LAPORAN PENELITIAN INTERNAL

A Conceptual Framework of Land Subsidence and Flood Assessment toward Hazard Management

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LAPORAN PENELITIAN INTERNAL YANG BERJUDUL:

A Conceptual Framework of Land Subsidence and Flood Assessment toward Hazard Management

Ini disusun sebagai bentuk pertanggungjawaban penelitian internal telah selesai dilakukan.

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DAFTAR ISI

Abstract

Following the controversy regarding the reclamation of Jakarta Bay in Indonesia, another embedded issue about land subsidence and flood also has become the major problem. As a metropolitan city, Jakarta City faced many unsustainable urban problems especially flood and land subsidence. Therefore, the primary goal of this paper is to contribute to a broader understanding in order to connect land subsidence, flood and some geotechnical strategies within and combined with enhanced polder system as the solution offered in this paper. The general methodological procedure to develop a conceptual framework of land subsidence and flood assessment has offered in this study. Once a conceptual framework system is established, supplementary indexes for specific purposes and location can be added. For one geotechnical project, particular important variables for certain geotechnical works are needed to be selected rather than using all variables to analyze. Therefore, this paper offered an Analytical Hierarchy Process (AHP) method to be performed. Combined with Geographic Information System (GIS), the thematic maps should be developed and layered from both land subsidence and flood digital map and then assigned weights on a certain scale depending on their contribution in order to create hazard potential zone. An increasing need for integrative assessment that measures the contribution of effects of the land subsidence and flood to the design of polder system has recently been recognized. This methodology developed in this work also emphasizes the simplicity and understandability as it must communicate to decision makers and the experts.

***Keywords*—flood, hazard management, Jakarta City, land subsidence, methodology**

Introduction

The global issues about land subsidence are overwhelmingly complex [1]. It is complex because the issues are not confined to the geotechnical structures themselves but also embrace the range of social, environmental and political choices on which the human aspiration to development and improved well-being depend. Working in geotechnical engineering is challenging and intriguing because of a lot of interests involved.

In Indonesia, geotechnical issues often related to water issues, for example the issue about reclamation of Jakarta Bay. Following the controversy regarding the reclamation of Jakarta Bay in Indonesia, another embedded issue about land subsidence and flood also has become the major problem. It is known that Jakarta City is the capital city of Indonesia and the largest metropolitan in South East Asia (Fig. 1). It was inhabited by approximately 10 million persons, within area of 600 km^2. As a metropolitan city, Jakarta City faced many unsustainable urban problems especially flood and land subsidence.

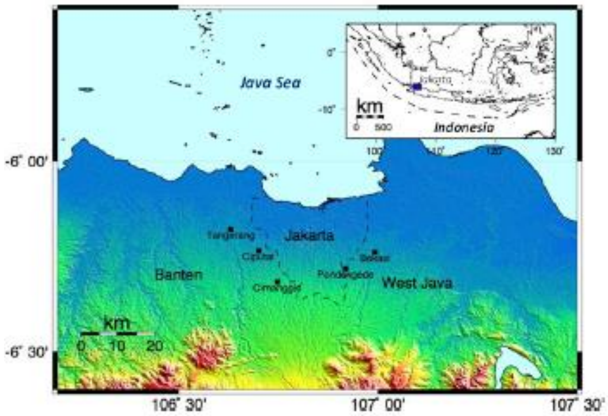

Figure 1. Location of study area (Source from: Abidin et. al., 2015)

On the other hand, polder system is an offered approach that considered appropriate and effective for flood control and supports the development of Jakarta City. Therefore, the primary goal of this paper is to contribute to a broader understanding in order to connect land subsidence, flood and some geotechnical strategies within and combined with enhanced polder system as the solution offered in this paper (Fig. 2). The paper initially develops the modest and effective methodology of assessment system in coastal urban area toward hazard management. The offered method is designed for ease of use since its main aim is as a rapid decision support tool for decision-makers.

