Planning for peri-urban development and flooding issues: The story of new urban areas in Can Tho City

Group of researchers

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1. Introduction

The Mekong Delta (MKD), in which Can Tho City is located, occupies a low-lying region in the center of South Hau River (Bassac River). The MKD is predicted to be one of the three most vulnerable deltas in the world caused by climate change. The topography of the city is flat and low with a height of 0,5-1m above sea level. Along Hau River, national highway 1 and national highway 91, the land raises to a height of 1,0-1,5m above sea level which has developed into the city center. From Hau River, the land is gradually lower in Northeast- Southwest direction.

Seasonal flooding is a typical natural characteristic of the MKD and Can Tho City. Rainy season often starts from May to November with highest rainfalls recorded from August to October at the same time of high flow discharge from upstream which annually creates “Mùa nước nổi” (water moving season). “Mùa nước nổi” provides livelihood the benefits of natural aquatic products and transports sediments to the fields, thus act as a natural mechanism of fertility recovery. People in Can Tho City have adapted their lives of this phenomenon and they strongly believe that their experiences can help them to deal with normal floods (Development Workshop France, 2010).

However in recent years, the water level of Hau River has unpredicted changed andhigher floods have occurred. Many parts of Ninh Kieu District are annually flooded, especially during the last 5 years including Hai Ba Trung ward, Cai Khe ward, An Hoa ward, An Khanh ward and An Binh ward. These flood events have severely impacted the living conditions, livelihoods of local people as well as economic development and urban environment.

The aim of this research is to determine the causes of flood in Can Tho City in general and developing peri-urban areas in Can Tho City. Notably, this research concentrates in the correlation of urbanization process, climate change and urban flooding.

2. Case studies

Case studies werechosen based on different criteria, for example: severe floods, new developing urban areas, peri-urban areas… After researches and discussions, three case studies were chosen as follow:

(1) Mixed area between planned development and spontaneous development – Neighborhood 4 – An Hoa Ward (located in the Northwest of Nguyen Van Cu Road, prolonging from Cach Mang Thang 8 Road to Mau Than Road).

(2) Developing areabased on city plan – Neighborhood 1 – An Khanh Ward (located in the Northwest of Nguyen Van Cu Road and Thoi Nhat neighborhood).

(3) Area with spontaneous development– Neighborhood 2,3 – An Khanh Ward (located in the Southeast of Nguyen Van Cu Road, prolonging to Bun Xang Lake).

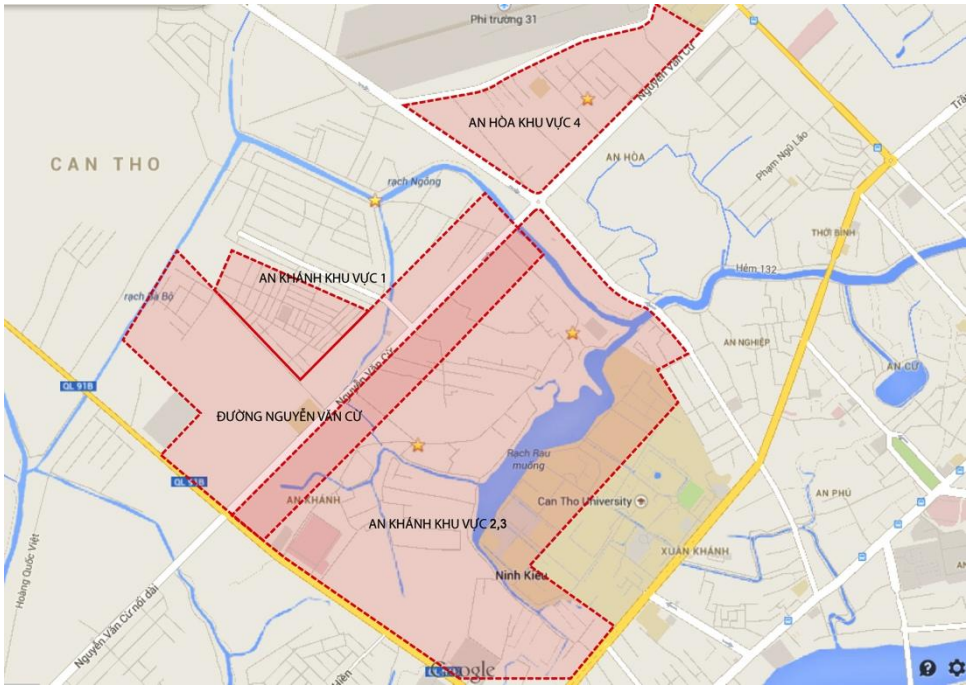

Figure 1Map of case studies

3. Methodology

In order to analyze the causes of the flood morphological changes in threecase studies, we inherited and used the available data and spatial database to generate a flood risk simulation model. Based on this model, the flood characteristics of the whole area were analyzed. In addition, we involved and interviewed local government, examined case studies and interview local households in order to verify our conclusion and results withdrawing from analyzing spatial database.

This research relied on two severe flood events in 2011 and 2013 which damaged extremely the city. Our main methods as follow:

- Researching water dischargerecorded in available data from 1961 – 2014.

- Researching data of rainfall and extreme rainfalls in Can Tho City and upstream.

- Investigating flooded areas in combination with analyzing urbanization data from 2006-2014 in the threecase studies.

4. Natural flooding in Can Tho City

4.1.“Mùa nước nổi” and flooding in Can Tho City

“Mùa nước nổi”: often starts from August to October, coinciding with the “old rain” period of the Mekong River basin which is characterized by continuous and heavy rains. In Can Tho City, “mùa nước nổi” is formed by different water resources including (1) Rainwater in MKD; (2) Water discharge from the Mekong River to the East Sea; and (3) Tidal water from the East Sea to the MKD.

Currently, “mùa nước nổi”(water moving season)called in the wrong name “mùa lũ” (flash flood season), is anannual and positive hydrological phenomenon in the MKD.

Flood: Instead of “mùa nước nổi”, flood as disaster also occurs in the MKD. From 1900-1960, there were only 4 severe flood events, however from 1961-2011, the number of severe flood events reached 11. In the year 1961, 1966 and 2000, water level recorded in Chau Doc station was remarkably high. (Chau Doc station is a gaging station closest to Cambodia - Vietnam border in Hau River).

In Can Tho City, from 2010 to present, there are 2 high-flow flood events in 2011 and 2013. 2011 is the year with extreme flood occurring in many countries of the Mekong River basin: Myanmar, Laos, Thailand, Cambodia and the MKD in Vietnam. In 2013,although “mùa nước nổi” occurred as usual, Can Tho City was flooded severely. Floodwater during these events rose higher than alarm level 3 (shown in Table 1).

Table1Flood alarm level of Hau River in Can Tho City

(According to Decision No.632 / QĐ-TTg issued on May 10th, 2010 by the Prime Minister)

River	Gaging station	Alarm level in height (m)		
		I	II	III
Hau	Can Tho	1,7	1,8	1,9

This regulation was outdated, as the water level in Can Tho City since 2013 has always exceeded alarm level 3. The alarm level 3 has soon become the annual water level.

4.2.Research in typical natural flooding

4.2.1. Progress of Floodingin 2011

Since May, 2011, in Mekong River Basin, Nockten storm started its route and followed by a series of heavy rainfalls lasting until the end of August. At the upstream of Mekong River, heavy rainfall continued September, October and November. During this time, high flow discharged from Myanma, Laos, and Thailand to Cambodia and slammed into the MKD in Vietnam.

In Can Tho City, flood in 2011 was caused by water discharge from upstream and tidal flow from the sea. Therefore, the water level fluctuated due to the tidal level. 2011 is the year when flood came quite late, stayed long and unpredictably high. Floodwater reached a height of 2,15m which is ranked 2nd among the previous measured records (2,16m). In total, flood season lasted for 4 months, from late August to mid-December and included 9 tidal cycles in the end of 2011.

Table 2 Progress of flooding in 2011 in Can Tho City (Source: Southern regional Hydrometeological center)

No.	Time of tidal cycle	Tidal peak (m)	Date	Note
1	from 25/8 to 7/9	1,89	31/8	Exceed alarm level 2=1,8m
2	from 8/9 to 21/9	< 1,7	Not exceed alarm level 1	
3	from 22/9 to 5/10	2,11	29/9	Exceed alarm level 3=1,9m
4	from 6/10 to 20/10	1,71	12 và 14/10	2 days
5	from 21/10 to 3/11	**2,15**	**27/10**	**Ranked 2nd among previous records**
6	from 4/11 to 17/11	1,87	11/11	
7	from 18/11 to 30/11	1,96	26/11	
8	from 1/12 to 17/12	<1,7	Not exceed alarm level 1	
9	from 18/12 to 31/11	1,81	26/12	

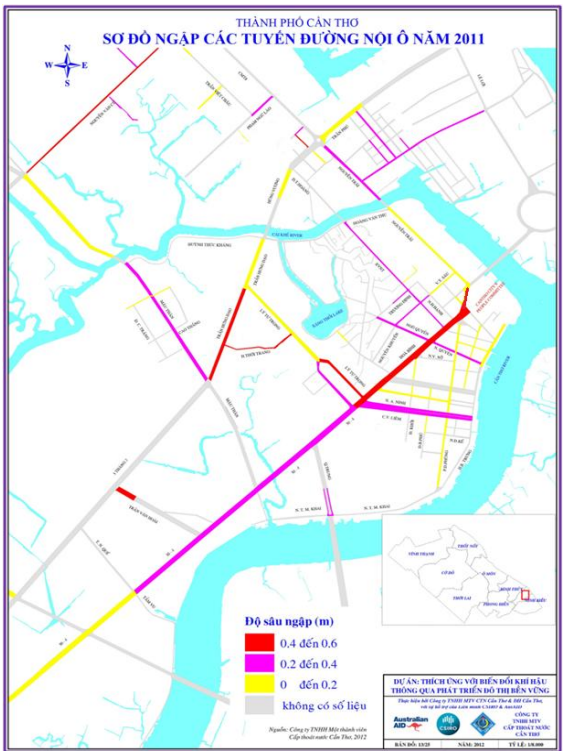

Figure1Map of urban flooding in Ninh Kieu District in 2011 (Source: Project "Adapting to Climate change through sustainable urban development, CSIRO-ĐHCT, 2012)

On October 27th, at around 3pm, water overflowed from sewer holes in lower alleys and natural waterways inside the city. Floodwater continued to flow to the main roads and Ninh Kieu Wharf. Until 4.30pm, floodwater was covered all urban roads including Ly Tu Trong Road, Phan Dinh phung Road, Hai Ba Trung Road, Hoa Binh boulevard, Mau Than Road, 30/4 Road, Nguyen Van Cu Road… In some roads, floodwater reached a height of 70-80cm, maximum 1m.

