Critical-phase sea dike construction of NCICD program in Jakarta as national capital city

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Abstract. National Capital Integrated Coastal Development Program (here in after called NCICD Program) in Jakarta as National Capital City has main function for flood protection and to countermeasure the land subsidence purposes. According to Bappenas (National Planning Agency), the Updated-Masterplan NCICD program has three phases; 1) Critical-phase 2) Mid-term phase 3) Option-phase. The critical-phase sea dike construction is projected to protect Jakarta until 2030. Land subsidence is the main factor that the critical-phase of sea dike must be constructed. Jakarta sinks down with the range of 2-20 cm/year. Therefore, the existing dike level also becomes lower along the time. Three focus area of sea dike construction under Ministry of Public Works and Housing (here in after called PUPR) are Muara Kamal, Kalibaru, and Muara Baru. At the moment, PUPR concentrates in Kalibaru and Muara Baru with the physical construction progress around 48% from the total length 4-8 km and it will be finished in 2019. These are essential due to many people live there. The construction of typical sea dike is spoon-pile with shifting construction to the sea between 50 m-100 m from mainland with the crest level +4.8 m from Lowest Water Spring. This type is chosen due to its efficiency on spatial and preventing social conflicts. In addition, the space between the main land and the spoon pile will be nourished by the sand to use it for public infrastructure, such as park. The material behind the dike and the toe protection in front the dike is used for stability purposes, avoid scouring, and reducing wave energy interact the dike itself.

1. Introduction

Jakarta is the national capital city of Indonesia, where the activity center of economy from regional, national, and international scale is located in this city. Jakarta has population about 9.5 million people [1]. According to Presidential Decree no. 54, 2008 Jakarta is one of the strategically area. Jakarta has coastline about 32 km and geographically has borderline with Bekasi City in Eastern part and in the Western part with Tangerang City. Nowadays, more than half of population in Jakarta lives in the coastal area.

The coastal zone area in the Northern Part has potential to be developed. In this area, port, warehouse, and trade center are located in the Northern Part of Jakarta. However, Jakarta in the Northern Part is also vulnerable of flooding from the river side and flooding from the sea side. In 1990 only 12% or about
1600 Ha land in Northern Jakarta is below sea level, the projection in 2030 almost 90% or 12500 Ha land in Northern Jakarta will be below sea level. In addition, the rate of land subsidence about 2-20 cm/year will cause river cannot flow to the sea gravitationally and hence it will lead to flood event from river side [1].

The current flood defenses in the coastal zone of Jakarta do not provide sufficient protection against flood. The coastal zone has subsided in the last decades and it is expected to continue doing so at an average rate of about 7.5 cm per year. At the same time, the crest level of sea dike will also decrease and it will lead to the flooding from sea side.

At the moment three focus areas of sea dike construction under Ministry of Public Works and Housing are Muara Kamal, Kalibaru, and Muara Baru. The selection of these are essential due to many people live there. This paper discusses the critical-phase of physical sea dike construction; parameter for boundary condition, design consideration, and progress construction. NCICD program has two main program; (1) No-regret Measure (2) Conditional Measure. No-regret Measure is obligatory program, where the program has to be conducted. Conditionl Measure is the program, where the program should be conducted if land subsidence can not be controlled. Figure 1 shows the development plan of NCICD program with conditional measure included.

Figure 1. NCICD masterplan program.

2. Literature Review

2.1. Updated-masterplan of NCICD

According to National Planning Agency of Indonesia, the Updated-Masterplan NCICD program has three phases; 1) Critical-phase 2) Mid-term phase 3) Optimum-phase [2]. The Critical-phase of sea dike is a compulsory phase, where the sea dikes have to be constructed, elevated, and strengthened the existing sea dike. The length of critical sea dike is about 20.1 km and it should be finished by 2019. The critical sea dike is constructed by the government (DKI Regional Government and Ministry of Public Works and Housing) and the private company.

