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Flood Frequency Analysis of Kelantan River Basin, Malaysia

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Abstract: The focus of this research was to study the problem of flood frequency that is occurring on Kelantan River Basin, Peninsular Malaysia. The research area covered four sub-basins namely Sungai Kelantan, Lebir, Galas and Pergau. This study attempted to identify the flood frequency trends and their implications to human being. Flood frequency study is important because often result in property damage and significant loss of life every year in Kelantan River Basin. Flood frequency analysis was conducted by referring to a rating table produced by the Department of Irrigation and Drainage of Kelantan. Results showed that the Guillemard Bridge, Lebir and Galas Stations have highest in flood frequency rather than Nenggiri Station. In conclusion, when flood frequently happen the value of damaged properties in Kelantan River Basin also increased.

Key words: Flood · Flood Damage · Human Risk · River Basin · Disaster

INTRODUCTION

History of early civilisations, such as in Egypt and Mesopotamia, have a unique pattern because they were all located on the fertile river deltas, or flood plains. The practice has continued to present day, as most big cities in the world are situated on flood plains, or in other words, by rivers [1]. In Malaysia, among the towns located near rivers (flood plains) are Kuala Lumpur, Kuantan, Kota Bharu, Alor Setar dan Kuala Terengganu. Based on the latest government cencus, the total population reside in Kelantan River Basin is estimated that there were about 2.5 million people in 1990. Between 1957 and 1990, these flood plain areas had rapid population growth of about 513.3 percent [2]. This means, Kelantanese are highly vulnerable to the risk of floods. Thus, the issue is related to the floods frequency that often pose the risk of loss of life and destruction of property in any one year in Kelantan River Basin. Frequent flooding can cause millions of dollars in property damages and loss of lives [3, 4, 5]. Natural disaster can be perceived as a problem or a phenomenon that is capable of causing damage to properties and loss of lives and its occurrence is normally sudden and without warning [6, 7]. The risk of disasters can be devided into three categories: first, involving life-threatening threats whether death or injury; second, level of property damage; and third, assessment of the risk faced by humans and their properties [8]. Moreover, the frequent occurrence of disasters reflects the vulnerability of the areas and individuals, communities and societies directly affected by the disasters.

Disasters that are caused by human activities, like economic development for their own well-being, will accelerate the level of vulnerability to disasters [9]. Development planning without considering the environmental harmony will heighten the level of the people's vulnerability to extreme or risky conditions. Various aspects of development activities are the source of this vulnerability. Increase in population and ecological dispersion and concentration are among the deciding factors of the people's vulnerability to disasters. Even a small increase in population in an environmentally sensitive area will cause more pressure to the resources, affecting the ecology in that area. Ecological equilibirium upsets have negative effects on the well-being of the people living in that area. There are many factors assist in increasing human exposure to the disaster for instance population boost [10-12]. These factors quite related to increasing in population, welcoming building settlement

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and lastly human will conquer hilly and high-rise area for many agendas intentionally for agriculture and development to meet their survival. In the other hand, human as such creates the risk and disaster to them and also increase the flood frequency. In Malaysia, food ia a national agenda and situated in third place ranking on the list of Malaysia disaster issues which cause so many deadness and property ruins. Therefore, this study aims to examine the frequency of floods and its impact on the number of victims, destruction of property and the number of lives lost.

MATERIALS AND METHODS

The flood plain of the Kelantan River Basin consists of several districts i.e. Kota Bharu, Pasir Mas, Tumpat, Tanah Merah, Machang, Kuala Krai, Jeli and Gua Musang. All of these districts straddle several main rivers including Sungai Kelantan, Lebir, Galas and Pergau. This flood-prone area has a population of 553,099, which is about one third of Kelantan's overall population of 1.3 million. While the total area of Kelantan River Basin is about 13,100 km^2 or 85 percent of the state land area. The study on the frequency of the flood episodes in the Kelantan River Basin is based on the rate of overflow of a given sub-basin by using a rating table produced by the government to categorise the total overflow of river water in a given basin. Hence, to monitor the trend of the floods in this area, an analysis of the river overflow was conducted by referring to a rating table based on three levels of importance i.e. cautious, warning and dangerous levels. The rating table of one basin is different from another and it changes according to a given time period. Therefore, only a few months were chosen to study the changes in the water level of each sub-basin, so as to illustrate the frequency and magnitude of its flood. Analysis of the data on water discharges based on the flood water level was used to look for changes or trends in terms of flood frequency and magnitude based on the frequency of occurrence of floods at flood measuring station. Data on flood frequency and magnitude collected will be divided according to the time interval of 10 years that is 1966-1975, 1976-1985, 1986-1995 and 1996-2005. River discharge data was analyzed using rating tables to examine the frequency of flood events based on some of the water levels namely warning level, alert level and danger level for each basin. The months with the highest frequency of flood and highest mean of overflow value in the basin in a year have been chosen, i.e. January, November and December. To explain the situation, the selection of overflow station is based on the chosen sub-basin. For example, Lebir Station in Tualang for Lebir River, Galas Station in Dabong for Galas River, Pergau Station in Batu Lembu for Pergau River and Guillemard Bridge Station for Kelantan River. Meanwhile, the analysis of flood damages is run based on the annual reports on floods produced by the government.

