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DEVELOPMENT OF FLOOD MITIGATION STRATEGIES IN FLOOD-PRONE SETTLEMENTS OF BERINGIN VILLAGE, MEDAN CITY

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ABSTRACT

Flooding is one of the most frequent urban disasters and remains a major challenge to sustainable settlement development. Beringin Village, Medan Selayang District, experiences recurrent flooding due to high rainfall intensity, inadequate drainage capacity, high building density, limited green open spaces, and extensive impervious surfaces. These conditions increase settlement vulnerability and affect buildings, the environment, infrastructure, and community activities. This study aims to identify the conditions of flood-prone settlements in Beringin Village and formulate appropriate flood mitigation strategies. A descriptive qualitative approach was employed using field observations, interviews, documentation, and literature review. Data were analyzed using a scoring technique based on indicators of building conditions, environmental conditions, settlement infrastructure, and flood mitigation measures. The results show that the overall condition of the settlement falls within the moderate category. Building conditions are generally adequate but remain vulnerable to flooding, while environmental conditions are characterized by high building density and limited infiltration capacity. Existing infrastructure, including drainage systems and river protection structures, requires further improvement. The recommended strategies include risk-based spatial planning, the development of green infrastructure, and the strengthening of drainage systems through improved capacity, connectivity, and maintenance. These measures are expected to enhance settlement resilience and reduce flood impacts sustainably

KEYWORDS: Flood Mitigation, Flood-Prone Settlements, Risk-Based Spatial Planning, Green Infrastructure, Drainage Enhancement.

1. INTRODUCTION

Flooding is one of the most frequent hydrometeorological disasters occurring in urban areas and represents a major challenge to achieving sustainable development. Flood events are influenced not only by natural factors such as rainfall intensity and topographical conditions, but also by human activities, particularly uncontrolled urbanization, land-use changes, and the limited capacity of urban

drainage systems. The conversion of open land into built-up areas reduces the soil's infiltration capacity, thereby increasing surface runoff and the risk of inundation in residential areas [1][2].

This phenomenon is commonly observed in major cities across Indonesia that have experienced rapid urban expansion, including Medan City. As the capital of North Sumatra Province, Medan faces recurrent flooding problems caused by rapid population growth, land-use changes, and the insufficient capacity of drainage infrastructure to accommodate stormwater runoff [3]. [4] found that a large portion of Medan City falls within flood-prone to highly flood-prone categories, including Medan Selayang District, where floodwater depths have reached approximately 1.2 meters.

Flood vulnerability in Medan City is also influenced by various environmental and physical factors. [5] explained that land use, elevation, slope gradient, rainfall intensity, and proximity to water bodies are key determinants of flood hazard levels. Similarly, [6] identified Medan Selayang District as one of the areas with high flood vulnerability due to dense residential development, reduced water infiltration areas, and limited drainage capacity. These findings were further supported by [7], who ranked Medan Selayang among the ten most flood-prone districts in Medan City.

In addition to urban factors, the hydrological characteristics of the region also contribute to flood occurrences in Medan Selayang District. According to [8], the area is influenced by the Babura Watershed, which forms part of the larger Deli Watershed. Land-use changes in upstream areas and the reduction of infiltration zones have increased surface runoff, leading to a higher potential for flooding in downstream areas, including residential settlements within Medan Selayang District.

One area that has consistently experienced recurrent flooding is Beringin Village. Several flood events have been recorded in recent years, causing significant impacts on local communities. In 2025, flooding affected hundreds of houses and forced thousands of residents to evacuate [9][10][11]. Previously, floodwaters ranging from 30 to 130 cm in depth were recorded in 2022 and 2023[12] [13]. These conditions indicate that Beringin Village has a high level of flood vulnerability and requires more effective mitigation measures.

Recurring flood events have direct impacts on residential areas, including physical damage to buildings, environmental degradation, and disruptions to the social and economic activities of local communities. The vulnerability of settlements is influenced by the physical characteristics of buildings, environmental conditions, and the availability of supporting infrastructure such as drainage systems and road networks. Settlements lacking adaptive capacity to withstand inundation tend to face higher risks during flood events [9].

Previous studies have examined flood characteristics, hazard mapping, hydrological conditions, and flood-causing factors in Medan City and Medan Selayang District [4][6][8][7]. However, most of these studies have focused primarily on hazard identification and the evaluation of physical environmental

conditions. Research specifically linking settlement characteristics to the formulation of flood mitigation strategies at the village level remains relatively limited, particularly in areas experiencing recurrent flooding such as Beringin Village.

Based on these conditions, this study aims to analyze flood mitigation conditions in flood-prone residential areas of Beringin Village, Medan Selayang District, and to formulate effective and sustainable flood mitigation enhancement strategies. The findings are expected to contribute to the development of settlement-based flood mitigation strategies and support efforts to improve the resilience of residential areas against flood disasters.

2. METHODOLOGY

2.1 Research Design

This study employed a descriptive qualitative research design to analyze the conditions of flood-prone settlements and formulate flood mitigation improvement strategies in Beringin Village, Medan Selayang District, Medan City. A qualitative approach was selected because it enables a comprehensive understanding of the physical characteristics of settlements, environmental conditions, and infrastructure systems that influence flood vulnerability [14].

