Socio-Economic Impact Assessment of Dam Break: A Case Study of Hulu Perak Dams in Malaysia

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Abstract In Malaysia, embankment dams are frequently constructed because they benefit the local population, particularly in agricultural activities and flood control. However, flood disasters caused by dam breaks have catastrophic consequences on human lives and immensely damage the environment, infrastructure, and socio-economic stability, especially in downstream areas. Despite the rapid advancement of risk analysis in dam engineering, there is limited research on the socio-economic impact of dam failure. This paper is deemed to provide a critical review of the socio-economic risks affected by dam breaks in Hulu Perak district, Malaysia. The findings have highlighted the communities, key facilities, and heritage sites are at high risk

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if there are dam breaks in the Hulu Perak district. İt is recommended that appropriate risk management measures be undertaken to reduce human catastrophy and negative socio-economic impacts. Hence, there is a need to conduct an empirical study to assess dam break threats to humans and the socio-economy and formulate a framework to mitigate the risks of flood disasters due to dam failures.

Keywords Dam break · Socio-economic impact · Flood · Perak · Malaysia

1 Introduction

Dams have long been acknowledged as a key infrastructure that has benefited mankind for centuries. Numerous studies revered that dams have been built for various purposes, accommodating daily human needs, for instance, domestic and industrial water supply, irrigation, aquaculture, hydropower, and recreation [1–4]. Besides, dams are pertinent components of economic, environmental and societal development from a single investment [5, 6]. Other than that, the key point to retain in constructing the dam is for water retention and flood mitigation to minimize risk to the local population in the downstream area and environment. Despite its benefits and being well-structured, dams worldwide are aging and will have reached the end of their intended lifespan as their design lifespan is only around 50–100 years [7, 8]. Besides, climate change, particularly unforeseen heavy rainfall and landslide, earthquake, and fault movements, can be the basis of dam breaks [9, 10]. There has been a growing interest in dam break studies, largely due to the catastrophic impacts of dam failures. While a dam failure immensely leads to fatal cases and loss of lives, it also causes devastating effects on the general environment and incurs high social and economic costs that must be borne by the community members, particularly those living in the downstream areas [11, 12]. The associated cost will increase if the breach parameters cannot be predicted with reasonable accuracy. Thus, any emergency and unusual events that occur at the dam could impose a huge risk on the downstream population. As a consequence, some researchers (e.g. [2, 13, 14]) were keen to investigate the effects of flash floods due to the dam break occurrence from social, economic, and environmental perspectives.

It is therefore pertinent to prudently identify conditions that could lead to the implementation of the necessary mitigative measures. With proper preparations through the implementation of an early flood warning system and emergency action plan, it is possible to obviate or at least reduce the loss of lives to a great extent, even in the case of a dam failure. For the purpose of emergency action planning, obtaining information about areas that would be inundated is a must. Nevertheless, studies that focus on assessing potential damages due to dam breaks from a socio-economic perspective are somewhat limited, especially in developing countries. Therefore, this study aims to assess the socio-economic impact of flooding due to dam breaks in Hulu Perak district, Perak State, Malaysia. Hence, the objective of the study is to

quantify the extent of damage and displacement caused by floods and their immediate impact on the communities in residential areas, public infrastructures/facilities, and heritage/cultural sites.

