THESIS

THE ESTABLISHMENT OF A CONCEPT OF AN EARLY WARNING SYSTEM (EWS) FOR DAM-BREAK EVENTS IN INDONESIA

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THE ESTABLISHMENT OF A CONCEPT OF AN EARLY WARNING SYSTEM (EWS) FOR DAM-BREAK EVENTS IN INDONESIA

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Dinyatakan: di Bandung

Tanggal: 7 Februari 2022

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ABSTRACT

Ketro Dam is one of several dams in Sragen District, East Java. The dam is located on the Bengawan Solo river network and fulfills irrigation water demand for 400 hectares of irrigation area. It has been running since 1984 and is considered one of the oldest dams in Indonesia. Like two sides of a coin that cannot be separated, the massive amount of water from this dam can either preserve human life or destroy it in times of disaster. One of the most catastrophic disasters that exist because of this infrastructure is the risk of having a dam-break event. Hence, this research seeks to create and implement an EWS (Early Warning System) for dam-break events in Ketro Dam. Dam-break cases have caused significant losses in life and economic damage due to the absence of the Early Warning System (EWS). A proper EWS in Indonesia is even more challenging due to insufficient data. Hence, this study proposes a simple-yet-effective EWS using a macro approach based on the evacuation time or the so-called Evacuation Clearance Time (ECT) for a data-sparse region. By comparing the ECT value with the arrival time of the floods from the affected areas, the required additional evacuation time can be obtained and used as the basis to determine the EWS. Based on the analysis, the proposed EWS for Ketro Dam is given in 3 levels of warning indicated by the reservoir water level: +100.35 m, +100.44 m, and +100.48 m. A dam-break disaster is an event that is difficult to predict. It is, therefore, possible for a catastrophic dam collapse to occur long before the hypotheses are carried out in the subsequent analysis. Therefore, to ensure that the proposed EWS can be accounted for, additional analysis of the downstream area of the dam is required for return period flooding without dam collapse. The research will be carried out by running a 2D flood inundation routing model using the HEC-RAS application. In addition to this analysis, the final EWS is proposed in the form of three warnings according to reservoir water elevation (+99.47 m, +100.44 m, and +100.48 m). With the proposed EWS, the results show that 100% of people are expected to reach the evacuation point safely. The case study show that the proposed EWS could reduce the risk impact of the dam-break events.

Keywords: Early Warning System, Dam-Break, Evacuation Clearance Time, Ketro Dam

PEMBENTUKAN KONSEP SISTEM PERINGATAN DINI UNTUK KEJADIAN KERUNTUHAN BENDUNGAN DI INDONESIA

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ABSTRAK

Bendungan Ketro adalah salah satu dari beberapa bendungan yang ada di Kabupaten Sragen, Jawa Timur. Bendungan yang terletak di jaringan sungai Bengawan Solo ini memenuhi kebutuhan air irigasi untuk wilayah irigasi seluas 400 hektar. Bendungan Ketro telah dibangun sejak tahun 1984 dan dianggap sebagai salah satu bendungan tertua di Indonesia. Bagaikan dua sisi koin yang tidak dapat dipisahkan, jumlah besar air dari bendungan ini dapat menjadi penyelamat kehidupan manusia atau menghancurkannya pada saat kejadian bencana. Salah satu bencana paling dahsyat yang ada karena infrastruktur ini adalah risiko terjadinya peristiwa jebolnya bendungan. Oleh karena itu, penelitian ini berupaya untuk membuat dan mengimplementasikan Sistem Peringatan Dini (SPD) untuk kejadian jebolnya bendungan di Bendungan Ketro. Kasus jebolnya bendungan telah menimbulkan kerugian jiwa dan kerugian ekonomi yang signifikan karena tidak adanya Sistem Peringatan Dini (SPD). Membuat SPD yang cocok di Indonesia menjadi sebuah tantangan karena minimnya ketersediaan data. Oleh karena itu, penelitian ini mengusulkan SPD yang sederhana namun efektif dengan menggunakan pendekatan makro berdasarkan waktu evakuasi atau yang disebut Evacuation Clearance Time (ECT). Dengan membandingkan nilai ECT dengan waktu datangnya banjir dari daerah yang terkena banjir, maka dapat diperoleh tambahan waktu evakuasi yang dibutuhkan dan digunakan sebagai dasar untuk menentukan SPD. Berdasarkan hasil analisis, SPD yang diusulkan untuk Bendungan Ketro diberikan dalam 3 tingkat peringatan yang ditunjukkan oleh ketinggian air waduk: +100,35 m, +100,44 m, dan +100,48 m. Bencana jebolnya bendungan merupakan peristiwa yang sulit diprediksi. Pada nyatanya, bencana keruntuhan bendungan mungkin terjadi jauh sebelum mencapai skenario keruntuhan yang ditetapkan. Oleh karena itu, untuk memastikan bahwa EWS yang diusulkan dapat dipertanggungjawabkan, analisis tambahan daerah hilir bendungan diperlukan untuk banjir periode ulang tanpa efek keruntuhan bendungan. Penelitian akan dilakukan dengan menjalankan model routing genangan banjir 2D menggunakan aplikasi HEC-RAS. Bedasarkan hal tersebut, SPD final diusulkan dalam bentuk tiga peringatan menurut ketinggian air waduk (+99,47 m, +100,44 m, dan +100,48 m). Dengan SPD yang diusulkan, hasilnya menunjukkan bahwa 100% orang berhasil mencapai titik evakuasi dengan selamat. Studi kasus menunjukkan bahwa SPD yang diusulkan dapat mengurangi dampak risiko peristiwa jebolnya bendungan.