The main functional requirement of NCICD is that to provide protection against flooding in the long-term period. The master plan has to be integrated solution from the upstream to the downstream area; beside engineering aspect, the environmental, regulation, socio-economic conditions are also considered. Figure 1 shows the design concept of how the NCICD will be developed in the long-term period plan.
2.2. Boundary condition
The crest elevation of the dike is based on the boundary condition of the coastal area [3]. The dike design is based on the tidal condition in this case we use Highest Water Spring (HWS), Extreme Wave Condition (EWC), Sea Level Rise (SLR), Land Subsidence (LS), Free Board (FB), and Wave Run-up (WR). HWS is the tidal analysis results, where we pick the highest value of the tidal during spring tide period. EWC is wave design with the return period 1:10000. Rate of SLR, the dike design is based on the IPCC projection. Rate of land subsidence is based on the land subsidence modeling.

\[ \text{Crest Elevation} = \text{HWS} + \text{EWC} + \text{SLR} + \text{LS} + \text{FB} \]  

(1)

2.3. Land subsidence
Coastal regions are increasingly exposed to flood damages due to growing population assets, rising sea levels and possibly more frequent and intense storms. Flooding in the context of future storm variability, sea-level rise and shoreline change is one of the most important issues facing coastal populations today. Flooding in Indonesia comes from the upstream due to heavy rainfall or from the sea side due to the high tides event as well as significant sinking of the land down below the sea level. There is a correlation between population growth and land subsidence in coastal areas (see Figure 2) [4]. They argued that the subsidence is primarily caused by excessive ground water extraction for industrial, water use, and agricultural use. According to population data density in 2000 consensus, population density in Java Island (about 250 to 999 person/km²) is higher than Sumatera Island (about 25 to 249 person/km²). Therefore, it indicates that the higher dense of population, the higher rate of land subsidence due to groundwater depletion.

3. Results and Discussion
3.1. Field situation and existing sea dike condition in 2013
Figure 3 shows the first survey was conducted in March-April 2013 and covered public areas within the area of DKI. The second survey was conducted in September 2013 covered privately owned areas,
Tangerang, and Bekasi. Figures 4 and 5 show field situation of Jakarta coastline in Muara Baru and Kalibaru respectively. These both figures show the area condition where the critical dike before constructed. In addition, the areas are also dense populated. The existing dike showed that the inland area is below the sea level. Therefore, the critical situation has to be solved by constructing the dike. Red circle and green circle show the area where the coastal dike will be constructed but by the private sector.

**Figure 3.** Field survey map location in 2013.

**Figure 4.** Field situation of dike in Muara Baru (Pluit Area).
Figure 5. Field situation in Kalibaru.

Table 1. Average height of coastal protections (from west to east)

| Section                  | Average height | Type of protection | Remarks                                         |
|--------------------------|----------------|--------------------|-------------------------------------------------|
| Teluk Naga (Survey II)   | 1.0 m +LWS     | Mangrove           | Fish ponds                                      |
| Tangerang (Survey II)    | 1.4 m +LWS     | Mangrove           | Fish ponds                                      |
| Pantai Indah Kapuk (Survey II) | 1.1 m +LWS | Mangrove           | Mangrove reserve, dike further inland          |
| Pantai Indah Kapuk (Survey I) | 3.7 - 4.0 m +LWS | Dike              | High end housing                               |
| Muara Karang             | 1.4 - 1.7 m +LWS | Seawall           | Housing                                         |
| Muara Karang (Survey I)  | 3.0 m +LWS     | Seawall           | PLTU                                            |
| Pantai Mutiara (Survey II) | 1.2 m +LWS | Seawall           | High end housing                                |
| Pluit (Survey I)         | 1.6 - 1.9 m +LWS | Seawall           | Fishing port                                    |
| Ancol (Survey II)        | 1.5 m +LWS     | Waterfront/Beach   | Recreational area                               |
| Tanjung Priok            | No data        | No data            | No data                                         |
| Kalibaru (Survey I)      | 2.5 m +LWS     | Sea dike/land reclamation | Land reclamation from crab-materials |
| Marunda (Survey II)      | 2.7 m +LWS     | Quay walls         | Port area, PLTU                                 |
| Bekasi (Survey II)       | 0.7 m +LWS     | Mangrove           | Fish ponds                                      |
At some locations (Teluk Naga, Tangerang, Pantai Indah Kapuk, Bekasi) the actual coastal protection is located further inland. At these locations the approximate topographical level at the coastline is provided in Table 1. The current design water level is approximately 1.7 m +LWS2012. Crest levels should be higher to accommodate for wave run-up. Crest levels are close to the current design water level at most locations. This means that a combination of high water and strong waves may lead to overtopping and inundation of the areas. To the east (Bekasi) and west (Tangerang and Kapuk) large mangrove areas and fishponds are present. These rely on a frequent inundation of seawater. A coastal flood defence might be found further inland. However, topographical elevations may be high enough so inundation will not occur further inland at present.

