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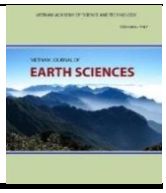

Determination of drainage corridor in the downstream Vu Gia-Han river, Da Nang city

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ABSTRACT

Flood is one of the most well-known phenomena in the Central Vietnam where Da Nang city is located. As the most area in the central coastal part, this city frequently suffers to flood without any prevented structure like sea dike or river levee. The only thing that can help to the response for flood is emergency plans. Therefore, flooding still causes great damages to the economic development and social stability in this region. For ensuring the sustainable development of Da Nang city under the impacts of climate change and sea level rising, it requests a change in direction of the solution, from the flood control to the adaptation and living with floods through spatial planning to make a good condition for optimal drainage corridors. This paper suggests a design flood drainage corridors for Da Nang city that was developed by combining of mathematical model, GIS, hydro-meteorological documents of Vu Gia-Thu Bon basin from 2009 to present. These proposal solutions include (i) widening of the riverbed and providing a river corridor protection along both river banks; (ii) creating of drainage channels for the land between the rivers and (iii) creating of space for floodwater in an appropriate time. The result was so good and it helps to reduce the flood in Da Nang from 5% to 10%. Therefore this would be a scientific basis for identifying the flood drainage corridors of other river basins in the central coastal region without typical dike cover.

Keywords: Flood drainage corridor; inundation; MIKE model; GIS; Vu Gia-Han; Da Nang city.

1. Introduction

Vietnam has a high ratio between its coastline over its terrier with the value of 11,1 m/km^2 (global average of 7.8 m/km^2). In fact, almost economic activities of the country take place mainly in the delta and coastal areas. However, this country frequently devastated by storm, flood and typhoons (Wang et al., 2014). In addition, climate change and sea-level rise are already increasing the frequency and intensity of such phenomena leading to serious flooding and inundation (Brunn et al., 2013, WB, 2012). Flooding in Vietnam has caused tremendous loss of life and property (SRV, 2007). As reported by World Bank (2012), over the past 20 years, the flooding results the loss of over 13,000 lives. The Central region is the most affected area which faced to natural disaster such as storm, flood and typhoon due to its topography, its long coastline and its climate. People here live with the quotes of Living with flood without major

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flood prevention solution. Within this region, Da Nang city is one of three biggest city in Vietnam, which locate in the coastal area of Vu Gia-Thu Bon river basin. Like the other coastal cities, Da Nang is also affected by storm, flood and typhoons which frequently occur and cause the highest damages compared with other forms of natural disasters. As the record of Da Nang City Steering Board for Storm and Flood Prevention and Search and Rescue in 2017, from the end of the twentieth century up to now, flood caused great damage to this city. Great flood event in 1999 made 37 deaths, 61 injuries and cumulative damage of 611 billions of VND. Extreme flood event in 2009 cause 8 deaths, 92 injuries, and 495 billion VND of cumulative damage. In 2011, big flood event caused 4 deaths, 7 injuries and the total damage of about 89 billion VND. More frequent flood events results the damage of 150 billion VND in 2013 and 35 billion VND in 2016. One of the major reasons that the natural disasters have great fluctuation, is the strong construction growth of infrastructure for socio-economic development Hence many studies suggested measures to limit the impact of floods on the socio-economic development of the city, but they mainly concentrate to respond when floods come such as Nguyen Song Giang, 2016, Dang Thi Kim Nhung, 2016, Nguyen Kim Loi, 2016, Da Nang Polytechnic University, 2014. However, these measures did not result any effective flood control production in this city. Therefore, it needs to change the solutions, from the flood control to the adaptation and living with floods for ensuring sustainable development of the city in the future under the accumulated impact of climate change and sea-level rise. This will be done through spatial planning to create appropriate flood drainage corridors included flood drainage areas, re-planning land-use planning approved by the Law on natural disaster preparedness and response in 2013 (Hoang Thai Binh et al., 2017). Based on the author's ongoing research, this paper proposes the specific flood drainage corridors aimed at ensuring flood reduction for sustainable development of Da Nang city.

2. The scientific basis for constructing the flood drainage corridor in the downstream of Vu Gia-Han river in Da Nang city

2.1. Approaching

Flood prevention frequency for Da Nang city, according to Decision No. 1590/QD-TTG dated 09 October 2009 of the Prime Minister approving orientations and standards for flood prevention in Vu Gia-Thu Bon river in Da Nang city, it should have a baseline elevation higher than the main flood frequency 5% after the participation of flood reduction at upstream storage reservoirs. Based on the frequency of flood peak water level of Cam Le hydrological station (controlling flood level in downstream Vu Gia-Han basin), we used the flood in 2007 with frequency 5% to determine the inundation in downstream Vu Gia-Han river (Hoang Thai Binh, 2017) and construct the flood drainage corridor as required.

For Ensuring the sustainable development of the city in the future with the cumulative impacts of climate change, sea level rise we must have a change in direction of the solution, from the flood control to the adaptation and living with floods through spatial planning included flood drainage areas, re-planning residential areas, agricultural land use plans requiring by the Law on natural disaster preparedness and response in 2013 (Hoang Thai Binh et al., 2017). From the point of view to ensure flood control and management, minimizing damages to infrastructure as well as human lives in Da Nang city accords to the principles (NRWA Waterways Section And BG & E Pty LTD, 2006):

Principle 1: There should be a space for water. Water is always present at the lowest place in the basin, and we need to have an urban planning project with a minimum space for water, similar to the space available for traffic, industry, residents,…; Especially in the uncertain condition of climate change, space for water will be changed in adaption with time.