2.2 Study Area and Research Period

The study was conducted in Beringin Village, Medan Selayang District, Medan City, North Sumatra, Indonesia. The area was selected purposively because it has experienced recurrent flooding events with significant impacts on residential settlements. The research was conducted from January to May 2026, covering field surveys, interviews, data processing, and analysis. (Figure 1)



Figure 1: Beringin Village, Medan Selayang

2.3 Research Subjects and Sampling Technique

The study involved six key informants selected through purposive sampling based on their knowledge and experience regarding flood events in the study area. The informants consisted of four residents affected by flooding, one village government representative, and one representative from the Regional Disaster Management Agency (BPBD).

The inclusion criteria comprised individuals who had experienced flood events in Beringin Village, stakeholders directly involved in flood management and settlement planning, and informants who were willing to participate in the interview process. Meanwhile, the exclusion criteria included residents with limited knowledge of flood conditions in the study area and individuals who were unavailable during the data collection period.

2.4 Data Collection Methods

2.4.1 Field observation

Field observations were conducted to assess the physical conditions of buildings, environmental characteristics, and settlement infrastructure associated with flood vulnerability.

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2.4.2 In-Depth Interviews

Semi-structured interviews were conducted with selected informants to obtain information regarding flood impacts, community adaptation measures, and mitigation efforts implemented within the settlement area.

2.4.3 Documentation and Literature Review

Secondary data were obtained from planning documents, demographic statistics, flood reports, maps, and relevant scientific publications. Documentation was used to support and validate the findings from observations and interviews [15][16].

2.5 Research Variables

The research variables were divided into two major categories

2.5.1 Flood-Prone Settlement Conditions

This category included building physical conditions (wall structures, roof structures, and floor elevation), environmental physical conditions (building density, land use, and distance from the river), and settlement infrastructure conditions (road network, evacuation system, drainage system, and river embankment).

2.5.2 Flood Mitigation Strategy Variables

This category included: risk-based spatial planning, green infrastructure and Nature-Based Solutions (NBS), and drainage system enhancement. The selection of variables was based on a literature review and the existing conditions of the study area [17][18].

2.6 Data Analysis

Data were analyzed using the interactive analysis model proposed by [16], consisting of data reduction, data display, and conclusion drawing and verification.

To strengthen the assessment process, each indicator was evaluated using a five-point Likert scale: very poor (1), poor (2), fair (3), good (4), and very good (5). The scoring results were used to determine the condition level of each indicator and identify priority issues requiring mitigation measures.

2.7 Strategy Formulation

The assessment results were compared with flood mitigation concepts derived from risk-based spatial planning, green infrastructure, and drainage enhancement approaches. The comparison process was used to formulate contextual, practical, and sustainable mitigation strategies aimed at improving the resilience of flood-prone settlements in Beringin Village.

3. RESULT AND DISCUSSION

3.1 Building Physical Conditions and Flood Mitigation Strategies

The results of this study indicate that the physical condition of buildings in Beringin Village remains highly vulnerable to flooding, particularly in terms of wall structures, roof structures, and floor elevations. This vulnerability is caused by repeated inundation resulting from river overflow and local flooding, which has the potential to reduce the quality of building materials and disrupt residential functions.

Therefore, the proposed mitigation strategies focus on enhancing the adaptive capacity of buildings to flood hazards through design approaches that are responsive to environmental conditions.

3.1.1 Wall Structure

Wall structures are the building components most frequently exposed to direct contact with floodwater. Field observations revealed that the lower sections of walls are the most vulnerable areas, often experiencing water seepage, moisture accumulation, plaster deterioration, and material degradation due to recurrent flooding. (Figure 2)



Figure 2: Flood-Affected Wall Condition

This finding is consistent with [19], who reported that building materials located closest to floodwater are subject to higher rates of deterioration compared to other parts of a building.

To address these conditions, several mitigation strategies are recommended. The application of a higher raised plinth can reduce direct contact between floodwater and building walls [20]. In addition, the use of modular wall systems or double-layer wall construction allows flood-damaged sections to be repaired or replaced without compromising the overall structural integrity of the building [21]. These strategies are expected to improve the durability of building envelopes and reduce maintenance costs associated with recurrent flooding. (Figure 3)



Figure 3: Wall Structure Design Strategy

3.1.2 Roof Structure

The findings indicate that roof structures have the potential to function as temporary safe spaces during high flood events. In several locations situated near riverbanks, roofs become the last usable area for residents when the ground floor is completely inundated. This condition demonstrates that roofs serve not only as protective building elements but also as integral components of flood mitigation and evacuation systems. (Figure 4)



Figure 4: Existing Roof Condition

These findings are consistent with [22], who emphasized the importance of vertical connectivity in flood-prone housing. Similarly, Piątek and Wojnowska-Heciak highlighted that the structural stability of upper building elements is a critical component of flood-adaptive design.

