Structural and Non-Structural Approaches as Flood Protection Strategy in Muara Angke Settlement, North Jakarta

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Flood has become a threat in the Northern part of Jakarta due to sea level rise, land subsidence, and extreme rainfall at present. Muara Angke is a region where land subsidence rate is about 12 cm/year, its location is adjacent to Pluit settlement, in North Jakarta. This region is a delta where surrounded by Asin River in the east, Adem River in the west, and Jakarta Bay in the north. Initiall, Muara Angke had an area of 62 ha in 1977, but it has grown to be 71,7 ha at present, consists of fishing settlements, fishing port and industries, bus terminal, and mangrove forest. As a delta, Muara Angke has become a flood prone settlement, so that several events of flood occurred. Therefore it is necessary to develop environmental protection and management to protect the settlement and fishing industries from floods.

The objective of this research to identify the kind of flood protection approaches and management of environmental to prevent flooding. This research was conducted with qualitative research method. Data were collected through depth-interviews with stakeholders and community leaders, survey to observe the recent condition of environmental protection system, and documentation about flood protection system which had been built . The result of this research, Muara Angke has structural and non-structural approaches to protect the environmental from the threat of flooding. Structural approach which uses a polder system, consists of flood retention pond, Waste Water Treatment Plant, two pumping stations which each station has four pumps, drains, and dike or seawall surrounding this region. Non-structural approach is relationship between Technical Unit of Muara Angke (government officials) and communities, their participation to maintain the settlement such as planting mangroves by the youth group, cleaning ditches before the rainy season come, and dissemination to communities. This study is useful to characterize of the flood resilience in flood prone fishing settlement.

Keywords: *flood protection strategy; non-structural approach; structural approach*

1. INTRODUCTION

Flood in Jakarta is not a new problem, but a latent problem. Dozens of the previous centuries, when it was still in the territory of the Kingdom Tarumanegara in the 5th century, the city was often flooded. During the Dutch colonial ruled in Batavia, the city was also flooded several times. The last major flood occurred in 1996, 1999, 2002, 2007, and 2013 (Zaenuddin, 2013). The phenomenon of coastal flooding occurs due to various factors, namely land subsidence, sea level rise, higher rainfall and river estuaries experiencing silting (Hidayati, et al., 2012). Land subsidence occurs due to the recent tectonic activity, earthquakes, unstable soil compaction, and the effects of human activities such as building loads and extraction of ground (Diposaptono, 2011). Land subsidence in the period of 2006 to 2007 approximately was ranging from 0 to 12 cm/year in Jakarta (Yoichi, 2009). Greatest land subsidence can be found in Penjaringan, Tanjung Priok, and Cakung (Bimantara, 2012). Meanwhile, the sea level rise in Jakarta Bay average was 1.45cm/year during the years of 2005 to 2011 (Hadi, et al., 2012).

Muara Angke is a delta in North Jakarta where surrounded by Asin River in the east, Adem River in the west, and Jakarta Bay in the north. Fishing port of Muara Angke was built since July 7, 1977, this region was prepared to accommodate the fisheries that spread over several locations in Jakarta. Muara

Angke has been designated as a center of fisheries development in Jakarta since 1990. At present, Muara Angke has grown to be ±71.7 hectares, it consists of fishing settlements, fishing port and industries, bus terminal, and mangrove forest. This delta had also several event of floods which be caused by land subsidence, heavy rain, spring tides, sea level rise, siltation of rivers and dike destroyed. If Jakarta experienced significant flooding, the flood will occur also in Muara Angke. City Government of Jakarta (DKI Jakarta) which represented by Technical Unit of Muara Angke (UPT Muara Angke) have developed a protection strategy of settlements as structural and non-structural approaches. They have constructed a polder system as structural approach, it consist of levees, reservoirs, and pumping station. They have also been collaborating with communities cope the flood as non-structural approach.