Principle 2: Minimizing damage along with minimizing risk, so it needs to have flooded control measures to prevent early, minimizing damage means being ready to respond and adapt. Based on the above requirements, the technical criteria of the flood drainage corridor in the study area include:

(1) Flood hazard: based on flood indicators, in which flood flow direction, flood peak velocity, depth and flooding time play an important role in determining flood damage. The combination between flood depth and flood peak velocity shows the ability to destroy objects in flood areas, that have affected directly to buildings, human lives and the health of the community. Besides, flooding time destroys indirectly to crops, interrupts socio-economic activities, pollutes the environment, causes epidemic diseases. Based on map overlaying method with flooding depth, flooding time and flooding velocity of frequency 5%, flood hazard mapping has been built (Hoang Thai Binh, 2017).

(2) Water resource protection Corridor (Government, 2015) for downstream Vu Gia-Han river in Da Nang city as follows: (i) Vu Gia riverside (including Yen, Cam Le and Han rivers) area: a distance of 30 m from the riverbank; (ii) Qua Giang, Vinh Dien riverside area: a distance of 30m from the river bank and (iii) Co Co Riverside area: a distance of 20m from the riverbank.

(3) According to calculations, the generated flow in Vu Gia river of 1,085m^3/s was determined to correspond to a water level of 6.1m (at Ai Nghi station) and of 0.3m (at Cam Le station). Hence, the width of the channel ensuring a drainage flow is 2,5 times greater than the width of the river (Dinh Phung Bao, 2013).

(4) Current land use status: This will be a scientific basis to propose active flooding areas for a certain time. It has slowed down the flood process and reduced flooding for key economic areas (Da Nang Statistical Office, 2016).

2.2. Database

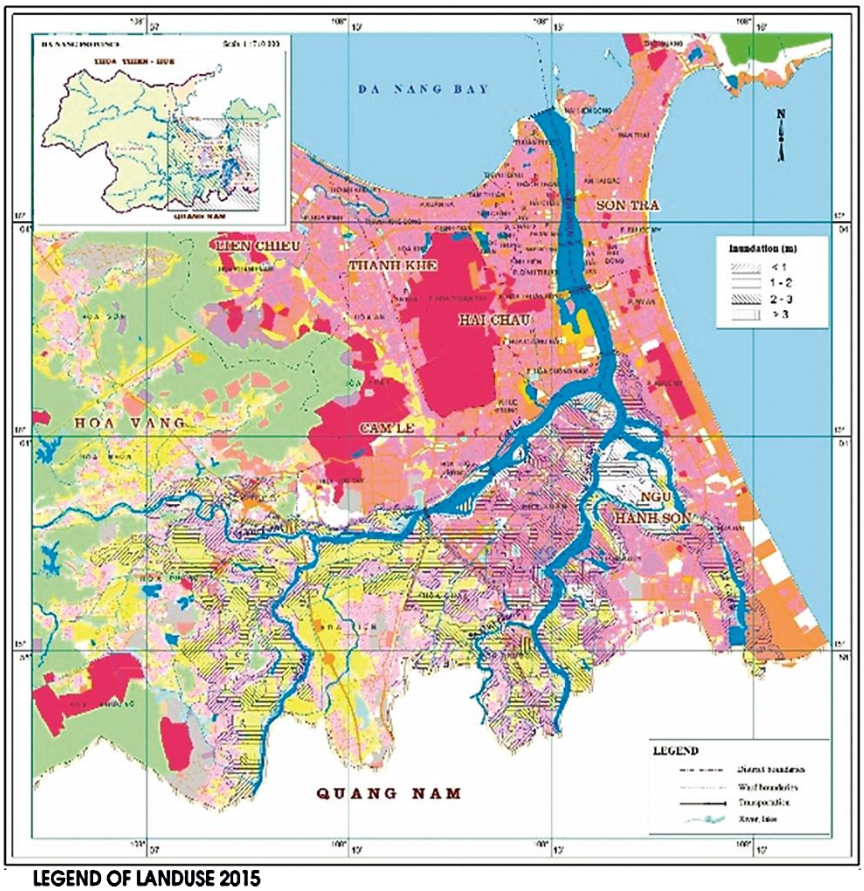
2.2.1. Map data

Using topographic map scale 1/10.000 (Natural resources and Environment published) and collected data of project in the period of 2009-2017 (on the ground and in the river) (Hoang Thai Binh, 2017).

Using current land use status map in 2015 supplied by Environment and natural resources department for proposing water spaces to ensure minimizing flood damage from point of view of adaptation (Da Nang Statistical Office, 2016).

2.2.2. Hydro-meteorological data for hydraulic and hydrological

Meteorological data: 13 stations (Hien, Kham Duc, Thanh My, Nong Son, Giao Thuy, Hoi Khach, Ai Nghia, Cau Lau, Hoi An, Da Nang, Tra My, Tien Phuoc, Hiep Duc): measurement of rainfall in a 6 hours period Hydrological data: flow rate per hour at Thanh My and Nong Son stations, water level per hour at Ai Nghia, Giao Thuy, Cau Lau stations Maritime data: sea level at Son Tra station Comparing data of Ai Nghia and Cam Le stations in Vu Gia river and data of Giao Thuy and Cao Lau in Thu Bon river to train flood simulation model.



