Assessment of flood risk reduction in DKI Jakarta: Cengkareng Sub-district

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Abstract. Due to geographical condition, Cengkareng is one of a well-known flood-prone area in West Jakarta, Indonesia. Annual floods may occur due to the limited bank full capacity of the local drainage system. This flood causes a significant loss of both infrastructures and human life. One of the most significant efforts in reducing this flood risk is the improvement of Cengkareng Drain channel as the main drainage system in the area. Cengkareng Drain conveys the flow of Angke River and Mokervaart River into the Java Sea passing through Tangerang and Jakarta. This paper discusses about the contribution of several alternatives of improvement in reducing the related flood risk. The flood hazard is analysed based on the standard criteria of PUPR. The risk analysis is done in accordance to the BNPB guidebook. Based on this study, it is found that the drainage existing condition may cause a high flood risk level in 5 areas and an average risk level in 1 area. This flood risk could be reduced by applying both structural and non-structural mitigation efforts. It this case, it is found that structural mitigation of dike development combined with non-structural mitigation of local community capacity development is the most effective solution.

1. Introduction
Most of a well-known flood prone area in Jakarta is a natural floodplain as it is concluded in several previous study such as Kusuma [1], Formánek [2], Farid [3], and Tambunan [4]. Most of those floodplain areas located in the flat riverine area and in the coastal area of northern part of Jakarta. Cengkareng sub-district is a part of that area located on the west side of DKI Jakarta and nearby with Java Sea. The current flood control system is developed based on its masterplan in 1996 with several update in the last decade to encounter the influence of land subsidence. However, several flood control structures proposed in that masterplan had not been done due to the lack of funding and policy support. Furthermore, the implemented structural effort could not significantly decrease its flood risk, in Sarminingsih [5] discussed the importance relationship of flood damage factor of the flooded area. Meanwhile, Kususma [6] and Papagiannaki [7] discussed influence of the urbanization to the rate of sedimentation, solid waste and land use change that could increase the flood hazard of most developed
area. This paper discusses the alternative solution for reducing the risk of flood in Cengkareng sub-district.

According to administration’s data, 27.93 km² area is divided into 6 urban villages called Cengkareng Barat, Cengkareng Timur, Duri Kosambi, Kapuk, Kedaung Kali Angke, and Rawa Buaya as shown in Figure 1. Based on the demographic location, Cengkareng area is quite sunken and located near to the sea. Disaster hazards in coastal area such as tsunami, storms and flood are very dominant in Indonesia [8]. That is why this area is categorize a flood prone area. Hydrologically, Cengkareng is crossed by Kali Angke River and Kali Pesanggrahan through Cengkareng Drain. Kali Angke and Kali Pesanggrahan receive runoff from Bogor where the rain intensity is quite high. The rivers passed along Jakarta and empties into the Jakarta Bay. The capacity of Kali Angke has been decreasing due to the sedimentation and rubbish pile. Due to the large water load, Kali Angke never dry all year round. Capacity decreasing and huge water load lead Kali Angke to overloaded in rain season and flooding the area surround it.

Social Welfare Agency for Disaster and Flood Management (BKSPBB) has stated there are 4 regions in high-risk for flood that is coastal area, floodplain areas, river border areas and basin area. Based on Cengkareng sub-district’s demography, Cengkareng located in river border areas. Part of Cengkareng area is prone to flood risk. To reduce the flood risk disaster management is assessed to prevent extended loss. Flood risk assessment by creating risk index map in the flooded area are necessary. The result is expected to help local stakeholders to create a quick-response act to flood.

![Figure 1. Cengkareng sub-district.](image1)

![Figure 2. Disaster management cycle.](image2)

Based on guide by the Head of National Disaster Management Agency or known as BNPB [9], Risks disaster is a potential loss caused by disaster in certain area and certain time. To calculate the risks disaster, we can measure by determine the threat by using formula that multiply by vulnerability and divided by capacity. With that formula, we conclude that risk disaster is depends on threat index. Calculation of risks disaster, vulnerability, threat, and capacity index are using the data that we gathered from National Statistic Centre and local government data [10]. Flood discharge calculated using nearest rain station. Flood simulation will be modelled using HEC-RAS.