This paper will describe result of study on the flood protection strategy in Muara Angke as a flood prone region. This result will elaborate the types of structural and non-structural approaches to cope the flood. Findings of this research will contribute to the knowledge on the characterize of the flood resilience in flood prone fishing settlement.

The following are the research objectives :

a. to study the knowledge about flood hazard mitigation in flood prone settlement;

b. to identify the kind of structural approach which protect the settlement from flood ;

c. to identify the kind of non-structural approach which protect the settlement from flood.

This research was conducted with qualitative research method on the basis of data related to the kind of structural and non-structural approaches to cope the flood. Data were collected through depth interview with stakeholders who consist of some employees of Technical Unit of Muara Angke and community leaders. Data were also collected through survey to observe the recent condition of environmental protection system from flood. At the same time, literature review about flood hazard mitigation was studied.

2. LITERATURE REVIEW : FLOOD HAZARD MITIGATION

Coasts are highly dynamic and geo-morphologically complex systems, which respond in various ways to extreme weather events. Coastal floods are regarded as among the most dangerous and harmful of natural disasters (Douben, 2006). It has been well known that the urban areas adjacent to the shorelines are associated with large and growing concentrations of human population, settlements and socio-economic activities. Human activities cause additional pressures that may dominate over natural processes. The damage is caused by flooding normally affects the environment and buildings with their contents. The amount of damage depends on the water level that reaches within the properties.

Present day problems related to the sustainable and effective management of floods should expand approach which incorporote an integrated view of strategies, policies, plans, and other measures of social and institutional character.The flood hazard mitigation can be broadly divided into structural and non-structural approaches according to whether engineering or administrative methods are employed (Thampapillai and Musgrave, 1985; Smith, 1996). Structural approaches are constructed permanent facilities to reduce the damage risk, meanwhile non structural approaches are responses to urban water problems that may not involve fixed or permanent facilities. Their positive contributions to reduce the damage risk are most likely through a process of influencing behavior, usually through building capacity in all stakeholders through active learning and appropriate and effective engagement between stakeholders (Taylor and Wong, 2002). Mixtures of structural and non-structural measures may often turn out to be the economically most attractive way of coping with floods.

2.1. Structural Approaches as Flood Protection Strategy

Structural measures are divided inextensive and intensive measures. The extensive structural measures include reshaping of land surface, soil conservation, flow delay, and increase of infiltration. The intensive measures consist of four categories: levees and dikes, water storage, increase of channel flow capacity, and floodplain polders and platforms. Increasing water storage pond as intensive structural measures, highly affect floods (Yevjevich, 1994). The advantages of structural approaches consist of runoff delay and increase of infiltration, flood attenuation, downstream discharge control, and ground water control. But disadvantages of these approaches consist of reduction of floodplain fertility, high potential of ecological impacts, morphological changes, and land subsidence (Petry, 2002).

One of the structural approaches which often implemented to cope with floods is polder system. Originally the name 'polder' was used in Holland nine to ten centuries ago, and was related to the land protected with dams from sea floods. Later, the same system of land protection was used on the floodplains of rivers, lakes, and shallow reservoirs, and they were called polders (Rusetski, 2009). There are three types of polders: a) land reclaimed from a body of water, such as a lake or the sea bed; b) floodplains separated from the sea or river by a dike; c) marshes separated from the surrounding water by a dike and consequently drained (Orfanus, 2009). The ground level in drained marshes subsides over time and thus all polders will eventually be below the surrounding water level. Water enters the low-lying polder through ground swell due to water pressure on ground water or rain fall and transportation of water by rivers and canals. This means that the polder has an excess of water that needs to be pumped out or drained by opening sluices at low tide, see Figur 1. Polders are at risk from flooding at all times and care must be taken to protect the surrounding dikes. The advantage of polder besides being able to control the water, polder system can also be used as a tourist attraction or recreation, agriculture, fisheries, and industrial and office environments. The disadvantage of polder system relies heavily on the pump. If the pump is off, then the area will be flooded, so it is necessary to control the pump. In addition, operating and maintenance costs are relatively expensive.

