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ANALYSIS OF THE CAUSES, IMPACTS, AND MITIGATION STRATEGIES FOR TIDAL FLOOD DISASTERS IN DUMAI CITY

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ABSTRACT

Tidal flooding in Dumai City has increased in recent years, causing damage to settlements, infrastructure, and community activities. However, previous research has focused on technical aspects and modeling, and few have reviewed field conditions post-2020, particularly regarding the effectiveness of recent mitigation efforts. This study aims to analyze the causes, impacts, and mitigation strategies for tidal flooding in Dumai by filling this research gap. A qualitative approach was used through semi-structured interviews with four informants: members of the Regional Disaster Management Agency, members of the sports and tourism office, and affected communities in the Dumai area, supported by field observations. Data analysis techniques, according to Miles & Huberman, consist of data reduction, data presentation, and conclusion drawing/verification. The results indicate that tidal flooding was triggered by high rainfall, tidal cycles, and inadequate drainage infrastructure before 2021. Impacts include damage to homes, furniture, vehicles, and public roads, as well as health and economic disruptions. Since the construction of 15 floodgates and pumps in 2021, along with a mangrove rehabilitation program and community participation, the duration of flooding has decreased from several days to around three hours. Research concludes that this strategy is effective but requires further maintenance and strengthening. The government is advised to improve drainage systems, expand mangrove areas, and expedite relocation plans for high-risk areas.
***Keywords**: causes; Dumai city; impacts; mitigation strategies; tidal flood disaster.*

A. INTRODUCTION

Flood hazards are difficult to avoid due to their rapid onset and the disruption of evacuation routes, especially for low-income households (Singh et al., 2023). Floods are one of the most common and dangerous natural disasters worldwide, with impacts including loss of life (Paterson et al., 2018; Sarkar, 2022; Shah et al., 2020), economic damage (Merz et al., 2021; Rentschler et al., 2022), health disruptions (Sarkar, 2022; Shah et al., 2020), and environmental damage (Raphela & Matsididi, 2024). Flood risk is expected to increase due to climate change (Merz et al., 2021; Raphela & Matsididi, 2024) and population growth in vulnerable areas (Pizzorni et al., 2024). Since the early 2000s, the frequency and duration of flooding have increased globally (Singh et al., 2023).

One of the impacts of global warming is rising sea levels (Kirikkaleli & Sowah, 2021; Shukla et al., 2017; Song et al., 2023). This increased saturation from sea level rise has created significant problems, particularly in coastal cities (Chakrabortty et al., 2025;

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Ohenhen et al., 2024). Sea level rise causes several losses, such as coastal erosion (abrasion) and tidal flooding (Griggs & Reguero, 2021; Passeri et al., 2015; Stephens et al., 2021). Tidal flooding is expected to continue to increase in both frequency and extent in the future (Kirezci et al., 2020; Taherkhani et al., 2020; Vitousek et al., 2017).

Global and regional research indicates that sea level rise will cause tidal flooding (TIB) to occur more frequently and extensively (Kirezci et al., 2020; Ritman et al., 2022; Taherkhani et al., 2020; Vitousek et al., 2017). Even a sea level rise of just 10–20 cm could double the frequency of extreme flooding in tropical and low-lying coastal areas by 2050 (Taherkhani et al., 2020; Vitousek et al., 2017). In some locations, floods that previously occurred once every 50 years are projected to occur annually, or even almost daily, by the end of the 21st century (Ritman et al., 2022; Taherkhani et al., 2020).

A study in Indonesia (East Luwu) projects that by 2050, almost the entire coastline in the region will experience tidal flooding, with the inundation area increasing annually and having a significant impact on agricultural land, fish ponds, and settlements (Devy et al., 2023). In coastal areas worldwide, more than 50% of the population and coastal assets are expected to be at risk of flooding by 2100 if adaptation is not implemented (Kirezci et al., 2020).

Dumai City in Riau Province is one of the coastal cities frequently affected by tidal flooding (Kausarian et al., 2018). Dumai's geographic location on the north coast of Sumatra, with an average elevation of only three meters above sea level, makes the city highly vulnerable to tidal flooding, especially during high tides (Kausarian et al., 2018). Besides Dumai, other cities such as Merauke, Banjarmasin, Medan, and Jakarta also frequently experience similar disasters due to their coastal locations (Kausarian et al., 2018; Putiamini et al., 2022; Seftiani et al., 2021). The area affected by tidal flooding in Dumai is expanding, extending beyond river estuaries and beaches to include residential areas and the city center (Kausarian et al., 2018).