2. Disaster management and flood risk assessment

2.1. Disaster management

Disaster management cycle is shown in Figure 2. Mitigation is an effort to prevent future emergencies and take steps to minimize the effects. Preparedness is to be prepared for an emergency and able to act ahead of time to. Preparedness usually includes training, education, full-scale exercises, and others. This ensures stakeholders know how to cope with an emergency. The response is to protect people and property in the state of emergency or disaster. The action focus will gradually shift as the response stage progresses. Immediate emergency issues gradually shift to conducting repairs, restoring utilities, re-establishing operations, and cleaning up. The stakeholders will also need to be planned the reconstruction of damaged infrastructure. The final step is recovery. Recovery is to rebuild after a disaster to return operations to normal. One of the most important in flood management is flood risk assessment.
2.2. Flood hazard level
Referring to General Guidelines for Assessment of Disaster Risk, flood hazard levels are divided into 3 groups based on the flood inundation depth. Depth of <0.8m categorized as low risk, medium risk between 0.8 m-1.2 m and high risk is greater than >1.2 m.

2.3. Vulnerability analysis
To calculate the vulnerability map, four elements are used. i.e. Social, Economy, Physical, and Environment. Then these four elements are converted into a certain index to gain total assets that exposed. The social vulnerability data consist of population density, sex ratios, poverty ratios, disability ratios, and age group ratios. The data was obtained from BPS [10]. The economic vulnerability data consist of total area income per land. In this study, income per village is used. The data obtained from BAPPENAS and BPS. Each component weighs 25% according to the BNPB regulation. Physical vulnerability in this study used data of the number of buildings both public and private, permanent, or semi/non-permanent. This amount of data is calculated by using the price of the building reparations due to the damaged. Half of the construction price is assumed as the cost of the repairs. Meanwhile, environmental vulnerability data obtained from Jakarta's park and forestry. Bush data is also needed. In this study, the authors use the assumption that shrubs are 30% of the total forest land available in this sub-district by using from Google Earth as the references.

2.4. Capacity analysis
Capacity is an ability to anticipate, prevent, and recovering when disaster occurred [11]. Capacity index is calculated with institutional disaster management data (15%), early warning system and disaster risk assessment (15%), disaster education (20%), reduction of basic risk factors (25%), and development of preparedness on all lines (25%). These 5 indicators have their own percentage based on the priority that appropriate in Cengkareng area.

2.5. Risk index
Prepared by the Indonesian National Agency for Disaster Management, there is a general basic formula to compute a simple risk analysis. The formula is:

\[ R = H \times \frac{V}{c} \quad [9] \]

R is disaster risk, H is hazard and V is vulnerability. However, the scope in this study only analyse the index of the Cengkareng Sub-district. Further analysis on disaster risk study using matrix is required to determined hazard level, vulnerability level, capacity level and risk level.

3. Results and discussions
Cengkareng sub-district is passed by Kali Angke watershed. Kali Angke often overflows during the rainy season and floods the Rawa Buaya, Duri Kosambi, and Cengkareng areas. The river has a length of 91.25 km with a river drainage area of 48 km². The Soekarno-Hatta rainfall station data is used (6.1253189, 106.6590957). The data obtained from BMKG for daily rainfall data from January 2000 to December 2015. The 100-year period is used due to outdated data and climate change effects. The 100-year rainfall return period then distributed for 6 hours using the Mononobe method. Hydrograph then processed by the SCS method. The peak discharge for 100-year period is 1276.653 m³/s.