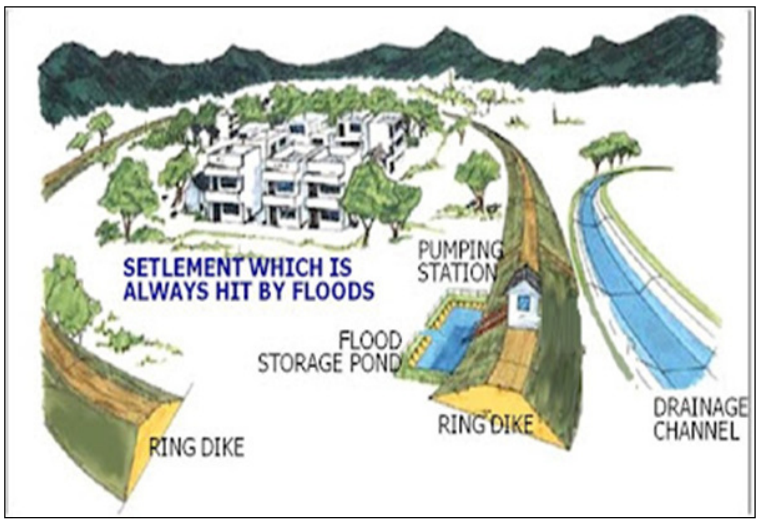

Figure 1. Polder system consists of ring dike, flood storage pond, and pumping station

(Source : The final report "Polder system in Pantai Indah Kapuk",
Research and Development Center of Water Resources, 2005)

2.2. Non-Structural Approaches as Flood Protection Strategy

There are three categories of non-structural measures : a) regulation for proofing of floodplains (zoning, coding); b) defense from floods (education and awareness, forecasting, warning, flood proofing, evacuation, relocation); c) and fiscal strategies (insurance, grant, a referendum to dedicate funding). Zoning or land use policies and regulations, such as development restriction, clustering, density bonuses, and transfer of development rights, can reduce the negative impacts of flood events by directing growth away from susceptible areas. Proactive land use planning strategies that steer development away from vulnerable areas can not only reduce flood damage, but also protect critical natural habitats and water quality (Whipple, 1998). Education can include printed materials, websites, training workshops, etc. Flood warning and forecasting are commonly used by local government to gather data, assess structures, and predict the consequences of flood events. Fiscal strategies can involve a referendum to dedicate funding for flood mitigation programs. Another type of fiscal strategy is to obtain government funding, where city government funds can be allocated to local jurisdictions for specific flood mitigation initiatives (Brody, et al., 2010).

The advantages of non structural approaches consist of improved organizational relations in the area, no significant environmental changes, and effectivity in dealing with flood impacts and damages. But disadvantage of these approaches consist of raise of property value and invasion of floodplains, and higher level of insurances coverage needed (Petry, 2002), see Table 1. The definition of strategies and policies for flood control is not an easy task and still represents an important challenge at present and for the future. Consideration has to be given to many aspects such as local conditions, awareness and concerns of population involved, availability of resources, advantages and negative impacts of adopted measures and the variable nature of social and economic perceptions and awareness.

Table 1. An overview of structural and non-structural approaches

MEASURES TO COPE WITH FLOODS	STRUCTURAL	NON-STRUCTURAL
Classification	**Extensive** – reshaping of land surface – protection from erosion – delay of runoff processes – increase of infiltration – urban works **Intensive** – levees, dikes, floodwalls – dams and reservoirs – floodways and diversion works – polders and fills – drainage works	**Regulation** – zoning/land use planning – coding **Flood defence** – education and awareness – flood forecasting/ warning – flood proofing – evacuation – relocation **Fiscal strategies** – insurance or grant (governmental, private, mixed) – a referendum to dedicate funding for flood mitigation
Advantages	– runoff delay and increase of infiltration – flood attenuation – downstream discharge control – groundwater control	– no significant environmental changes – improved organizational relations – effectivity in dealing with flood impacts and damages
Disadvantages	– reduction of floodplain fertility – high potential of ecological impacts – land subsidence – high financial or costly	– raise of property value and invasion of floodplains – higher level of insurance coverage needed

