thâm Khê	huyện Hải Lăng		
200		Vườn nhà ông Hưởng	làng Phú Liêu, xã Triệu Tài, huyện Triệu Phong		

201		Khu danh thắng Cửa Tùng	huyện Vĩnh Linh		Natural heritage
202		Bãi tắm Cửa Việt	thôn Tân Lợi, xã Gio Việt, huyện Gio Linh		
203		Khu du lịch sinh thái trằm Trà Lộc	làng Trà Lộc, xã Hải Xuân, huyện Hải Lăng		
204	ADDITIONAL	Đình làng Điếu Ngao	khu phố II, phường II, thành phố Đông Hà		Artistic and architectural monument
205		Nhà thờ họ Đặng làng Câu Hoan	làng Câu Hoan, xã Hải Thiện, huyện Hải Lăng		
206		Nhà thờ họ Nguyễn Đức làng An Thơ	làng An Thơ, xã Hải Hòa, huyện Hải Lăng		
207		Khu mộ cổ thời các chúa Nguyễn ở Văn Qũy	làng Văn Qũy, xã Hải Tân, huyện Hải Lăng		
208		Địa điểm ấp chiến lược Lễ Môn	làng Lễ Môn, xã Gio Phong, huyện Gio Linh		Historical and cultural monument

209		Địa điêm đình làng An Tiêm	làng An Tiêm, xã Triệu Thành, huyện Triệu Phong		
210		Địa điểm đồn Mỹ Á	xã Vĩnh Lâm, huyện Vĩnh Linh		
211		Địa điểm ghi dấu tội ác vụ hành quyết nữ anh hùng Lê Thị Tuyết	thôn Duân Kinh, xã Hải Xuân, huyện Hải Lăng		
212		Địa điểm ghi dấu trận chống càn thôn Nại Cửu	thôn Nại Cửu, xã Triệu Đông, huyện Triệu Phong		
213		Địa điểm huyện đường Gio Linh	xã Gio Châu, huyện Gio Linh, nay thuộc thị trấn Gio Linh		
214		Động Đàn Bầu	xã Cam Thanh, huyện Cam Lộ		
215		Nghĩa trang Liệt sĩ Quốc gia đường 9	phường 4, thành phố Đông Hà		
216		Nhà ông Bộ Lãnh	xã Triệu Vân, huyện Triệu Phong		

** Monuments were kept in accordance with the local language to avoid altering the meaning of heritage.*