2 Literature Review

2.1 Overview of Dam Break Incidents

Over many centuries, thousands of dams have been built worldwide. For example, China had over 98,000 dams in 2013, making it the country with the most dams in the world [15], followed by the United States and India. Due to high river flows, sea storm surges, and other factors, hundreds of dams have failed, and numerous dikes breach each year, frequently with disastrous results. According to previous dam failure risk assessments, the breaching risk and dam failure process could be predicted based on past dam failure events. Furthermore, such studies provide valuable insights into how to improve dam safety. There have been a number of incidents that occurred a long time ago, such as three dam failure cases in Italy: the Marib dam (Yemen) in A.D. 575, the earthen dam near Grenoble (France) in 1219, and the earthen dam near Grenoble (France) in 1923, 1935, and 1985 all caused the death of hundreds of people in the regions of Gleno, Molare, and Stava [16]. Around 200 people were killed in Mascara, Algeria, in 1881 by a dam known as "Fergoug I" [17]. Furthermore, The Banqiao Dam and the Shimantan Dam catastrophically failed in August 1975 in Henan Province, China, as a result of the overtopping brought about by torrential rains, making it by far the worst dam disaster in history. Flooding claimed the lives of about 85,000 people, and thousands more perished from subsequent epidemics and starvation. Millions of people also lost their homes [18]. Additionally, a high-tide storm in the Netherlands in February 1953 resulted in the highest recorded water levels and breached the dikes in over 450 locations, killing nearly 1,900 people and causing enormous economic damage [19]. In Indonesia, there have been two dam breaks in the past 10 years. The first instance happened in 2009 when the 1933-built Gintung Dam suddenly burst, releasing about 2 million cubic meters of water into its downstream region. In contrast, the second incident took place in 2013, when the Way Ela Dam, which had been naturally formed in 2012 as a result of the cliff landslide that blocked the main river, suddenly broke and released about 20 million cubic meters of water to its downstream area [20]. Although the reasons for each dam's failure are unique, data showed that overtopping, toe erosion, loss of storage contents, failure of the auxiliary structure, earthquake, foundation failure, and movement or cracking in the dam structure have been highlighted as the leading causes of dam failures [21].

2.2 The Implication of Dam Breaks

The goal of dam breaks social impact evaluation is to examine the effects of a dam break from a variety of macro factors. The main factors considered in this assessment are the number of casualties (including mortality cases), the political impact (i.e. how it may have a negative impact on the nation's and society's stability), the decline in living standards and quality of life, and the disappearance of irreparable cultural artifacts, priceless works of art, flora, and fauna. According to [22], social risk can be assessed through an index system, as depicted in Fig. 1. The social impact consists of people at risk, town level (i.e. community settlement), important facilities, agriculture, public facilities, cultural heritage, etc.

An earth-rock dam break has put people at risk. Generally, the larger the number of people at risk, the greater the risk of a dam break causing death and the greater the social impact. The town level is critical to the region's development and stability. In addition to important facilities, a number of social concerns also need to be addressed. A few examples of important facilities include transportation, power transmission, oil and gas pipelines, factories, mines, enterprises, and military facilities. Relics of culture, art treasures, and rare animals and plants are examples of cultural heritage. Social attention is paid to cultural heritage, but its monetary value is hard to estimate. Cultural heritage must be repaired when damaged.

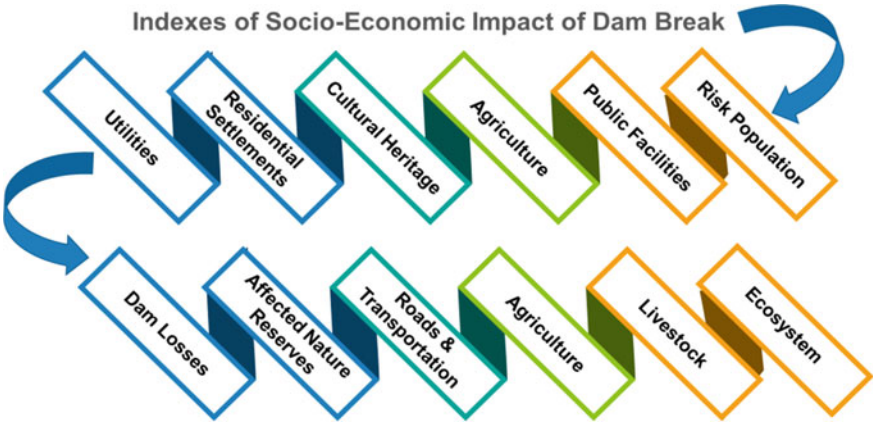

Fig. 1 Index system of the social impact of dam break

3 Methodology

3.1 Study Area

Perak is one of the 13 states of Malaysia and is located on the west coast of Peninsular Malaysia. The Perak River (Sungai Perak 4.040651° 100.858159°), approximately 400 km in length, is the second longest river in Peninsular Malaysia and serves as the main river that makes up most of the drainage system in Perak, which forms the backbone of socio-economic activities and development of Perak. It starts from the Hulu Perak district that borders Thailand and the State of Kelantan and ends at the Straits of Melaka in Bagan Datoh. These rivers have been primary sources of water supply for the state population. However, these rivers have also resulted in massive floods arising from excessive rainfalls.