(Source : Petry, 2002; Brody, et al., 2010)

3. MUARA ANGKE AS FLOOD PRONE SETTLEMENT

Jakarta is located in a flat low-lying fan-shaped region intersected by thirteen rivers originating from the mountains to the south. Every year, large parts of the city are flooded during the rainy season. Muara Angke is located in North Jakarta, Pluit Village, Penjaringan Sub District, and as a delta at the edge of the Jakarta Bay. This delta is surrounded by Asin River in the east, Adem River in the west, and Jakarta Bay in the north A delta is an area where the river sediment is building out intothe sea. Deltas are biologically rich and diverse systems with waterflows, fish and vegetation, and they support a large economic system based on tourism, agriculture, hunting, fishing, harbour and industry development (Prakasa and Murty, 2005). Consequently, deltas are often densely populated (Ericson et al., 2006). Many people in deltas are already subject to flooding from both storm surges and seasonal river floods.

Muara Angke was built since July 7, 1977, this region was prepared to accommodate the fisheries that spread over several locations in Jakarta. Muara Angke has been designated as center of fisheries development in Jakarta since 1990. Initially, this region had an area of 62 ha, but Jakarta Government reclamated this region in 2006, so that this area covering ± 71,7 ha at present (see Figure 2). This region consists of fishermen housing (21,2 ha), fish landing bases (5 ha), mangrove forests (8 ha), fish processing (5 ha), ship docking (1,4 ha), vacant land (6,7 ha), market (1 ha), terminal (2,6 ha), soccer field (1 ha), and ferry ports to Thousand Islands (2 ha). Muara Angke had been managed by Environmental Management Body of Muara Angke from 1977 to 1994, and since 1995 it has been managed by the Technical Unit of Muara Angke who represents the City Government of Jakarta.

Flooding occurred several times in Muara Angke, the last floods occurred in 1999, 2002, 2007, 2012, and 2013. Flooding occured due to several factors such as spring tide, heavy rainfall, land subsidence, river silting, garbage piled up, and the dike collapse. The land subsidence of Muara Angke is about 0-12 cm/ year (Yoichi, 2009). Flood elevation of tidal flood is about 20 cm, and elevation of the last flood in 2012 varied about 40 cm, this flood was caused by heavy rainfall and dike collapsed (see Figure 3). Technical Unit of Muara Angke have collaborated with theMinistry of Public Work in order to cope the flood in this floodplain. They have constructed a polder systemwhich consist of dikes, two flood storage ponds, two pumping stations beside the ponds, several pumps, and several canals.

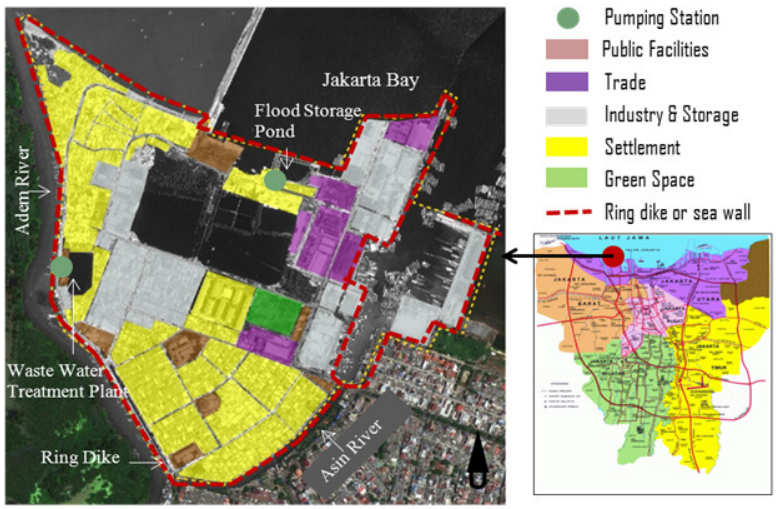

Figure 2. Muara Angke is a delta in North Jakarta

(Source : Technical Unit of Muara Angke, 2011)