Urban flooding only lasted for 3 hours and after that water gradually lowered below road level. However, this event had a negative impact on the livelihood of many households. When floodwater comes, local stalls and shops have to close earlier because local people have difficulties to go shopping in floodwater.

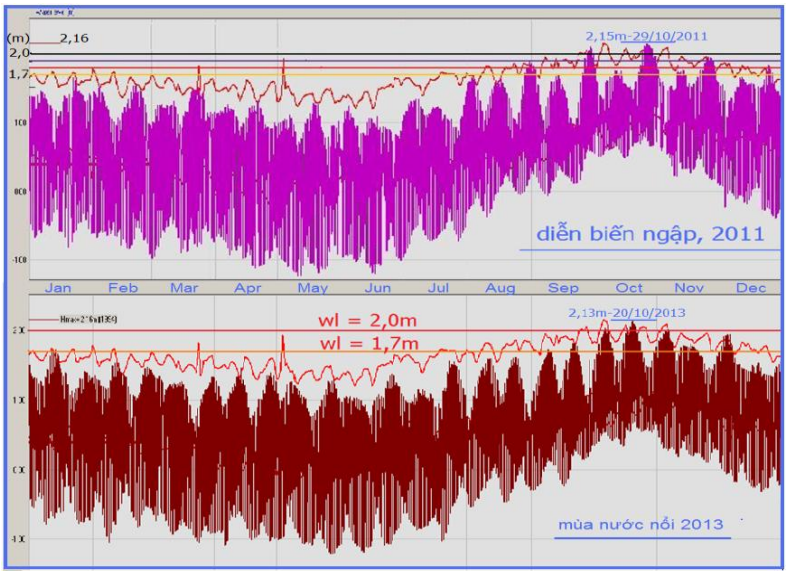

Figure2Fluctuation in water level in Can Tho City from 2011-2013 (Source: Hydmet)

4.2.2. Progress of flooding in 2013

In 2013, "mùa nước nổi" occurred as usual and there was no high-flow discharge in Mekong River. However, in Can Tho City, floodwater rose unpredictably to a height of 2,13m which is ranked 3rd among the previous measured records. Totally the flood season in 2013 lasted for 3 months and 15 days, from the early September to mid-December, including 6 tidal cycles in the end of 2013.

From 18th to 21st of October, 2013, high tide surged in Can Tho City. Tidal flow inundated most of the city's road including Nguyen Van Cu Road, Mau Than Road, national highway 91B, February 3rd Road, Cach Mang Thang 8 Road and small alleys with the highest water level of 1m. Notably, many high-density roads were inundated which caused difficulties for local people, especially in the junction of national highway 91B and February 3rd Road, roundabout of Mau Than and Nguyen Van Cu Road.

Table2Progress of tidal flooding in 2013 in Can Tho City (Source: Southern regional Hydrometeological center)

No	Time of tidal cycle	Tidal peak (m)	date
1	từ 15/9 đến 1/10	1,82	21/9
2	từ 2/10 đến 14/10	2,04	7/10
3	từ 15/10 đến 29/10	2,13	20/10
4	từ 30/10 đến 11/11	2,02	4/11
5	từ 12/11 đến 27/11	1,82	19/11
6	từ 28/11 đến 11/12	1,95	4/12

Can Tho City Hydrometeological center informed: because of the combined effect of water discharge from upstream, tidal flow and Northeast monsoon, daily tidal peak in waterways in Can Tho City continued to rise. Local people described that water rose from 3pm to 5 pm on October 20th. Many urban roads, such as: Hoa Binh boulevard, February 3rd Road, Nguyen Van Linh Road, Tran Van Hoai Road… were deeply flooded.

Figure3Flooding in Alley 4 in neighborhood 2,3, An Khanh District, 2013(Source: Can Tho City Newspaper October, 2013)

Despite a year of normal “mùa nước nổi” and not high rainfall, water level in Can Tho City at the time of tidal peak still reached high. Notably, tidal peak exceeded alarm level 2 in all 6 tidal cycles in the end of 2013. Total number of days with more than 1,7m high floodwater level is approximately 50 days. This huge number resulted in many difficulties and obstructs for the livelihoods and daily lives of poor people who live in low-lying areas.

The highest water level or tidal peak is considered as an **indicator** determining the level of flooding in Can Tho City.

4.3.Sources of water causing higher floodwater level

4.3.1. Rainfall and highest water level

Rainy season in Can Tho City annually starts from April to November. The annual total rainfall in the period of 1978 – 2013 has tended to decrease. On average, total rainfall in this period is 1589mm/year. However, from 1978 to 2000, it is 1661mm/year and 1462 mm/year from 2001 to 2013.

1996 is the year with highest rainfall of 2111.3mm/year which was recorded with no flooding. In 1990, rainfall dropped to the lowest of 1160.2mm/year. In 2002, despite of the light rainfall of 1186.8mm/year, flooding occurred.

In 2000, high flooding occurred in the MKD. This is the year with total rainfall of 2075mm/year, ranked 2nd among previous measured records and also the year with highest rainfall in a day of 211.4mm/day recorded on June 9th, 2000 when was 3 months sooner than the recorded time of highest water level in Can Tho City.

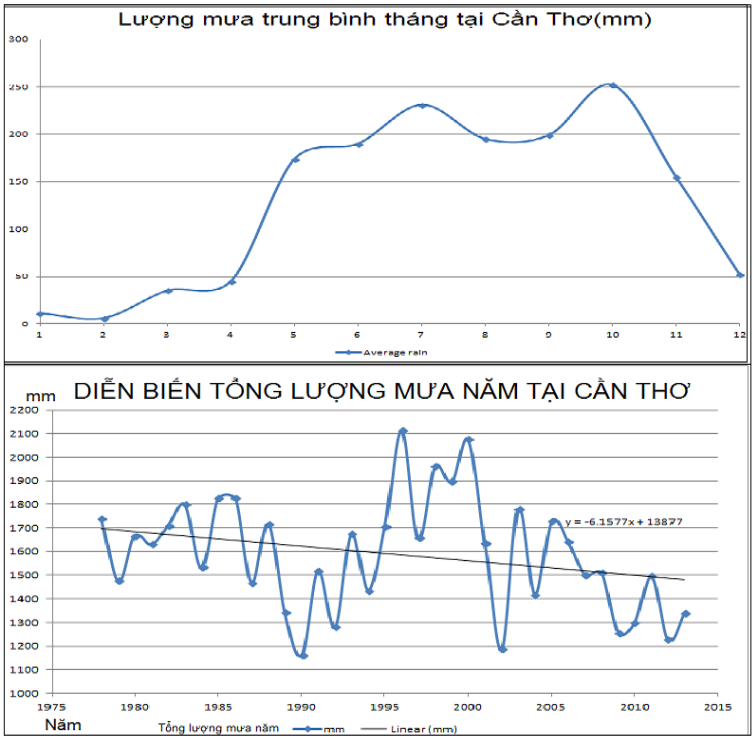

Figure4Progess of rainfall in Can Tho City (Source: Southern regional Hydrometeological center)

Statistical characteristics of rain and flooding in Can Tho City:

- During 35 years (1978-2012), the MKD has 9 flood events. However, there is an unclear correlation between years with flooding and years with high rainfall.
- Years with high rainfall are not the same as years with high rainfall days.
- Annual total rainfall ranges from 1160 to 2111mm. During 36 years, there are:
  - 13 years with light rainfall below 1500mm
  - 23 years with total rainfall over 1500mm including 13 years with total rainfall ranged from 1600 to 1800mm. In 1996 and 2000, the total rainfall exceeded 2000mm.

Days with highest rainfall occursscatter from March to December andconcentrates in August.

- According to Vietnamese folk, "tháng 7 nước nhảy khỏi bờ" (in July water jumps out of the bank). July in Lunar calendar coincides to August in Solar calendar. Taking August as a point of reference to define the effects of days with highest rainfall to flooding in Can Tho City, the results are shown below:
  - 18 years had days with highest rainfall occurring before August. Among these, there are 2 days with highest rainfall: 211,4mm and 131,8mm occurring in June.
  - 17 years had days with highest rainfall occurring after August. Remarkably, in 1994 flooding, day with highest rainfall (115mm) occurring on December 11th after the flooding.

Table3Comparison between highest water level and rainfall from 2011-2014 (Source: CCCO accumulated the statistics and data provided by Southern regional Hydrometeological center and Mekong River Hydrological center)

Year	Highest water level (cm)	Date	Rainfall in day (mm)	Total rainfall in the previous 3 days (mm)
2011	215	27/10	2,2	2,4
2012	193	19/10	0	0
2013	213	20/10	0,3	10,6
2014	208	10/10	22	24

In the 2 years of this research 2011 and 2013, provided data shows that the rainfall in a day and even the total rainfall in 3 days before the day with highest rainfall in 2011 and 2013 were very low. Based on table 5, it can be said that there is almost nocorrelation between rainfall and floodwater level in Hau River.