RESULTS AND DISCUSSION

Results and discussion can be devided into two analysises namely flood frequency and property damages.

Trend of Flood Frequency and Magnitude

Flood-level gauge station at Guillemard Bridge is located in the District of Tanah Merah, bordering the District of Machang (upstream of Kelantan Basin). In terms of development, these two districts are being rapidly developed, including big-scaled housing projects, roads, buildings and infrastructure. The water level at Guillemard Station is 12.2 metres for cautious level, 15.2 metres for warning level and 17.7 metres for dangerous level. Due to the abundance of data over a very long time, the data was broken into five periods of 10 years, in order to look more closely at the trend of the floods (frequency and magnitude). The periods are: Period 1 (1961-1969), Period 2 (1970-1979), Period 3 (1980-1989), Period 4 (1990-1999) and Period 5 (2000-2006) (Table 1).

For Period 1 (1961-1969), floods occured 30 times with its magnitude exceeding the cautious level, i.e. 12.2 metres which frequently occurred in 1963, 1965 dan 1969. Meanwhile, readings exceeding the warning level were recorded five times, with the highest on the 30th November 1969, i.e. 8057 metres (16.7m^3). During this period, there were no records of readings exceeding the dangerous level. The mean frequency of floods for the eight-year duration (1961-1969 excluding 1966 dan 1967) was four times a year. The duration of each flood differs from one episode to another. For example, in November 1963, the flood only lasted for three days, i.e. on the 28th to the 30th November, compared to the flood in December 1965, which lasted for 15 days beginning from the 1st to the 15th.

Period 2 (1970-1979) recorded high frequency of floods in Kelantan River. Flood at cautious level was recorded 68 times, warning level 30 times and dangerous level 5 times. The mean of flood days for this period was more than 10 days. Furthermore, flood occurred every year with different frequency and magnitude. Floods also occurred longer, i.e. more than 14 days. For example,

Table 1: Frequency of the Flood in Kelantan

Year	Cautious Level (12.2 metres) Frequency	Warning Level (15.2 metres) Frequency	Dangerous Level (17.7 metres) Frequency
Period 1: 1961-1969 (except 1966 & 1967)	30	5	0
Period 2: 1970-1979	68	30	5
Period 3: 1980-1989	54	18	13
Period 4: 1990-1999 (except 1995)	71	23	4
Period 5:2000-2006	52	16	1
Total	275	92	23

Note: Data for 1966, 1967 and 1995 is incomplete.

the flood in December 1971 lasted for 21 days from the 8th to the 28th. Besides, the magnitude of the flood in that month was also high, i.e. water at warning level was recorded for 11 days and the highest reading was recorded on the 16th December 1971 at 16.7m^3. Similarly, in December 1973 the floods lasted for 26 days beginning from the 1st to the 26th. The 1973 flood episode also recorded frequent high magnitude at warning level, with the highest on the 16th December 1973 at 18.3m^3. However, the highest water level for this period was recorded on the 28th November 1979 at 20.2 m^3.

Period 3 (1980-1989) recorded 54 floods exceeding the cautious level and 18 at the warning level. The frequency of water level at dangerous level was 13 times, which was the highest during this period. No flood was recorded in 1980 dan 1989. The mean number of flood days was more than 10 days, except for the years without floods. However, in reality, the total number of days for each of the flood episodes was rather high; for example, 17 days in December 1983. Also in 1986, the flood began on the 28th November until the 10th December and reoccurred on the 18th to the 22nd December. In December 1987, the flood lasted for 14 days, from the 3rd to the 16th. As for the flood magnitude, among the highest water levels were recorded on the 21st and the 22nd November 1988, with readings at 20.2m^3 and 20.3m^3 respectively.

Period 4 (1990-1999) recorded readings exceeding cautious level 71 times, warning level 23 times and dangerous level 4 times. During this period, the record for 1995 was not complete, hence excluded from this study. The mean number of flood days showed an increase, i.e. 11 days a year, except for 1995. Different frequency of floods was recorded every year. For example, in 1990, 1992, 1993 and 1994, floods accurred twice in a year, while in 1991 and 1998 three times. Similar to the previous years, flood lasted for quite long; for example, eight days in 1990, nine days in 1991, 15 days in 1992, 19 days in 1993 and 30 days in 1994. In terms of magnitude, more readings were recorded at cautious level and the highest was on the 23rd December 1993 at 19.2m^3.