Despite the growing body of literature on tidal flooding, several critical knowledge gaps remain. First, most existing studies emphasize hydrodynamic modeling, spatial analysis, or climate projections, while empirical, field-based evidence capturing how tidal flooding is experienced, managed, and mitigated at the local level remains limited (Bariroh & Surtikanti, 2024; Septian et al., 2022). Consequently, the interaction between physical drivers of tidal flooding and institutional responses as perceived by affected communities is still poorly understood.

Second, although Dumai City is frequently cited as a tidal flood–prone coastal area (Hanif et al., 2021; Seftiani et al., 2021), no systematic post-2020 studies have examined how the severity, duration, and impacts of tidal flooding have evolved following the peak flooding period. Current literature largely focuses on other coastal regions in Indonesia or presents generalized national assessments, leaving local, city-specific evidence from Dumai largely absent.

Third, and most critically, there is a lack of empirical evaluation of the effectiveness of government-led mitigation interventions implemented after 2021, particularly the construction of floodgates, water pumps, and pumping stations. While such structural measures are widely promoted in coastal flood management literature, evidence-based assessments linking these interventions to actual reductions in inundation duration and community-level impacts remain scarce, especially in small and medium-sized coastal cities.

These gaps indicate the need for a context-specific, field-based study that integrates community experiences, institutional perspectives, and post-intervention conditions to generate practical knowledge on how and to what extent tidal flood mitigation strategies work in real-world settings.

This research aims to fill this gap. Through a qualitative approach involving interviews with the Regional Disaster Management Agency, relevant agencies, and affected communities, this study offers a novel integrative analysis that combines three main aspects: the causes, impacts, and mitigation strategies for tidal flooding based on the actual conditions in Dumai City. This research is also the first to systematically document community experiences before and after the implementation of the floodgate and water pump policy, providing an empirical overview of the effectiveness of disaster mitigation at the local level. Therefore, this research not only enriches the literature on tidal flooding in coastal areas but also has the potential to serve as a reference for decision-making and improving disaster management policies in Dumai City.

B. MATERIALS AND METHODS

Type of Research

This research is a qualitative study. According to (Sugiyono, 2018), qualitative research is a research method based on post-positivism or interpretive philosophy, used to examine the natural conditions of objects, in which the researcher acts as a key instrument.

Location and time of research

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This research was conducted in Dumai City from May to July 2024 (figure 1).

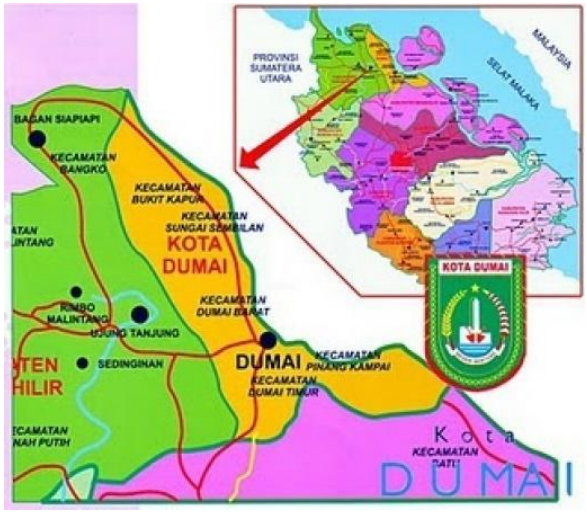

Figure 1. Map of Dumai city area (Sumber:Database Peluang dan Potensi Investasi Kabupaten-Kota di Provinsi Riau)

Research procedures

This research was conducted through interviews and observations. Researchers interviewed members of the Dumai City Regional Disaster Management Agency (BPBD), members of the Dumai City Tourism Office, and residents. The interview method used in this study was semi-structured.

Observation is the systematic recording of phenomena. Observations were conducted by going directly to the field/research location in Dumai City to assess and observe flood conditions.

Data Analysis

The data analysis procedures used, according to Miles & Huberman (1992), consist of: data reduction, data presentation, and conclusion drawing/verification.

a. Data Reduction

Reducing data means summarizing, selecting the main points, and focusing on the important points.

b. Data Display

The data display stage involves processing semi-finished data that has been uniformly written and has a clear thematic flow into a categorization matrix according to the themes that have been grouped and categorized. The data summary obtained from the reduction stage is briefly described and supported by tables created by the researcher to facilitate readers' understanding of the information presented more simply.

c. Conclusion Drawing (Verification)

The third step is concluding the data findings in the field. At this stage, the researcher analyzes the data more specifically to reach a comprehensive conclusion. Conclusions are drawn based on the facts presented in the field. The conclusion leads to the answer to the research question posed and reveals the "what" and "how" of the research findings.

