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Proposed Framework for the Flood Disaster Management Cycle in Malaysia

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Abstract: Floods have been reported to be an important disaster in any country and Malaysia has faced similar disasters in the past, resulting in disturbance in daily community routine issues, financial losses, infrastructure damage including railway tracks, bridges, roads, vehicles, properties, and the worst is the loss of lives. The Sarawak region of Malaysia also witnesses yearly disasters in rainy seasons. The purpose of this paper is to explore the possible challenges to manage the flood disaster in Sarawak and to identify the possible solutions to manage floods. In this research, secondary data was used for qualitative assessment. The newspaper articles were collected from the year 2015 until 2019. Targeted interviews were conducted with experts working in flood management disaster schemes to rank and validate the most important factors after content analysis from the past news reports. It is concluded that poor drainage systems, rapid development, heavy rainfall, lack of public awareness, and lack of coordination in executing the disaster management cycle among agencies are the key challenges. Thus, it is recommended that the drainage systems should be upgraded in the case study area. Proper flood management schemes should be planned and flood forecasting should be strengthened. An effective early flood warning system should be designed to activate the plans and a proper public awareness campaign should be initiated to educate and train the local community to deal with such disasters. It is also suggested to assure and maintain proper collaboration among different agencies during such disasters. In the last phase, this paper also proposes a framework for future flood disaster management. The framework will assist the stakeholders to make informed decisions to save human lives and substantial financial losses. The framework can also be used in similar terrain countries.

Keywords: flood; disaster management; challenges; Sarawak; flood disaster management cycle; Malaysia

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1. Introduction

Floods are the most successive cataclysmic event and are regularly brought about by substantial precipitation, quick snowmelt, or a tempest flood from a typhoon or torrent in beachfront regions, floods and other cataclysmic events influence countless individuals around the world consistently. As the climate changes, extreme weather events such as floods are expected to become more frequent and more intense [1]. Evaluations of both

influenced individuals and financial misfortunes change broadly. Environmental change is expanding the recurrence and power of flood fiascos worldwide, which almost multiplied in 2000–2009 contrasted with the earlier decade [2]. As per the Organization for Economic Co-activity and Development (OECD) [3], floods influence up to 250 million individuals on the planet consistently. In 2019, floods caused more than 5000 setbacks around the world [4]. In 2019, floods caused USD 45.9 billion in monetary misfortunes and almost 4500 passed away in the world [5]. Figure 1 shows the death rate in the world due to natural disasters, including floods.

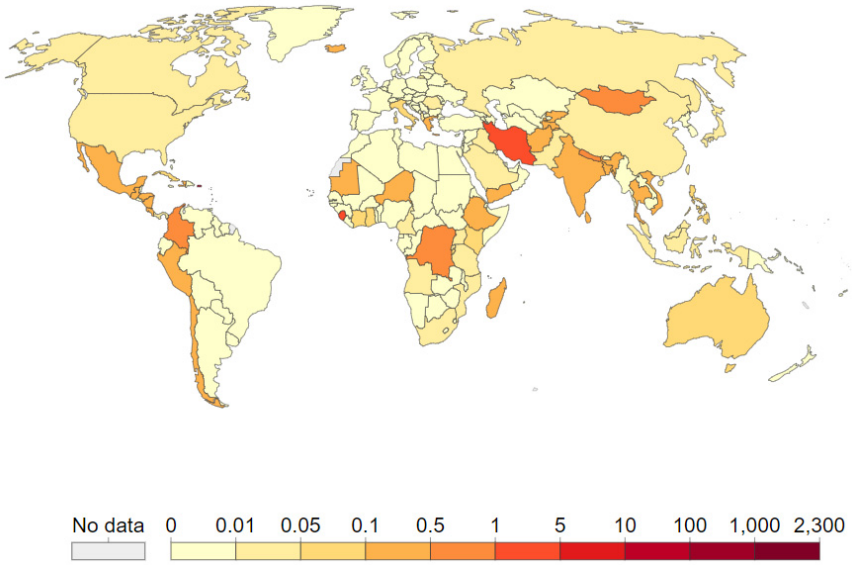

Figure 1. World death rate from natural disasters, 1990 to 2017 [6].

It can be observed that the yearly number of passed away from all types of catastrophic events per 100,000 people is vulnerable in various countries. It is recorded that Iran has the highest annual number of deaths with 1.03 per 100,000. Meanwhile, Magnolia and Nepal with 0.52. Malaysia recorded the annual number of deaths with 0.03, and the lowest one is Thailand with 0.11 deaths.

New information reported by the World Resource Institute in April 2020 figures the number of individuals hurt by floods to two-fold internationally by 2030. As per the projections acquired in 2019 by the Aqueduct Floods displaying apparatus of the World Resource Institute, harm to the metropolitan property are required to ascend from USD 174 to USD 712 billion every year. Floods can cause far and wide decimation, bringing about the death toll and harm to individual property and basic general well-being framework. Between 1998–2017, floods influenced more than 2 billion individuals around the world. Individuals who live in floodplains or non-safe structures, or need cautioning frameworks and consciousness of flooding danger, are generally powerless against floods. According to World Resources Institute, by 2030, 15 million individuals and USD 177 billion in the metropolitan property will be affected yearly by beachfront flooding, while 132 million individuals and USD 535 billion in the metropolitan property will be affected by yearly riverine flooding [5].

The construction of effects is not uniform across the world: low-pay nations endure higher fatalities, though top-level salary nations register higher upsides of harm to properties and foundations. Floods in Malaysia have brought tremendous impacts on people's livelihood, damaged properties and infrastructures, and caused many fatalities in recent years [7]. Sarawak was influenced by Northeast Monsoon winds which strike from November until March. Similarly, Southwest Manson winds strike from Jun until September. The reports also mentioned that Northeast Monsoon winds from South China brought about 50% of total rainfall in Sarawak, especially in the beach area [8].

It can be analyzed that the statistic of the flood disaster in Malaysia is an unstable performance. It shows the statistic in the average record from the year between 1990 and 1993. It rises slowly in the year 1994. It rises to the peak in the year of 1996 more than 1.2 scales. The flood graph records slightly down and upwards starting from the year 2000 until 2017. Inside dislodged people are characterized as individuals or gatherings of individuals who have been constrained or obliged to escape or leave their homes or places of routine home because of regular or human-caused fiascos and who have not crossed a global line. Figure 2 shows the displaced persons from natural disasters.

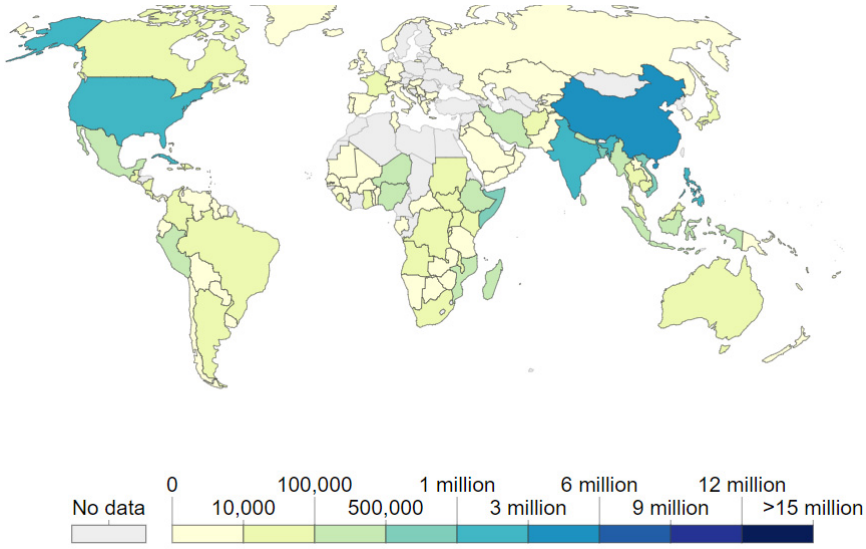

Figure 2. Internally displaced persons from natural disasters, 2017 [9].