As a result, highest rainfall is not a water source causing flooding in Can Tho City in 2011 and 2013.

4.3.2. Correlation between Water level in Mekong River and highest water level

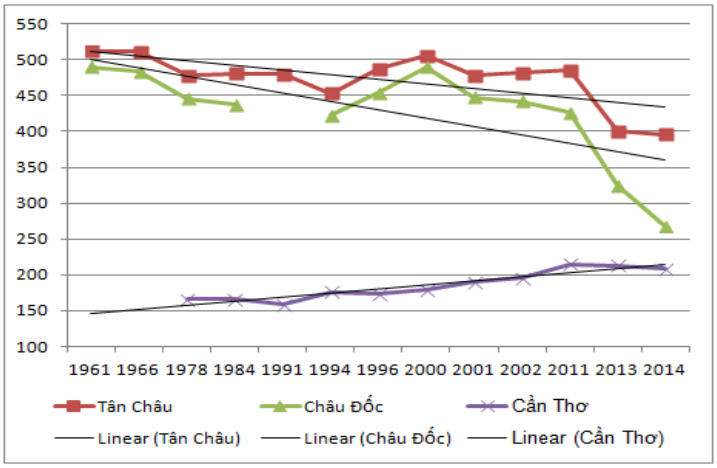

Figure5:Figure 6 Flood peak in Tan Chau, Chau Doc and highest water level in Can Tho City (Source: CCCO accumulated the statistics and data provided byVietnam Academy for Water Resources and Southern regional Hydrometeological center)

Tan Chau and Chau Doc are 2 upstream gaging stations located closest to the Vietnam – Cambodia border where Mekong River flows into Vietnam. Based on Figure 6, the highest water level in Can Tho City has tended to increase year after year although the flood peak in Tan Chau and Chau Doc station stayed stable even lower than the previous year. Particularly, in Tan Chau and Chau Doc station, in 2011, 2013 and 2014, the flood peaks were lower than the flood peak in 2000, but the water level in Can Tho City was still higher than the water level in 2000.

In Table 5 below, recorded data of the days with highest water level in 2000, 2011, 2013, and 2014 in Tan Chau, Chau Doc and Can Tho City does not show any correlations between the highest water level upstream and Can Tho City. Correlation between time when the highest water levels in Tan Chau and Chau Doc were recorded and when the highest water levels in Can Tho City were recorded is ambiguous.

Table4Table 5 Comparison between highest water level in Tan Chau, Chau Doc and Can Tho City (Source: Mekong River Hydrological center and Vietnam Academy for Water Resources)

Year	Highest water level (cm)			Time			Average flow in Can Tho City(m^3/s)	
	T.Chau	C.Doc	C.Tho	T.Chau	C.Doc	C.Tho	Day with flood	Day with highest flow in month
2000	506	490	179	23/9	24/9	30/09	13.000	(23/09)17.700
2011	486	427	215	30/9	14/10	27/10	16.100	(05/10)19.600
2013	401	325	213	3/10	8/10	20/10	12.290	(30/10)18.180
2014	396	268	208	9/8	12/8	10/10	-	-

Thus, water from upstream of the Mekong River is only a necessary condition, not a sufficient condition for causing high water level in Can Tho City.

4.3.3. Tide and highest water level

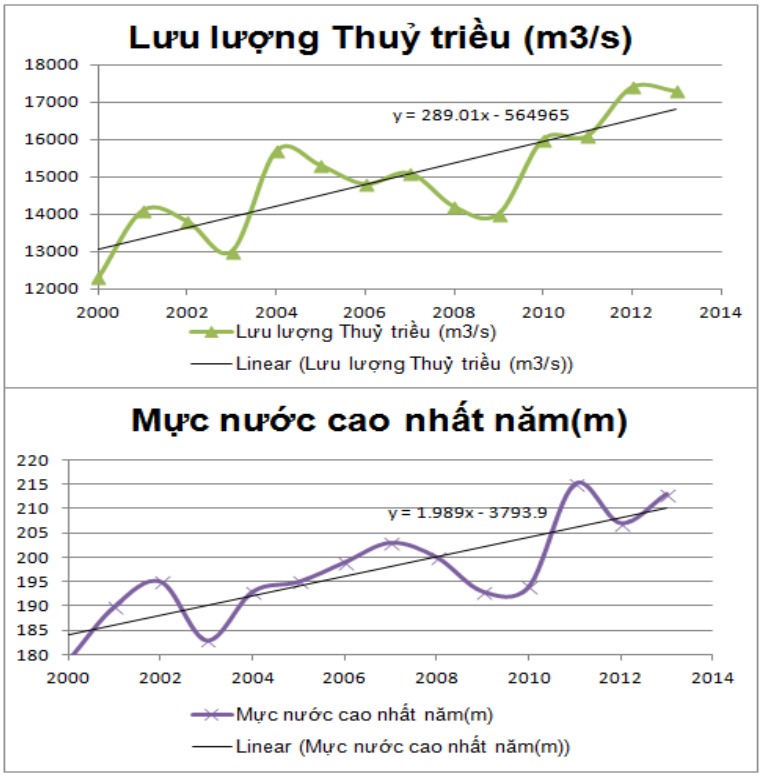

Figure6Tidal flow and highest water level in Can Tho City from 2000-2013 (Source: Southern regional Hydrometeological center)

Tide works as a natural mechanism to supply water to paddy fields,drainage floodwater and reduce flooding in the MKD and Can Tho City. When the tide rises, it becomes a water supply source. And when tide falls, it suctionsout water toward the sea including inland water and floodwater.

Data of flow in Hau River recorded from 2002 to 2013 was shown in Figure 7 and Table 6. Accordingly, the highest flow in Hau River barely rose. Conversely, tidal flow coming from the sea to inland increased from 12.300m^3/s to 17.400 m^3/s. Average flow slightly decreased from 6.700m^3/s to 6.000m^3/s.

In Table 6, the times when highest water level occurred in 2011 and 2013 in Can Tho City coincide with the times when tide reached its peak, similar to 2014. Only in 2012, it occurred 2 days later then the time when tide reached its peak.

Table5Comparison between highest water level and tide in Can Tho City (Source: CCCO accumulated the data provided by Mekong River Hydrological center)

Year	Highest water level (cm)	Tidal situation	Date
2011	215	Tidal peak	27/10
2012	193	Tidal peak + 2 days	19/10
2013	213	Tidal peak	20/10
2014	208	Tidal peak	10/10

Therefore tide is the most important source affecting the rising of water level in Can Tho City in 2011 and 2013.

Annually, water discharge from Mekong River to Can Tho City in combination with high tidal flow creates “flushing” phenomenon that results in the rising of water level.

4.3.4. Flooding caused by land subsidence?

Land subsidence is a major problem in the MKD. Land subsidence in deep layer (more than 80m below) caused the apparent rising of water level. Based on the research of a group of experts from Stanford University published in 2014, exploitation of groundwater is a major reason of land subsidence. Especially in coastal areas, people have to deal with a double threat: flooding caused by land subsidence and flooding caused by sea level rise.

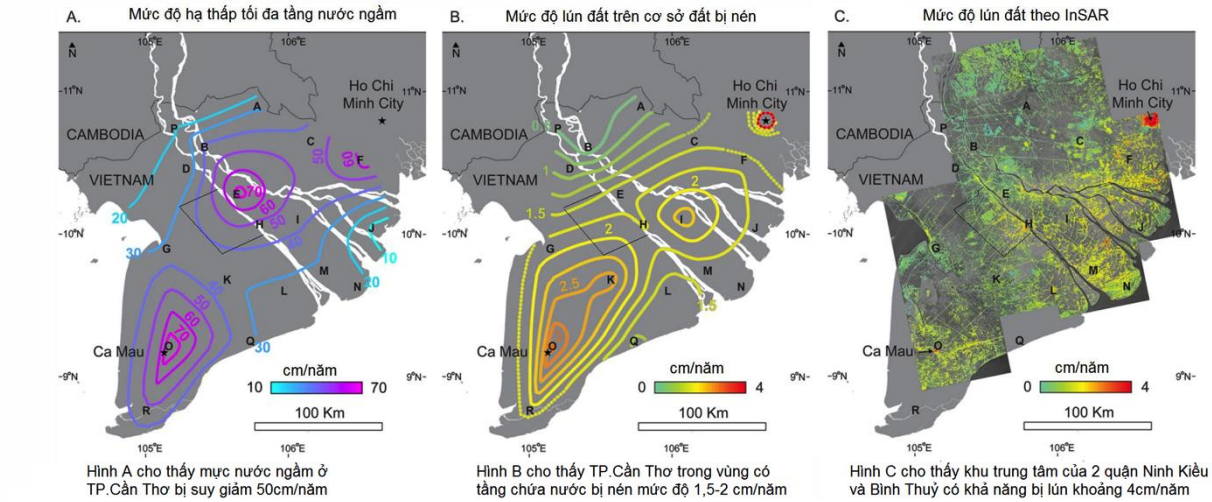

Figure7Cause and progress of land subsidence in the MKD 2006-2010 (Source: IOP Science, 2014)

The ground levels of the MKD are mainly lower than 2m above sea level. The overuse of groundwater is a reason of the decline in groundwater resources. According to the data in time series of 79 wells in 18 locations, the average rate of this decline is about 0.3m/year.Consequently, water-bearing layers of sediment in these locations are pressed down causing land subsidence with average rate of 1,6cm/year.By using remote sensing technology and other appropriate software in order to measure annual rate of subsidence from 2006 to 2010, the group of authors has created the first map of subsidence caused by groundwater extraction in the MKD. If the process of groundwater extraction continues with current rate, it is estimated that ground level will subside about 0.88m (0,35-1,4m) until 2050. Sea level is predicted to rise 0.1m (0,07-0,14 m) until 2050. Based on calculation, the MKD will be added 1m floodwater (0,42-1,54 m).