Kata Kunci: Sistem Peringatan Dini, *Dam-Break, Evacuation Clearance Time,* Bendungan Ketro

PREFACE

This thesis is made as a requirement to complete a masters's degree in Civil Engineering from the Faculty of Engineering at Parahyangan Catholic University. There are a lot of people around the writer that gave the writer technically guidance and mental support in the making of this thesis. Therefore, this page is specially dedicated to thanks to those people who always be on the writer's side while making on this thesis. The writer would like to express the gratitude to:

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The writer realizes that this thesis may contain many limitations and there is still a lot of room for improvement. Therefore, the writer would greatly appreciate any suggestions and critiques to improve this thesis. Nonetheless, the writer wish that this thesis can be useful for any reader.

Bandung, February 2022

Farrell Wiguna

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CHAPTER 1
INTRODUCTION

1.1 Background

A dam (or reservoir) is undoubtedly an essential piece of water management infrastructure. Since 2015, the Indonesian government has been actively building more than 50 dams to meet the increased demand for water supplies, and still, more dams will be constructed in the following years (Purnamasari, 2021). In Indonesia, reservoirs are primarily used for several functions. This include providing water for irrigation systems, distributing clean water for urban and industrial areas, as a resource of hydropower plants, and acting as a flood control system. However, this all-around resourceful infrastructure works by regulating the flow of water with a massive quantity. Like two sides of a coin that cannot be separated, the massive amount of water can either preserve human life or destroy it in times of disaster. One of the most catastrophic disasters that exist because of the presence of this infrastructure is the risk of having a dam-break event. A dam-break is a partial or complete failure of a dam, resulting in a tremendous amount of water being discharged in an uncontrolled manner (Sun et al., 2014), and with the increasing number of a dam, the greater the risk of the occurrence of dam-break. Based on the records, Indonesia has experienced two disasters of dam-break event, Situ Gintung incident and Way Ela incident. Both of these disasters took place in 2009 and 2013. More than 100 people were killed, many were evacuated, and hundreds of homes were damaged as due to these two tragedies (Andryanto, 2021)-(Melisa, 2013). Furthermore, In fact, this disaster occurs rather frequently; between 2019 and 2020, five dam-break disasters were recorded, including Brumadinho Dam (Brazil), Spencer Dam (US), Tiware Dam (India), Sanford Dam (US), and Edenville Dam (US) (Campbell, 2019; Ennes, 2021; Hayes, 2021; Ratnagiri, 2019). Due to severe rain, the Edenville Dam, which was completed more than a century ago, fell on May 18, 2021. The rain was so intense that the dam couldn't keep up, resulting in 7.3-meter-high floods. As a result of the accident, almost 10,000 people were forced to

abandon their homes, and 2,500 homes and businesses were damaged. Asset losses are estimated to have totaled $200 million due to the incident (Hayes, 2021).