Period 5 (2000-2006) recorded 52 times of water level exceeding the cautious level, 16 times exceeding warning level and once at dangerous level. During this period, only in 2002 was free of floods, while a total of 69 flood days brought the mean of more than 11 days a year. However, the duration of each flood episode was quite long; for example, 15 days in December 2001, nine days in December 2003 and 20 days in December 2005. As for the depth, the water levels were mostly recorded at cautious level, i.e. 52 times and the highest was recorded on the 11th December 2003 at 17.7m^3.

In conclusion, floods for the duration of 45 years (1961-2006) recorded readings at cautious level 275 times, warning level 92 times and dangerous level 23 times. The mean number of flood days is 9.2 days, excluding the years without complete record (1966, 1967 and 1995). This shows that the Kelantan River is one of the basins with floods of high frequency and magnitude but most of the floods occurred in December.

The 1961-2006 record from the Galas Station shows that floods occurred every year, beginning from 1960 until 2004. There are several physical and human factors that contributed to the floods in this area. The magnitude of a flood is divided into three categories: cautious level at 32 metres, warning level at 35.4 metres and dangerous level at 38.1 metres. So, the analysis of flood frequency and magnitude is done according to these water levels. The duration is also divided into periods of 10 years (Table 2).

Period 1 (1975-1979) recorded three times of floods exceeding the dangerous level, all of which occurred in 1979, i.e 57.0 m^3, 56.6 m^3 and 42. m^3. Warning level was recorded twice in 1975 and 1976 at 35.4 m^3 and 34.6 m^3 respectively. As for cautious level, it was recorded three times, all of which occurred in 1975 at 35.2 m^3, 34.3 m^3 and 34.9 m^3. There were not any flood in 1976, 1977 dan 1978 and the water level remained between 26 and 31 m^3.

For Period 2 (1980-1989), floods exceeding the dangerous level were recorded nine times with the highest reading recorded in 1983 at 55.0 m^3. The frequency of

Table 2: Frequency of the Flood in Galas

Year	Cautious Level (32 metres) Frequency	Warning Level (35.4metres) Frequency	Dangerous Level (38.1 metres) Frequency
Period 1: 1975-1979	3	2	3
Period 2: 1980-1989 (Except 1982)	21	4	9
Period 3:1990-1999	29	6	2
Period 4: 2000-2006	20	5	2
Total	73	17	16

Table 3: Frequency of the Flood in Lebir

Year	Cautious Level (27.4 metres) Frequency	Warning Level (32 metres) Frequency	Dangerous Level (35.1 metres) Frequency
Period 1:1976-1979	9	1	2
Period 2:1980-1982	1	2	0
Period 3:1990-1999 (except 1991, 1993 and 1994)	34	13	1
Period 4:2001-2006	27	10	7
Total	71	26	10

floods at warning level was four times, twice each for 1987 dan 1988. Cautious level was recorded 21 times, most frequently in 1983 (five times), 1984 (twice), 1986 (three times), 1978 (seven times) and 1988 (four times).

Period 3 (1990-1999) recorded floods exceeding dangerous level twice with the highest in 1993 and 1899 at 40.4m^3 and 30.59m^3 respectively. Floods exceeding the warning level were recorded six times, i.e. in 1992, 1993, 1997 and 1999. While the frequency of floods exceeding the cautious level was 21 times, recorded in 1991, 1992, 1994, 1995 and 1999.

During Period 4 (2000-2006), readings exceeding the dangerous level were recorded twice in 2004 and the highest was 39.8m^3. As for warning level, readings were recorded five times, with the highest in 2000 (36.2m^3) and 2003 (36.1m^3). Readings exceeding cautious levels were recorded 20 times within these seven years. Floods were most frequent at cautious level occurring in 2000, 2004 and 2005.

In conclusion, the floods frequency in Galas River was high with magnitudes mostly exceeding the warning and dangerous levels. In addition, between 1975 and 2006 (except 1982 - incomplete data), floods did not occur only in 1976, 1977, 1978, 1981 and 1989, although between 1970 and 2000, Kelantan Basin was flooded almost every year. Therefore, in the duration of 31 years, only five years the Galas Basin was not flooded. This indicates that the frequency and magnitude of the floods here is significant. Heavy rain or other significant factors could have contributed to the seriousness of the floods here.