Based on the simulation in Figure 3 and Table 1, most of Cengkareng Sub-district hazard is categorized as a high index. The adjacent area around river such as Rawa Buaya, Kedaung Kali Angke, Kapuk, and East Cengkareng categorized as high. Duri Kosambi and West Cengkareng categorized as low because it located far from the river.
Table 1. Flood simulation class index.

| Location                  | Flood’s Height (m) | Score | Class Index |
|---------------------------|--------------------|-------|-------------|
| Duri Kosambi              | 0.8                | 1     | Low         |
| Rawa Buaya                | 1.3                | 2     | High        |
| Kedaung Kali Angke        | 1.3                | 3     | High        |
| Kapuk                     | 1.3                | 2     | High        |
| Cengkareng Timur          | 1.5                | 2     | High        |
| Cengkareng Barat          | 0.8                | 1     | Low         |

The result then processed into a hazard map shown in Figure 4a. The vulnerability is calculated for each category of social, physical, economy, and environment. All Cengkareng area is categorized as medium vulnerability as shown in Figure 4b.

Figure 4. (a) Hazard index; (b) Vulnerability index; (c) Capacity index; (d) Risk index.

Capacity map created using 5 components based on BNPB i.e. Disaster management policies, early warning system, people's knowledge about a disaster, reduction of basic risk factors, and the preparedness of the institution. The index for capacity varies because all urban villages do not have a similar risk factor reduction and preparedness to flood hazard (Figure 4c). Three areas in high index because they have a decent risk reduction factor meanwhile other areas did not have. Based on the hazard, vulnerability, and capacity of the area, using equation [7] risk index was obtained. Two areas have a low risk while other four areas have a high risk (Figure 4d).

4. Mitigation efforts

A comprehensive method is needed because there are many complexities issues. Giving education to local people about the importance to have a quick-response act to floods is necessary for initial step. Then early warning system is developed to increase the preparedness and to evacuate to the safest place quickly. However, this mechanism of evacuation needs to be practiced. Besides non-structural mitigation, the over-topped flow needs to be contained by dike to prevent the flood impacts. Dike is an effective mitigation plan because most of the flood occurred because the rising of sea level and land subsidence around the sub-district area. Dike also much easier than widening the Cengkareng drain because the social and economy factor and groundwater limit.

Dike construction for structural mitigation assessed in this study. Several scenarios of dike of 3 m, 5 m and 7 m are simulated using HECRAS. The risk then compared with existing scenario. As shown in Figure 5, we can see that the dike construction can decrease the inundation significantly. The affected area decreases especially in West Cengkareng Sub-District area. The 3 m dike can eliminate the risk in West Cengkareng village. However, the upstream area of Cengkareng Sub-District are still affected. The 7 m dike only affect three village districts. Dike demonstrated effectively to reduce flood by increasing the river capacity.
5. Mitigation evaluation

To achieve the target of sustainable disaster urban development, evaluations are needed in disaster management. These evaluations aim to maximize the outcome. Evaluation also become a checkpoint for each stage. The evaluation is expected to avoid accumulate mistakes that lead to difficulties in recovery. Evaluation can be done at several crucial stages. This means that the stage is a very important factor to solve the disaster problems and risks. A crucial factor that must be evaluated is the risk map. The risk map serves as a guideline for optimizing the implementation of disaster management in an area. Using risk map, mitigation plan can be implemented effectively and aligning the policy of disaster management between the central, provincial and district/city governments. The following things must be evaluated from the risk map to obtain the accurate risk map:

1. Evaluate the data and information used. The data used must come from a trusted source and the validity of the data can be accounted for. If the information about the data needed is limited, an approach with an appropriate theory can be used.
2. Evaluate threat parameters by comparing the results of modeling inundation height with actual conditions.
3. Evaluate the level of risk in the area. The way to do this is to compare the level of risk according to the risk map made with previous risk studies. Risk level trends in the region used as a benchmark.

Another thing that must be evaluated is the recommendation and chosen flood control effort. Things that must be evaluated include 3 important things are:

1. Evaluate the adequacy of the design of control activities.
   Aspects that need to be considered in assessing the adequacy of flood risk control measures include on-time, balanced, accountable, placed correctly, tools achieve results, discuss causes and effects.
2. Evaluation of control effectiveness
   Evaluate the effectiveness of control activities to determine whether the ineffectiveness of the existing control activities is due to incompatibility or inadequacy of the design or due to problems at the time of its implementation.
3. Determine the control gap.
   Control gaps are conditions that occur if risks according to priority do not have controls or controls that are inadequate to bring risks to the level of residual risk. Risks with control gaps will require improvement of control activities.