Figure 3. Flooding in Muara Angke, December 2012
(Source : foto.detik.com & merdeka.com)

4. ANALYSIS OF FLOOD PROTECTION STRATEGY IN MUARA ANGKE

In Muara Angke, strategy of flood hazard mitigation can be broadly divided into structural and non-structural approaches. Mixtures of structural and non-structural measures may turn out to be the economically most attractive way of coping with floods.Technical Unit of Muara Angke has sustainable responsibility to manage and maintain this settlement from floods. Therefore, the Technical Unit of Muara Angke has collaborated with the Ministry of Public Work and some technical consultants in order to construct the structural approach with a polder system, and the other hand, collaborated with communities to flood hazard mitigation as non-structural approach (education, dissemination, etc).

4.1. Polder System as Structural Approach

Based on interviewed with some employees of Technical Unit of Muara Angke and community leaders, they cope the flood with structur approach which use a polder system. The following are the polder system in Muara Angke :

a. A flood storage pond or retention pond, wide of pond is about ±3800 m^2 (80x50m^2) which be constructed in 1999. This pond is located to the west of the port, it serves to control flooding caused by rainfall and tides. It is also as a reservoir of waste water from the port, terminal, fish market, fish industries and storage. The dike of this pond has been elevated since 2003 because the water level of pond is lower than sea level. Now, it is 1,5 m higher than before (see pictures above of Figure 4).

b. Waste Water Treatment Plant (IPAL), wide of this pond is about ±7000 m^2 which be constructed in 1984. This pond is located in the traditional processing of salted fish, serves to control flooding and as a reservoir of waste water from the processing of salted fish and houses. This pond has been renovated in 2005 (see pictures below of Figure 4).

c. Two pumping stations, they are located on the edge of flood storage pond and Waste Water Treatment Plant. Each of pumping station has four pumps, two pumps operate to pump water from the pond to the sea (flood storage pond) and to Adem River (IPAL). In the flood storage pond, there are two electricity pumps which velocity of 250 litre/second and two diesel pumps wich velocity of 500 litre/second. Two pumps operate at 6.00 am until 3.00 pm in dry season, meanwhile they operate for 24 hours in rainy season.

d. Ring dike, wide of the dike is 744.240 m^2 to protect the Muara Angke settlement from the ocean waves and overflow water from two rivers (Adem and Asin River) in the surrounding. Muara Angke is protected with break water from the ocean waves.Wide of break water which be the edge of Jakarta Bay is 633.000m^2 in the west and 746.000 m2 in the north.

Figure 4. Flood storage pond and waste water treatment pond with their pumps

(Source : Field observation, 2013)

Figure 5. Ring dike or sea wall to protect port and settlement

(Source : Field observation, 2013)

4.2. Cooperation of Government and Community as Non-Structural Approach

In Muara Angke settlement, City Government of Jakarta which represented by the Technical Unit of Muara Angke has collaborated with communities to cope the flood, this strategy as non-structural approach. The Technical Unit of Muara Angke has several activities to preserve settlement of the threat of flooding. The following are the activities :

a. Dredging waterways, Muara Angke consists of several waterways which connect drainage systems from land to Jakarta Bay. The water flows from the land to the sea at low tide, conversely the water flows from the sea to the mainland at rising tide. Sea water flows through the waterways, leaves the mud and mixes with the sewage of the market and houses. The result causes silting of waterways, so that the Technical Unit of Muara Angke do dredging of waterways periodically.

b. Maintenance of retention pond and Waste Water Treatment Plant, these activities consist of cleanup the trash of the ponds, dredging the ponds periodically, and maintenance of the pumps.

c. Cleaning and transportation of garbage, there are $43m^3$ bins around the fishing port, fish industries, and market at every day. Garbage piled up can clog drains and causes odor. Therefore, the garbage is transported and disposed to landfill (TPA).

d. Promoting the net movement in the community, these activities consist of planting trees along the roads, clean up the port and surrounding together with communities as sustainable program, notification to maintain cleanliness with posters and banners were installed in several places, and race hygiene for the communities.

e. Meeting the community leaders and explained to them about causes of flood, what should people do when event of flooding and post-flood, and teached them the methods of flood socialization to the communities.