3.2 Geographic Location and Dam Characteristics in Hulu Perak

There are three dams in the Hulu Perak district: Bersia, Kenering, and Temenggor. The Temenggor Dam is situated in Gerik, Perak, Malaysia. It is located on the Perak River, about 200 km northeast of Ipoh. Construction of the dam impounded Temenggor Lake. The power station is a hydroelectric power station, using four Hitachi turbines of 87 MW installed capacity, and the average annual energy generation is 900 million units. The Bersia Dam is the second dam in the Sungai Perak hydropower cascade system. It is located about 20 km away from the Temenggor Dam, at an elevation of 143 m above sea level. It is about 16 km East of Gerik, Sungai Perak, Perak. This infrastructure is of TYPE Hydro Power Plant with a design capacity of 72 MWe. Lastly, the third dam in the hydropower cascade system is the Kenering Dam, located about 45 km downstream of the Bersia Dam. It is situated 110m above sea level. Figures 2, 3, and 4 show the study area location and a zoomed view of the dams.

Fig. 2 Temenggor Dam in Hulu Perak (5.406234° 101.300704°) *Source* Google EarthPro

Fig. 3 Bersia Dam in Hulu Perak (5.429616° 101.208815°) *Source* Google EarthPro

Fig. 4 Kenering Dam in Hulu Perak (5.215335° 101.097910°) *Source* Google EarthPro

4 Findings and Discussion

4.1 Risk Assessment on the Social Impacts of Dam Break

Hulu Perak has a total population of 89,926, Gerik has a population of 29,391, the highest among the sub-districts, followed by Pengkalan Hulu, with a population of 16,150 people. In terms of gender, it was observed that a higher number of male population than females in respective sub-districts of Hulu Perak is indicated in Fig. 5. A mix of ethnic groups represents the Hulu Perak community. Besides Malays, Chinese, Indians and non-citizens, there are 11,271 indigenous people (Orang Asli) in Hulu Perak, who make up 13% of the total population in this district (Figs. 6 and 7).

Hulu Perak is one of the most populated districts in Perak state and contains three dams. It can be seen topographically that the series of dams are interconnected with sub-districts within Hulu Perak. According to each sub-district, Tables 1, 2, and 3 present the main public facilities, which are promptly used by local communities. Similarly, Tables 4 and 5 show the public utilities and infrastructure, such as transportation, which is an important means of import and export. Such places with dense populations at high risk can be affected due to dam break/failure.

