

Strategic Planning for Climate Resilience: Safeguarding Gamat Bay Beach through Collaborative Efforts with the Sakti Tourism Village Development Team

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Abstract. Climate change profoundly impacts Indonesia's coastal regions, where approximately 60% of the population resides, making them particularly vulnerable to its effects. Apart from the looming threat of rising sea levels, the escalating erosion rate along Indonesia's coasts presents a formidable challenge. This gradual erosion trend is anticipated to persist over the next two decades. Recognizing the urgency of the situation, the Indonesian government, through the Ministry of Public Works and Public Housing (PUPR), has taken proactive measures to address coastal damage induced by climate change. However, the repercussions of climate change have hit close to home at Gamat Bay Beach in Nusa Penida, where erosion has emerged as a primary concern. The erosion has disrupted the natural landscape and severely damaged Gamat Temple, as evidenced by the wave-induced destruction in August 2022. In response, the partners involved in developing coastal tourism at Gamat Bay are devising strategies to transform the area into a thriving tourist destination within Sakti Village. Community service initiatives propose implementing beach safety designs tailored to the unique coastal dynamics to combat the erosion challenge. This comprehensive approach entails conducting surveys, analyzing data, and developing designs capable of mitigating erosion and adapting to rising sea levels. One such recommended design solution is the construction of a seawall, utilizing locally sourced mountain stone abundant in Nusa Penida.

Keywords: Climate change; erosion; seawall

1. Introduction

Climate constantly changes during the interaction of the Earth and the sun. The duration of exposure and the amount of radiation the earth receives has varied over thousands of years. Climate changes that occur are closely related to sea level related to sea surface warming. When temperatures increase, seawater rises due to melting ice in Antarctica, Greenland and mountain glaciers [1]. Based on the Intergovernmental Panel on Climate Change report, rising sea levels will impact increasing storm waves and coastal flooding in coastal areas [2]. These coastal areas are generally dense urban areas that are very vulnerable to damage to infrastructure, property and public safety [3]. Because of

these conditions, coastal areas are a priority for climate change adaptation. Without appropriate and effective adaptation, many coastal areas will be drastically reduced [4]. Coastal areas in the lowlands are very vulnerable to coastal disasters due to rising sea levels. Throughout the world, coastal management strategies focus on three adaptation approach concepts: retreat, accommodation and coastal protection [5].

This climate change has an impact on Indonesia's coast. Around 60% of Indonesia's population lives in coastal areas which will be threatened by climate change [6]. Apart from increasing sea levels, the increasing erosion rate on coasts in Indonesia has an impact. This impact is slow and will continue for the next 20 years. Unlike tsunamis and earthquakes, this disaster can be felt directly and quickly [7]. This coastal damage significantly impacts vital areas such as tourist areas and beaches in Bali Province. The rate of erosion on Bali's beaches, which reaches two m/year, has a huge impact on the existence of beach tourist attractions in Bali [8]. The government has handled coastal damage caused by climate change through the Ministry of Public Works and Housing (PUPR). This climate change also impacts the coast of Gamat Bay Beach, Nusa Penida. Erosion occurred due to increasing wave height and tides, which damaged the Gamat Temple at that location.



Fig. 1. Erosion in Gamat Bay and Gamat Temple

The erosion that occurs is the main problem experienced by partners in efforts to develop coastal tourist attractions in Gamat Bay. This erosion caused Gamat Temple to experience serious damage due to waves in August 2022. The partners' plan for the Gamat Bay area is to carry out arrangements so that it can become a tourist attraction in Sakti Village. This plan must begin with protecting coastal areas from erosion, so partners need assistance with coastal protection designs that can overcome erosion and climate change. This activity aims to assist partners in designing coastal safety buildings and provide disaster mitigation-based and architectural planning concepts.