To address these conditions, several mitigation strategies are recommended. Roof structures should be designed to be strong and stable in order to maintain building functionality during flood events. In addition, integrated vertical access should be provided to upper building levels to function as evacuation routes during emergencies [22]. Furthermore, the concept of usable roof space can be developed as a temporary evacuation and refuge area during flooding, thereby enhancing the adaptive capacity of residential buildings [23][24]. These strategies are expected to strengthen the role of roof structures not only as protective elements but also as critical components of flood resilience systems. (Figure 5).

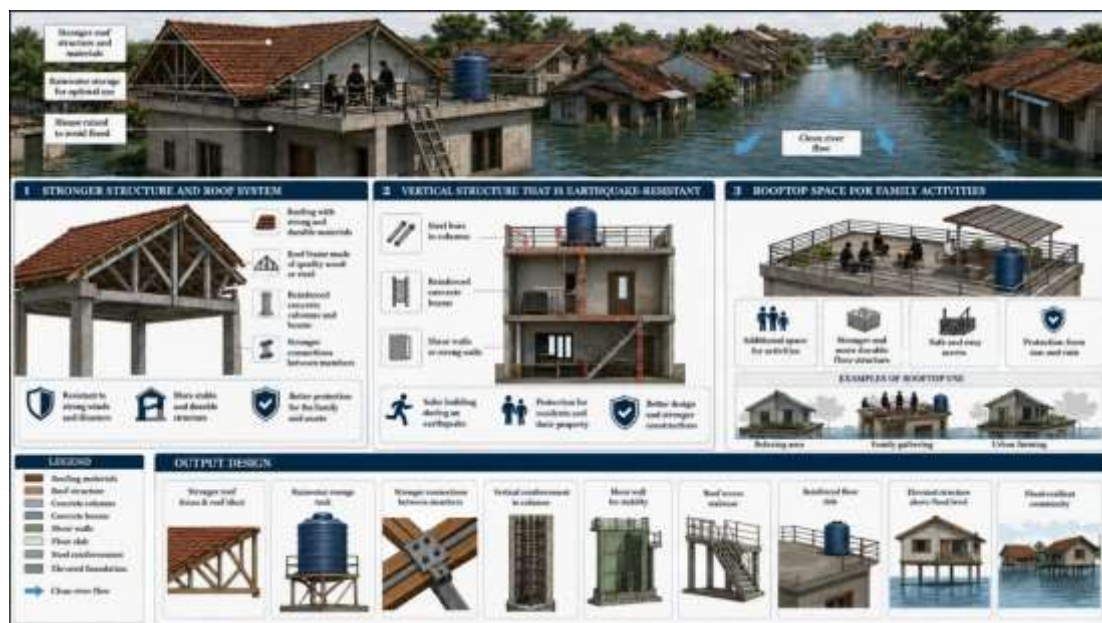


Figure 5: Roof Structure Design Strategy

3.1.3 Floor Elevation

Floor Floor elevation is one of the primary building elements for reducing the direct impacts of flooding on residential spaces. Field observations revealed that most houses in Beringin Village are situated at relatively low elevations, making them highly susceptible to inundation during periods of increased river discharge and heavy rainfall. These conditions disrupt residents' daily activities and increase the risk of damage to the main living areas of buildings. (Figure 6)



Figure 6: Existing Floor Condition

This finding is consistent with [25], who identified stilt houses as a traditional form of flood adaptation. Similarly, Asti and Utami (2018) found that increasing floor levels is one of the most common architectural adaptation measures implemented in flood-prone areas.

To address these conditions, the recommended mitigation strategies include raising the main floor level above the expected flood elevation or adopting the stilt-house concept to minimize flood impacts on residential spaces [25][26]. In addition, installing threshold barriers (door sills) at building entrances can help reduce the inflow of floodwater into buildings during inundation events [27]. These measures are expected to enhance the resilience of residential buildings by minimizing physical damage and maintaining basic living functions during flood events. **(Figure 7)**