Figure 2 observes the internally dislodged people from a catastrophic event in 2017. It is recorded that Iran has the highest internally dislodged people from catastrophic events between 12 to 15 million in 2017. Meanwhile, Magnolia and Nepal with less than 10,000. Malaysia recorded the number of internally displaced persons from natural disasters less than 100,000 and Thailand between 100,000 and 500,000 persons. Similarly, Figure 3 shows the direct disaster economic loss in Malaysia.

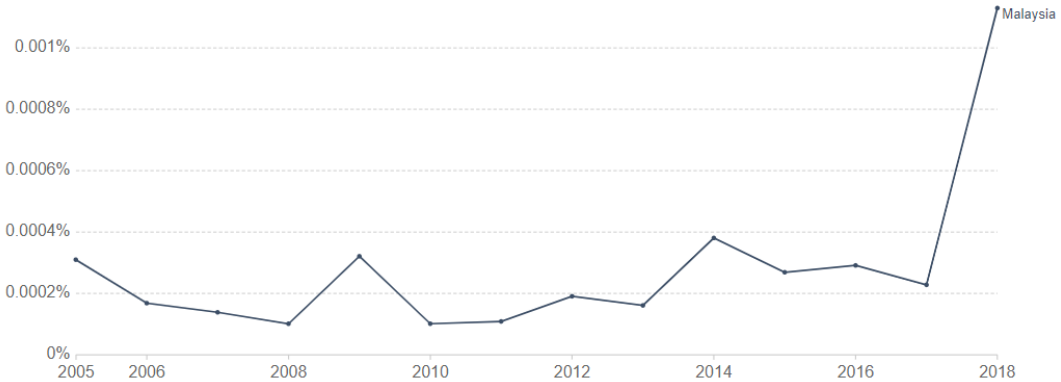

Figure 3. Direct disaster economic loss as a share of GDP, 2005 to 2018 [10].

Figure 3 analyzes the direct economic loss as a share of GDP, 2005 to 2018, in Malaysia. It is seen that the graph is moving down from 2005 until 2008. Then, the economic loss rises in 2009 with 0.0003% and back to moving down in 2010 until 2013. The economic loss as a share of GDP, 2005 to 2018, in Malaysia in the year 2014 and the rise up to the peak in 2018 with more than 0.001% can also be observed. Figure 4 shows the disaster risk reduction progress in the world.

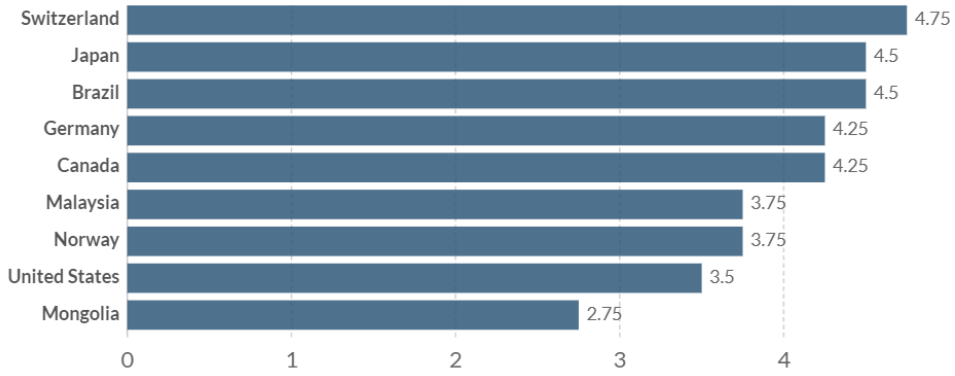

Figure 4. Disaster risk reduction progress score, 2011 [10].

It is reported that Switzerland has the best score at 4.75 in disaster risk reduction, followed by Japan and Brazil, both at 4.5 scores of disaster risk reduction. Malaysia shows a 3.75 score of disaster risk reduction, which classifies as a medium stage. The country that has the lowest score on the disaster risk reduction progress is shown by Mongolia with 2.75 only. There are four phases in the disaster cycle known as mitigation, preparedness, response, and recovery.

Productivity is a key element and mitigation measures of any activity are linked with productivity [11]. Mitigation refers to activities taken before a peril turns into a fiasco. Preparedness advises the local area from the forthcoming debacle, having an alternate course of action and methods for scattering preparation, guaranteeing that ready frameworks are working, and preparing networks for the fast and first reactions. The response is characterized as "activities and capacity to respond to the abrupt debacle under pressure, vulnerability, different limitations, and restricted assets". Recovery includes the action such as search and salvage exercises, giving food, medical aid and departure help, and the fast correspondence and transport office to the influenced region. Finally, integrated flood management (IFM) is a cycle that advances an incorporated, as opposed to divided, way to deal with flood as displayed in Figure 5.

Figure 5. Integrated flood management [12].

There is a requirement for a way to deal with floods that improves the working of the waterway bowl, all in all, perceiving that those floods have beneficial effects and can never be completely controlled. Such a methodology looks to boost the net advantages from the utilization of floodplains and to limit death toll, subjecting flood shortfall decrease to the general objective of augmenting the effective utilization of the flood [12].

It is observed in the literature that there are existing studies conducted on flood disaster management, but the existing studies do not fit and solve the local condition in

the case study area. The previous studies are conducted in various other regions whereas limited attempts are made for Malaysia. In such cases, the stakeholders and policymakers face problems in designing a proper flood disaster response plan. Therefore, this paper aims to fill this gap, and the factors added in this study are aligned with the local conditions of the case study area.

Nowadays, flooding has been a significant danger around the globe and has become familiar in Malaysia. Every year, flood disasters represent a substantial number of setbacks, infection pestilences, property and harvest harm, and other immaterial misfortunes [13]. According to the National Academy of Sciences (2019) among Malaysia, including Sabah and Sarawak, toward the South China area, there are 189 drainage areas with the primary drainage streaming straightforwardly while 85 of them are inclined to repetitive flooding (78 in Sabah and 22 in Sarawak with the total 89 of drainage areas in Peninsular Malaysia). Therefore, this paper aims to investigate the key challenges to flood management during the disasters in the study area and it also suggests the key solutions for effective flood disaster management in the future. In the end, it also proposes a framework to assist the stakeholders to make better decisions in such challenging conditions. To reach the research aim, the following research questions are selected.

1. What are the recent flood disasters reported in the study area?
2. What are the key current challenges the stakeholders are facing to manage the flood disasters?
3. What can the possible suitable remedial measure to improve flood disaster management?

2. Literature Review

Geographically, Malaysia is in a steady locale, away from volcanic eruption areas. However, Malaysia was still affected by floods and human-made disasters such as deforestation, global warming, and others. According to [14], Sarawak is moderately free from catastrophic events, such as storms, quakes, and hurricanes. In addition, profoundly populated metropolitan territories convey high values and result in flood disasters, setting back the urban development for years [15].