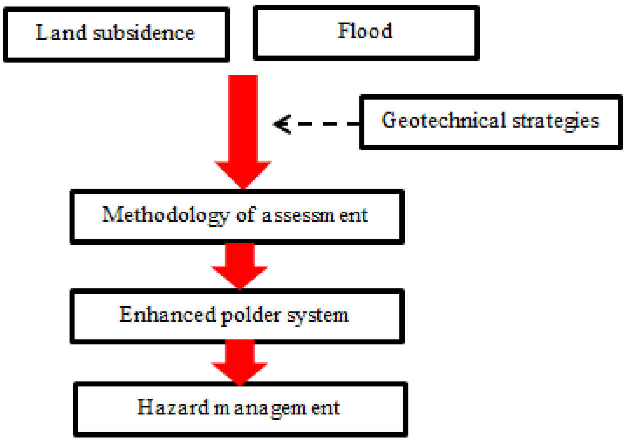

Figure 2. Flowchart thinking of the study

Conceptual Framework

The general procedure to develop a conceptual framework of assessment methodology has offered in this study (Fig. 3). Several regulations from the government should be prepared to complete literature review study. In order to check the available data, several approaches have completed: collecting secondary data from related agencies, interviews and questionnaire, official reports or academic papers. Filling gaps is necessary to do if available data and literature and regulation reviews were considered inadequate. In context of design and method study, it seems essential to develop and validate formulas or index for land subsidence and flood assessment. A serious attempt was put to design an index system that can measure the overall condition of study area. Once a conceptual framework system is established, supplementary indexes for specific purposes and location can be added.

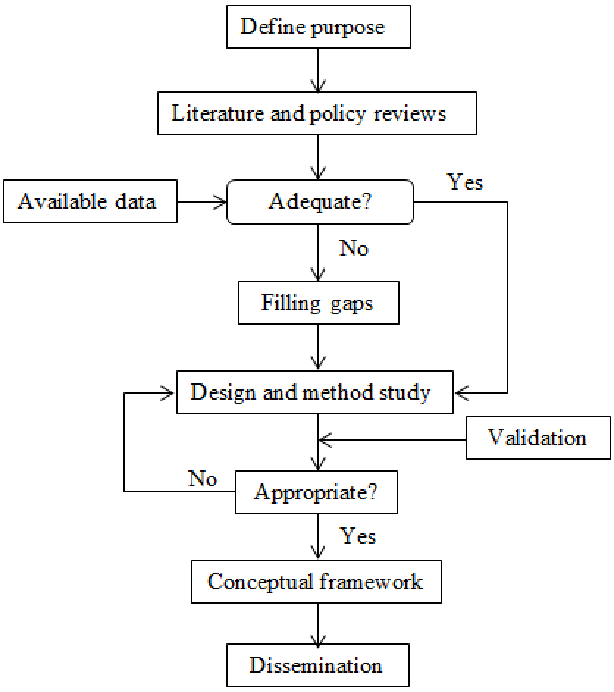

Figure 3. General procedure to develop methodology

The methodology commonly consists of the following phases:

- Phase 1. Data collection and investigations
- Phase 2. Technical Design
- Phase 3. Construction
- Phase 4. Management System Development
- Phase 5. Evaluation and Monitoring

Regarding polder system, it is obligated to examine topography, geological and meteorological data, hydrological data, soil properties, soil subsidence and geological investigations, land use change, socio-economy, and environment data. All the required works are very complex; however it is necessary to execute selective works for all phases. For example in the soil investigation works, several field test and laboratory test common do, such as Standard Penetration Test (SPT), Cone Penetration Test (Sondir), Pressure meter Test, Vane Shear Test, Soil Boring for Undisturbed Samples, Volumetric and Gravimetric, Atterberg Limits, Sieve analysis and Hydrometer Sedimentation, Triaxial Test (UU, CU & CD), Direct Shear Test and Consolidation Oedometric Test. For one geotechnical project, particular important variables for certain geotechnical works are needed to be selected rather than using all variables to analyze. Therefore, this paper offered an Analytical Hierarchy Process (AHP) method to be performed.