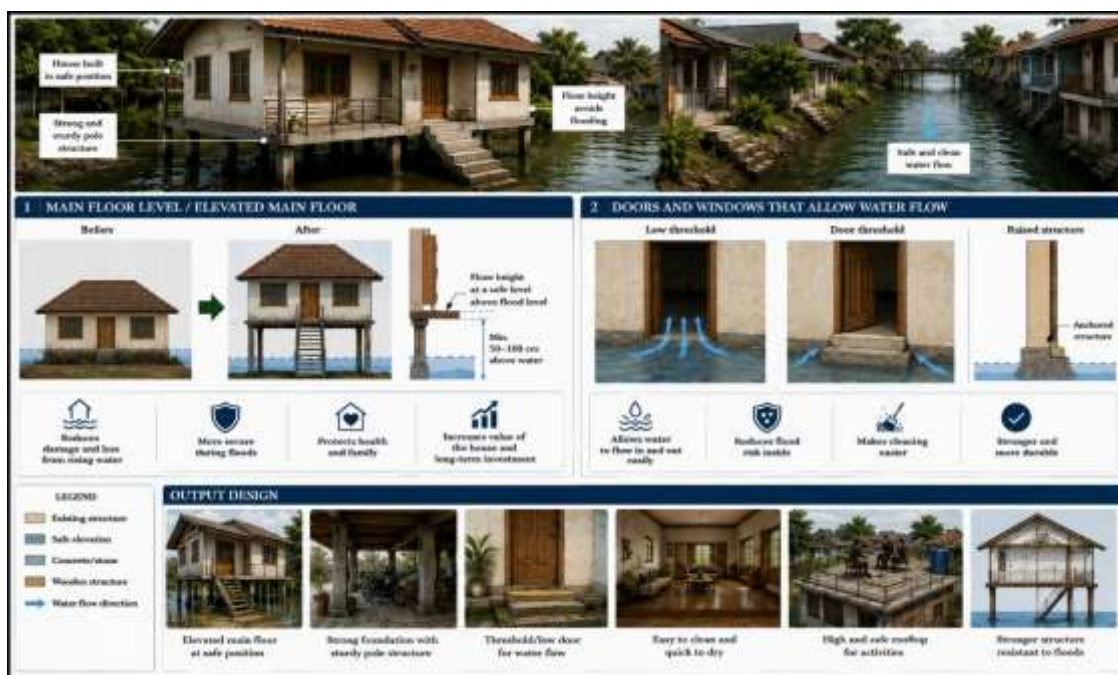


Figure 7: Floor Elevation Design Strategy

3.1.4 Synthesis of Building Physical Condition

Overall, improving the physical resilience of buildings in Beringin Village can be achieved through modifications to wall structures, strengthening the adaptive functions of roof structures, and increasing floor elevations. These strategies not only help reduce the extent of flood-induced damage but also enhance the ability of buildings to maintain their residential functions during flood events.

Therefore, buildings should be designed not only to resist flooding (flood resistance) but also to adapt to recurrent inundation conditions (flood adaptation). By integrating these adaptive measures, residential structures can better withstand flood impacts while ensuring the safety, functionality, and continuity of daily activities for residents during and after flood events.

3.2 Environmental Physical Conditions and Flood Mitigation Strategies

The findings indicate that the physical environmental conditions in Beringin Village significantly influence flood vulnerability. High building density, the dominance of impervious built-up surfaces, and the proximity of residential areas to the river contribute to the limited capacity of the environment to absorb, retain, and regulate water flow. These conditions increase surface runoff, reduce infiltration capacity, and heighten the exposure of residential areas to river overflow.

Therefore, the proposed mitigation strategies focus on enhancing the ecological and hydrological functions of the environment through adaptive and infiltration-based design approaches.

3.2.1 Building Density

Field observations revealed that several residential areas in Beringin Village have developed organically, resulting in relatively narrow spacing between buildings, particularly in areas adjacent to the riverbanks. High building density reduces the availability of open spaces that function as rainwater infiltration areas, thereby increasing surface runoff and making the area more susceptible to flooding. (Figure 8)



Figure 8: Building Density in the Riverbank Area

This finding is consistent with [28], who explained that residential development along riverbanks with intensive land utilization can diminish the ecological and hydrological functions of river buffer zones. Furthermore, [29] stated that high building density in riverbank settlements can increase flood risk due to reduced flow capacity and the narrowing of river corridors.

To address these conditions, the recommended mitigation strategies include the reorganization of building masses in riverbank areas that do not comply with river setback regulations in order to restore the protective functions of river buffer zones [30]. In addition, the optimization of spaces between buildings as micro-infiltration areas through the implementation of infiltration wells and biopore infiltration holes is essential to enhance rainwater absorption and reduce surface runoff [31][32]. These interventions are expected to improve local hydrological performance and reduce flood vulnerability in densely built residential areas. (Figure 9)



Figure 9: Building Density Design Strategy

3.2.2 Land Use

The findings indicate that land use in Beringin Village is predominantly characterized by built-up areas with a high proportion of impervious surfaces. This condition causes a significant portion of rainfall to be directly converted into surface runoff, thereby increasing the burden on the drainage system and elevating the potential for flooding and waterlogging. (Figure 10)



Figure 10: Dominance of Impervious Surfaces in the Settlement Area

This finding is consistent with [33], who explained that land-use changes resulting from urbanization increase the extent of impervious surfaces, which directly contribute to higher surface runoff and flood risk. Similarly, [34] emphasized that reduced infiltration capacity in built-up areas is one of the primary drivers of urban flooding.

To address these conditions, the recommended mitigation strategies focus on improving surface permeability and enhancing local water retention capacity. This can be achieved through the use of permeable materials such as grass blocks, porous paving, and permeable pavements in residential yards and pedestrian pathways to facilitate rainwater infiltration and reduce surface runoff [35][34]. In addition, the development of integrated micro-infiltration systems, including infiltration wells, biopore infiltration holes, and rainwater harvesting systems, is essential to improve rainwater absorption and increase local water storage capacity [31]. These measures are expected to reduce runoff generation and mitigate the risk of urban flooding in the study area. (Figure 11)



Figure 11: Land Use Design Strategy

3.2.3 Distance from the River

Field observations revealed that some residential areas have developed in close proximity to the river channel, and in several locations, the development does not fully comply with the prescribed river setback regulations. As a result, these settlements experience a high level of exposure to riverine flooding, particularly during periods of increased river discharge caused by heavy rainfall. (Figure 12)