Most disasters nowadays are due to climate change, urbanization, social, financial precariousness, illegal intimidation, cataclysmic event, digital assault, neediness, and endemic flare-up [16]. Due to its geographical and climatic circumstances, Pakistan is one of the most severely impacted countries by climate-related catastrophic occurrences such as floods. Flood frequency and intensity have grown in Pakistan during the last two decades, causing chaos on the livelihood and well-being of millions of people [17,18]. Flood disasters experienced by many countries are caused by several reasons such as weighty downpours, over streaming waterways, broken dams, metropolitan drainage basins, storm flood, tsunami, absence of vegetation, a channel with steep sides, melting snow and ice, and many more. Floods are principally caused by consistent, substantial rainfall, a quick turn of events, unplanned urbanization, a helpless drainage system, and ecological debasement. As [17] stated, the atmosphere in Malaysia is encountering precipitation with an average rainfall of 2500 mm (98 inches), 3000 mm a year in Sabah and 3500 mm a year in Sarawak, making flood measurement records an average calamitous occasion in Malaysia. The Department of Irrigation and Drainage (2016) stated that the assessed territory vulnerable against flood disaster was about 29,800 km^2 or 9% of the all-out Malaysia locale and affected all intents and purposes of 4.82 million people who were around 22% of the outright people of the country.

It is progressively perceived that a thorough comprehension of the current flood framework is essential to oversee waterfront flood hazards successfully. New information shows many individuals' trillions in property are at danger from flooding, yet current framework speculations can fundamentally bring down flood hazards [5].

Floods occurred spontaneously because of consistent, substantial precipitation, high floods and elevated tides, and human action such as impeding of channels or disturbance of drainage, unlawful development, over-exploitation, and so forth. As [18] stated, floods

have achieved 40–50% of a wide range of calamities causing deaths globally. Similarly, floods are catastrophic events that have ruled from the 1880s until now and affect different populaces in Malaysia. The flood number periodically rises in every annual occurrence in Malaysia. Figure 6 shows natural disasters in statistics in Malaysia in 2020.

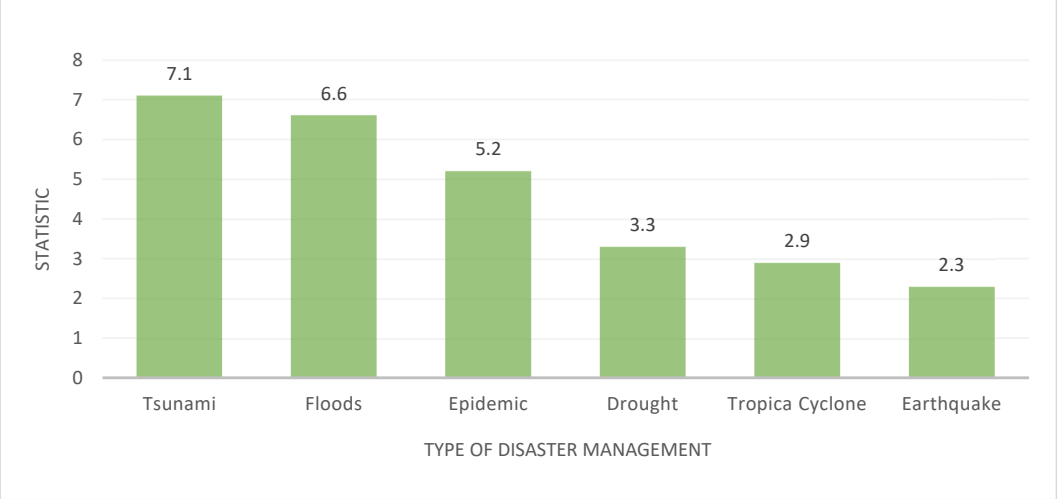

Figure 6. Natural disaster data in Malaysia.

It can be analyzed that the risk index for a tsunami occurring in 2020 is the highest at 7.1 followed by a flood located in the second-highest natural disasters risk index at 6.6 out of 10. According to the Flood Malaysia Indicator, Malaysia experienced significant floods from December 2014 to January 2015. Pretty much every state was hit by floods during that period, with more than 200,000 individuals affected. In 2016, it was recorded that Selangor, Kedah, and Penang were the states with the most floods. The ongoing floods also occurred in various areas such as Johor, Pahang, Melaka, and Sarawak. Floods can happen anytime, anywhere, unpredictably. Figure 7 shows the flood frequency in Sarawak from 2015 until 2019.

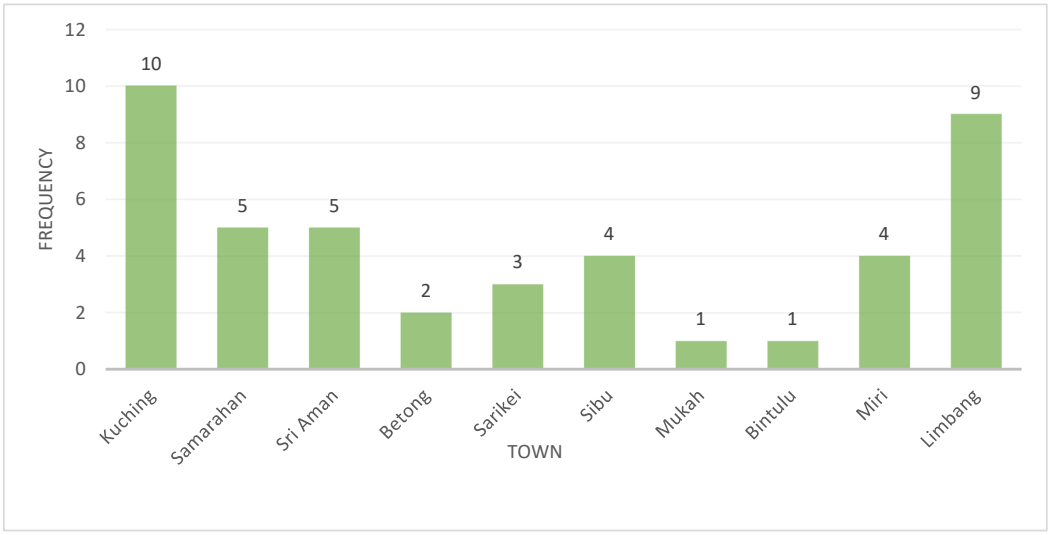

Figure 7. Flood frequency data in Sarawak from 2015 until 2019 [19].

It is observed that Kuching stated the highest frequency of flooding within the previous five years. Next, it was followed by Limbang, Samarahan, Sri Aman, and the lowest one is from Mukah. These data have been summed into the month-to-month, occasional, and yearly sums to figure out the extraordinary rainfall event in Sarawak. According to the

Sarawak Government (2020) [20], the winter monsoon, generally between November and February, brings weighty downpour, while the summer monsoon from June to October is typically breezier. For instance, in December 2014 and January 2015, another substantial amount of precipitation occurred practically all through Sarawak, where explicitly a focused energy precipitation over 250 mm of precipitation occurred in Kuching between 18 and 19 January 2015 due to critical flood catastrophes in Sarawak [21]. Flood control includes an integrated ecosystem approach, including members of the local community, such as farmers, as well as financial decentralization to local organizations [22]. It is also reported that elderly persons are the most affected group during disaster events [23].