AHP method

AHP basically is a multi-criteria decision making method which allows decision makers to model a complex problem in a hierarchical structure, showing the relationships of the goal, objective or criteria, and alternatives. AHP have been successfully implemented in many fields and study areas. In general, the AHP method consists of five main steps (Fig. 4), and for solving decision problems by comparing several alternatives on the basis of the same set of attributes. This method was used to derive ratio scales from paired comparisons, with the measurement being based on the relative importance of the selected variables. This process was performed using Expert Choice 11.0 software.

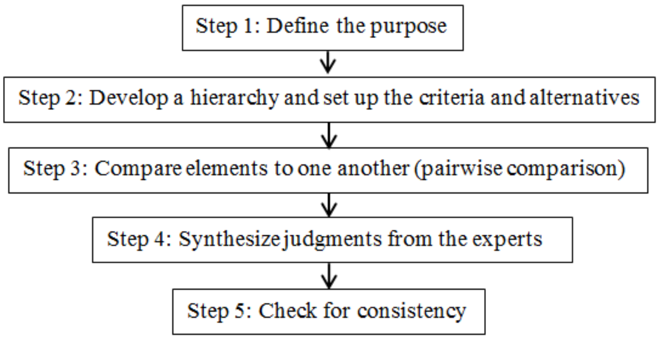

Figure 4. The main step of the AHP method

For example, variables dealing with embankment stability were either excluded or integrated via a survey of experts and brainstorming among civil engineers who review applicable techniques of this geotechnical work. The AHP analysis in this study involved the following steps: (1) identifying some experts from geotechnical and professional engineers for civil engineering structures, water and urban development; (2) assigns weights for each category and variable through geometric average for acceptable consistency ratio related to a value less than or equal to 0.1 for each group; (3) calculating integrated weights by considering both groups to produce an index. The example categories and variables in geotechnical subject can be seen in Table 1.

TABLE I. Example categories and variables in geotechnical subject

Categories	Variables
Topography	Slope angle; Aspect; Slope length; Slope height; Slope type
Soil	Porosity; Soil hardness; Water content; Soil texture; Tensile strength; Permeability coefficient
Geography	Ground layer; Seepage water

GIS method

Following the AHP, the other method should be used is Geographic Information System (GIS). GIS offer ideal environments to accomplishing comprehensive regional data needed for any geo-hazard assessment including land subsidence and flood. It has ability to amass, influence, examine and depict an immense amount of indispensable spatial and tabular data. After the data from land subsidence (Fig. 6) and flood (Fig. 7) are gained. The thematic maps should be layered from both land subsidence and flood digital map and then assigned weights on a certain scale depending on their contribution in order to create hazard potential zone.

Methodology Offered

This paper outlined a methodology for hazard potential zone maps for Jakarta City (Fig. 5). The planning work of this study is an integration of all the developed maps is attempted based on weights and ranks. A final hazard index map is created by using Analytic Hierarchy Process (AHP) on GIS platform. Considering geotechnical investigation works within, there are some important questions have to answer in detail such as: what kind of soils is found and at what depth; i.e. soft soils such as sand, clay or peat or hard soils such as limestone and calcareous sandstone, or very hard soils such as quartzite and basalt; what are the mechanical properties of the various soils with respect to their strength and deformation characteristics; how pervious is the soil and does it contain water; is the soil fissured or weathered; will the soil degrade in (short) time etc.