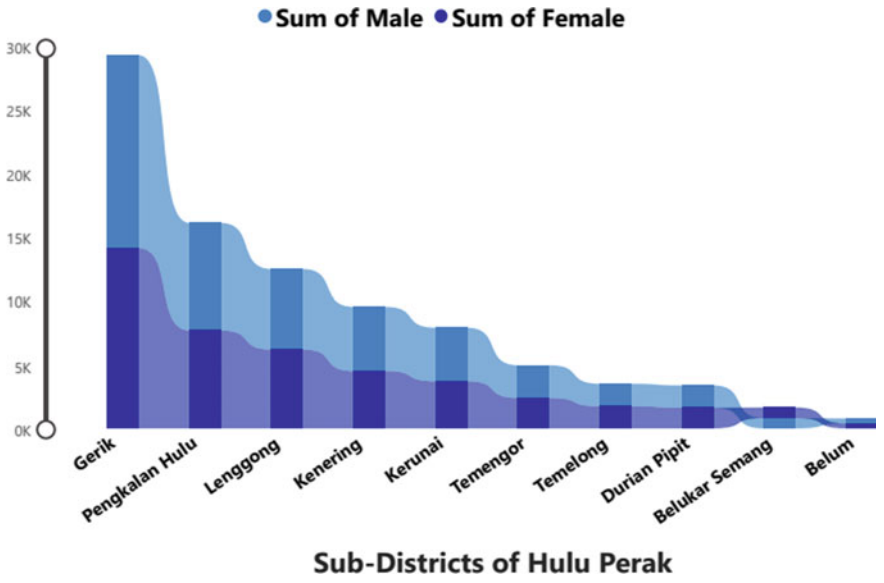

Fig. 5 Hulu Perak sub-districts population

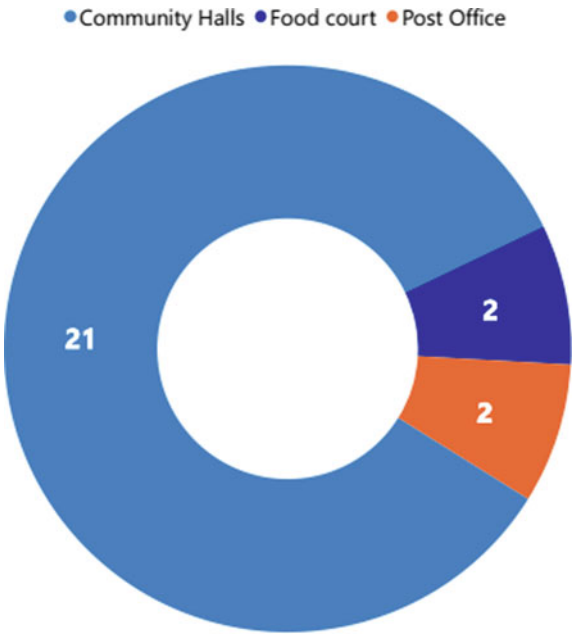

Fig. 6 Total Public facilities in sub-districts in Hulu Perak

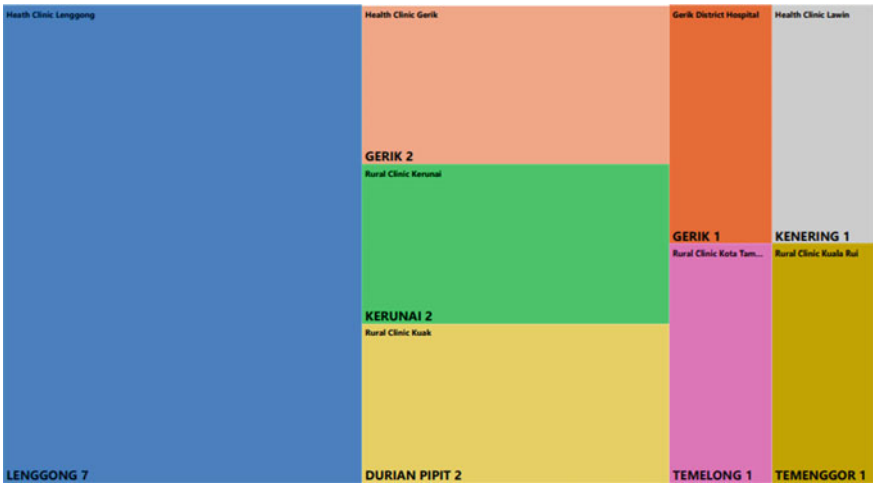

Fig. 7 Health facilities in sub-districts in Hulu Perak

4.2 Cultural Sites

Tourism-attractive places and resources in the district of Hulu Perak are divided into two main categories: natural and artificial attractions. The main tourism products

Table 1 Main public facilities in sub-districts in Hulu Perak

Public facility	Details	Total	Sub-district
Community Hall	Community hall Kota tampan air Pavillion Taman Kota Tampan Multi-purpose Hall Kota Tampan Community service center Kampung Luat	4	Temelong
	Merdeka hall Lenggong	1	Lenggong
	Community hall Kampung Kuak	1	Durian Pipit
	District community Hall Lawin Community hall Kg. Air Jeda Aman Jaya square Lawin	3	Kenering
	Community hall Bandariang UMNO Community hall Kg. Bersia Baru Public hall Kuala Kenderong Public hall Kg. Padang	4	Temenggor
	Community hall Kg. Jong Multi-purpose Kg. Pahit Tgh Community hall Kg. Pahat	4	Kerunai
	Multi-purpose Majlis Daerah Gerik Multi-purpose Gerik Community hall Kg. Gerik	4	Gerik
	Total	**21**	

(continued)

Table 1 (continued)

Public facility	Details	Total	Sub-district
Post Office	Post office Lenggong	1	Lenggong
	Mini post office Lawin	1	Kenering
	Total	**2**	
Food court	Pavillion Lenggong	1	Lenggong
	Pavillion Tasik Raban	1	Kenering
	Total	**2**	

in Hulu Perak District include eco-tourism and historical heritage tourism. Each sub-district presents tourism activities and categories as shown in Tables 6, 7 and Fig. 8.