LEGEND OF LANDUSE 2015

- Production forest
- Land for cultivation of perennial trees
- Hilly land for other annual crops
- Flat land for other annual crops
- Land of other annual crops
- Land for special-use forests
- Land for protection forests
- Land for aquaculture
- Organization office
- Land for Government offices
- Urban residential
- Rural residential
- Ceramic and construction materials
- Mining
- Non-agriculture production land
- Export production
- Non-agriculture production
- Other non-agriculture
- Social services
- National defence
- Paddy rice only
- Land for construction of cultural
- Land for post and telecommunications facilities
- Land for energy facilities
- Land for irrigation systems
- Remain paddy rice
- Land for Science and technology
- Land for Sport construction
- Education and trainning
- Health and medical care
- Land used for cemeteries
- Believes institutions
- Religious institutions
- Land for waste dumping and treatment
- Land with historical-cultural relics
- Market
- Security
- Land use transport / Transportation
- Unused hilly lands
- Unused flat lands
- Unused land
- Other non-agriculture
- Land with special-use water surface
- Land with water surface of rivers

Figure 1. Land use types of Vu Gia-Han river in Da Nang in 2015

2.3. Using method

2.3.1. Hydraulic-Hydrological modeling

MIKE model (Mike Nam, Mike 11, Mike 21FM and Mike Flood) is used to determine inundation area of downstream Vu Gia-Thu Bon river in Da Nang city in Fig. 2 (DHI Denmark, 2011).

HEC Ressim is used to simulate the operation of irrigation works that affect the flow of Vu Gia-Thu Bon river system.

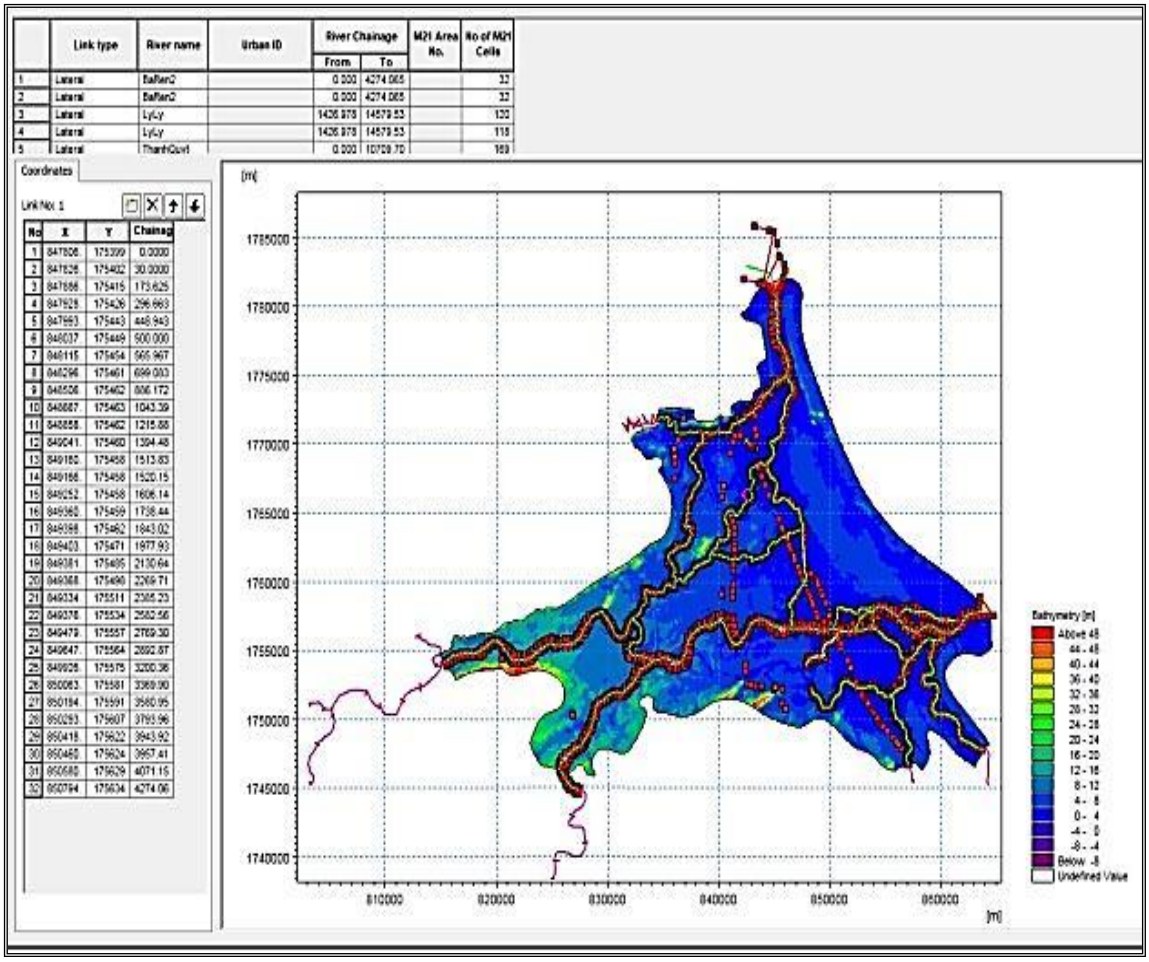


Figure 2. Flood simulation hydrograph

2.3.2. Geographic information system

For collecting, storage, transformation and showing space data; Using for synchronous processing of spatial information layers (map) that associated with attribute information to serve research, planning, and management of the impact of floods and inundation in the studied territory.