Actualmeasurements showed that the highest water level in Can Tho City has increased approximately 15mm/year including 4mm sea level rise/year. Thus, the research's assumption that land subsidence can be up to 10mm/year is very close to this result. In Chau Doc in recent years, the phenomenon of peak floods affected by tide can be seen as an evident of land subsidence (Figure 11).

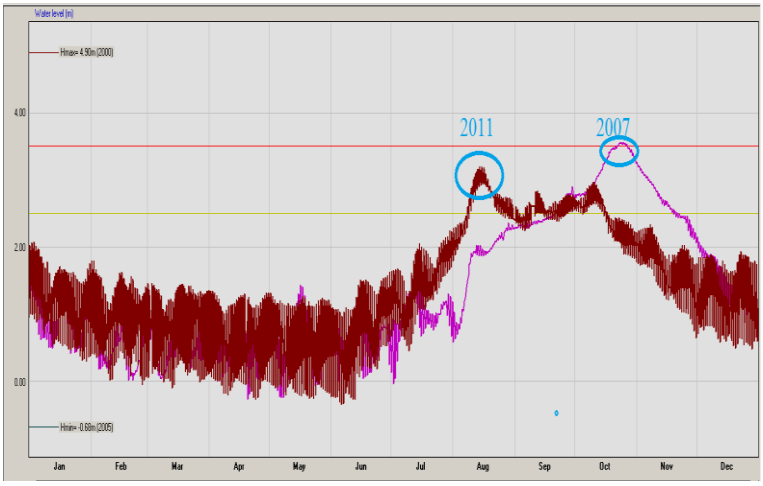

Figure8Comparison between tidal oscillation in 2007 and in 2014 in Chau Doc (Source: Hydmet)

Annual land subsidence in combination with tide can be a main reason causing the increase in water level recorded in Can Tho Station year by year.

In conclusion, among the 3 flooding causes (rainwater, water discharge in Hau River, and tide), rainwater is the least impacted source and tide is the most impacted source. High flooding in Ninh Kieu District, Can Tho City only happens when tide reaches high in flooding season. And land subsidence is a catalyst worsening the flooding in this region.

5. Flooding in new urban areas in Can Tho City

5.1.Flooding profile due tolocal community surveys

This research has conducted surveys in 3 areas which are all new developing areas of Can Tho City. In 2000, only 10% of households had previously settled there, 90% of households had been new settlers. Some of them were re-settlers through urban development projects of Can Tho City.

In the Neighborhood 1, An Khanh Ward, there are more than 70% of the interviewed households resettling through urban development projects of Can Tho City (mainly the renovation

project of Xang Thoi Lake, renovation project of Tham Tuong Canaland other urban renovation projects).

Excluding resettled households with subsidized land, resettlement community is living on low-based and small area land. This community includes households belonging to same-location-resettlement or waiting for the construction project of Medical University. More seriously, some households even don't have any land to settle, they have to lend the land from relatives then set up a temporary shelters with extreme low living conditions. According to these households, they have to "lift the house's furniture up" due to the flooding issue.

5.1.1. Spontaneous urbanized area (Neighborhood 4 of An Hoa Ward)

According to Mr. Do Hoang Phuoc, who lives in no.79 Vo Truong Toan Road, the current population in Neighborhood 4 of An Hoa ward has been 15 times as many as the population in 2000. In 2000, there was a waterway connecting this area and Sao Canal. In "mùa nước nổi", this area was naturally flooded twice a day because of the tidal cycle. Totally, flooding could last for 40 days. In recent years, many water surfaces were filled, replacing by new houses which were built in low-lying ground. People raised their ground floor 100cm higher. As a consequence, since 2004, flooding happenswhen there are heavy rains. During the flooding in 2011, his house was flooded 15cm deep. In front of his house, Vo Truong Toan Road was 50cm under floodwater. During the flooding in 2013, floodwater raised lower but totally lasted for 50 days.

Mrs. Ha Thuy Ngan who lives in no.4 Vo Truong Toan Road, near 256 Alley, considered "mechanical apartment building" as a major flooding in this neighborhood. She said that in 2013, her house and Vo Truong Toan Road were flooded low. However, 256 Alley was about 50-60cm under floodwater. Recently, this alley is flooded whenever there are rains. Since April to the end of rainy season, the heavier the rain is the higher floodwater raise. These flood events caused pollution and difficulties for the living conditions and livelihoods of local people.

Mr. Le Xuan Toan, whose household have lived in 256 Alley since 1999, said that tide is also a flooding reason. However, flooding caused by tide is not serious and it does not last long. Rains cause more serious floods which last longer. If the rain lasts for 30 minutes, floodwater can reach 30 cm in height. Normally, these floods last from 120 to 360 minutes. If the rain comes at the same time of the tide, flood can last for 12 hours.

Both rain and tide are water sources causing flooding in Neighborhood 4 in An Hoa Ward. Rain is the major source while tide is just a supplementary source for flooding in this case study.

Figure9Flooding caused by rain in 256 Alley, 2014

Mr. Phuoc and other people living in this neighborhood depicted that there arefewer spaces for water retention and water drainage because in recent years, many houses have been built up and

natural waterways and orchards which work as water storages have been filled. Before the construction of Nguyen De Road, part of the rainwater drained to the North through a system of small ditches and canals. Since Nguyen De Road was built, rainwater drains to street gullies and directly to sewer system of Nguyen Van Cu Road.Wastewater and rainwater pour in the same sewer pipe which was designed smaller than the needed capacity of water drainage in this area. The sewer system collects wastewater and rainwater directly from households to Vo Truong Toan Road (ø=80cm). However, this system which was built a long time ago and at different stages cannot be asynchronous with the sewer system in Nguyen Van Cu Road. The sewer system of Nguyen Van Cu Road (ø=80cm)transporting water to Sao Canalwas built shallowerthan previous sewer system. As a result, until the sewer system of households and Vo Truong Toan Road are full, water starts to drain to the sewer system of Nguyen Van Cu Road.

The lack of a masterplan for this area resulted in the incorrect calculations of the drainage demands and an insufficient drainage system. Moreover, climate change with more heavy rains puts additional risks on the situation.

5.1.2. Urbanized area based on city plan (Neighborhood 1 of An Khanh Ward)

Neighborhood 1 of An Khanh Ward have urbanized from agricultural area. Starting in 2000 with 60 households in Thoi Nhut Hamlet, An Binh Commune, it became Neighborhood 1 of An Khanh Ward with 800 households in 2007. After the implementation of the city plan, this area covered by large natural waterways is barely flooded.

Mr. Nguyen Van Thanh, 45 years old, who lives in 264 Thoi Nhat 2 Hamlet said that he has been living here since he was born. The rapid urbanization process since 2000 has resulted in the increasing number of resettled households and new residential areas (almost 10 times), including Thoi Nhat 1, Thoi Nhat 2 and currently Thoi Nhat 3 being constructed.

In 2011, there were orchards and paddy field in his owned land. The natural ground was about 60cm lower than the firstfloor. Every year, when the “mùa nước nổi” came, he had to embank around his land in order to prevent floodwater from approaching his house and harming the crops. Floodwater used to last for 120 days including 60 days of flooding caused by tide. Tu Ho Canal is a natural waterway transporting floodwater as well as draining floodwater. Notably, at 17:30 on September 17th, 2011, his built embankment was broken and his house and orchards were dumped 60 cm of floodwater. Despite of conforming the city plan, other areas in An Khanh Ward also experienced flooding with at least 10 cm in depth. Until 2013, Thoi Nhat 2 residential area was planned and invested in construction. Ground floor was raised up 200 cm. Mr.Thanh’ first floor was also raised 20cm higher than the ground. This residential area has not been flooded since 2013. Water level in Tu Ho Canal has never exceeded 60cm under new ground level.

Figure10Neighborhood 1, An Khanh Ward, 2014

Mr. Dang Van Deo who used to live in no. 201 Neighborhood 1, An Khanh Ward, told that before the implementation of city plan, his house was flooded annually. As his land was located in the planned site, he was accepted to resettle to no. 7B Nguyen Tri Phuong Road in Thoi Nhat 1 residential area. Since then, his house has never been flooded. However, not all new residential areas are successful in dealing with flood. He knew that the new resettlement area in the renovation project of Xang Thoi Lake is still flooded because of the inappropriate plan, low-lying ground, small and combined wastewater – rainwater sewer system. The new resettlement area where he is now living was well designed with sufficient sewer system (1m in dimension), high ground, and separated sewer system. In addition, there is a planned residential area behind his house which will be built with emphases on drainage and environmental protection.

5.1.3. Waiting area for the implementation of city plan (Neighborhood 2,3 of An Khanh Ward)

Mr. Do Thanh Nhon, 56 years old, has been living with his family in no. 53 Group 7, Neighborhood 3, An Khanh Ward since 1969. From the time he arrived, the current number of houses in this area has increased by 10 times. Many new hostels and private enterprise buildings have been built. Before 2000, around his house, there were few houses, mainly natural ponds, ditches and canals. The ground level was only 100cm in height. Therefore, in order to prevent from flooding, first floors were raised up to 120 cm which exceed the tidal height.During flooding season from July to October in Lunar calendar, flooding caused by rain rarely happened because of the system of natural ponds, ditches and canals. Annually, flooding caused by tide lasted for 60 days. Floodwater fluctuated with the tide.