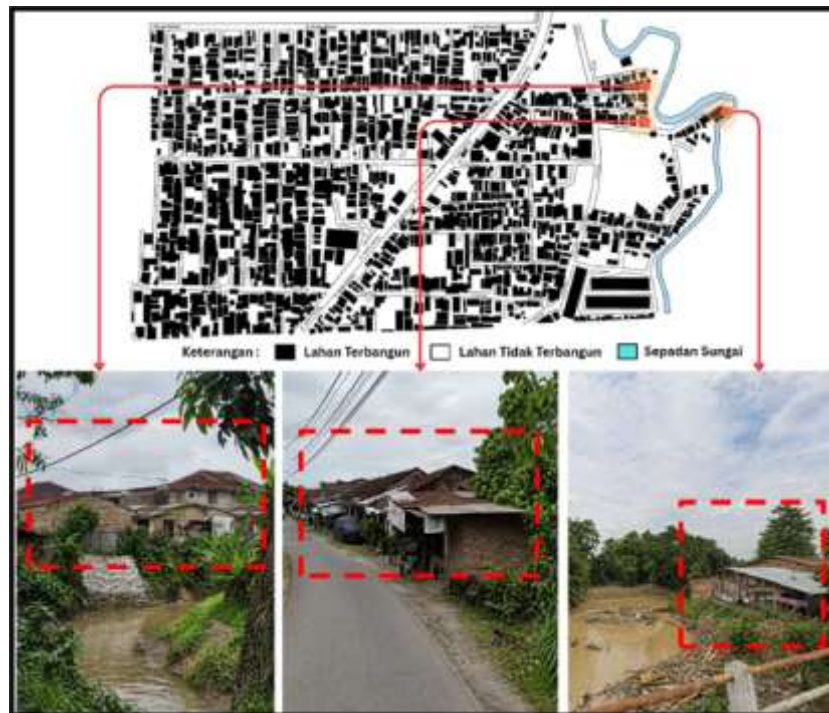


Figure 12: Residential Settlements within the River Setback Area

This finding is consistent with [29], who explained that settlements located within river setback areas are more vulnerable to flooding due to the loss of the natural protective functions provided by riparian zones. Furthermore, [36] emphasized that river setback areas function as buffer zones that help maintain hydrological balance and reduce the intensity of water flow reaching built-up areas.

To address these conditions, the recommended mitigation strategy focuses on strengthening the river setback buffer zone as an area for water retention and flow attenuation through the enhancement of vegetation cover and the provision of green open spaces, thereby improving its ecological and hydrological functions [36]. This approach is expected to reduce flood exposure and restore the protective role of riparian areas. (Figure 13)



Figure 13: Residential Distance to River Design Strategy

3.2.4 Synthesis of Environmental Physical Conditions

Overall, enhancing flood mitigation in terms of environmental physical conditions in Beringin Village can be achieved through the regulation of building density, the optimization of land use to support water infiltration, and the strengthening of river setback areas as hydrological protection zones. These strategies can increase rainwater infiltration capacity, reduce surface runoff, lower the level of exposure to river overflow, and reinforce the role of the environment as a flood control system.

Consequently, residential environments should function not only as living spaces but also as integral components of a broader flood mitigation system that supports long-term community resilience. By improving the ecological and hydrological performance of the built environment, flood-prone settlements can better adapt to recurring flood events while promoting sustainable and resilient urban development.

3.3 Residential Infrastructure and Flood Mitigation Strategies

The findings indicate that residential infrastructure in Beringin Village still faces several limitations in supporting effective flood mitigation. These challenges are reflected in circulation systems and neighborhood roads that lose functionality during flood events, the limited availability of evacuation signage and routes, suboptimal drainage network performance, and river embankments that are not yet fully capable of controlling floodwaters. These conditions demonstrate that residential infrastructure serves not only as an environmental service facility but also as a critical component of the flood mitigation system that determines the resilience of the settlement to flood hazards.

Therefore, mitigation strategies should focus on enhancing the adaptive capacity of infrastructure so that it can continue to function and support public safety during flood events.

3.3.1 Circulation Systems and Neighborhood Roads

Field observations revealed that several neighborhood roads in Beringin Village are relatively narrow and experience a significant reduction in functionality during flood events. In some locations, access for emergency and relief vehicles becomes difficult, thereby hindering community mobility and evacuation processes. This condition indicates that the existing circulation system is not yet fully capable of supporting emergency operations during flooding events. (Figure 14)