Sarawak, a state in Borneo in Malaysia, experienced yearly precipitation around 3000 to 4000 mm [21]. Meanwhile, [24] stated that the low-lying landform, notwithstanding the very high yearly precipitation, adds to streak flooding events in Kuching, the capital city of Sarawak. Meanwhile, the hydroelectric dams project located in the woodland regions of southern and north-eastern Sarawak are still ongoing and are estimated to be finished in 2030 [25].

3. Stages of Flood Disaster Management

Flooding can happen rapidly and all of a sudden. In flood-inclined zones, itis imperative to have an arrangement set up to battle rising water. As [26] stated, there are four stages of a crisis flood executive plan, including mitigation, preparedness, response, and recovery. Figure 8 shows the four phases of the flood management plan.

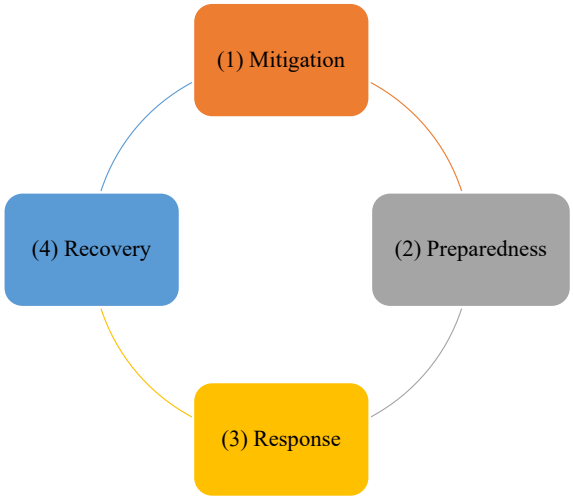

Figure 8. Flood management plan [27].

According to the Federal Emergency Management Agency [28], mitigation activities were expected to lessen or even take out the danger of flooding before it happens. The activities included conducting audits and updating construction laws and drafting, implementing geographic information systems, and others. Mitigation was used as the strategy to cut down hazards before, during, and after the catastrophe. Mitigation was an action taken before a hazard became a disaster [29]. The second phase was preparedness. The preparedness phase was to accomplish a sense of readiness for the flooding crisis, including developing a plan and utilizing emergency warning systems. As [30] mentioned, the hazard recognizable proof from cataclysmic events such as floods, earthquakes, fire perils, and typhoons is a significant prerequisite for readiness and relief. Preparedness educated the community to be ready and well-prepared for any catastrophe that would occur, increase awareness of the flood warning system, and train the community for immediate and fast action [31].

Meanwhile, the third phase in the disaster management cycle was the response. According to [32], the response phase was engaged with giving help, for instance, crisis alleviation and search and salvage. As [33] stated, this phase involved receiving information

about the hazard, organizing appropriate rescue and relief operations, and providing temporary shelters and basic facilities while developing a command system for rapid allocation funds. The last phase in the flood management plan was recovery. This phase emphasized giving transitory lodging, recreation, occasion advising, and training. In this phase, the activity conducted in the flood management plan was search and rescue practice, giving food, medical aid, and discharge support, and the quick communication and transport facility to the affected area [26].

4. Research Methodology

This research is conducted in three phases. In phase one, the detailed literature review is conducted for previous research carried out on flood disaster management. The previous research includes journal papers, conference proceedings, and news articles. In phase two, the detailed qualitative assessment of the data and news published in the news articles specifically in the Sarawak region and Malaysia in general. The possible challenges and solutions were collected from the detailed process and in the last phase, interviews were conducted with 20 selected experts working in academia and authorities managing the flood disasters. The final findings of this research are based on the experts' opinions and feedback on different challenges and possible remedies to improve the flood management system in the case study area.

5. Case Study Area

This research is solely conducted for the Sarawak region of Malaysia which experienced a higher number of floods in recent years. Sarawak's coastline in the South China Sea is low-lying and extensively indented. Primary rain forest covers a large portion of the land. The alluvial, marshy coastal plain is backed by undulating land with mountains and a plethora of navigable rivers. The case study area is shown in Figure 9.

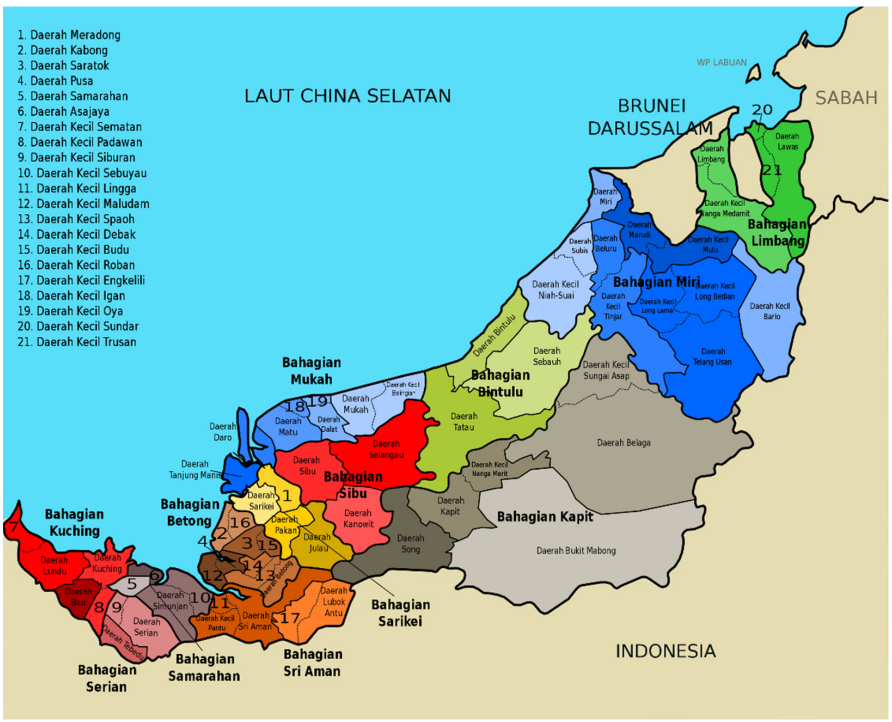

Figure 9. Case study area, Sarawak, Malaysia [34].

6. Impact of Flood Disaster in Sarawak

The floods result in negative and positive impacts which depend upon the area, spam, significance, water flow speed, vulnerability, estimation of the influenced characteristics, and developed conditions [33]. Floods had an enormous assortment of cultural effects

that range across space and time. As [35] mentioned, the effect of the flood debacle on correspondence association and systems, for instance, environment, social, and economy. Due to the flood, some of the victims had to lose their homes. These flood issues significantly impacted property damage, but it also affected the time spent with family members. It is also observed that such disasters impact the transportation facilities in affected areas [36].

As [37] mentioned, the direct impacts included direct economic losses such as demolition of living arrangements, organizations, beneficial capital, framework, harvests, animals, and (adapted) physical and enthusiastic prosperity impacts. Meanwhile, [38] stated that in the future, flood perils are extended to additional expansion in numerous locales attributable to climate change's impacts on the hydrological cycle. Table 1 shows the direct and indirect flood impacts.

Table 1. Direct and Indirect Flood Impacts [38].