Because of the city plan approved in 2000, the number of houses in this area has increased sharply and in 2011 almost reached the current number of houses. Spontaneous houses were built based on the financial ability of the owners and the location of the land. People with better financial ability could level their first floorup 150cm and fill natural ponds and ditches in order to expand their floor. As a result, there were differences in height between the alley and the floors of houses in this neighborhood. Both flooding caused by tide and rain started to occur due to the slow drainage. Flood still occurred even in light rains. Although the height of floodwater decreased, the duration of flooding seemed to be much longer. Floodwater flew to lower areas and drained languidly.These areas worked as concrete hoppers trapping rainwater. Until 2013, the city plan has not been implemented. However, the number of houses in this neighborhood has continued to increase and natural water surfaces have been increasingly encroached. Consequently, floodinghas occurred more frequently.

The same problem was experienced by Mrs. Pham Thi Ut Em, Mr. Nguyen Van Minh, Mr Huynh Van Cao, Mr. Le Van Khanh who all live in Neighborhood 2,3 in An Khanh Ward. In

addition, they said that before 2000, flooding was mainly caused bytide. Presently, flooding caused by tide and rain occur after each other. Many reasons were mentioned, for example: the encroachment of natural water surfaces, elevating first floor blocking water flow to natural water surfaces, the lack of street gullies harvesting and draining floodwater, insufficient and unsynchronized sewer system…

Mr. Huynh Van Chao has been living in no. 38/7 Neighborhood 3 in An Khanh Ward since 1983. He described that Ong Ta Canal used to be the major drainage way which was big enough for boat to go to Dau Sau Canal. Since Ong Ta Canal was filled, flooding in Dien Thanh Bakery Alleyhas been occurred whenever it rains.

5.2.Urbanization process and its correlation with flooding

5.2.1. Mixed area between planned development and spontaneous development (Neighborhood 4, An Hoa Ward)

Neighborhood 4 in An Hoa Ward is a highly urbanized area with an increase of 20% in number of buildings in 10 years (shown in Table 7 and Figure 12).

Table6Land-use transformation in Neighborhood 4, An Hoa Ward in 2004, 2006 and 2014

No	Land-use type	2004		2006		2014	
		Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)
1	Building	379.417	**53,00**	440.549	**61,60**	536.018	**74,90**
	Residential housing	158.538		247.113		306.035	
	Infrastructure, public building	220.879		193.436		229.983	
2	Vegetation (paddy field, orchard…)	187.668	**26,20**	150.709	**21,10**	20.808	**2,90**
3	Water surface	92.639	**12,90**	68.019	**9,50**	30.598	**4,30**
4	Transportation	55.989	**7,80**	56.433	**7,90**	128.286	**17,90**
	* Total	715.710	**100,00**	715.710	**100,00**	715.710	**100,00**

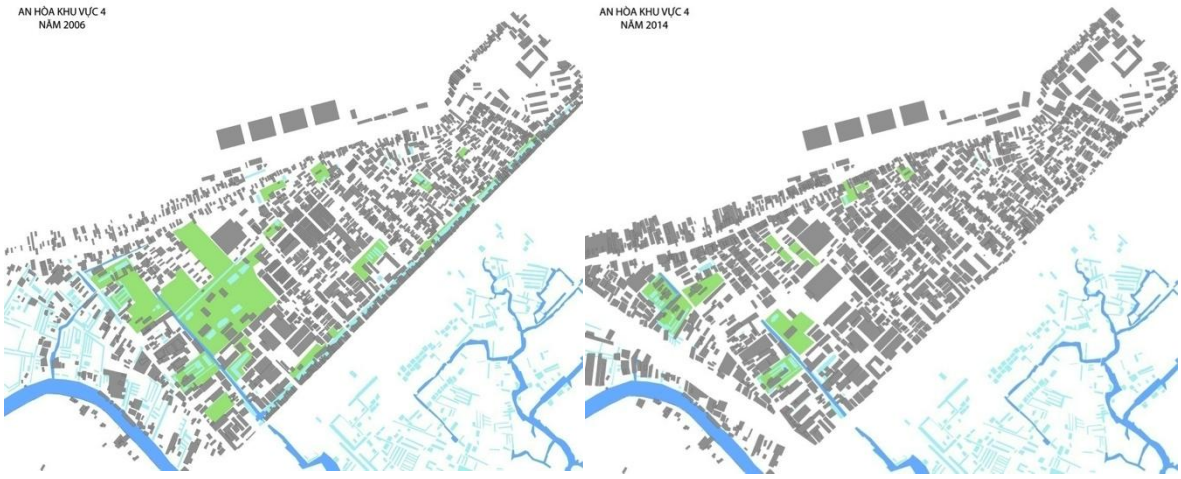

Figure11Change in building density in Neighborhood4, An Hoa Ward in 2006 and 2014

a) From 2002 to 2004

"Lộ 20" is an old name of Section 1 of Nguyen Van Cu Road, prolonging from Cach Mang Thang 8 Road to Mau Than Road with the width of 20m. Before 1975, a residential area was

built along the two side of this road. Road elevation ranged from 1,75 – 1,80m. Average elevation of the residential area located in the Northwest of Nguyen Van Cu Road was 1,35 – 1,52m. There was also a canal named "Lộ 20" Canal along the Northwest of Nguyen Van Cu Road which soil had been dug for the construction of this road. Additionally, the canal was used to transport rainwater from this road to other canals, ditches and ponds connecting with Sao Canal which used to be the major natural waterway of the whole area.

The density of the area between Nguyen Van Cu Road and Nguyen De Road was quite low. Instead of public buildings such as local schools, Hau Giang Pharmaceutical factory, police station, Medical College, Mau Than apartment building…, there were only semi-permanent houses, temporary houses, gardens, canals, ditches…

In the period of 2002-2004, rainwater and sewage water directly drained to adjacent ditches, "Lộ 20" canal and Sao Canal. Tide and rain did not make a strong impact on this area. Floodwater easily drained right after rains.

b) From 2004 to 2006

Some households living in the Northwest of Nguyen Van Cu Road had encroached the canal, expanded their floors, buried sewers under the floors and disposed directly to the canal. Consequently, water flow was narrowed down causing local flood when heavy rain occurred.

Many houses and public buildings was built and expanded, for example: Medical school, Hau Giang Pharmaceutical factory, police station, Vo Truong Toan primary school, Can Tho Technical Economic College…

The density of building and transportation increased sharply while the density of vegetation and water decreased.

c) From 2006 to 2014

By filling up the canal, Nguyen Van Cu Road was widened to 34 m (14m wider to the right from the road's center). In the late 2013 - early 2014, the entire of road has been completely upgraded. Nguyen Van Cu Road had a new width of 34m. New road elevation ranged from 2,32 to 2,4 meters. Average elevation of the neighborhood 4 ranged from 1,40 to 1,55 m. Some houses and public buildings have leveled to 2,05-2,06 m height. The whole area was planned in the Masterplan of Center III An Hoa - An Thoi urban area, Can Tho City (Scale 1:2000).

Nguyen Van Cu Road in Neighborhood 4, An Hoa Ward connects the two main routes of the city namely Cach Mang Thang 8 Road and Mau Than Road with many schools, offices, factories… causing traffic congestion during peak hours. Widening Nguyen Van Cu road to 34 m aimed at not only ensure the traffic flow in the city but also encourage local people to embellishment their façade. However, since the completion of Nguyen Van Cu road, this area has been flooded frequently, mainly caused by rain. When heavy rains continuously occurred, the new widen part of the road was submerged with 10-15cm floodwater height. In the alleys along this road, floodwater level reached 20-25 cm in height, particularly in some place 40 cm. Floodwater drained slowly after the rain.

Causes of flood in An Hoa Ward:

The completed Nguyen Van Cu Road is 2.32 – 2.4 m in height which exceeds the current highest tidal peak (2,15m in 2011) as well as 30-35 cm higher than the neighborhood.

Based on the design of drainage system, rainwater is harvested in D-80cm sewer pipes, transported to D-80cm sewer system at the junction of Mau Than and Vo Van Kiet and finally discharged to natural canal. Rainwater harvested in Tran Viet Chau Road is transported to Cach Mang Thang 8 Road and discharged to Khai Luong Canal. However, sewer manhole was not

designed big enough to harvest rainwater efficiently, thus, remained rainwater discharged back to the alleys (with lower elevation) resulting local flood inside the neighborhood.

Current drainage system used in Vo Truong Toan Road and its small alleys in Neighborhood 4 is the old and congested system which is lower than the new sewer system built under the pavement of Nguyen Van Cu Road. When it rains, sewer system in Neighborhood 4 cannot connect to the sewer system used in Nguyen Van Cu Road.

These above issues are major reasons causing flooding in Neighborhood 4 in An Hoa Ward when heavy rains last longer than 30 minutes.