At Muara Karang, Pantai Mutiara, Pluit and Ancol existing protection levels are dangerously low. At present they are already below the design water level. During combined high water and wind/wave setup or seasonal water level increase, the protections may overflow and inundate the populated hinterland.

At Pantai Indah Kapuk the coastal protection level is above the current design water level. Here the risk of overtopping is small. Also, the new port area of Marunda is constructed well above current (still water) the current design water level and overtopping is not likely on the short-term. The dike protection level at Kalibaru is approximately 2.5 m +LWS2012. It is above the current design water level. However, this land reclamation is developed using coarse material. The permeability of the material is high and therefore the construction may not be able to protect the (low-laying) hinterland from inundation.

3.2. Crest elevation
The crest elevation is based on the boundary condition of the coastal area. The critical-phase sea dike is projected to protect the inland until 2030. The parameter and the value for the dike height calculation is showed in the Table 2 below. For the wave calculation, the wave model with 10,000 years return period yields significant wave height 2.27 m around location and at the shore around 1.75 m. According to IPCC projection the SLR projection is about 8mm per year and until 2030 it will predict linearly around 0.12 m [7]. The land subsidence around location is about 100 mm per year and projection until 2030 linearly is 1.4 m.

| Parameter                          | Value (meter) |
|------------------------------------|---------------|
| Highest water spring               | 1.19          |
| Extreme wave elevation             | 1.59          |
| Sea level rise                     | 0.12          |
| Land subsidence in Muara Baru and Kalibaru | 1.40        |
| Free board                         | 0.50          |
| Dike height                         | +4.80 LWS     |

3.3. Sea dike design
The dike design at Kalibaru and Muara Baru use vertical dike at the sea side and slope dike at the land side (see Figure 6). The vertical dike at the sea side is chosen because it will reduce the space, whereas at the land side the dike has slope due to public area development later on. The dike is made from series of spun pile made from concrete with the strength K500. Between the concrete pile there is steel pile and joint the series of the concrete pile. It is constructed to provide additional strength among the series
of pile form the dike and avoid seepage. The capping beam also to unite the concrete pile series and to splash the wave impact. Toe protection and armor are located in front of the dike. This is to reduce the wave impact and to avoid local scouring due to return flow of the undertow current. Geotextile is used as the mattress below the armour. In order to minimize the seepage as well, the pile is constructed with the depth around -20 m from LWS. In addition, inside the dike is filled by clay and covered by sand and grass.
3.4. Physical construction

At the moment, PUPR concentrates the physical construction of sea dike at Kalibaru and Muara Baru. Figure 6 shows dike construction at Muara Baru and the green line is under PUPR responsibility and red line shows the construction progress. The construction shift to the sea side around 80-200 m from the current coastline due to the relocation issue. The determination of the distance is based on the field condition where the dikes are possible to be constructed. The physical construction dike is started by piling the concrete one by one until the depth -20 m from LWS. The distance between the concrete pile is around 165 mm.

Figure 7 shows physical dike construction in Muara Baru around Nizam Zachman Port. The pile is shipped by boat and one by one the pile is drilled to the ground until -20 m depth reached. The design of the dike also will accommodate the port design. The length of the dike in the inner site is longer than in the East side with the length difference is around 2,2 km. The dike design is the same along the coastal area using vertical dike design at the sea side and the slope dike at the land side.
Figure 7. Dike construction area and their process in Muara Baru.