By these above methods, flood drainage corridor in Vu Gia-Han in Da Nang shown in Fig. 3.

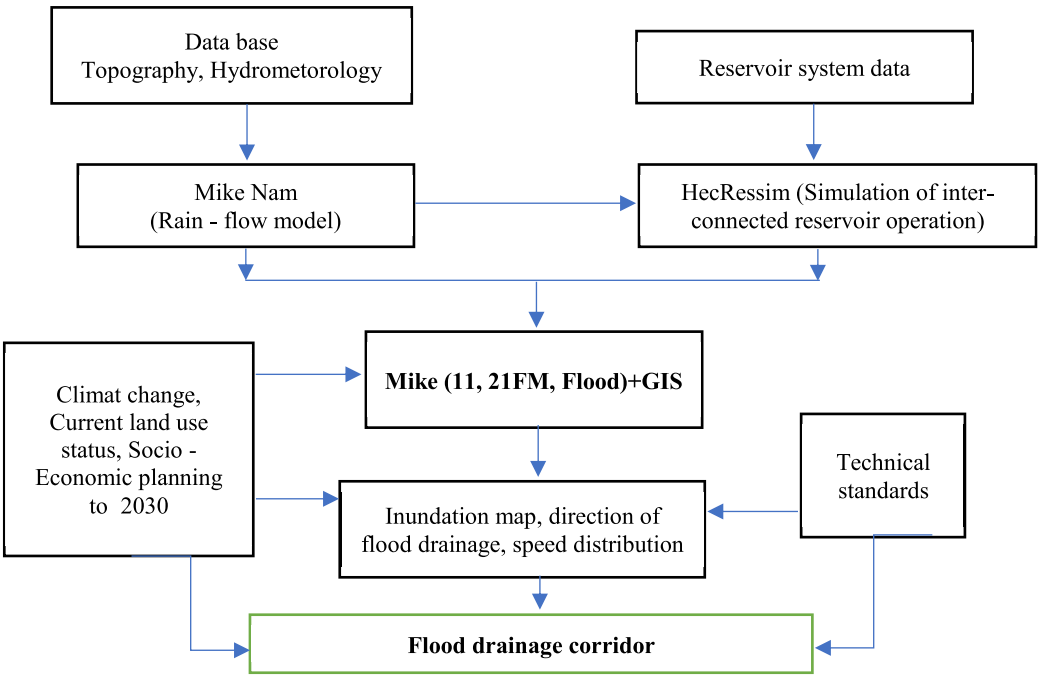


Figure 3. Flood drainage corridor determination method diagram in downstream Vu Gia-Han river

3. Results and Discussions

3.1. Characteristics of flood and inundation in downstream Vu Gia-Han river in Da Nang city

Water resources in downstream Vu Gia-Da Nang consists of two main sources: rainwater supplied for Tuy Loan river system and water transported to the sea of Vu Gia-Thu Bon system. With the annual total average rainfall of over 2,500 mm, the water that originated from surface flowing to the Vu Gia-Han river in Da Nang city reaches 1.0 billion m^3 (Dinh Phung Bao, 2013). The water of Vu Gia-Thu Bon River flows into the sea at Cua Han, reaches about 5.92 billion m^3 (average flow monitoring data through years at Cam Le station). Affected by the seasonal regime, up to 65% of the annual flow is concentrated during the three months of the flood season, from October to December. The month with the largest flow is concentrated in November (average flow at Red bridge is 510 m^3/s). This month is impacted by weather disturbances such as storms, tropical depression, cold air causing heavy rain in this area (Vu Thi Thu Lan, 2013). This is the reason for severe flooding and inundation in this area. According to statistics from 1976 up to now, every year, in Da Nang City, an average of 2-3 floods has been recorded and even 8 to 9 floods in 2007 and particularly heavy floods occurred in November (Table 1). During 40 years of monitoring, floods exceeded the level 3 at Cam Le station in 1999 (peak flood is 4.28 m), in 2007 (3.98 m), in 2009 (3.16 m), and in 2013 (2.67 m).