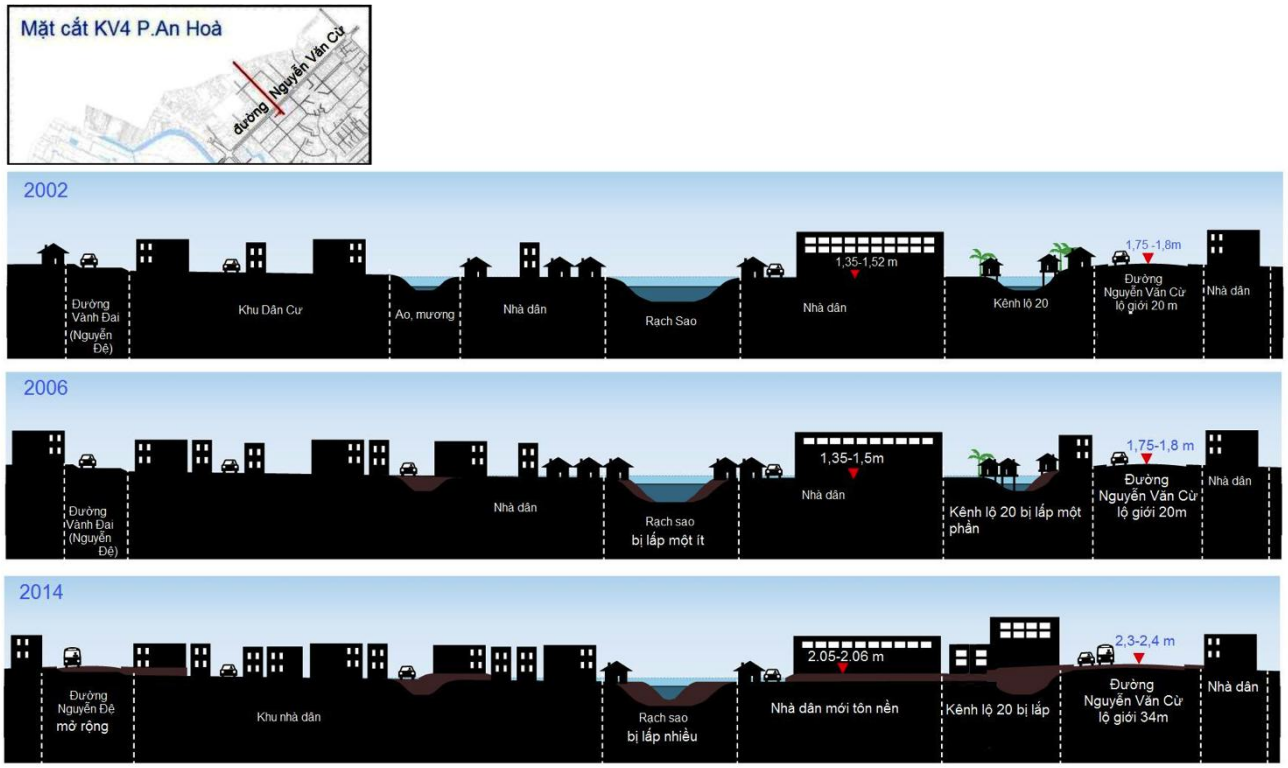

Figure12Simulating the causes of flood in Neighborhood 4, An Hoa Ward

5.2.2. Developing area based on city plan (Neighborhood 1, An Khanh Ward)

The urbanization process in Neighborhood 1 in An Khanh Ward can be shown clearly in Table 8 and Figure 14 below:

Table7Land-use transformation in Neighborhood 1, An Khanh Ward in 2002, 2004 and 2014

No	Land-use type	2002		2004		2014	
		Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)
1	Building	261.011	**11,80**	213.456	**12,1**	811.611	**46,2**
	Residential housing	171.530		86.195		344.635	
	Infrastructure, public building	89.481		127.261		466.976	
2	Vegetation (paddy field, orchard…)	1.455.892	**65,60**	1.117.986	**63,6**	421.386	**24**
3	Water surface	298.660	**13,40**	329.326	**18,7**	133.482	**7,6**
4	Transportation	205.148	**9,20**	97.457	**5,6**	391.746	**22.2**
	* Total	2.220.711	**100,00**	1.758.225	**100,00**	1.758.225	**100,00**

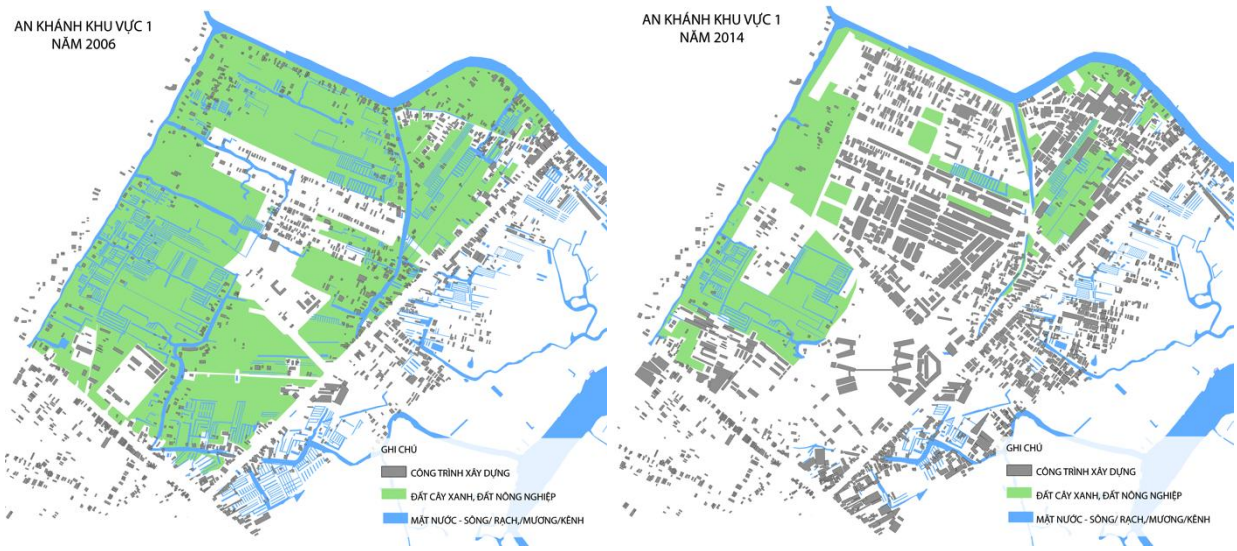

Figure13Change in building density in Neighborhood 1, An Khanh Ward in 2006 and 2014

a/ From 1994 to 2002

In 1994, the construction of the Section 2 Nguyen Van Cu Road started. At this time, Neighborhood 1, 2, 3 of An Khanh Ward was typically low density rural areas.

Average elevation of this area ranged from 1,20 to 1,40m. Local people lived close to waterways. Along Nguyen Van Cu Road, there were only paddy fields, gardens, and a small number of buildings such as semi-permanent houses and temporary houses.

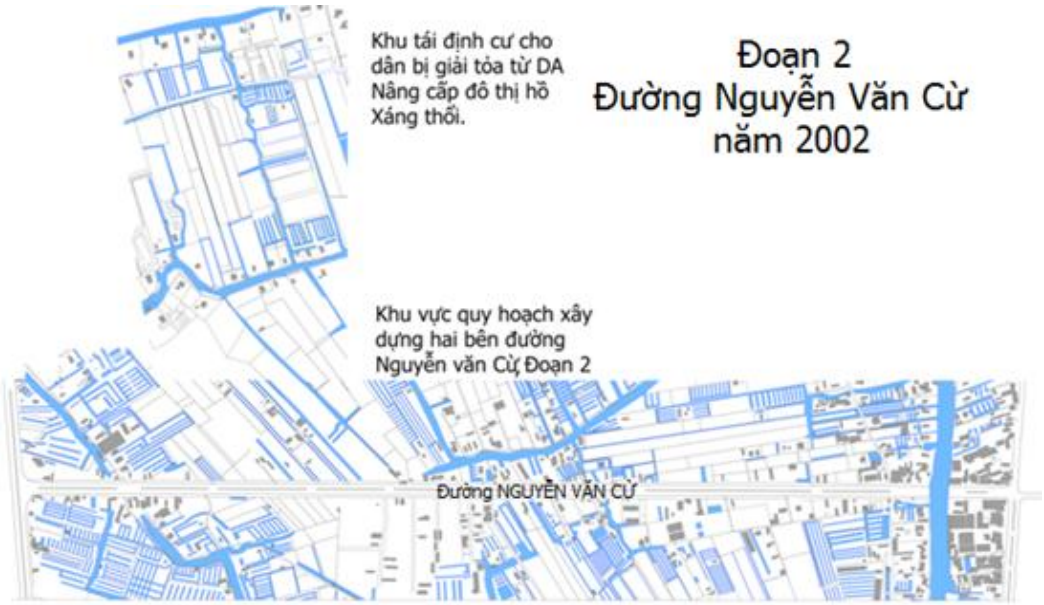

Figure14Planned area, Detailed construction planning of the two side of Nguyen Van Cu Road, Section 2

Flood and Causes:

In order to construct the road, some waterways connecting Sao Canal, Tu Ho Canal to Bun Xang Lake were filled up. The elevation of Nguyen Van Cu Road was raised to 1.75 - 1.85m.

From 1994 to 2002, there was only one on-going projects for the area: Detailed construction planning (Scale 1:500) of the two side of Nguyen Van Cu Road (section from Ngong ditch to National Highway QL.91B).

During this time, causes of flood were: (1) Rain: occurred from May to October. When heavy and long lasting rains occurred, rainwater was not able to discharge easily to natural waterways in this area and to Tu Ho and Ba Bo Canal. (2) Tide: occurred from September to October, especially on October. Water discharge from Hau River in combination with high tidal flow creates "flushing" phenomenon. Floodwater raised and inundated paddy fields, orchards, roads… However, houses were not flooded because local people had already heightening their ground floor and embanked surround their own land.

b/From 2002 to 2006

From 2002 to 2006, construction planning of the two sides of Nguyen Van Cu Road was implementing.

Located in the Northwest of the Section 2 of Nguyen Van Cu Road Neighborhood 1 in An Khanh Ward was planned to be a residential and resettlement area in the project of Upgrading Xang Thoi Lake urban area, An Cu Ward, Ninh Kieu District. Many office building and residential houses were built up. There was a sharply increase in the building density because of the heightening first floor and filling small ditches and canals for the constructions of new buildings.

In addition, there were two on-going projects implemented in this area: (1) Detailed construction planning (Scale 1:500) of Thoi Nhat resettlement area (1B) and (2) Detailed construction planning (Scale 1:500) of Thoi Nhat resettlement area (1A-1C).

Flood and Causes:

During this time, in Neighborhood 1, there was almost no flood. The planned neighborhood had been leveled to 2,20 m, higher than the peak of tidal flood and invested in constructing a reinforced concrete sewer system for the resident area.

c/ From 2006 to 2014

The number of office buildings and houses along the two sides of Nguyen Van Cu Road increased sharply. A new residential and resettlement area was planned namely Thoi Nhat 2, in order to support other projects implementing in Ninh Kieu and Binh Thuy District. From 2006 to 2014, there was also an on-going project for the area: detailed construction planning (scale 1:500) of Medicine and Pharmacy University resettlement area.