Figure 8 shows the physical dike construction progress until July 2017. The pile is already constructed then the joint steel pile will fill up between the concrete pile and it will be tied by the ring
at the same time. Everyday we are able to pile 6 to 8 piles of concrete pile, depend on the field situation as well. Until July 2017, the physical dike construction progress in Muarabaru is about 1.2 km from 1.8 km the total length of the dike. It is both located in the western and eastern part. In particular area, if the soil is hard less than -20 m then the concrete pile will be excavated continuously until the depth reached. After the series pile are constructed then the cap beam is installed and the armour unit in front the dike will be deployed.

According to Presidential direction, the physical dike construction has to consider social, environment, economical, and regulation aspects. There are social issue at the site, where the fisherman cannot park their boat. During the dike construction they are facilitated by temporary port. Therefore, all the development design must be integrated with their program. For example, if the reclamation area behind the dike is already reclaimed by the sand then the land will be used by the Ministry for fisherman facility or another processing industry for fish packaging. However, the regulation to legalize the program, especially in spatial planning, has to be discussed with regional government DKI, PUPR, and Ministry of Marine and Fisheries. Figure 9 shows spatial planning to utilize the space behind the dike, where some areas are used for relocation, fish industry, and public space.
Figure 8. Physical dike construction progress in Muara Baru.

Figure 9. Spatial planning after dike constructed.
Figure 10 shows the physical dike construction progress at Kalibaru. The dike design and their construction process are nearly the same with Muara Baru since the typical dike design is also the same, where there is concrete pile series and steel pile in between the concrete with the same dimension. The total length of dike in Kalibaru is 4.1 km, until July 2017 the progress construction is 1.3 km. In Kalibaru behind the dike will be used for public area, for example the jogging track with the sea and apartments building as the landscape around the area, inspection road, and park. In addition, there will be prototype green facility, such as garden, around 100 m length in the certain area (see Figure 11).

Social and environmental aspects are still the big challenges at the field. We put an extra effort to convince people about the urgency of the program. Communication public is the best way to communicate before the dike constructed. In addition, the social media is also used to publish about NCICD program. Sometimes social conflict is occurred at the field, where people think that the dike construction is directly related with reclamation program. Therefore, before physical construction of the dike socialisation stage of the program is compulsory process to make people understands about the critical-phase program and to have one perspective about NCICD program. In addition, the regulation and the procedural process.
Figure 10. Dike construction progress in Kalibaru.
4. Conclusion
Critical-phase of NCICD program is a no regret policy, where the program has to be conducted in a current situation. Critical-phase of sea dike construction is one of the program. PUPR concentrates in Muara Baru and Kalibaru for the critical dike construction at the moment with the physical construction progress around 48% from the total length 4.8 km and it will be finish in the beginning of 2019. The critical-phase of sea dike is projected enable the flood defense from sea side until 2030.
The two areas selection because these are essential and many people live there. The shifting of the dike construction to the sea side is to avoid relocation issue. The sea dike design has vertical profile at the sea side and slope at the land side. The unit armors are placed to reduce wave impact and local scouring.
The additional space behind the dike, where the reclamation is conducted, will be used for public space or residential area. However, the decision for utilization of the space has not decided yet and will wait for the agreement of another ministry.

References
[1] National Capital Integrated Coastal Development (NCICD) 2014 Technical report of NCICD
[2] NCICD-Updated Masterplan Report 2016 Technical report of NCICD
[3] Shore Protection Manual (SPM) 1984 Boundary condition of sea dike design guideline
[4] Chaussard E, Amelung F, Abidin H and Hong S 2012 Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction. Remote Sensing of Environment 128 150-161
[5] Wöppelmann G and Marcos M 2016 Vertical land motion as a key to understanding sea level change and variability. Reviews of Geophysics 54 64-92
[6] National Research Council (NRC) 1987 Responding to Changes in Sea Level: Engineering Implications (Washington DC: National Academy Press)
[7] IPCC Report 2013 Projection of sea level rise.