	Market Inventory	Non-Market Inventory
Direct	Effect of floodwaters on financial resources, example: (1) Infrastructure; (2) Agriculture goods; (3) Houses.	Effect of floodwaters causing, example: (1) Death; (2) Wounds; (3) Loss of natural products.
Indirect	Cultural effects outside of the flood zone (existence), example: (1) Loss of turnover because of supply chain interruptions; (2) Traffic interruptions.	Cultural effects outside of the flood zone (existence), example: (1) Long-haul well-being impact; (2) Devastation of social life.

Direct impacts referred to the actual contact between floodwater and people, monetary resources, or different articles, while indirect effects were alluded to the misfortunes in turnover because of graceful disturbances or traffic interruptions.

7. Challenges Faced in Managing Flood Disaster

Given the susceptibility of coastal areas and cities to numerous climate-disaster hazards, disaster risk is a critical concern. As a result, the urban population and planning managers and stakeholders are struggling to design an approach to incorporate response strategies into human lives and planning processes [39]. According to [32], three main challenges in managing flood disasters are a lack of integration in executing disaster catastrophe circle among agencies, unproportionate arranging in debacle hazard control, and inadequacy in preparing for long-haul recuperation. As [40] highlighted, the lack of awareness, communication difficulty, lack of resources, lack of food supply, and the social and economic situations are the key challenges in flood disaster management. It is also reported that education about disaster risk, the endowment of equipment, tools, infrastructure, financial resources, and the planning process are also key challenges [41]. Additionally, [42] also added that resource constraints, contrasting objectives, needs, administrative climate, public commitment, and public desires are the important challenges in managing the flood disasters. In addition, [43] mentioned three challenges are important in managing flood disasters which include changes in flood hazard teams, practices, multiple dimensions of flood risk evaluation measures, changing land use, and uncontrolled developments in a flood-prone areas.

Furthermore, [44] stated five main challenges in managing flood disasters which include: restricted specialists and absence of required power, collaboration among organizations, absence of labor, resources for coordination, low subsidizing, and communication barriers. As [45] also highlighted, there are three core challenges in managing flood disasters including: economic loss, agricultural damages, geographical location, and land characteristics. In addition, lack of access to clean water, vulnerability to various dis-

eases, and changes in demand in health services also contribute to the challenges faced in managing flood disasters [46]. In addition, [47] emphasized three other challenges in managing flood disasters including quality of communication collaboration, new kinds of information and vulnerabilities, and advancing new co-appointment and information. Table 2 summarizes the challenges reported in managing the flood disasters.

Table 2. Challenges to Flood Disaster Management.

No.	Author	Source Title	Challenges Highlighted
1	Chong & Kamarudin (2018) [32]	Disaster risk management in Malaysia: Issues and challenges from the perspective of agencies	(1) Lack of coordination in executing disaster management cycle among agencies (2) Unproportionate planning in disaster risk management (3) Inadequacy in preparing for long-haul recuperation
2	Yazid et al. (2017) [40]	Flood Risk Mitigation: Pressing Issues and Challenges	(1) Lack of awareness (2) Communication difficulty (3) Lack of assets (4) The lack of food supply (5) The social and economic situation
3	Al-Dahash et al. (2016) [41]	Challenges during Disaster Response Planning Resulting from War Operations and Terrorism in Iraq	(1) Education about disaster risk (2) Endowment of equipment, tools and infrastructure (3) Financial resources (4) Planning process
4	Rubinato et al. (2019) [42]	Urban and river flooding: Comparison of flood risk management approaches in the UK and China and an assessment of future knowledge needs	(1) Resources constraints (2) Contrasting goals, needs, and administrative climate (3) Public commitment and public desires
5	Shah, Rahman, & Chowdhury (2018) [42]	Challenges for Achieving Sustainable Flood Risk Management	(1) Changes in flood hazard the board strategies and practices (2) Multiple dimensions of flood risk evaluation measures (3) Changing area use designs and uncontrolled developments in flood-prone areas
6	Mabahwi & Nakamura (2020) [44]	The Issues and Challenges of Flood-related Agencies in Malaysia	(1) Restricted specialists and absence of requirement power (2) Collaboration among organizations (3) Absence of labour, resources for coordination (4) Deficient subsidizing (5) Communication barrier
7	Ali et al. (2019) [45]	Challenges for flood risk management in flood-prone Sirajganj region of Bangladesh	(1) Economic loss (2) Agricultural damages (3) The geographical location and land characteristics

Table 2. *Cont.*

No.	Author	Source Title	Challenges Highlighted
8	See, Nayan, & Rahaman (2017) [46]	Flood Disaster Water Supply: A Review of Issues and Challenges in Malaysia	(1) Lack of access to clean water (2) Vulnerable to various disease (3) Changes in demand in health services
9	Waylen et al. (2018) [47]	Challenges to enabling and implementing natural flood management in Scotland	(1) Quality of communication and collaboration (2) New kinds of information and vulnerabilities (3) Advancing new co-appointment and information
10	Nurashikin, Rodger, & Rumaizah (2019) [48]	Reducing Flooding Impacts to the Built Environment: A Literature Review	(1) Larger attention being given to greening the environmental factors (2) Raising knowledge and awareness

8. Flood Disaster Mitigations

Source [49] reported three mitigation measures including: framing good macroeconomic policies, financial plan in crisis, and public investment in hazard reduction. Moreover, other primary mitigations highlighted are good disaster delivery systems by government, the cooperation of government, private sector, non-governmental organization (NGO), and public awareness [50]. Furthermore, [49] added other mitigation measures to manage flood disasters: flood forecasting, control of flood plan development, catchment management, flood insurance, floodproofing, flood emergency response planning, and emergency assistance and relief. It is also reported that environmental education, hydrological structures, and construction engineering, such as the development of new structures and improving existing water framework efficiency [51].

Meanwhile, four other primary mitigations identified include: waterway rebuilding activity, bowl-scale ecological-based flood countermeasure plan, reconstructing water impeding capacity, and public mindfulness and interest are also very important in such cases [52]. It is also reported that improving the hydrological system, flood risk assessment and management, and application of systems thinking are also critical in dealing with flood disasters [53]. In addition to, [54] also suggested some mitigation measures to manage flood disasters such as: comprehend calamity hazard identification system, reinforcing disaster risk administration, availability of sufficient resources into catastrophe hazard reduction, improving readiness for reaction phase, and bounce back better in recuperation and restoration. Table 3 shows the solutions to manage flood disasters.

Table 3. Mitigation Measures for Flood Disaster Management.