This disaster has become very dangerous compared to the others due to several reasons. One of them is that the flood caused by this disaster occurred at a very high-velocity flow, considerable flood depth, along with a significant value of discharge. In addition, due to the large volume of floods, dam-break floods sometimes flow through residential areas that are rarely flooded, so that awareness levels of disasters are low. For example, in one study, the collapse of a relatively small dam, namely Ketro Dam, with a volume of approximately 2.9 million m^3, can result in a 1.002 ha flooding area with a maximum depth of more than 1.5 m and a maximum velocity of 1 m/s. Based on the projection, the flood will flow through residential areas and affect approximately 9,023 people (Yudianto et al., 2021). the combination of the unawareness of the people and the very flash floods that occurred made this disaster even more deadly. Although dam-break disasters are generally rare for dams built to high safety standards (or newly built dams), dams that have been made in the past or were built to low safety standards pose a high risk of dam-breaks like many dams in Indonesia. In a study, it was said that many dams on the island of Java, Indonesia, have critical conditions both in terms of sedimentation and structural problems, which of course, can increase the risk of dam-breaks (Samekto, 2016). Therefore, an anticipatory solution is needed (besides maintenance, which is mandatory) to reduce the risk of possible dam-breaks in Indonesia.

The Early Warning System or EWS is one of the anticipatory solutions that reduce the impact of a disaster. By definition, EWS is a valuable system to minimize the losses due to a disaster by promptly generating and disseminating disaster-related information to the affected individuals, communities, and organizations (Cools et al., 2016). However, to the best of the writer's knowledge, there is still no standard EWS procedure that specifically discusses the case of dam-break. Because dam-break events are unpredictable, properly predicting their risk is still challenging (Sattar et al., 2011). For example, in the case of a dam collapsing due

to an overtopping failure, the dam-break event can somehow be guessed by looking at the reservoir water level. In this way, the dam operator and the residents living downstream would have time to prepare and evacuate. However, in the case of piping failure, it will be more challenging to detect the possibility of a dam-break event, especially for dams without advanced instrumentation records, which is the majority of dams in Indonesia. Furthermore, this problem statement is expected to be resolved with this study.

This study proposes a simple-yet-effective EWS that is easy to interpret and universally applicable (can be used for any dam). The initial idea of making this EWS was to create a system with a universal basis, namely Evacuation Clearance Time (ECT). By definition, ECT is a period of time within which people must prepare and arrive at a predetermined evacuation shelter. Knowing the time it takes for each resident in the affected area to evacuate, the time to warn before a disaster occurs (as part of the EWS) can be estimated. That way, the time allotted for evacuation will be sufficient. However, in order to be an effective system, warnings also need to be ensured that they are not given too early. As a form of risk management, very early warning also becomes unnecessary, considering that a dam collapse might not happen. To prevent this, the proposed EWS will also be linked to the downstream condition of the dam. In other words, if conditions in the downstream area are already dangerous before the dam collapse occurs, then a warning can already be started. On the other hand, if conditions downstream of the dam are not considered hazardous, then a warning may not have been given.

Hence, this study will be carried out to determine EWS at the study site based on ECT and downstream conditions. After the EWS has been successfully created, an Emergency Action Plan (EAP) will also be provided for this study. This study will be conducted at Ketro Dam

1.2 Aim and Objective

This thesis aims to create and implement an EWS for dam-break events in Ketro Dam.

The objectives are formulated as follows:

1. To create an ECT Formula suitable for Indonesia region
2. To perform ECT calculation for every affected village
3. To analyse dam's downstream area condition due to flooding
4. To synthesize an effective EWS based on ECT and downstream area
5. To implement the proposed EWS for Ketro Dam
6. To create EAP for Ketro Dam

1.3 Scope of Study

This study focusses on synthesizing and implementing EWS for Ketro Dam based on ECT and dam's downstream area due to flooding. The socio-economic factor only considered when formulating evacuation mode (walking or by motorized vehicle) based on data from Central Bureau of Statistics Indonesia (BPS). All evacuation processes carried out in this study is assumed to carried out by the community themselves without any assistance from the government or other agencies.