Table 1. Real-time of flood water level at alert levels at Cam Le station

Group of year	Real-time of flood water level (day) >= Alert level		
	Alert level 3: 2,5 m	Alert level 2: 1,80 m	Alert level 1: 1,00 m
High flood	5–7	7–12	15–27
Average flood	None	2–5	5–22
Low flood	None	None	12–15

Inundation in downstream Vu Gia-Han river in Da Nang has frequently occurred with short cycles because of simultaneously occurring of heavy flood and rain. Flood from Yen River (before and after An Trach Dam) and from Vinh Dien River (in Da Nang City) overflowed the riverbanks and run into the sea causing inundation in Cam Le district, Ngu Hanh Son district. In addition, in the lower areas on both sides of the river, over flowing water from the west to the east (along Vu Gia river) and from the south to the north (along Vinh Dien river) caused wide-spreading inundation because of heavy rain with deep flooding spots and longlasting flooding time. According to statistics, in 2013, the city has 85 flooding spots including 13 spots in Thanh Khe, 20 spots in Son Tra, 8 spots in Ngu Hanh Son, 7 spots in Cam Le, and 7 location in Hoa Vang. Based on actual data and flood mark surveys as follows, the inundation level in this area is as follows (Vu Thi Thu Lan, 2013, Hoang Thai Binh, 2017):

- Inundation depth under 1m: area of the three-way cross of Yen-La Tho-Qua Giang rivers in Hoa Vang and Cam Le district.
- Inundation depth of 1-2 m: wide spreading in two bank-sides of Vinh Dien river.
- Inundation depth of 2-3 m: the area along Vu Gia river (Yen river, Qua Giang river) in Hoa Vang and Cam Le district.
- Inundation depth over 3 m: a coastal area where lowland close to sand dunes in Ngu Hanh Son, Cam Le district.

Besides the flood flow that inundated the riverside area, heavy rains with the flood have impacted strongly on inundation of urban and increased flood levels in the river. Actually, the capacity of rivers is not enough to carry flood water. According to calculations, the drainage capacity of the downstream Vu Gia-Thu Bon river is 20 times lower than the necessary capacity to minimize the impacts of floods (Hoang Ngoc Tuan, 2016). Calculations of the authors have shown that the main drainage capacity of Vu Gia River is less than 30% and capacity of Vinh Dien river only reaches 5-20% of the total flood volume of the flood in 2007 (corresponding to frequency 5%). Thus, 70 million m^3 of flood water overflow the river. Therefore, the drainage of floods with the frequency of 5% for the city does not only rely on natural river beds.

3.2. Combining of Mike model and GIS to determine inundation for Da Nang city

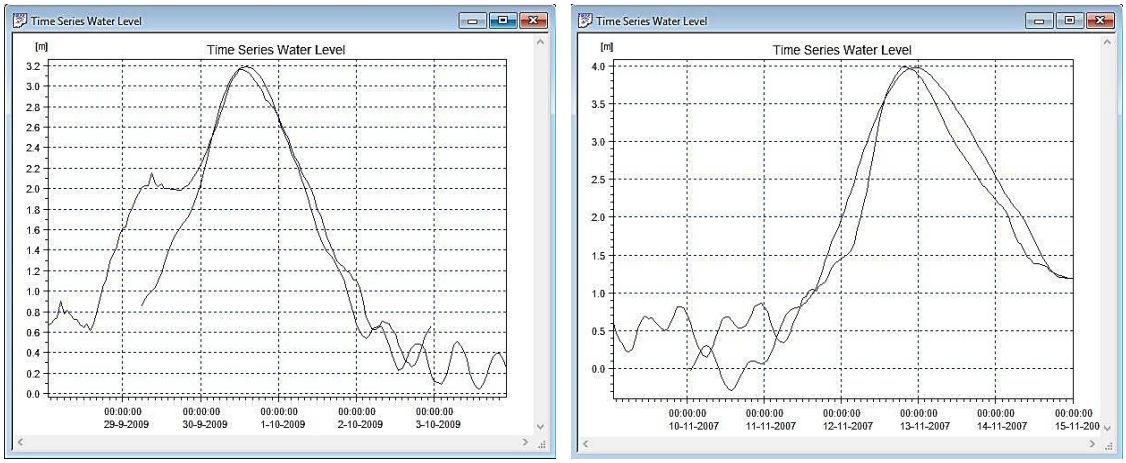
The results of using the Mike model (Mike Nam, Mike 11, Mike 21FM, and Mike Flood) for specific frequency floods (model correction for flood data in 2009 and verifying for the flood data in 2007) obtained relatively stable roughness parameters, simulating hydraulic processes on the river system.

Flood simulation using the 1-D hydraulic model Mike 11 with the Nash index varied from 0.85 to 0.9 for all four hydrological stations shown that the test results had almost exactly simulated the flood peak value of checkpoints (Table 2).

Table 2. Correction and testing results of model MIKE 11

Order	Station	River	Correction for the flood in 2009		Testing for the flood in 2007	
			Nash index	Evaluation	Nash index	Evaluation
1	Ai Nghia	Vu Gia	0,89	Good	0,86	Good
2	Cam Le	Vu Gia	0,85	Good	0,85	Good
3	Giao Thuy	Thu Bon	0,90	Good	0,90	Good
4	Cau Lau	Thu Bon	0,86	Good	0,87	Good

Testing of model simulation Mike 21FM and Mike Flood. In this model, only Cam Le hydrological station has actual water level data, so we carry out correct and verify water level (Fig. 4). Correction results for the floods on Sept 28th to 1st Oct 2009 and flood control on 8–14 Nov 2007 in Cam Le are greater than 80%.



Flood in 2009 Flood in 2007

Figure 4. Correction results of water level at Cam Le station

Thus, after correction and verification, it is possible to see that the model parameters of Mike are suitable for the natural conditions of the Vu Gia-Thu Bon river basin. The flood map of the area calculated with the parameters (1) inundation area and (2) velocity field. The results of the inundation area are shown in Table 3 (columns 2 and 3) in 4 levels. To determine the suitability of the flood map, we compared the flooding altitudes with 165 flooding traces collected in the basin as well as in the city area (Lucci, 2015). The difference of the flooding altitudes is negligible (less than 1%) and is presented in Fig. 5.