Based on interviewed with the head of family welfare education and committe of community organization, the community activities which have been done to cope the flood as non-structural approach as the following :

a. Mutual aid activities which be done by communities once in two months such as cleanup the ditchs and roads in front of their houses, especially before rainy season comes.

b. Dissemination to communities about the flood and how to cope with flood through meeting periodically with mothers of organization of family welfare education, giving information to mothers at infant health service activity, and explanations to teachers and pupils in the pre-schools. They have cooperated with Indonesian Doctors Association, Holy Mother Foundation, etc to conduct socialization.

c. Providing suggestions to the deliberations of region development which be in the village. They have given suggestions such as repairs and raising of the main roads in order to protect their settlement from flood. Government have financed the cost of main road improvements.

d. Discussion with residents to improve and elevate the roads in front of their houses in order to protect them from flood. They shared the cost of the road improvements to each of family in the communities.

e. They have invited youth through youth organizations to plant mangrove trees at the edge of the pond near the flats.

f. When event of flooding, they built soup kitchen through collaboration with the head of village and sub district, also the Technical Unit of Muara Angke. They have received assistance packages from outsiders and distributed to the communities. Contents of packages such as instant noodles, rice, sugar, mineral water, medicines, toiletries, blankets, etc.

The Technical Unit of Muara Angke has a master plan for the next 5 years, zone of dense residential at present will be changed become flats, green yard, and recreational place of eco-marine to decrease impact of flood damage. The weakness of the non-structural approach is the financial strategy because all of public buildings and houses have not been covered by insurance. Similarly, communities are difficult to obtain the financial aid or grant to repair their houses, post-flood.

5. CONCLUSION

Flooding occurred several times due to several factors such as spring tide, heavy rainfall, land subsidence, river silting, garbage piled up, and the dike collapse, in Muara Angke. City Government of Jakarta (DKI Jakarta) which represented by Technical Unit of Muara Angke (UPT Muara Angke) have developed a protection strategy of settlement with structural and non-structural approaches. Structural approaches are constructed permanent facilities to reduce the damage risk. The advantages of structural approaches consist of runoff delay and increase of infiltration, flood attenuation, and ground water control. But disadvantages of these approaches consist of reduction of floodplain fertility, high potential of ecological impacts, land subsidence, and costly. Meanwhile, non-structural approaches are responses to urban water problems that may not involve fixed or permanent facilities, such as regulation for proofing of floodplains, defense from floods (education and awareness, forecasting, warning, evacuation, relocation), and fiscal strategies. The advantages of non-structural approaches consist of improved organizational relations, no significant environmental changes, and effectivity in dealing with flood impacts and damages. But disadvantage consist of raise of property value and invasion of floodplains, and higher level of insurances coverage needed.

Technical Unit of Muara Angke copes the flood with structur approach which use a polder system. Polder consists of a flood storage pond, Waste Water Treatmant Plant, two pumping stations with four pumps in each station, and ring dike. The Technical Unit of Muara Angke has several activities to preserve settlement of the threat of flooding as non-structural approach, such as dredging waterways, maintenance of the ponds, cleaning and transportation of garbage, promoting the net movement in the community, and meeting the community leaders to teach them to cope the flood. It has collaborated with community organization to cope the flood. The community activities consist of mutual aid activities to clean ditch, dissemination to communities, giving suggestions to the deliberations of region development, discussion with residents to improve and elevate the roads, youth organization plant mangrove trees, and they built soup kitchen when event of flooding. The weakness is the financial strategy because all of public buildings and houses have not been covered by insurance.

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