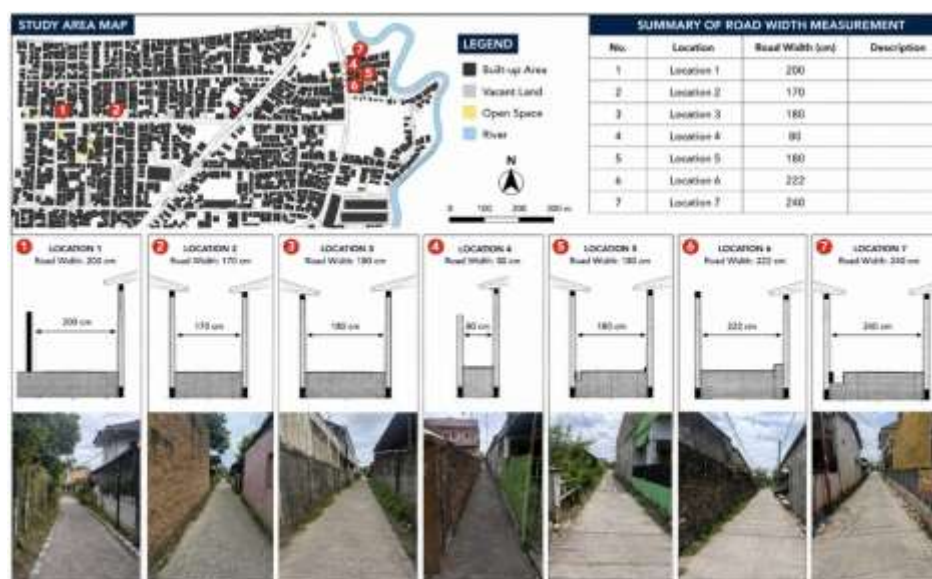


Figure 14: Existing Condition of Narrow Neighborhood Roads

These findings are consistent with [37], who emphasized that evacuation routes in disaster-prone areas must provide adequate connectivity and accessibility to facilitate the movement of residents toward safe locations. Similarly, [38] stated that the effectiveness of evacuation routes is strongly influenced by the ability of the road network to maintain accessibility during emergency conditions.

To address these challenges, the recommended mitigation strategy includes the construction of elevated walkways along residential corridors that are frequently inundated, in order to maintain connectivity and ensure continuous accessibility during flood events [39]. This approach is expected to support evacuation processes and improve overall mobility and safety during flooding situations. (Figure 15)



Figure 15: Circulation System and Neighborhood Road Design Strategy

3.3.2 Evacuation Routes and Signage System

Field observations indicate that evacuation signage and designated evacuation routes in Beringin Village remain limited and are unevenly distributed across the settlement. This condition creates difficulties in spatial orientation during flood events, particularly under low-visibility conditions such as nighttime or adverse weather. Consequently, residents may face challenges in identifying and following safe evacuation paths when rapid movement to safer areas is required. (Figure 16)



Figure 16: Evacuation Route Signage and Flood Hazard Warning Signs in the Settlement Area

These findings are consistent with [40], who emphasized that wayfinding systems play an important role in helping users understand spatial orientation and circulation patterns within the built environment. Similarly, [41] stated that the integration of visual information systems with physical environmental elements can enhance spatial legibility and improve navigation effectiveness.

To address these challenges, several mitigation strategies are proposed. Evacuation signage should be integrated with architectural elements such as walls, utility poles, and building façades to improve visibility and ensure consistent placement of emergency information throughout the settlement [41]. In addition, evacuation routes should be designed to be easily recognizable both visually and spatially through clear directional cues and strong route connectivity, ensuring intuitive navigation toward safe areas during emergency situations [42][43]. Furthermore, lighting elements can be utilized as directional markers to enhance the visibility of evacuation routes under low-light conditions, thereby improving safety and response effectiveness during flood events [44][45]. **(Figure 17)**



Figure 17: Evacuation Signage and Route System Design Strategy

3.3.3 Environmental Drainage System

Field observations indicate that drainage problems in Beringin Village are not solely caused by limited channel capacity, but also by the uneven distribution of the drainage network, channel narrowing, blockages, and additional inflow from external areas. These conditions lead to localized flooding in several areas despite the presence of drainage infrastructure. (Figure 18)

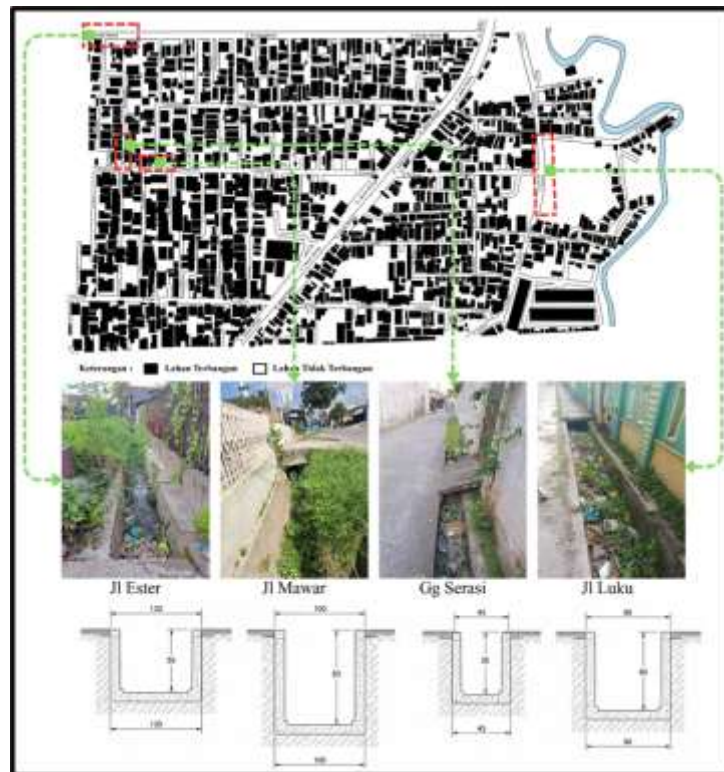


Figure 18: Drainage Channels Obstructed by Waste and Sedimentation

This finding is consistent with [46], who explained that the effectiveness of urban drainage systems is strongly influenced by the connectivity between drainage channels. In addition, [47] emphasized that an integrated drainage network is required to ensure the system's ability to distribute water flow evenly across the area.