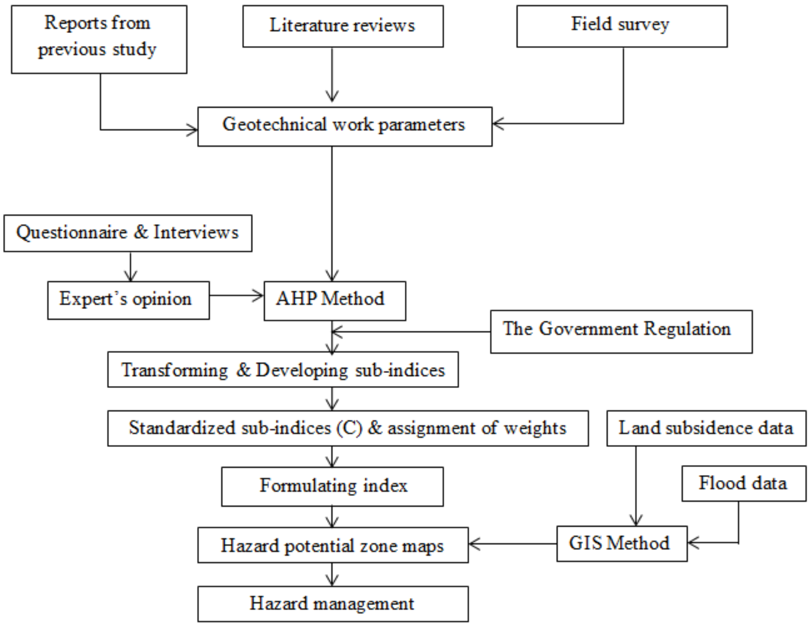

Figure 5. The methodology offered in this study

Geotechnical aspects in polder system

General

It is generally accepted that a polder system together with reclamation is the best high-tech engineering solution for Jakarta City. A polder system is an engineering alternative that is appropriate and effective for flood control and supports the development of coastal area. It consists of dikes, drains, retention ponds, outfall structures or pumping stations and other components, that create one integrated system. Construction of a polder system also involved geotechnical works in the implementation. Related to the planning and design activities, description of soil and its geological conditions around the potential locations for water management system components (dikes, pumping stations, hydraulic control structures and canals) have to be made available and the related filed and laboratory investigations have to be done.

Technical Process

Information on the geological conditions in the polder area is used for many purposes in the planning and design phase, such as to determine the stability of the polder water management and flood protection components; to determine possible settlement as well as land subsidence; to check groundwater conditions and possible salinity intrusion in the groundwater; and to formulate the design criteria for the polder water management and flood protection components. Geological investigation should also be done in case other construction projects will be done in the surrounding areas. Based on the geological investigation, possible impact of the development (stability of the polder water management and flood protection components and its performance) to the surrounding areas can be avoided or minimized.

Land subsidence can be defined as the differential sinking of the ground surface in urban area with respect to the surrounding terrain or the sea level. There are several causes of the land subsidence: thick soft sediments with high compressibility (geological condition) and groundwater overdraft and loaded engineering construction (dynamic condition). Besides, rapid expansion and development of industrialization and urbanization are also most important causes for land subsidence in urban area. In case of Jakarta City, the previous results indicated that urban land subsidence in Jakarta City especially in northern area is very high compared to other areas (Fig. 6).

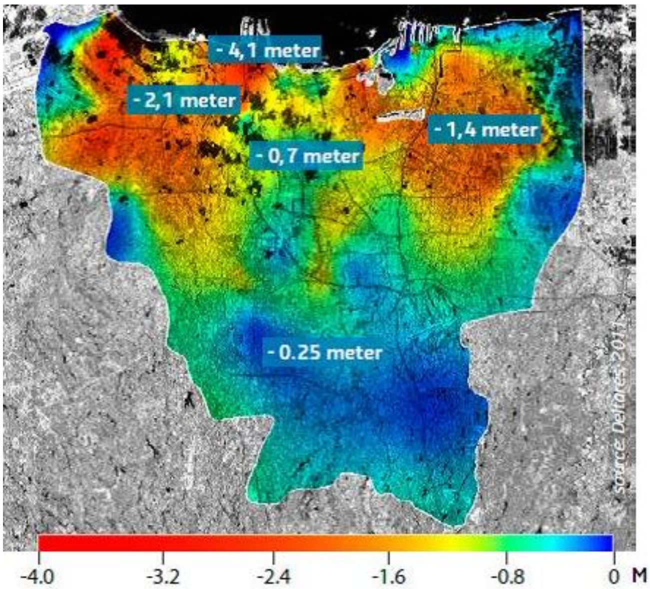

Figure 6. Land subsidence in Jakarta City during 1974-2010 (Source from: Abidin et. al., 2015)