4.3 Economic Impacts of Dam Breaks

Research on the economic activities of each district in Perak is obtained from official government documents. The analysis of these secondary documents is important to

Table 2 Health facilities in sub-district in Hulu Perak

Health facilities	Location	Total	Sub-district
Clinic	Rural clinic Kota Tampan	1	Temelong
	Heath clinic Lenggong Rural clinic Kg. Chepor Dental clinic Lenggong Rural clinic Kg. Gelok Rural clinic Kg. Sumpitan Clinic Ok Ong Polyclinic Dr. Azhar	7	Lenggong
	Rural clinic Kuak Rural clinic Kg. Beng	2	Durian pipit
	Health clinic Lawin	1	Kenering
	Rural clinic Kuala Rui	1	Temenggor
	Rural clinic Kerunai Health clinic Plang	2	Kerunai
	Health clinic Gerik Health clinic Ibu Dan Anak Gerik	2	Gerik
Government hospital	Gerik district hospital	1	
	Total	**17**	

deepen and understand the strength and main focus of the district. The documents referred to include materials from the official website of the NCER Strategic Development Plan 2021–2025 and the Perak State Structure Plan 2040. Referring to the table below (Table 8), in 2012, agriculture, being the main economic activity in Hulu Perak, contributed 45.42% of gross domestic product (GDP), followed by industry/mining (38.77 % of GDP), business, and services (15.81% of GDP).

The main economic activities in Hulu Perak are eco-tourism, tin mining, and agriculture, focusing on plantation/crops (mainly rubber, oil palm and paddy), livestock farming, and fisheries. Indeed, these income-generating activities will be directly affected during flash floods and dam break incidents. Such uncalled hazards will affect the socio-economic of the living communities with loss of income, employment, shelter, and personal belongings. Hence, to reduce the damage and negative impacts, it is critical for mitigative measures to be identified as alerts to the living communities for their survival and socio-economic sustainability.

Table 3 Public authorities in sub-districts in Hulu Perak

Public authorities	Location	Sub-district
Mosque	Mosque Al Aliah Kg. Cha Ain Mosque Kota Tampan Mosque Warisan Kg. Temelong	Temelong
Police station	Lenggong police station	Lenggong
Government offices	Magistrate court Lenggong district office Lenggong district council Co-operative development department Lenggong chief office Lenggong RISDA office LPP quarters Lenggong national registration department Puskep mara (student leadership center) Lenggong Farmers organization office	Lenggong
Government offices	Durian Pipit chief district office	Durian Pipit
Police station	Kuak police station	
Police station	Lawin police station	Kenering
Police station	Gerik district police headquarters Police station Kg. Lalang	Kerunai
Fire station	Gerik fire station	
Government offices	Bandariang forest ranger office Teacher quarters Bersia	Temenggor
Police station	Police station Bersia	
Government offices	Hulu Perak veterinary office Department of indigenous affairs Department of work (JKR) Gerik Road Transport Office (JPJ) Office Gerik Bn303 Gerik military camp Lembaga Air (Water) Perak Gerik Gerik magistrate court Gerik Shariah lower court Gerik district council Gerik religious office Youth and sports office Hulu Perak district and land office Tawai felda office Gerik forest office Gerik social welfare office Gerik KWSP office District education offices Gerik agriculture office Hulu Perak district RISDA office	GERIK

Table 4 Utility facilities in sub-districts in Hulu Perak

Utility facilities	Location	Total	Sub-district
Gas station	Caltex Lenggong BHP Lenggong PETRONAS Lenggong	3	Lenggong
	Shell	1	Kenering
	Petron Bandariang Shell Bandariang BHP Desa Baiduri Buraq oil Simpang Perah Buraq oil Bersia Lama Oil Felda Bersia	6	Temenggor
	Shell Gerik Petron Gerik	2	Gerik
Water treatment plant	Water treatment plant	1	Kenering
Water supply	Water pump house	1	
Electric infrastructure	Power generation sultan Azlan Shah Kenering Hydro power dam Kenering	2	
Water supply	Metrological Kuala Kenderong	1	Temenggor
Electric infrastructure	Power generation Temenggor PMU Temenggor	2	