Table 3. Inundation area in flood drainage options

Inundation level (m)	Current inundation area		Estimated inundation with flood P = 5% (*)	Inundation area in flood drainage options		
	Flood 2007 (P = 5%)	Flood 2009 (P = 10%)		Option 1	Option 2	Option 3
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
< 1m	30,45	23,47	26,27	20,47	16,29	6,49
1–2m	29,86	29,97	15,69	15,28	15,18	4,67
2–3m	24,58	17,37	9,61	9,35	4,81	3,05
> 3m	2,97	1,27	4,66	0,63	0,13	
TỔNG	**87,86**	**72,08**	56,23	45,73	36,41	14,21

(*)Estimated inundation depth of Da Nang city in 2030 corresponding to flooding frequency P = 5% (considering the inter-reservoir operation, city planning, and climate change)

Most of the inundation areas at level 1 (below 1 m) and level 2 (1-2 m) occupy 65-75% of the inundation area of the whole study area. In four districts, the largest inundation area is in Hoa Vang (over 40 km^2); Cam Thuy district (over 18km^2) and Ngu Hanh Son district (over 17 km^2); However, the highest density of wetlands is in Cam Le district. In the flood in 2007 (corresponding to the frequency 5%), over 54% of the inundation

area with the flood level from 0–3 m. The deep inundation in a long-lasting impacted on the socio-economic development of the Da Nang city, especially when the infrastructure is solid.

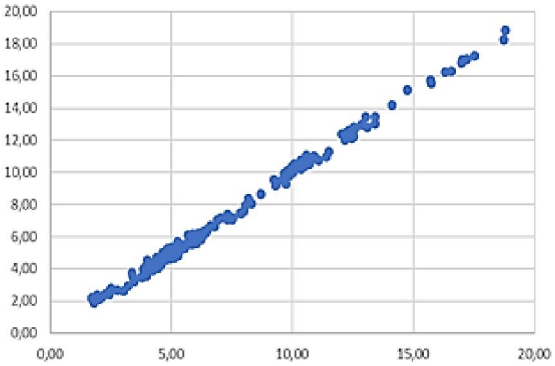


Figure 5. Correlation between flood trace elevation and inundation elevation calculated from the model

The results mentioned above will be a tool to determine the inundation map for the downstream with the floods having specified frequency to determine the flood drainage corridor with the requirements of standards for flood prevention of the Da Nang city.

The inundation level for 2030 is determined by the conditions :

- Flood with frequency 5% at Cam Thuy station has been regulated through the reservoir system in upstream using HEC RESSIM model in accordance with Decision 1537/2016 of the Prime Minister.
- Space planning of Da Nang city to 2030 Approved by the Prime Minister in Decision No. 2357/QD-TTG dated on 4/12/2013.
- Impact of climate change and SLR following scenario 4.5 of the Natural resource and Environment Ministry ((Natural resource and Environment Ministry, 2016).

The expected inundation area is shown in Table 3 (column 4) and Fig. 6.

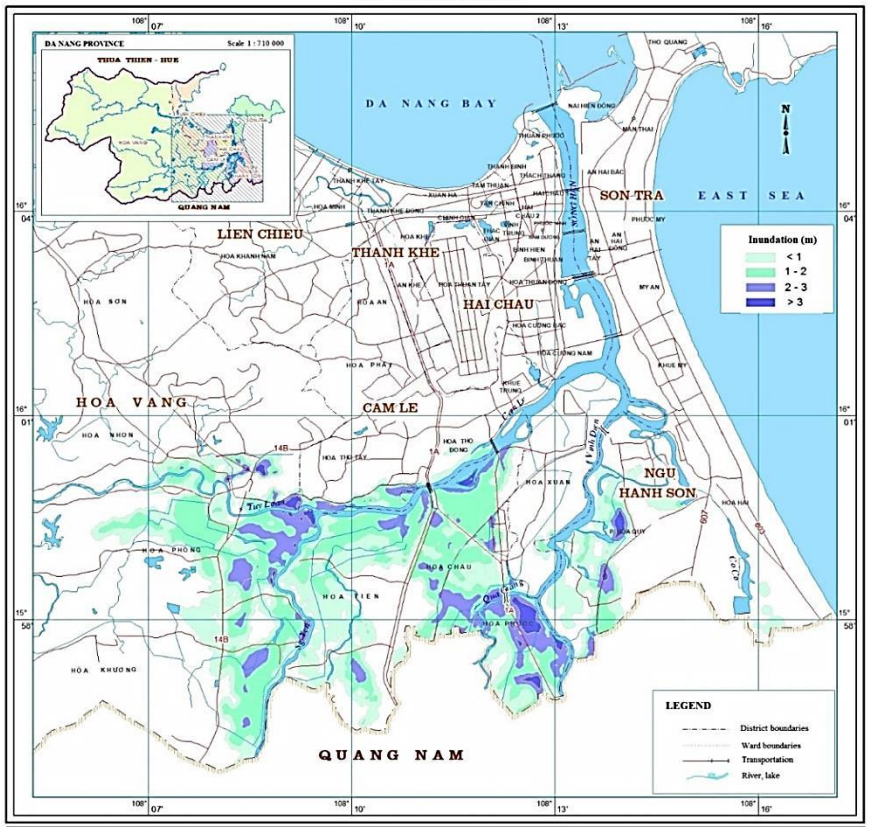


Figure 6. Expected flood map of Da Nang city to 2030

3.3. Proposing flood drainage corridor for downstream Vu Gia-Han river in Da Nang city

Based on the technical standards mentioned in Section 2.1, the flood drainage corridor of Da Nang city was determined on the sustainable development including:

(i) Option 1: Expanding the sections of Yen, Cam Le, Tuy Loan, Vinh Dien rivers and ensuring drainage corridors

According to calculations, now the sections of rivers only adapt to 5–30% of flood water corresponding to flood frequency of the flood with frequency 5%, so the improvement of river dredging solutions is essential:

- Keep the stability of current river bed, widen some narrow sections
- Create a drainage corridor with a minimum distance of 100m to each side of the river. In this area, there are no big constructions to renovate and shape the riverbed but only to build the coastal protection works as well as some important social and cultural works which cannot be relocated.
- No permanent constructions, no perennial trees and moving gradually people out of the area of the flood drainage corridor to ensure the safety of life and property and increase the ability of flood drainage.
- Focusing attention on rural planning, especially lowland in the direction of flood flow to minimize damage to people and property.

With specific objectives, based on the measurement data we propose:

On the Yen River, the river section of Thach Bo hamlet, Hoa Tien-Duong Lam commune, Hoa Phong commune should be widened with a cross-section of at least 250 m.

The section's width of Cam Le River in the area of Cam Ne Hamlet and Hoa Tien Commune is at least 270 m.

On Tuy Loan River, it is necessary to ensure the smallest cross section's width at the confluence area with Yen River about 110 m.

Vinh Dien riverbed should be widened at least 250 m (Hoa Chau commune, Hoa Quy ward).

Creating a drainage corridor along two riversides (adapted to Da Nang's urban development planning in creating green parks along the banks of Cam Le, Han, Vinh Dien and Co Co rivers) ensure the flood drainage flow to the sea and does not affect to the other areas along the river (Prime Minister, 2013).

Using the calculation tool with the identified scenario up to 2030 (section 3.2), the inundation area will decrease negligibly (column 5) and hardly decrease at a depth of 1-3 m. This indicates that we can not reach to the desired requirements if only relying on the drainage of the current riverbed.

(ii) Option 2: Formation of the flood drainage channel system along with the widening of the river cross section as mentioned above *option1*.

Along with the expansion of riverbed, it needs to build drainage channels with a total length of 14.4 km, include 2 channels from Yen river and Cam Le river to Vinh Dien river:

- Channel 1 is 4.2 km long, draining water from the upstream Red Bridge to the Vinh Dien River.
- Channel 2 is 10.2 km long, draining water from inundation areas of Hoa Phong commune, Hoa Tien district out to Qua Giang and Vinh Dien river.

Combining two options, the estimated inundation area is significantly reduced, especially in the submerged area of more than 2m (column 6). However, this combination still does not guarantee flood drainage according to local flood prevention requirements.

(iii) Option 3: Set aside flood-slowing areas in combination with flood drainage canals.

For communes frequently flooded in Hoa Vang district, the people have selected to live with floods, arranged suitable crops to avoid floods (Da Nang Statistical Office, 2016). Based on the map of current land use status in 2015 (Fig. 1), it is proposed to retain 1,400 ha of agricultural land in Hoa Phong, Hoa Tien, Hoa Chau and Hoa Phuoc communes which are the floodwater storage spaces in a maximum of 32 hours:

- Hoa Phong area is 294 ha, between the Yen and Tuy Loan rivers. Flood water comes from the convergent point of the Yen and Tuy Loan rivers. After the flood peak time, the water from these areas comes back to the Tuy Loan River flowing to the drainage channel.
- For areas affected by floodwaters from Cam Le, Qua Giang, and Vinh Dien rivers, the main flood direction is from the west to the East. We proposed an area of 794ha (in Hoa Tien, Hoa Chau, Hoa Vang district) for agriculture to ensure water storage space.
- For areas affected by floods from Vinh Dien, Co Co rivers, we should keep an area of 300 ha in Hoa Phuoc commune, not concretized to store floodwater and then flood water is drawn into the Vinh Dien river.

The flood mitigation results of the Option 3 presented in column 7, Table 3, have shown that the submerged area is basically solved. However, the inundation area of 11ha in Hoa Cuong Bac ward (Hai Chau district) is still flooded in about 8 hours.

This submerge area is mainly due to the rain and the old drainage system which do not adapt to drainage capacity of the area. The areas such as Hoa Xuan (Cam Le district), Khue My (Ngu Hanh Son district) are resolved relatively well with the drainage channel system. Some small areas are still in an inundation due to the rain.

Thus, it can be seen that for each of the above-mentioned options, the inundation problem of downstream Vu Gia-Han River has not been resolved thoroughly. Therefore, the flood drainage corridor for the Vu Gia-Han basin will be the combination of all three above solutions as in Fig. 7.