2. Method

Over the last decade, significant progress has been made in developing various methods for assessing climate change-driven coastal erosion based on our present knowledge and resources. Modeling strategies composed of different physics-based (or empirical) models simulating cross-shore or long-shore processes and other sinks or sources that contribute to the sediment budget have proven able to reproduce observed shoreline changes over a broad range of time scales to a fair degree of accuracy while accounting for uncertainty [9]. An appropriate solution method is needed to produce

a coastal protection design that can overcome the problem of climate change. The technique used in this activity is to use numerical simulation to obtain the appropriate dimensions of the beach safety structure to be implemented in Gamat Bay. The data required are topographic and bathymetric maps and wave and tidal data. Topographic data was obtained from a survey that used a combination of drones and RTK for measurements.

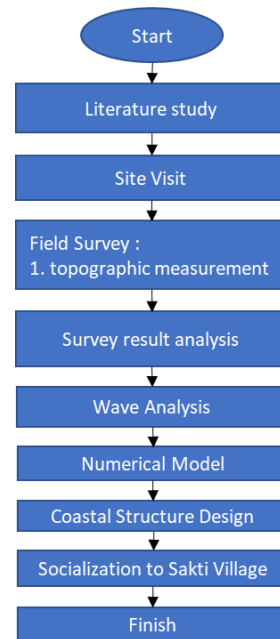


Fig. 2. Flowchart of work

3. Result and Discussion

Survey Result

The first step in implementing is to conduct an initial visit with partners. The site visit aims to determine the current conditions of Gamat Bay, which is experiencing erosion due to high waves at high tide. Figure 3 shows the initial visit and beach conditions at Gamat Bay. It can be seen that the cliffs are scrubbed or eroded by waves.



Fig. 3. Documentation of erosion during site visit

After the site visit, a field survey was conducted to map the condition of Gamat Bay. The mapping method used is photogrammetry using a UAV. Mapping using the photogrammetric method can produce accurate maps and be used in further analysis [10]. The results of drone mapping are corrected with tides and readings from geodetic GPS to obtain a map tied to sea level elevation. Figure 4 is documentation of implementing a field survey using a combination of drones and GPS RTK for mapping.



Fig. 4. Documentation of drone mapping (a) and RTK Surveying (b)

Data Analysis

Data analysis from mapping surveys using the photogrammetry method using PIX4D Mapper software. In this analysis, a combination of the photogrammetry mapping system and terrestrial GPS measurement results was carried out. Figure 5 shows the data processed and combined with GPS measurement data.

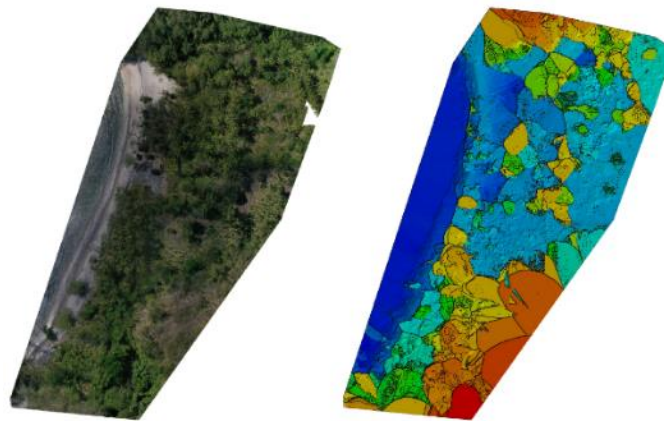


Fig. 5. Mapping from survey result

The measurements only cover the land area, so they must be combined with a water depth map in Gamat Bay. Water depth data is needed to determine wave transformation patterns due to changes in seabed depth. Data processing from National Bathymetry (BATNAS) is carried out for the combination process with seabed depth maps.

Wave Analysis

Wave analysis was done by analyzing wave observation data from the ERAA-5 satellite. This satellite wave processing uses Ocean Data View (ODV) software. ECMWF data can provide accurate wave height, period and direction for the wave simulation process [11]. The following are the results of wave analysis off the coast of Gamat Bay.