Flood and Causes:

Parts of Neighborhood 1 were often flooded when heavy rainfall occurred. It caused by the lack of awareness and responsibility of local people. In order to prevent odors, local people threw garbage into gullies and manholes that obstructed floodwater to drain; disposed construction wastes such as soil, sand and building materials that also blocked the water flow.

The other reason is the lack of investment in dredging and maintaining sewer system periodically, especially in the early of rainy season.

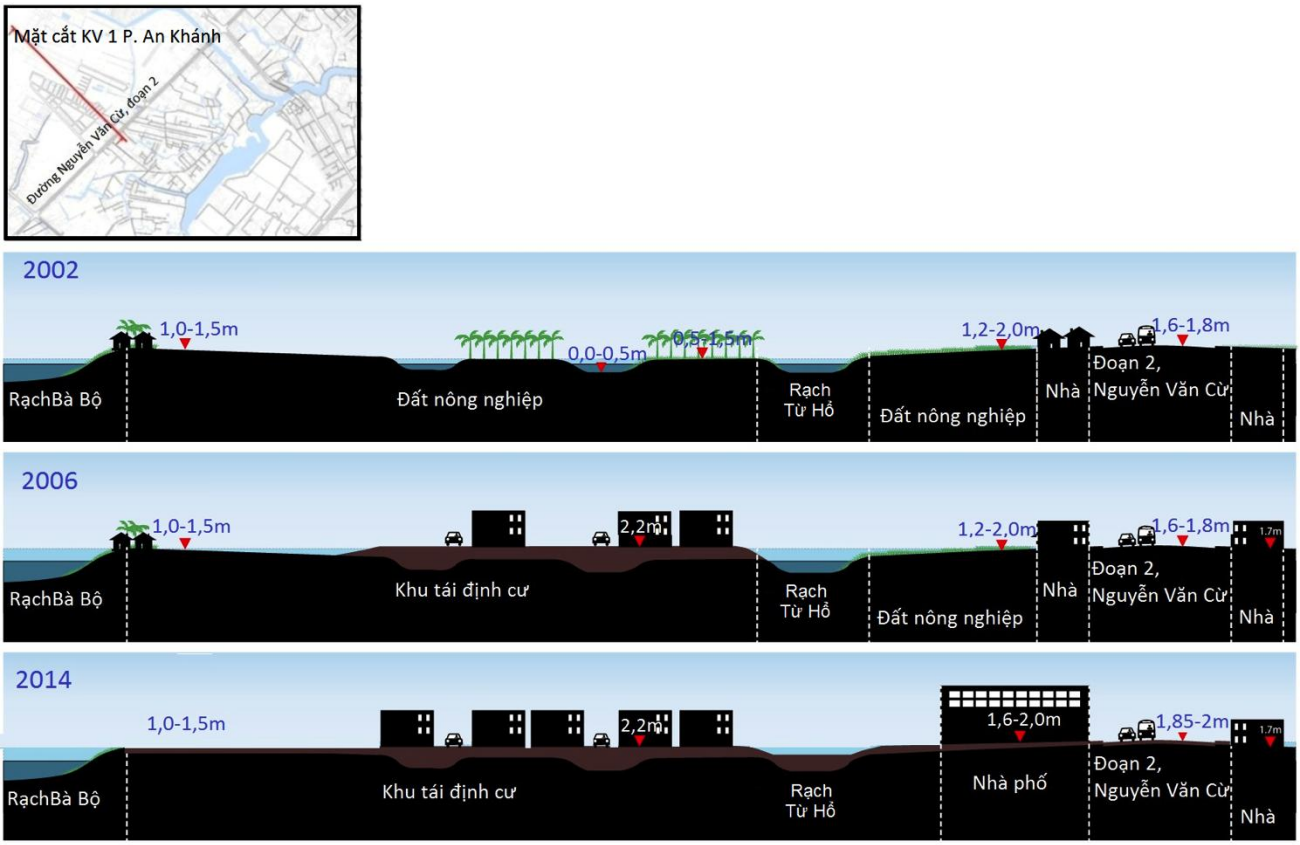

Figure15Simulating the causes of flood in Neighborhood 1, An Khanh Ward

5.2.3. Waiting area for the implementation of city plan (Neighborhood 2,3 of An Khanh Ward)

The urbanization process in Neighborhood 2 and 3 in An Khanh Ward can be shown clearly in Table 9 and Figure 17 below:

Table8Land-use transformation in Neighborhood 2 and 3, An Khanh Ward in 2006 and 2014

No	Land-use type	2006		2014	
		Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)
1	Building	508.813	**22,90**	1.124.655	**50,60**
	Residential housing	354.360		590.808	
	Infrastructure, public building	154.453		533.847	
2	Vegetation (paddy field, orchard…)	1.208.428	**54,40**	605634	**27,30**
3	Water surface	298.322	**13,40**	285.274	**12,80**
4	Transportation	205.148	**9,20**	205.148	**9,20**
	* Total	2.220.711	**100,00**	2.220.711	**100,00**

a/ From 2002 to 2006

During this period, part of Neighborhood 2 and 3 in An Khanh Ward was planned in the Detailed construction planning (Scale 1:500) of the two side of extended Nguyen Van Cu Road. However, the project had not been implemented. Local people spontaneously built their houses and minor structures without any building standard and city plan. As a result, there were arbitrary differences in height between residential houses and public buildings' first floor and alleys.

Both Neighborhood 2 and 3 experienced frequent flood events. Floodwater stagnated when heavy rainfall continuously occurred. Additionally, when tide surged, water from Hau River rushed

through Ngong ditch and Bun Xang Lake, overflowed the vacant lands and flooded roads and houses. Floodwater with roughly 0,3 – 0,4m in depth stagnated for hours.

Causes of flood:

- Average elevation of these neighborhoods was low, ranged from 1,2 to 1,6 m, particularly 0,8m in some areas. Therefore, when heavy rainfall continuously happened, roads were flooded promptly.
- Approved planning projects were implemented slowly and infrastructure was not invested, thus local people constructed spontaneous settlements.
- Sewer system was degraded and not well- maintained.
- During heightening the first floor, canals and sewers were filled up intentionally or unintentionally.

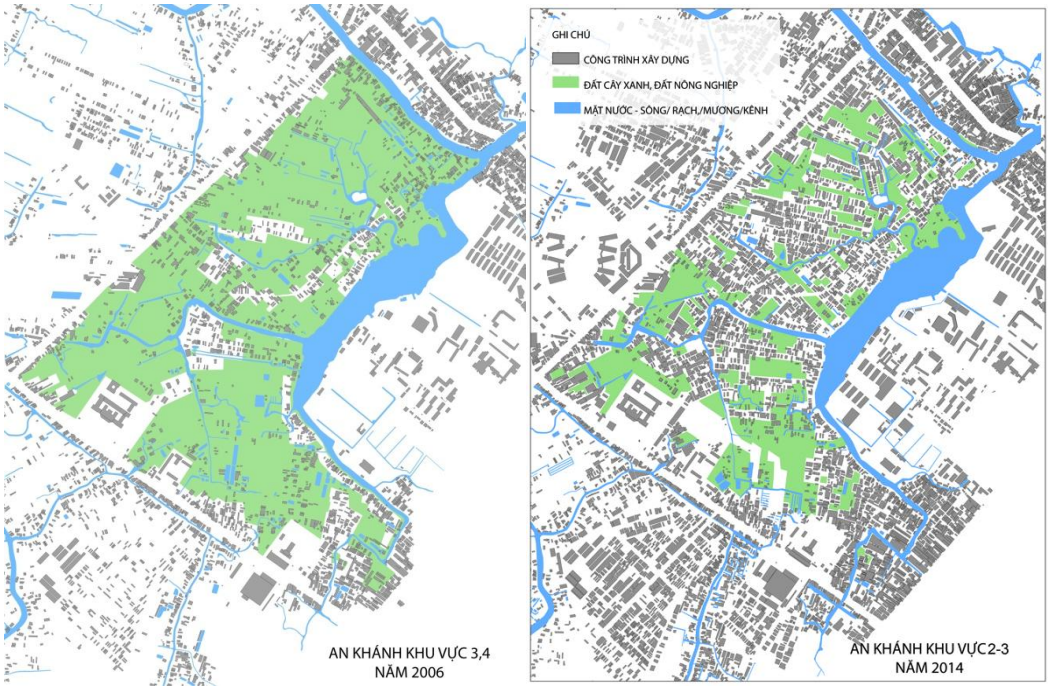

Figure16Spontaneuos urbanization process in neighborhood 2 and 3, An Khanh Ward in 2006 and 2014

b/ From 2006 to 2014

The implementation of the city plan in Neighborhood 2 and 3 was still delayed. Although there was no investment in the infrastructure system, the number of office buildings and houses along the two sides of Nguyen Van Cu Road has still increased sharply. During this time, the process of urbanization started to flourish that made a great change of the whole area. The density of the neighborhood has increased as well concrete surfaces. Many waterways have been filled and area for vegetation has decreased.