C. RESULTS AND DISCUSSION

Causes of Tidal Flooding in Dumai City

Based on the results of interviews with members of the Dumai City Regional Disaster Management Agency (BPBD) and residents, it is known that tidal flooding in Dumai City is caused by high rainfall and tidal cycles of sea and river water. Tidal flooding in Dumai City has occurred for a long time, but in 2020, several areas in Dumai City were hit by tidal floods reaching 20-30 centimeters in height on Sunday, July 10, 2020. The flooding lasted for 5.00 to 10.00 a.m, and the most severely affected areas were Dumai City and West Dumai because these areas are located in coastal and sea areas. The high tide phenomenon causes seawater to enter the land, especially in coastal areas such as Dumai City and West Dumai (Kausarian et al., 2018). In 2020, Dumai City's infrastructure was inadequate to prevent this situation. Regular tidal flooding hit several coastal areas such as Dumai City, West Dumai, Rimba Sekampung Village, Laksamana Village, and Sungai Sembilan District, inundating roads, entering yards and even into residents' homes, and filling gutters. The regular tidal flooding that hits Dumai's coastal areas is closely related to the city's limited infrastructure, particularly its suboptimal drainage and water management systems. This condition causes high tides and heavy rain to be unable to drain properly, resulting in frequent flooding in residential areas and main roads. Poor drainage systems, the absence of water gates, artificial lakes, or reservoirs, cause high tides to directly enter the land (Haque & Nurfaida, 2023; Kausarian et al., 2018). Tidal flooding usually occurs at the beginning and end of the month. Then there will be a large tide that occurs every three months.

The Impact of the Tidal Flood in Dumai City

One informant, Mr. DC, who lives on Sultan Hasanuddin Street, West Dumai, stated that he had to buy a water pump to drain the floodwater that had entered his house at that time, because he was too tired to drain the water manually. Another impact he felt was that the walls of his house began to peel and turn rusty. The place where he lived became a damp area due to regular flooding in the 2020-2021 period. Because of this, Dody moved with his

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family to an area that was not affected by the Dumai tidal flood disaster. Another informant also said that his house on Jeruk Street, Rimba Sekampung, was damaged because the floodwaters frequently entered his house, and motor vehicles could also be damaged and rusted if exposed to floodwater. Flooding causes direct damage to furniture, electronic devices, and the structure of the house. Studies in flood-prone areas show that more than 50% of households report damage to furniture and electronics after repeated flooding (Bayón et al., 2024; Koller, 2025; Martínez-Gomariz et al., 2018; Patankar, 2017).

The Head of the Emergency Department of the Dumai Regional Disaster Management Agency (BPBD) stated that public infrastructure in flood-affected areas also suffered significant damage. Public roads, which are usually inundated by floodwaters, have also begun to rust, become slippery, and some have been damaged due to high salt content. Water with a high salt content accelerates the corrosion process of metal materials in road infrastructure, such as steel reinforcement in concrete and drainage components. This process also occurs on road surfaces containing metal or asphalt, accelerating damage (Habel et al., 2024; Kaushal et al., 2021). This is certainly very uncomfortable, especially for residents living in flood-affected areas. The many negative impacts experienced by them and property losses, such as material damage, were caused by this tidal flood (Patankar, 2017). The Secretary of the Youth, Sports, and Tourism Office stated that tourism in Dumai City was fortunately not affected by this tidal flood disaster, because it is located in an area that is not affected by flooding. In the 2020-2021 period, Dumai City experienced this disaster without any disaster mitigation strategy from the government at that time, until finally, in 2021, the elected Mayor of Dumai City, Mr. H. Paisal, was inaugurated. During his leadership, this tidal flood disaster mitigation strategy began to be formulated and realized.

Tidal Flood Disaster Mitigation Strategy in Dumai City

At the end of 2021, the elected Mayor of Dumai City began formulating mitigation measures for tidal flooding. Dumai Regional Disaster Management Agency (BPBD) staff stated that the collaboration between the BPBD and the Mayor involved formulating the construction of floodgates and water pumps. The use of floodgates can significantly reduce inundation areas and water levels during tidal flooding and extreme rainfall. Studies in Central Kalimantan show that the operation of floodgates reduces inundation areas by 75–95% and lowers water levels (Kamil et al., 2024b, 2024a; Yasmin et al., 2022). Water pumps are crucial for channeling water from land to sea when sea levels

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are higher than land, especially during tidal floods and rainfall (Choo et al., 2021; Hall et al., 2019; Zhou & Liao, 2024). Furthermore, the Mayor's construction of floodgates and water pumps helps educate the public on how to deal with flooding more effectively and efficiently. A total of 15 floodgates and water pumps were built along 15 rivers in Dumai, including one in West Dumai.