To address these issues, the proposed mitigation strategies focus on strengthening an integrated micro-drainage network by improving connectivity between channels and resolving bottleneck sections within the system [46]. Furthermore, a detention- and retention-based drainage approach is recommended, which aims to slow surface runoff through the implementation of infiltration wells, micro-retention basins, and other infiltration facilities to enhance local water absorption capacity [48]. These strategies are expected to improve drainage performance, reduce surface runoff accumulation, and minimize localized flooding within the settlement. **(Figure 19)**



Figure 19: Environmental Drainage System Design Strategy

3.3.4 River Embankments Function

The findings indicate that the flood protection function of river embankments in Beringin Village is not yet operating optimally. The identified issues include the deterioration of embankment physical conditions, uneven protection across river segments, and sedimentation that reduces river conveyance capacity. These conditions increase the risk of overflow into residential areas when river discharge rises. (Figure 20)

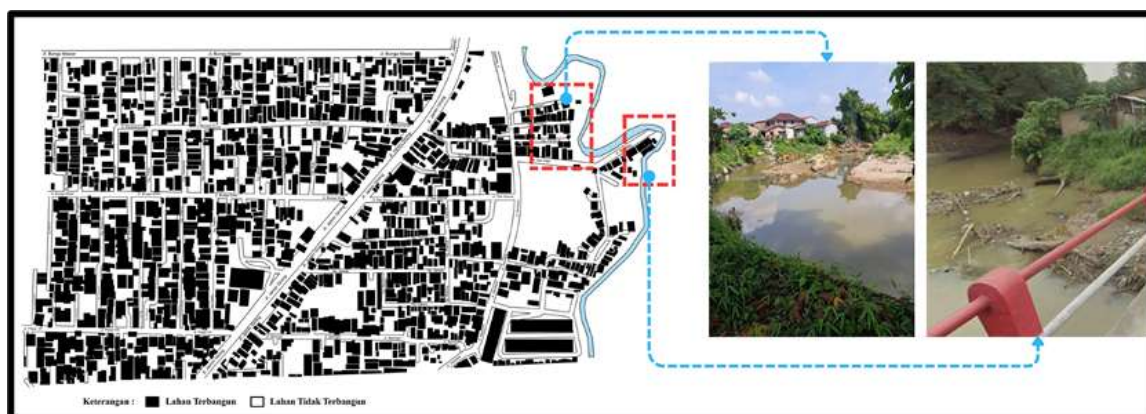


Figure 20: Existing Residential Area Lacking River Embankment Protection

This finding is consistent with [29], who explained that flood control in riverbank areas does not depend solely on physical infrastructure but also on the maintenance of river functions and their

protective zones. Furthermore, [17] emphasized that riverbank protection plays a crucial role in reducing the exposure of surrounding areas to flood hazards.

To address these challenges, several mitigation strategies are recommended. Routine maintenance of embankments and sedimentation control should be implemented through periodic inspections, channel cleaning, and dredging of river sections experiencing sediment accumulation in order to maintain adequate river conveyance capacity [29]. In addition, local embankment protection should be strengthened through the construction or reinforcement of low embankments at critical locations that frequently serve as pathways for floodwater intrusion into residential areas [17][49]. These measures are expected to enhance the effectiveness of river protection systems, reduce flood exposure, and improve the resilience of flood-prone settlements. (Figure 21)



Figure 21: River Embankment Design Strategy

3.3.5 Synthesis of Residential Infrastructure

Overall, improving flood mitigation in terms of residential infrastructure in Beringin Village can be achieved through the development of circulation systems that are adaptive to inundation, strengthening of signage and evacuation route systems, optimization of neighborhood drainage networks, and enhancement of river embankment protection functions. These strategies are capable of maintaining area accessibility during flood events, accelerating evacuation processes, improving the effectiveness of water conveyance, and reducing the risk of river overflow into residential areas.

Consequently, residential infrastructure should not be viewed solely as a component of environmental services, but also as an active mitigation system that supports community resilience and safety in the face of flood hazards. By integrating adaptive infrastructure systems, settlements can better sustain functionality during emergencies while minimizing disruption and risk to residents.

4. CONCLUSIONS AND RECOMMENDATIONS

This study aimed to formulate strategies for improving flood mitigation in flood-prone settlements in Beringin Village, Medan Selayang District, through an architectural approach. The findings were derived from the identification of existing conditions, the assessment of flood mitigation indicators, and the formulation of design-based mitigation strategies. Overall, the level of flood mitigation in Beringin Village was categorized as moderately good, with an average score (NV) of 2.93. Nevertheless, several aspects still require improvement to enhance the resilience of the settlement against recurring flood hazards. The aspects with relatively lower levels of preparedness include building physical conditions, environmental physical conditions, and residential infrastructure, particularly those directly related to flood control and adaptation.