1.4 Research Methodology

This study was conducted with seven methodological stages. First, the study begins by conducting a literature study and data collection. Literature study was conducted to find out and understand the state of art of the studies carried out while data collection was carried out to collect all data needs to be used in the analysis. Data that has been collected are flood map data, shelter locations, study area maps, socio-economic data, flood data, dam-break data, and downstream area flood data. Second, the calculation of ECT or Evacuation Clearance Time. This stage is carried out using the help of a GIS (Geographic Information System) application. The result of this stage is the ECT value for each affected village. Third, by using the ECT data that has been obtained plus flood arrival time data, the ETN (Extra Time Needed) value for each affected village can be obtained. Fourth, the ETN value

combined with the dam break data (reservoir depletion curve) results in the first EWS formulation. Fifth, the formulated EWS will be correlated with downstream area flood conditions to obtain the final EWS. Sixth, with the formulated EWS, an Emergency Action Plan (EAP) can be generated. Finally, the study closed with conclusions, recommendations, and thesis writing. The visualization of the process mentioned above shown in **Figure 1.1**.

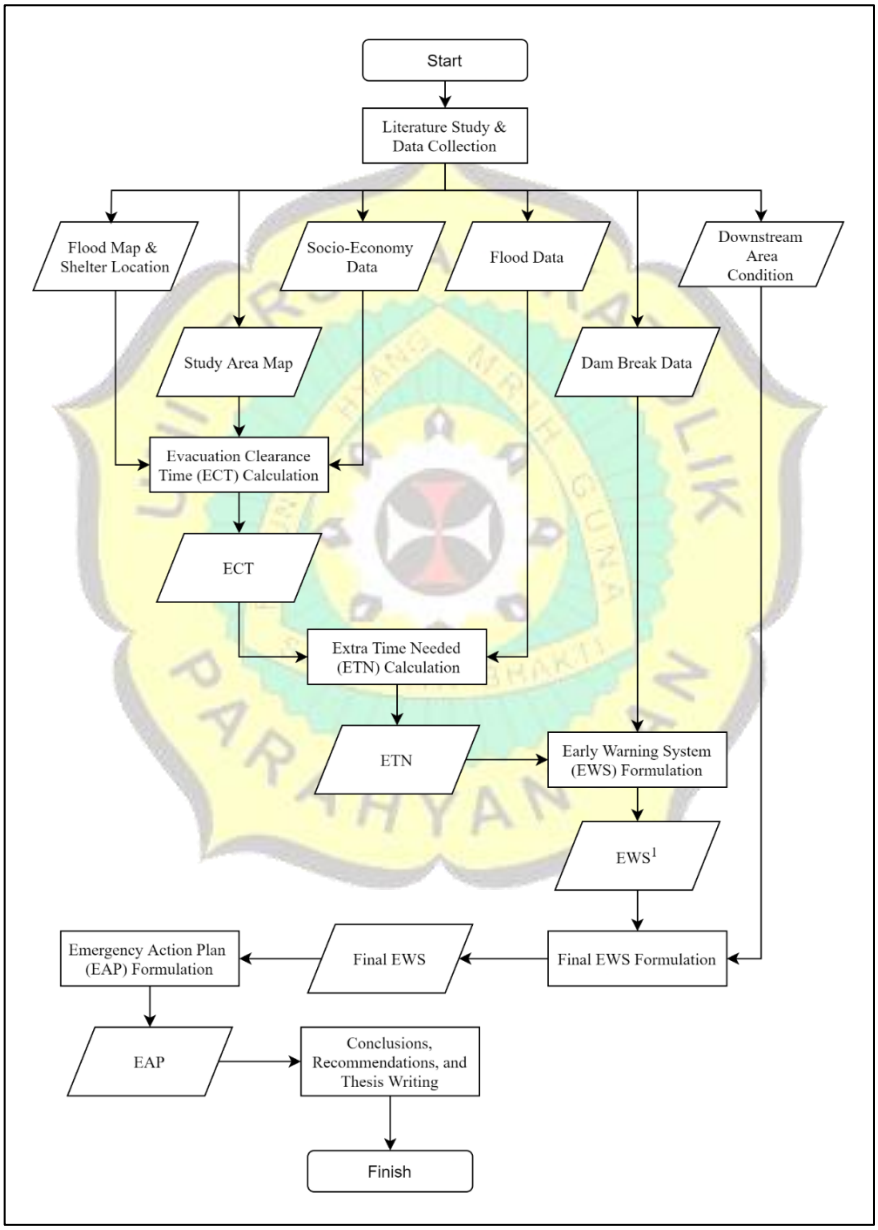

Figure 1.1 Flow Chart