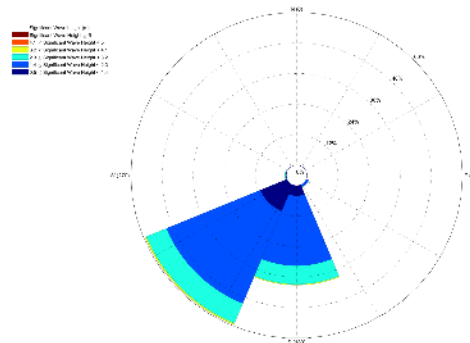


Fig. 6. Waverose offshore of Gamat Bay

Numerical Simulation

Numerical simulations were conducted to determine the wave transformation from offshore to the coastline. The simulation results provide information on wave height on the beach for input data in determining the dimensions of coastal safety buildings. The modeling used is the Coastal Modeling System (CMS) Wave. The CMS modeling results produce wave heights that match the observed data and have a high level of accuracy [12].

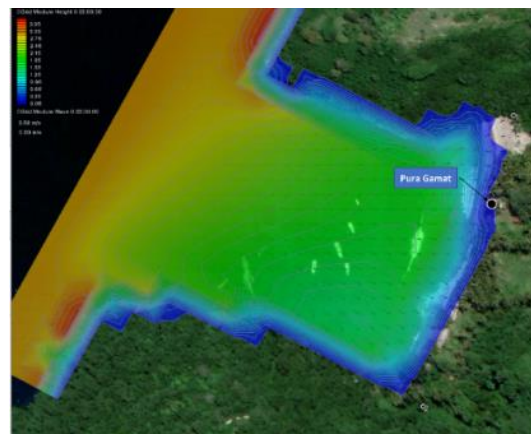


Fig. 7. Wave transformation result of Gamat Bay

Figure 7 shows that the waves reached the location of Gamat Temple. This condition causes damage to the Gamat Temple area, so beach protection is needed to overcome this problem.

Coastal Structure Design

The recommended beach protection for Gamat Bay is a seawall made from coral. The choice of this type considers the availability of stone on Nusa Penida Island, which is different from Bali

Island, where the availability of andesite stone means that the kind of beach protection applied is predominantly in the form of revetment. The recommended seawall design takes into account the stability of the building due to wave forces, tides and soil-bearing capacity conditions.



Fig. 8. Design layout of Gamat Bay coastal structure

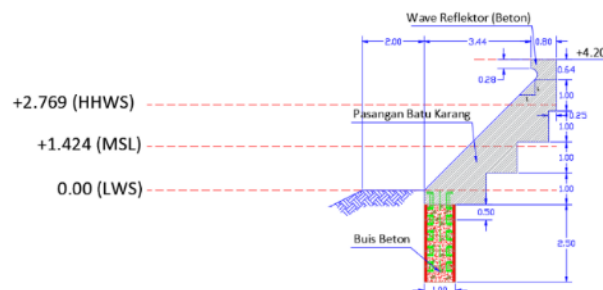


Fig. 9. Typical section of Gamat Bay seawall

Socialization and Discussion

The team's socialization aimed to convey the results and recommendations for designing and handling erosion in the Gamat Bay area. This socialization was carried out at the Sakti Village Office, attended by the Village Head, Head of Development and the Sakti Tourism Village Development Team (Figure 10). The result of this socialization was that village officials agreed to the proposed design and hoped for assistance from the team to sustainably participate in overcoming the erosion problems that occurred in Gamat Bay, particularly, and other erosion areas in Sakti Village.



Fig. 10. Documentation of socialization with Sakti Village, Nusa Penida

4. Conclusion

Based on the implementation of this activity, several things can be concluded, namely:

The coast of Gamat Bay is vulnerable to climate change, which impacts erosion due to rising sea levels and high waves.

To overcome the problem, it is recommended to build a seawall to overcome erosion due to waves.

The proposed seawall is a mountain stone set with material easily obtained on Nusa Penida Island.

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