Cause of flood:

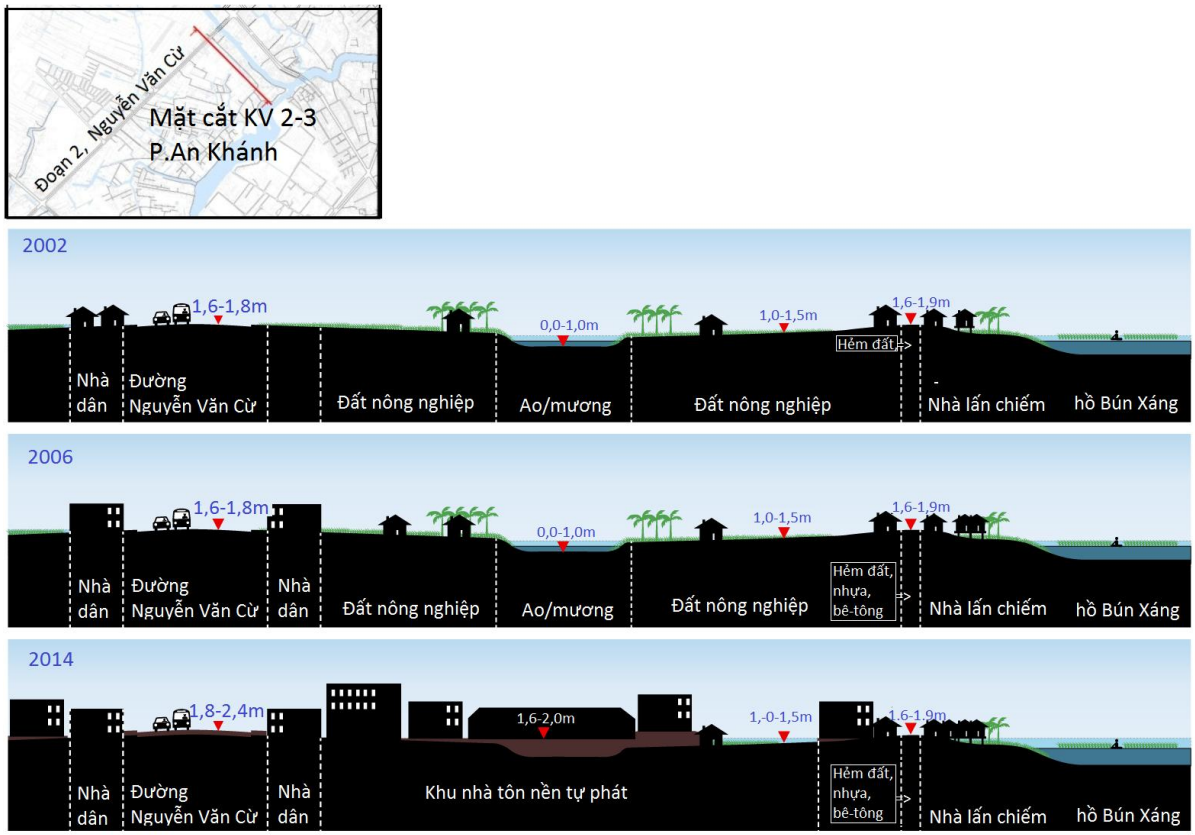

Figure17Simulating the causes of flood 2 và 3, An Khanh Ward

Floods in these neighborhoods were mainly caused by rain and tide.

- Local people arbitrarily constructed their house without conforming the city plan; new houses were built with higher first floor than the old ones. Therefore, floodwater struggled between neighborhoods.
- Most of waterways in these neighborhoods were filled causing the blocking of discharge flow.
- Building along the waterways filled in the spaces for retaining floodwater temporarily and discharging when rain and tidal flood occurred.
- Manholes were lacked and small in size that could not collect floodwater efficiently. Floodwater stagnated for long.

5.3.Community involvement in local planning

In all three case studies, local communities and the heads of these neighborhoods said that they had no chance to get involved in surveys or officially inform during the preparation of the planning process. Until the masterplan had been approved and prepared to implement, a meeting between community, consultants and government officers was organized. People living in neighborhoods adjacent to the planning site were hardly informed.

These meetings focused on informing communities about the aims of the plan, location, boundaryand compensation level for households who would be affected by the plan. Important issues about environment and engineer such as planned elevation, underground sewer system, electrical cables… effects of new buildings on households, their livelihoods and environment were not mentioned and discussed.

5.4.Local people and local government in dealing with flood

5.4.1. Spontaneous reaction of local people in dealing with flood

- People with low income or living in rented houses and hostels: they build temporary walls to block floodwater in rainy season and flood season. After that, these walls can be partly removed and used as motorcycle walkways.

- People with medium income: they elevate their first floors or build new house with first floors higher than the regular flooding level.

- In case of flooding caused by tide or not able to construct temporary wall, people can use sand bags as temporary barriers surround their houses. This solution is more flexible than heightening first floor and constructing temporary wall.

- In order to prevent incidents during and after the flood events, people lift all their houses' furniture, valuables and perishables up by other wood and brick furniture.

- Other solutions: after constructing temporary walls, people use buckets, pots or pumping machines to scoop water out of their houses.

5.4.2. Local government in dealing with flood

Interviewed households said that local government has different contributions to cope with flood:

- Asking District and City government for supports and approvals of planning projects.
- Encouraging local people to heighten their alleys by reusing disposed materials (sand) from other housing demolitions…
- Digging local drainage ways.
- Constructing temporary embankments and sandbag walls in order to deal with tide.

6. Conclusion

There are two forms of flooding in Can Tho City namely flooding caused by nature ("mùa nước nổi" as an example) and urban flooding caused by the inadequacies of planning and urbanization process.

6.1.Flooding caused by nature

Flooding in Can Tho and the MKD is a normal annual phenomenon which is called "mùanước nổi". However, high flowdischarge from Mekong River occurs frequently. From 1961 to 2014, 11 years were recorded with high flow discharge from Mekong River. Recent records were in 2000 and 2001.

- Local rain is a minor reason causing flooding in the whole of Can Tho City. However, it contributes significantly to the local flooding occurring in roads and neighborhoods. Notably, in urban areas located far from natural waterways, An Hoa Ward as an example, flooding caused by rain is the main problem.
- High flow discharge from Mekong River is a minor reason causing flooding.
- Tidal flow from the sea is main reason causing flooding in Ninh Kieu District, in Can Tho City. Especially, when tidal flow occurs at the same time of high flow discharge from upstream, flooding becomes much more serious.

6.2.Flooding caused by the inadequacies of planning and urbanization process.

- Spontaneous urbanization process in areas such as Neighborhood 2 and 3 in An Khanh Ward worsens the tidal flood situation. In these areas, infrastructure has not invested (due to phasing plan) and concrete surfaces have increased sharply. On the otherhand, a synchronized drainage system has not been built. As a result, these neighborhoods are often inundated.
- Heightening urban roads without providing sufficient drainage system is a reason of flooding in most of the case studies.
- The inadequacy in standardizing construction level between old and new drainage systems. Consequently, floodwater can flow back from main roads to minor roads and neighborhoods.
- Natural waterways was filled and encroached.
- Local people have developed different spontaneous adaptive activities such as: heightening floor level, self-building drainage system, constructing floodwall…These solutions are somehow effective. However, the same solutions cause serious problems. Floodwater has no way to escape and stagnates for long.

- Heightening road level is an essential solution to cope with flood. But these heightened roads can also be considered as dikes obstructing natural drainage.

Appendix I: Data of rainfall, high flow and flood

a/ Flooding from 1978 to 2013 in Can Tho City

Year	Rainfall (mm)	Day with highest rainfall		Year	Rainfall per year (mm)	Day with highest rainfall	
		Rainfall (mm)	Date			Rainfall (mm)	Date
1978*	**1739.1**	**91.2**	**20/11**	1996*	2111.3	112.0	15/05
1979	1475.2	48.4	02/09	1997	1658.6	94.6	02/11
1980	1666.1	90.4	09/06	1998	1962.0	104.8	24/10
1981	1630.0	69.7	11/05	1999	1895.9	77.9	12/10
1982	1710.2	83.6	28/09	**2000***	**2075.2**	**211.4**	**09/06**
1983	1799.3	117.8	16/09	2001*	1634.0	126.3	05/10
1984*	1533.8	66.5	26/04	2002*	1186.8	86.0	18/07
1985	1825.5	77.5	04/06	2003	1780.6	111.0	23/07
1986	1825.5	116.4	02/11	2004	1417.3	54.9	17/05
1987	1465.5	67.3	07/10	2005	1728.9	90.3	05/11
1988	1716.9	73.4	22/10	2006	1642.5	97.1	15/03
1989	1341.2	82.2	15/07	2007	1500.7	106.8	13/05
1990	1160.2	67.3	04/08	2008	1509.7	60.9	09/06
1991*	1516.3	64.0	30/06	2009	1254.2	82.1	30/11
1992	1280.8	67.2	28/07	2010	1299.5	79.4	10/10
1993	1676.2	111.6	03/09	**2011***	**1495.7**	**107.6**	**05/07**
1994*	1434.1	115.0	11/12	2012	1226.9	86.1	24/03
1995	1704.3	131.8	18/06	2013	1339.7		

Note: * Years with flood;

Source: Southern regional Hydrometeological center

b/ High flow discharge in Mekong River from 1961 to 2014 and water level in Can Tho City

No	Year with flood	Water level (cm)			Cause of flood
		Tan Chau	Chau Doc	Can Tho	
1	1961	512	490		2 Storms in Laos and Cambodia/303 billion m^3
2	1966	511	484		2 storms entering VN Laos Cambodia
3	1978	478	446	166	3 storms entering VN Laos Cambodia
4	1984	481	437	166	Heavy rain caused by monsoon
5	1991	480		158	Storm entering Tay Nguyen and Laos
6	1994	453	423	176	Heavy rain in Laos upstream
7	1996	487	454	173	Heavy rain in Laos/303 billion m^3
8	2000	506	490	179	High flow discharge from upstream + 2 storms
9	2001	478	448	190	Heavy rain in Laos/465 billion m^3
10	2002	482	442	195	Early and heavy rain in Kratie/456 billion m^3
11	2011	486	427	215	No rainfall and high flow discharge
12*	2013	401	325	213	No rainfall and high flow discharge
13*	2014	396	268	208	Rain with 22 mm

Source: CCCO accumulated the statistics and data provided by Southern regional Hydrometeological center and Mekong River Hydrological center

Note: * Year without flood.