Table 5 Transportation infrastructure in Hulu Perak

Transportation infrastructure	Location	TOTAL	Sub-district
Bus station	Lenggong bus terminal	1	Lenggong
	Gerik bus station	1	Gerik
	Total	**2**	
Bridge	Raja Muda Nazrin bridge	1	Durian Pipit
	Belum Baru bridge	1	Kenering
	Total	**2**	
Jetty	Trojan Tnb Jetty	1	Temenggor
	Kg. Air Ganda Jetty	1	
	Total	**2**	
Airport	Gerik Military airport	1	Gerik
	Total	**1**	

Table 6 Sub-district and main focus of tourism activity

Sub-district	Sector/activity
Pengkalan Hulu	Mining heritage
Gerik	Natural heritage
Lenggong	World historical heritage

Table 7 List of categories and tourism places in sub-districts in Hulu Perak

Category	Type of products	Number of products		
		Pengkalan Hulu	Gerik	Lenggong
Natural attractions	Eco-tourism	4	18	4
Man-made	Sports and recreation	1	–	1
	Historical heritage	4	2	1
	Cultural heritage	1	–	1
	Shopping	1	1	–
	mining heritage	1	–	-
	Agro tourism	–	–	2
	Homestay	–	–	1
	Total	**12**	**21**	**10**

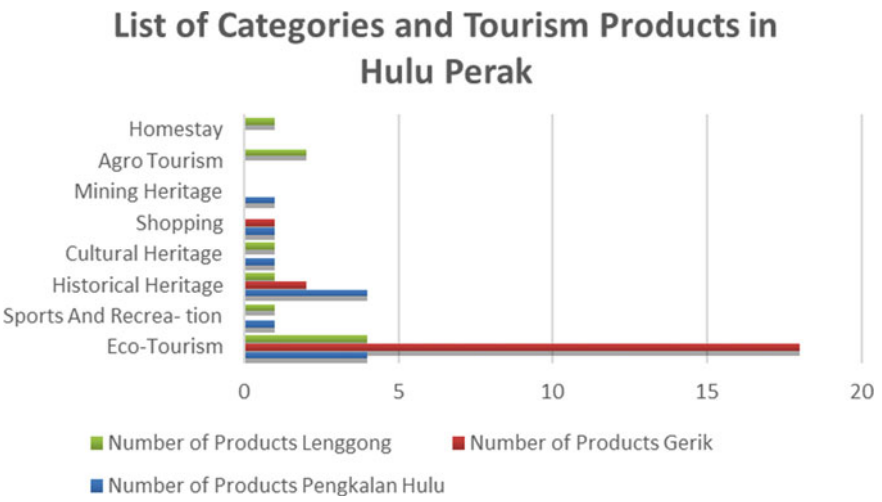

Fig. 8 Total number of tourism products in sub-districts in Hulu Perak

Table 8 Hulu Perak's GDP contribution

Type of land use	Hulu Perak district		Perak state	
	Estimated GDP (RM)	Percentage (%)	Estimated GDP (RM)	Percentage (%)
Industry/ mining	483.33	38.77	6,831.97	17.51
Business and services	197.11	15.81	26,425.00	67.71
Agricultural	566.18	45.42	5,770.00	14.78
Total	1,246.62	100.00	39,026.97	100.00

5 Conclusion

Hulu Perak is located in one of the districts with significant contributions to socio-economic activities, especially in eco-tourism and forest activities by indigenous communities. Temenggor, Bersia, and Kenering dams are located in Hulu Perak and the confluence with the joined river Sungai Perak. Hulu Perak has been identified as one of the districts with a frequent record of flood disasters. It recorded 11 cases of flood in 2020, mainly due to flash floods that happened because of heavy rain. Hence, this district has been identified as a high-risk area in Perak. Previous flood disaster, as reported, shows the failure to notify the communities with sufficient preparation and evacuation. Therefore, the impact of the occurrence of the flood might cause heavy damage to the socio-economy of Hulu Perak.

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