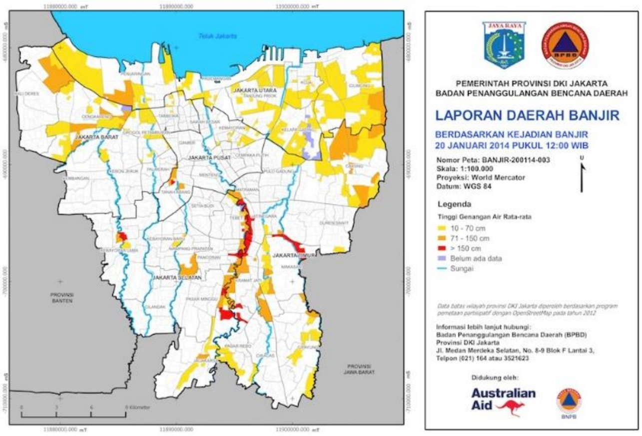

Figure 7. Flood Area in Jakarta City (Source from: https://mkusumawijaya.files.wordpress.com/2014/02/banjir-20-januari-2014-jam-12.jpg)

For urban development in polders, the lands are often raised by landfill. This may be realized to get a sufficiently high surface level, or to create better drainage and bearing capacity conditions, especially during the building phase. Due to the landfill and additional subsidence and settlement process will be induced. In the planning stage of a polder, the assessment of the extent of subsidence is of vital importance, as subsidence will influence the levels of watercourses and the lifting heights of pumps.

Soil investigation in reclamation project

Soil investigation in reclamation project consists of: project location survey; tide of the sea, river, wave height and flow survey; bathimetric survey; topographic survey (if the location is not sea), soil investigation, quarry survey (material source for reclamation) and cost survey. After reclamation through impoldering, the soil will ripen. This ripening process stands for all physical, chemical and microbiological processes by which a freshly deposited mud is transformed to a dry land soil. It essentially involves an irreversible loss of water. Freshly deposited mud, rich in clay and organic matter, has water content of as much as 80% by volume. This water content can be reduced by consolidation, evaporation from the surface, drainage and/or extraction of groundwater.

The removal of water from the soil leads to a partial collapse of the initial, very open micro structure, shrinkage and consequent fissuring of the soil, and an increase in the area of close contact between individual particles and aggregates. Consequently soil ripening results in an increase of the cohesive strength of a sediment. As a result, the sediments will shrink and settle, leading to a subsidence of the surface.

Conclusion

The conclusion was while there is no denying the fact that the development of Jakarta City is under great threat from the pressure of the increasing land subsidence and flood problem, it must be realized that no simple and appropriate methodology for assessment can succeed by keeping the pristine condition. Moreover, it is necessary to pay attention on the land subsidence and flood in the same time in order to construct the polder system, for example some structures and dykes often have a pile foundation, which implies that the level of the construction is more or less fixed. When after construction subsidence occurs the surrounding land, as well as the soil under the structure of the polder system will subside. Besides, land subsidence may result in the requirement of lower preferred water levels in the urban canals, resulting in less discharge capacity in case of drainage by gravity through flap gates, or tidal gates, gradually increasing requirement of drainage by pumping and finally increase of the lift in pumping station. The other example is subsidence of dikes will result in the need to raise the dikes from time to time. Consequently, flood protection around polders means the construction of dikes, which may cause side effects.

What is presented in this paper is to offer a conceptual framework of land subsidence and flood assessment towards sustainable hazard management. An increasing need for integrative assessment that measures the contribution of effects of the land subsidence and flood to the design of polder system has recently been recognized. This methodology developed in this work also emphasizes the simplicity and understandability as it must communicate to decision makers and the experts. Further, stakeholders, as well as the engineers and scientists making the studies and plans in detail for land-use zoning and urban developments need to know about the potential hazards, costs, and socio-environmental impacts that can result from land subsidence and flood.

Acknowledgment

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