The construction of these floodgates and pump houses has brought numerous benefits, especially to residents whose homes are located in flood-prone areas. One community member stated that this strategy is very effective and beneficial. Even when flooding does not approach its maximum level, the situation is no longer as severe and frequent as before. When floods do occur, water that used to take 4-5 days or even a week to recede completely now only takes an estimated 3 hours. Furthermore, other community members also stated that this strategy is quite effective because it can help reduce the height of previous floods. The integrated operation of pumps with floodgates and drainage systems has been shown to significantly reduce the volume and duration of flooding in coastal cities (Choo et al., 2021; Zhou & Liao, 2024). The combination of floodgates with other infrastructure (e.g., embankments, reservoirs) can further enhance flood resilience (Schroder et al., 2022). In addition to building floodgates and pump houses, the Dumai City Government also plans to relocate and rebuild homes affected by previous flooding. This plan is still being formulated and has not yet been implemented, said a Dumai City Regional Disaster Management Agency (BPBD) staff member.

The Dumai City Government is also promoting the planting of mangrove seedlings around Purnama Beach to help absorb water rising inland. Mangrove roots, stems, and leaves create a physical barrier that slows water flow, reducing current speed by 29-92% and reducing wave height and sea level rise (Dasgupta et al., 2019; Weaver & Stehno, 2024; Zhou & Liao, 2024). Mangrove root structures retain and stabilize sediment, thus preventing erosion and increasing coastal land accretion (raising) (Hongwiset et al., 2022; Karimi & Farivarsadri, 2024). Models and simulations show that the presence of mangroves significantly reduces the area and volume of floodwaters, as well as property damage and loss of life (Juanico, 2022; Menéndez et al., 2020). Optimal protection is achieved when mangroves are planted at sufficient density and width, and with attention to tree species and age (Dasgupta et al., 2019; Gijón Mancheño et al., 2024; Zhou & Liao, 2024).

Preventive measures taken by local communities include cleaning and repairing nearby drains, engaging in community service (gotong royong), cleaning around riverbanks, and installing an app called TIDES to monitor tidal forecasts and prepare ahead of flooding. These community service activities and environmental cleanups, particularly waterways and riverbanks, significantly reduce the risk of flooding by maintaining drainage function and preventing blockages (Muhammad Ilzam Maulana et al., 2024). The use of mobile applications for tide monitoring and flood early warnings significantly assists communities in preparing before floods occur (Alsabhan & Dudin, 2023; Landaverde & Torres, 2023). Applications such as TIDES and community-based early warning systems have been shown to improve preparedness, accelerate information dissemination, and enable earlier preventive action (Kangana et al., 2025; Nikolić et al., 2022).

D. CONCLUSIONS

Tidal flooding in Dumai City is the result of a combination of natural factors, such as high rainfall and high tides, combined with limited city infrastructure, particularly the drainage system, which is unable to withstand the inflow of water from the sea or drain rainwater runoff. This condition causes regular flooding in coastal areas such as Dumai City, West Dumai, and Rimba Sekampung, and has significant impacts on the community, including damage to homes, furniture, vehicles, and public infrastructure. Since the construction of 15 floodgates and water pumps in late 2021, coupled with a mangrove rehabilitation program and increased community participation through cooperation (gotong royong) and the use of the TIDES application, the duration and height of flooding have drastically decreased from days to approximately three hours, proving effective in reducing the risk of tidal flooding.

Based on the research findings, it is recommended that the Dumai City Government continue to strengthen mitigation infrastructure, particularly the maintenance of floodgates, water pumps, and drainage systems to ensure optimal function in the face of tidal dynamics and climate change. The government also needs to expand mangrove planting zones as natural coastal protection, while also developing relocation plans for households living in areas at very high flood risk. Furthermore, communities need to increase preparedness by keeping gutters clean, participating in community service activities, and utilizing tidal monitoring technology. Further research requires quantitative studies of changes in inundation height and extent following interventions, as well as hydrodynamic modeling to predict long-term tidal flood threats to support more targeted mitigation policies.

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