The assessment of building physical conditions revealed that the primary vulnerabilities are associated with wall structures, roof structures, and floor elevations. Recurrent exposure to floodwater has the potential to accelerate material deterioration and disrupt the functionality of residential spaces. To address these challenges, the proposed strategies focus on increasing the adaptive capacity of buildings through the implementation of raised plinths, modular or double-layer wall systems, strengthened roof structures, integrated vertical access, the utilization of roofs as temporary evacuation spaces (usable roof space), and the elevation of floor levels combined with threshold barriers at building entrances. These measures are expected to reduce flood-related damage while enabling buildings to maintain their residential functions during flood events.

Regarding environmental physical conditions, the study found that high building density, the dominance of impervious surfaces, and the close proximity of settlements to the river significantly contribute to flood vulnerability. These conditions limit the environment's ability to absorb and regulate rainwater, resulting in increased surface runoff and a higher risk of inundation. Therefore, the recommended strategies emphasize the enhancement of ecological and hydrological functions through the reorganization of buildings within river setback areas, the optimization of inter-building spaces as micro-infiltration areas, the use of permeable materials, the development of infiltration wells, biopore systems, and rainwater harvesting facilities, as well as the strengthening of river setback transition zones as water retention and flow attenuation areas. These interventions are expected to improve infiltration capacity, reduce runoff, and decrease the exposure of residential areas to flooding.

The evaluation of residential infrastructure highlighted several limitations related to circulation systems and neighborhood roads, signage and evacuation routes, environmental drainage systems, and river embankments. During flood events, some roads lose their functionality, evacuation guidance

remains limited, drainage performance is constrained, and river embankments do not provide adequate protection in all locations. To enhance the role of infrastructure as an active flood mitigation system, several strategies are proposed, including the construction of elevated walkways, the strengthening of wayfinding systems and evacuation routes, the optimization of integrated micro-drainage networks, the implementation of detention- and retention-based drainage systems, routine embankment maintenance, sedimentation control, and the construction of low embankments at critical flood-prone points. These measures are intended to improve accessibility, safety, and the overall resilience of the settlement during flood events.

In conclusion, the findings demonstrate that improving flood mitigation in flood-prone settlements requires an integrated approach that combines adaptive building design, environmentally responsive land-use management, and resilient infrastructure development. Rather than relying solely on conventional flood-control measures, the proposed strategies emphasize the importance of enhancing the capacity of buildings, environments, and infrastructure to adapt to recurrent flooding. Through the integration of these architectural and environmental interventions, flood-prone settlements can achieve greater resilience, reduce vulnerability, and support sustainable community development in the long term.

Based on the findings of this study, several recommendations can be proposed to support the improvement of flood mitigation in Beringin Village and similar flood-prone settlements. For local governments, greater attention should be given to strengthening policies related to river setback area management through stricter land-use control and the regulation of building development within flood-prone zones. In addition, regular maintenance programs for drainage systems and river embankments should be enhanced to preserve hydraulic capacity and reduce the risk of river overflow. Local authorities are also encouraged to promote the implementation of green infrastructure, such as infiltration wells, biopore systems, and green open spaces, as part of an environmentally based flood management strategy.

For local communities, increasing awareness of flood-adaptive building practices is essential. Residents are encouraged to adopt measures such as raising floor elevations, protecting building openings from floodwater intrusion, and conducting routine maintenance of building components to improve resilience against recurrent flooding. Community participation is also necessary in maintaining the cleanliness and functionality of drainage channels and river setback areas to ensure the effectiveness of water conveyance systems. Furthermore, residents should actively support the development of micro-infiltration facilities within residential environments to reduce surface runoff and enhance rainwater absorption.

For future research, further studies are recommended to incorporate hydrological and hydraulic simulations in order to evaluate the effectiveness of the proposed mitigation strategies in reducing flood risk. Future investigations may also integrate architectural approaches with emerging concepts

such as Nature-Based Solutions (NBS), Blue-Green Infrastructure (BGI), and Water Sensitive Urban Design (WSUD) to develop more comprehensive and sustainable flood mitigation frameworks. In addition, quantitative assessments of the effectiveness of individual design strategies would provide valuable insights into their contribution to enhancing the resilience of flood-prone settlements.

From an architectural perspective, the findings of this study demonstrate that architectural approaches play a significant role in flood disaster mitigation through the development of adaptive building designs, environmentally responsive settlements, and resilient infrastructure systems. Therefore, the concept of flood-resilient settlements should continue to be advanced as an integral component of sustainable urban planning and design practices. Ultimately, improving flood mitigation in Beringin Village requires not only the strengthening of conventional flood-control infrastructure but also the transformation of building and environmental design toward more adaptive, resilient, and sustainable forms. Such an integrated approach can contribute to the creation of safer and more resilient communities capable of facing future flood risks.

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