No.	Author	Source Title	Mitigations Reported
1	Mohamad Yusoff et al. (2018) [54]	Exploring the managing flood disaster: A Malaysian perspective	(1) Flood catastrophe readiness and reaction preparation of both organization and clinical staff (2) Conventional working systems for each degree of flood debacle reaction should be practiced (3) Utilize an effective communication system during rescue and relief operations

Table 3. *Cont.*

No.	Author	Source Title	Mitigations Reported
2	Ramanuja (2015) [49]	Challenges in Disaster Management	(1) Frame good macroeconomic policies before and aftershocks (2) Arrangement in the financial plan for crisis, protection inclusion, and low open obligation (3) Public investment in hazard reduction
3	Khalid & Shafiai (2015) [50]	Flood Disaster Management in Malaysia: An Evaluation of the Effectiveness Flood Delivery System	(1) Governments or authorities developed the flood delivery systems (2) The cooperation of government, private sector, non-governmental organization (NGO), and public as a rule (3) Flood cautioning data framework given previously in an ideal way and all through the flood term
4	Ogie, Adam, Perez (2020) [55]	A review of the structural approach to flood management in coastal megacities of developing nations: current research and future directions	(1) Flood forecasting (2) Control of flood plain development and catchment management (3) Flood insurance (4) Flood proofing (5) Flood emergency response planning (6) Emergency assistance and relief
5	Yang & Liu (2020) [51]	A General Overview of the Risk-Reduction Strategies for Floods and Droughts	(1) Environmental education (2) Hydrological taxes (3) Engineering constructions such as the development of new supplies and improve existing water framework proficiency
6	Sulaiman et al. (2019) [56]	Multi-Agency Collaboration in Flood Disaster Management in Sarawak, Malaysia	(1) Strong collaboration between agencies (2) Provide the maximum resources (3) Exchange information and improve coordinated working
7	Jongman (2018) [57]	Effective adaptation to rising flood risk	(1) Adaptation to flooding (2) Financing the residual risk (3) Risk perception
8	Hapsari & Zenurianto (2016) [52]	View of Flood Disaster Management in Indonesia and the Key Solutions	(1) Waterway rebuilding activity (2) Bowl-scale ecological-based flood countermeasure plan (3) Reconstructing water impeding capacity (4) Public mindfulness and interest
9	Rehman et al. (2019) [53]	Applying systems thinking to flood disaster management for a sustainable development	(1) Improve hydrological system (2) Flood risk assessment and management (3) Application of systems thinking
10	Raikes et al. (2019) [54]	Pre-disaster planning and preparedness for floods and droughts: A systematic review	(1) Comprehend calamity hazard (2) Reinforce disaster risk administration. (3) Put resources into catastrophe hazard reduction (4) Improve the readiness for reaction phase and to bounce back better in recuperation and restoration

It is observed that there are a number of researchers who proposed that the challenges in managing flood disasters in Sarawak were continuous substantial precipitation, fast evolution, unplanned urbanization, and ecological challenges. The solutions that have been discussed in managing the flood issue were the formation of a permanent flood control commission (FPCC), flood catastrophe contentment appliances, flood mitigation measures, flood gauging, and hydrological and flood alert systems. Meanwhile, it is important to recognize that property damage and underdeveloped areas are two of one of the core challenges in managing flood disasters in Sarawak. It is also observed that coordination is very important between emergency food aid and cooperation of related agencies in flood disasters [58].

The report [59] identified similar challenges in managing flood disasters in Sarawak, which include: substantial precipitation, insufficient waste limit, and absence of flood water storage and divergent system. Furthermore, [60] added some other challenges in managing flood disasters in Sarawak, such as poor drainage systems and weather patterns. Table 4 presents the challenges and possible solutions reported in different local newspapers and online sources.

Table 4. Challenges and Solutions in Managing Flood Disasters.

No.	Year	Newspaper Title	Challenges in Managing Flood Disaster in Sarawak	Solutions in Managing Flood Disaster in Sarawak	Source	Reference Link
1	2019	Managing Flood Problems	(1) Continuous substantial precipitation (2) Fast evolution (3) Spontaneous urbanization (4) Helpless seepage framework (5) Ecological corruption	(1) Formation of Permanent Flood Control Commission (FPCC) (2) Flood catastrophe contentment appliances (3) Flood mitigation measures (4) Flood forecasting, hydrological, and flood warning system	New Straits Times (NST)	https://www.nst.com.my/opinion/columnists/2019/10/532457/managing-flood-problems (accessed on 11 February 2022)
2	2019	Sarawak prepares for floods as two river basins register daily rainfall above 100 mm	(1) Heavy rainfall	(1) The Sarawak Drainage and Irrigation Department monitored the river basins	The Star	https://www.thestar.com.my/news/nation/2019/11/14/sarawak-prepares-for-floods-as-two-river-basins-register-daily-rainfall-above-100mm (accessed on 11 February 2022)
3	2019	Over 1000 people affected as floods cause damage in Sarawak	(1) Properties damage (2) Underdeveloped areas	(1) Collaborating the formation of a food supply team (2) Cooperation of related agencies	The Straits Times	https://www.straitstimes.com/asia/se-asia/over-1000-people-affected-as-floods-cause-damage-in-sarawak (accessed on 11 February 2022)
4	2018	New approach in overcoming flash flooding in Sarawak	(1) Heavy rainfall (2) Inadequate drainage capacity (3) Lack of flood storage	(1) Urban drainage improvement project (2) Introduced the Sarawak Urban Stormwater Management (SUStoM)	The Borneo Post	https://www.theborneopost.com/2018/07/17/dr-sim-new-approach-in-overcoming-flash-flooding-in-sarawak/ (accessed on 11 February 2022)
5	2018	Northern Sarawak put on flood alert after rivers breach danger level	(1) Continuous heavy rain	(1) Flood warning system	The Star	https://www.thestar.com.my/news/nation/2018/11/07/northern-sarawak-put-on-flood-alert-after-rivers-breach-danger-level/ (accessed on 11 February 2022)
6	2018	Crocodiles and snakes are among the challenges faced during flood relief efforts	(1) Typhoons (2) Encountered with dangerous species	(1) Coordination and cooperation with related agencies (2) Food supply resources	New Straits Times (NST)	https://www.nst.com.my/news/nation/2018/02/334509/crocodiles-and-snakes-among-challenges-faced-during-flood-relief-efforts (accessed on 15 February 2022)
7	2018	Malaysia-Thousands Evacuated After Floods in Sarawak State	(1) Heavy rain	(1) Collaboration and cooperation among disaster agencies	Flood List	http://floodlist.com/asia/malaysia-sarawak-february-2018 (accessed on 15 February 2022)

Table 4. *Cont.*

No.	Year	Newspaper Title	Challenges in Managing Flood Disaster in Sarawak	Solutions in Managing Flood Disaster in Sarawak	Source	Reference Link
8	2017	Flood risk in parts of Sarawak	(1) Poor drainage system (2) Weather patterns	(1) Upgrade the drainage system (2) Flood mitigation project	New Straits Times (NST)	https://www.nst.com.my/news/nation/2017/11/302927/flood-risk-parts-sarawak (accessed on 15 February 2022)
9	2017	'Kuching may adopt Hiigate City's example to solve flood woes.'	(1) Poor water management	(1) Diversion channel (2) Existing Kuching Barrage	The Borneo Post	https://www.theborneopost.com/2017/02/24/kuching-may-adopt-hiigata-citys-example-to-solve-flood-woes/ (accessed on 15 February 2022)
10	2017	State steps up flood mitigation effort	(1) Continuous flooding	(1) Flood mitigation project (2) Private finance initiative	The Star	https://www.thestar.com.my/metro/community/2017/01/09/state-steps-up-flood-mitigation-effort-sarawak-may-seek-foreign-expertise-to-find-best-solution (accessed on 15 February 2022)
11	2017	Government revs up preparation to face the possibility of a major flood in November	(1) Delay in the dissemination of help to flood casualties	(1) Government deployed essential assets, the Community Emergency Response Team (CERT) (2) Cooperation among related agencies	New Straits Times (NST)	https://www.nst.com.my/news/nation/2017/10/288787/government-revs-preparation-face-possibility-major-floods-november (accessed on 16 February 2022)
12	2016	Poor drainage led to flooding	(1) River flooding (2) Drainage issues (3) Storm waters	(1) Flood drainage reformation (2) Stream control component and repository appropriating (3) Public safety awareness campaign	The Star	https://www.thestar.com.my/metro/community/2016/06/21/poor-drainage-led-to-flooding-floods-in-february-and-may-were-storm-water-related-says-state-governm (accessed on 16 February 2022)
13	2016	Floods wreak havoc in Sarawak	(1) Heavy rain and high tides (2) Poor drainage system	(1) Upgrade the drainage system	The Star	https://www.thestar.com.my/news/nation/2016/02/28/floods-wreak-havoc-in-sarawak (accessed on 16 February 2022)
14	2015	Long-term solution needed to turn the tide	(1) Overdevelopment (2) Helpless water operation (3) Populace pressure (4) Deforestation	(1) Built more barrages or dams (2) Diversion channel	The Borneo Post	https://www.theborneopost.com/2015/02/01/long-term-solution-needed-to-turn-the-tide/ (accessed on 16 February 2022)
15	2015	New Disaster Unit to be set up soon	(1) Communication difficulty (2) Education about disaster risk (3) Lack of coordination in executing disaster management cycle among agencies	(1) An adequate correspondence framework to be utilized during salvage and help activity (2) Direct actions to more readily set up to assist the victims (3) Introducing a new disaster unit and collaboration with many agencies in managing flood issues	The Borneo Post	https://www.theborneopost.com/2015/01/24/rohani-new-disaster-unit-to-be-set-up-soon-says-rohani/ (accessed on 16 February 2022)