Hence, the floods with the frequency of 5% at Cam Le station, and inundations of the downstream Vu Gia-Han River in Da Nang city are controlled and responds actively.

4. Conclusions

In recent years, the rapid urbanization of Da Nang city, the operation of large hydropower plants on the upstream and the impact of climate change, sea-level rise has caused a great effect on the variation of flood and inundation. The flooding area is less in narrow (79% of reduction and the flood pattern) but greater in deep, and the flooding time tended to longer. Consequently, for an adaption to floods, we need control flood as one of the objects in the urban. Application of mathematical models, including HEC Ressim reservoir system simulation, Mike Nam, Mike 11, Mike 21FM and Mike flood and the geographic information systems (GIS) has simulated almost exactly the variation of flood and inundation in the downstream Vu Gia-Han river in Da Nang city in the whole Vu Gia-Thu Bon basin. A downstream floodplain scenario up to 2030 has been built under the impact of climate change, sea-level rise and urban development planning for Da Nang city. Based on the current land use situation, this paper proposes appropriate plans to ensure the sustainable socio-economic development as well as avoid the increase and prolonged inundation in the upstream areas. (i) widening the narrow pass of riverbed and the water protection corridor of 100m in width along two river banks (green park); (ii) building 5.9 km of drainage channel for the land between Yen-Cam Le-Qua Giang-Vinh Dien rivers and (iii) forming 1,400 ha of agricultural land in Hoa Phong, Hoa Tien and Hoa Chau communes and Hoa Phuoc as flooding the reservoir for up to 32 hours maximum.

In development processes, a series of urban centers and central key economic zones have formed. Floods have frequently caused great damage to the society as well as the environment and are increasing in intensity, time and level of damage. However, the determination of flood drainage corridors in these areas is almost wholly lacking. Therefore, this research result will be a contribution to the development in the method of calculating flood drainage corridors from the point of view of flood management and control for sustainable socio-economic development of short and steep river basins in the central region of Vietnam.

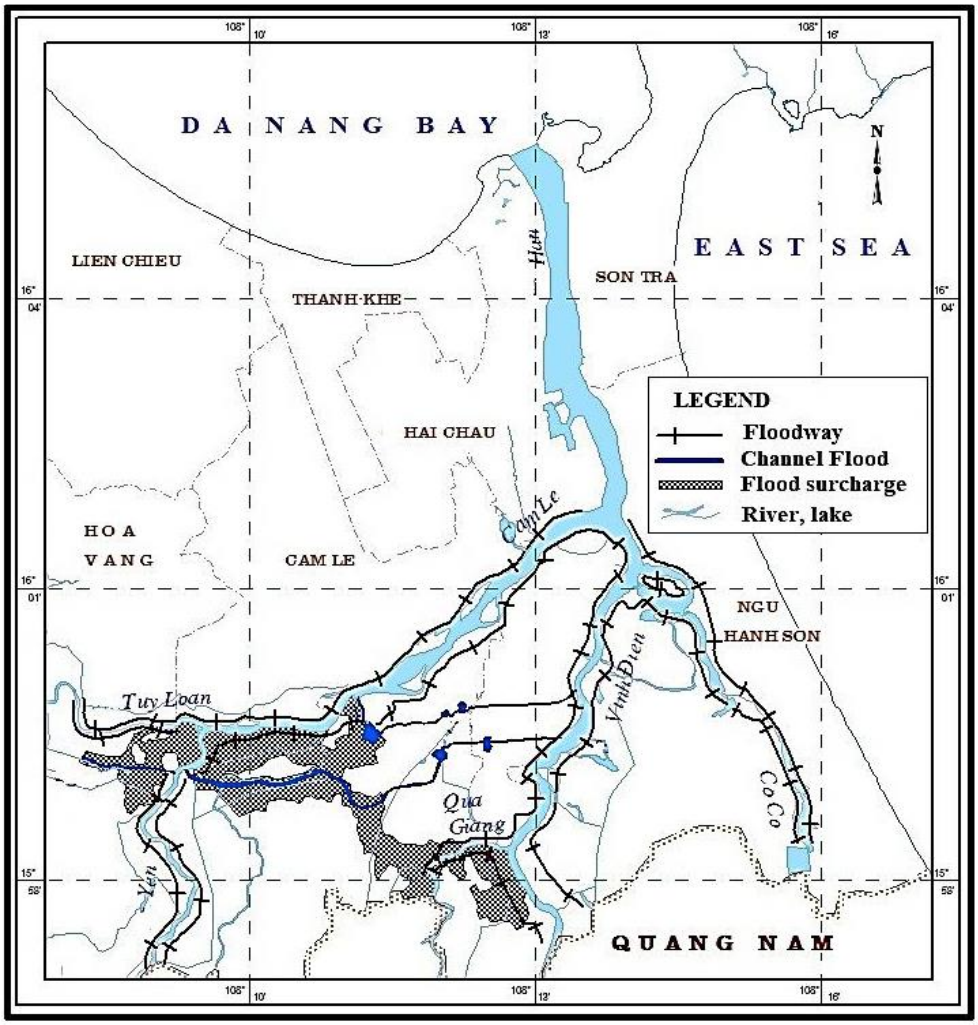


Figure 7. Flood control corridor planning map of downstream Vu Gia-Han river in Da Nang city corresponding to the flood frequency 5%

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