6. Conclusion

Based on the simulation and result, by conducting a 100-year period floods, 4 sub-areas in Cengkareng Sub-district are at high risk of flood. There are Kapuk, Kedaung Kaliangke, Cengkareng Timur, and Rawa buaya. While Duri Kosambi and Cengkareng Barat are in low risk. The high risk is cause by
The high hazard of flood inundation and low capacity index, while the vulnerability index is the same for all areas. To reduce the flood risk, some mitigation efforts are needed. Dike selected as the effective mitigation because most of the flood occurred because the sea level rise and land subsidence around the sub-district area. Dike also easier than normalization of the Cengkareng drain due to the social and economy factor. Dike of 3m, 5m and 7m assessed and compared to the existing risk index. The dike shown a significant effect in reducing flood height in the sub-area. Others mitigation plan also important to implemented. Local villagers need to be educated about flood and all-lines preparation to decrease the vulnerability index and increase capacity index. For further disaster management, mitigation evaluation also recommended to maximize the outcome. The key points need to be evaluated are explained in this study. A further study in needed because the proposed dike is still cause flooding in other areas outside Cengkareng Sub-district, especially in the upstream area.

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References
[1] Kusuma M S B, Rahayu H P, Farid M, Adityawan M B, Setiawati T and Silasari R 2010 Studi pengembangan peta indeks resiko banjir pada Kelurahan Bukit Duri Jakarta Jurnal Teknik Sipil 17 2 123-134
[2] Formánek A, Silasari R, Kusuma M S B and Kardhana H 2014 Two-dimensional model of Ciliwung river flood in DKI Jakarta for development of the regional flood index map J. of Eng. and Tech. Sci. 45 3 307-325
[3] Farid M, Pusparani H H, Kusuma M S B and Natasaputra S 2017 Study on effectiveness of flood control based on risk level: case study of Kampung Melayu Village and Bukit Duri Village Matec Web Conf. 101 05003
[4] Tambunan M P 2016 The pattern of spatial flood disaster region in DKI Jakarta IOP Conf. Series: Earth and Environmental Science 56 doi: 10.1088/1755-1315/56/1/012014.
[5] Sarminingsih A, Soekarno I, Hadihardaja I K and Kusuma M S B 2014 Flood vulnerability assessment of upper Citarum river basin, West Java, Indonesia Int. J. of App. Eng. Res. 9 23 22921-22940
[6] Kusuma M S B, Kurnoro A A and Silasari R 2011 Preparedness effort toward climate change adaptation in upper Citarum river basin, West Java, Indonesia Society for Social Management Systems Internet Journal 78
[7] Papagiannaki K, Kotroni V, Lagouvardos K, Ruin I and Bezes A 2017 Urban area response to flash flood–triggering rainfall, featuring human behavioral factors: the case of 22 October 2015 in Attica, Greece. Weather Clim. Soc., 9 621-638 https://doi.org/10.1175/wcas-d-16-0068.1
[8] Chrysanti A, Adityawan M B, Widyaningtias, Yakti B P, Nugroho J, Zain K, Haryanto I, Sulaiman M, Kurniawan A and Tanaka H 2019 Prediction of shoreline change using a numerical model: case of the Kulon Progo Coast, Central Java Matec Web of Conf. 270 p 04023
[9] Bencana, B N P 2012 Peraturan Kepala BNPB nomor 02 tahun 2012 tentang Pedoman Umum Pengkajian Risiko Bencana Jakarta (ID): BNPB
[10] Statistik B P 2019 Kecamatan Cengkareng dalam angka 2018. BPS Kecamatan Cengkareng
[11] Benson C, Twigg J and Rosetto T 2007 Tools for mainstreaming disaster risk reduction: guidance notes for development organizations Prevention Consortium