9. Interviews with Experts

After content analysis and the literature review, the factors of flood disaster management challenges and possible solutions are identified. The unstructured interviews were conducted with 20 experts and academicians who have more than 15 years of experience in managing disasters. The experts were requested to share their feedback on the significance of the key challenges to flood disaster schemes. The feedback was given on a Likert scale from 1 to 5 where 1 is the least significant and 5 is the highly significant challenge. A similar approach is followed for mitigation measures in this study.

10. Key Findings

After the content analysis, the experts' feedback was received to rank and validate the key challenges to properly managing the flood disaster. The ranks are classified into each category of themes, as shown in Figures 10 and 11.

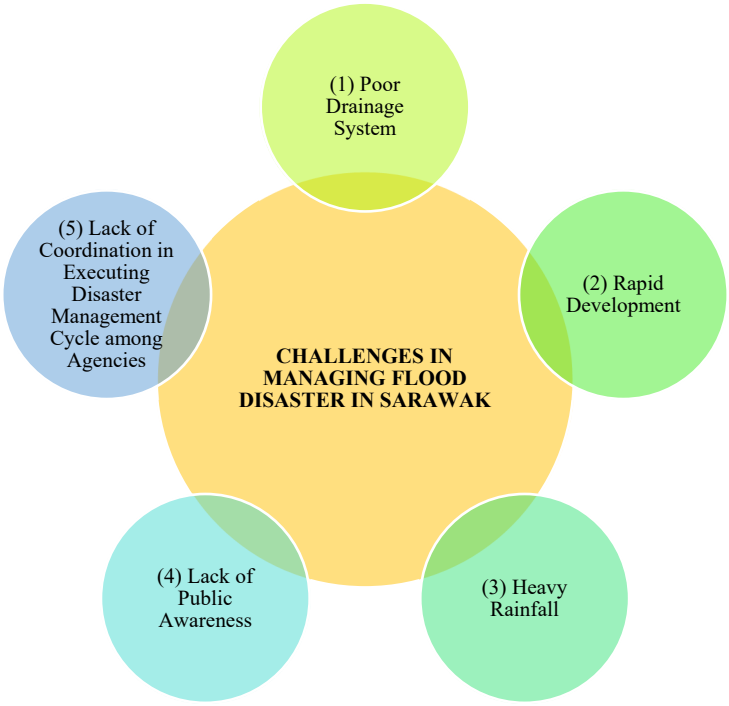

Figure 10. Key challenges for flood disaster.

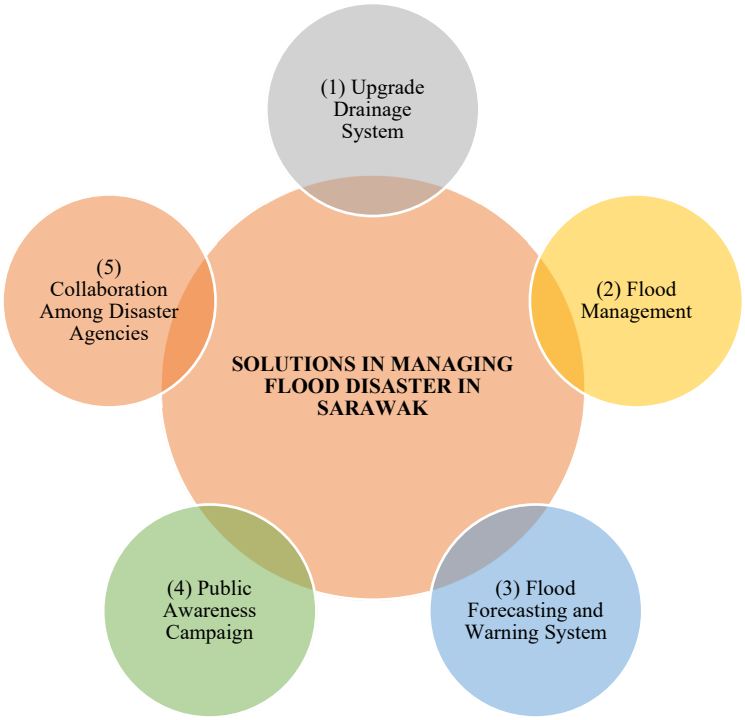

Figure 11. Key mitigations for flood disaster management.

Five primary challenges have been identified from reviewing the five year's previous newspaper articles, literature, and expert feedback. In Sarawak, the challenges in managing

flood disasters were the poor drainage systems, rapid development in water catchment area, heavy rainfall, education and training about flood disaster risk, and lack of coordination in executing disaster management cycle among agencies.

The issue of inadequate drainage systems has resulted in tremendous environmental challenges globally, especially floods. Residents are mostly affected by these flood events due to inadequate drainage systems and in particular, those residing along flood plains, low land areas, and other coastline areas. At the same time, the challenge in managing floods is additionally impacted by the community's attitude or advancement that does not consider the principle of ecological preservation [61]. Extensive rainfall during the rainy season is also one of the challenges in managing flood disasters [62]. The vast varieties of the precipitation in recurrence and force have inclined to vacillations in the waterway streams that have brought about atmosphere-prompted disasters such as floods, landslides, and so forth [63]. The lack of coordination in executing the disaster management cycle among agencies is also identified as a primary challenge in managing flood disasters. According to [64], it is mentioned that the absence of authoritative coordination and participation can prompt hindering impacts on people and budgetary assets.

Local institutions can play a critical role in delivering first-hand rescue and assistance to communities to reduce the effects and vulnerability to natural disasters such as floods [65]. Therefore, the feedback from experts is taken in this research to highlight the possible solutions to enhance the flood management system in the case study area.

Five key mitigation measures have been identified after reviewing the five year's previous newspaper articles, literature, and expert feedback. Upgrading drainage systems, flood management schemes, flood forecasting, warning system, public safety awareness campaign, and collaboration among disaster management agencies are the key mitigation measures.

The possible actions required by any flood hazard program are the proactiveness, for example, basic flood protection measures, early warning detection framework, hazard education and training, nature-based arrangements, and social life assurance [57]. The risk reduction strategies include technological advances in logistics and water systems, upgrade drainage in combination with advances for flood control developments [66]. As a significant figure, natural disaster management agencies (NADMA) have responsibilities in handling any of such catastrophe. For instance, in Sarawak, the agency responsible for managing the catastrophe, is Sarawak State Disaster Management Committee (JPBNS). Under this agency, 26 sub-agencies play their roles and responsibilities [16]. Public awareness is very important for such disasters and proper arrangements should be made by the responsible agency to resist the effects of the disaster. It includes creating websites for information discrimination and to empower individuals and advancing families to take basic actions in such disasters [67].

Finally, according to [56], in pursuit of optimal disaster risk prevention, reduction, and resilience, many Malaysians also prefer to work closely within local communities to ensure their communities are more resilient and agile to the disaster challenges. This concept of the Faith-Based Organisation (FBO) model can be observed everywhere when the disaster hits Malaysia. This is one of the unique strengths and solutions in facilitating agencies while dealing with disasters in Malaysia.

11. Framework

In a climate of severe flood occurrences, the normative elements of flood harm in flood risk management have grown to be prominent [68]. Therefore, this study also proposes a flood management framework in Sarawak, Malaysia, to improve the disaster management system and practices in the case of floods. Figure 12 shows the proposed framework for the flood disaster management cycle.

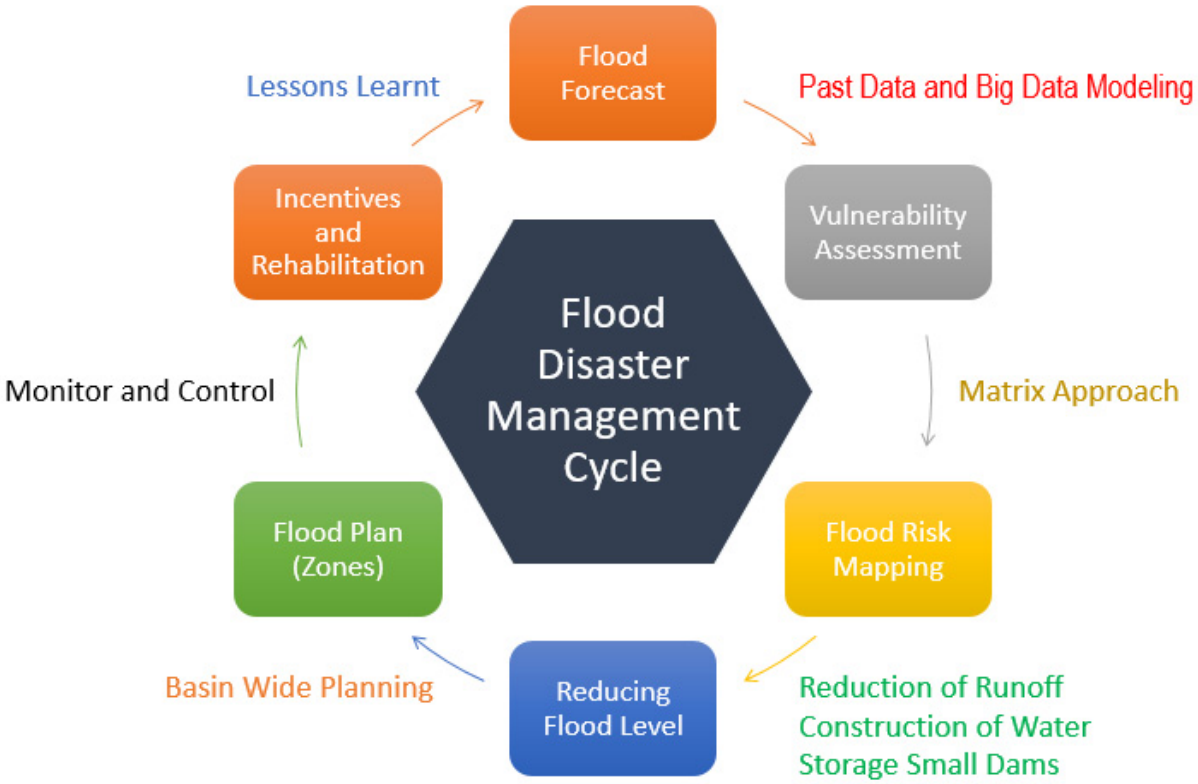

Figure 12. Framework for flood disaster management.

The disaster management schemes are variant because every disaster class has a different response approach. Similarly, it is essential to utilize the new big data management approaches. Past data are also available in many countries, so big data analysis methods should forecast the flood trends and possible impact levels. Based on the forecast, the framework proposes using a matrix approach to rank the areas that are vulnerable to floods. The attention should be given to higher vulnerable areas and state resources can also be utilized accordingly. Based on the vulnerability matrix, suitable actions to be taken include: maintenance of the existing reservoirs and construction of new water storage dams ranging from small- to large-scale dams. Possible suitable actions should be taken to reduce the runoff or divert the flood into various reservoirs. These should be at a certain safe distance from the populated areas and special attention should be given to the city drainage system. Runoff water should be diverted to possible flood pocket zones to save the cities and human lives. In case of possible resettlements, incentives should be given to people for rehabilitation if any damage occurred due to floods. Pertinent data should be managed, including all possible data requirements needed for the framework. State-level and country-level special data centers should be developed to keep a proper track of the rain records and the possible vulnerability to floods. In the last phase, a lesson learned session should be conducted, and the results should be integrated with the framework to improve the framework in future disasters and their management. The proposed framework can also be used in other countries facing flood disasters with similarities. There can be some minor variations that can be carried out in the framework to meet the local conditions of any country. The main spectrum of flood disaster management will remain the same.

12. Conclusions

It is concluded that Malaysia has suffered from some major flood disasters since 2015 and Sarawak also suffered from major flood disasters in recent years. It is concluded that poor drainage systems, the rapid development of infrastructure activities, heavy rainfall, lack of public awareness, and lack of coordination in executing the disaster management

cycle among agencies are observed as the critical challenges for a proper flood disaster management system in Sarawak. The drainage channels get choked due to waste and tree leaves. It is recommended that the existing drainage systems should be upgraded and the size of the channels should be widened in critical points of the city. A proper drainage cleaning plan should be implemented especially in peak rain times. Flood management, flood forecasting, and warning systems should be planned and an action plan should be designed to be proactive in dealing with such key disasters. Public awareness, companion and collaboration should be made. The local community should be trained to act immediately in such disasters and the government should assure a proper communication channel with the local people to assist them in basic needs and safety. Many agencies, particularly in Sarawak, identified the challenges and solutions to make it more resilient and inform communities in Sarawak to become more prepared and resilient to face the climate challenges and overcome flood disasters in the future. According to [56], resilience in the context of this paper refers to the ability and capacity of the state of Sarawak to be able to absorb, bounce back, and recover from stress and shock from such disasters. This is because flooding is one of the common natural disasters that hits the state of Sarawak every year. The proposed framework in this study should be implemented to manage flood disasters in the future. State-level and country-level special data centers should be developed to keep a proper track of the rain records and the possible vulnerability to floods. This framework and proposed center can also be extended for other disasters including earthquakes, hurricanes, droughts, and others.

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