For the Lebir Station, Period 1 (1976-1979), water level readings at cautious level were recorded nine times, warning once and dangerous twice. Within this four-year duration, floods occurred ever year, but the most serious were in 1979. The duration of flood occurring at Lebir Basin was basically short. For example, flood occurred for one or two days only, except for November 1979 - six days. The depth of the water was also not extreme, i.e. the highest was recorded at 35.2m^3 on the 27th November 1979 (Table 3).

For Period 2 (1980-1982), which was only of three-year duration, only three flood episodes were recorded, i.e. once at cautious level and twice at warning. As data for the previous years were incomplete, the real situation could not be fully illustrated.

For Period 3 (1990-1999; except 1991, 1993 and 1994), flood episodes in this basin had a decreasing trend, i.e. cautious level was recorded 34 times, warning level 13 times and danger level once. This is illustrated by the 1990 floods, which occurred for three days in January, three days in November and six days in December. This shows that in 1990 alone, floods occurred three times. Besides, the flood duration also decreased - 10 days in 1992, five in 1995 and 12 in 1998. In terms of the flood magnitude, most readings were recorded at cautious level and only once exceeding the dangerous level at 35.5m^3 namely on the 1st January 1999.

For Period 4 (2001-2006), floods were quite frequent, i.e. 27 times exceeding the cautious level, 10 times warning level and seven times dangerous level. The frequency of floods during this period was almost the same like the previous years, whereby the duration was almost the same for this period, but the magnitude showed an increase. For example, in the 2001 floods, readings exceeding dangerous level were recorded on 3 days, in comparison to warning level only on one day. The same was recorded for the flood in December 2004. The highest reading was recorded on the 12th December 2004, i.e. 45.8m^3.

Table 4: Frequency of the Flood in Pergau

Year	Cautious Level (37 metres) Frequency	Warning Level (38 metres) Frequency	Warning Level (39 metres) Frequency	Total
Period 1: 2000-2006	27	19	7	53

In conclusion, the floods in Lebir Basin have the potential to become worse particularly in terms of its magnitude, or the depth, if the natural ecosystem is disturbed. This prediction is based on the flood episodes between the years 2001 and 2006, which shows increase in flood frequency and magnitude.

Due to the lack of data recorded by the Department of Irrigation and Drainage, only one period is used to describe the flood at the Pergau Station. Data was only available between 2000 and 2006 and within the duration, readings exceeding cautious level were recorded 27 times, warning level 19 times and dangerous level seven times. This indicates that Sungai Pergau is also highly at risk to get flooded frequently. In the seven-year duration, there were 53 flood episodes with its mean duration exceeding seven days in each year. Besides, there were many flood days in this basin. For example, 10 days in 2000, 11 days in 2001, nine days in 2003 and 14 days in 2005 (Table 4).

In terms of the flood magnitude, the frequency exceeding the warning and dangerous levels was high. For instance, in 2003 readings exceeding the warning level were recorded for five days, dangerous level once and cautious level twice. Similarly, in 2005, only 6 out of 14 flood days exceeded the cautious level, while the remaining were recorded at warning and dangerous levels. This situation is rather worrying due to the potential for floods to occur if mitigation steps are not taken.

Property Damages Within Year 1967-2004

Flood frequency in Kelantan River Basin has caused extensive property damage. This implies that the people need to be prepared and adapted to the disaster as the damage valuation increases every year. The damage valuation in Figure 1 encompasses all types of damages and evaluated according to the respective year of floods in Kelantan. For example, damage evaluation of the 1967 flood was estimated at RM30 millions, but if the amount is compared to the value in the year 2000, the amount would be more.

For example, Japan Cooperation Agency (JICA) estimated that the mean yearly potential damage by flood in Peninsular Malaysia is high. For instance, in 1982, an estimated RM72 million and the value increased to RM92 million in 1993 and this value will increase parallel to the country's economic development [13]. According to the Department of Irrigation and Drainage Report, Kelantan River Basin faced the highest damage compared to other river basins in Malaysia. The damage in 1967 was estimated to be RM 30 million, but when the amount is compared to the value in 1993, it would be equivalenet to RM199.3 million, affecting 320,000 victims with 38 casualties. Besides, the flood episodes in 1988 and 2004 were also among the worst, with a high number of casualties, i.e 12, as well as increased property damage [14].

In addition, the increase in the value of damaged properties in Kelantan also indicates the socio-economic improvement of the people in Kelantan Basin because they could afford to furnish their houses. However, floods recurring every year were causing damage to this household furniture and appliances. This is such a disadvantage for the flood plain dwellers; hence adaptation steps ought to be taken by the people as well as the government to reduce the burden. Besides individual property damages, infrastructure damages- i.e damages to roads, bridges, schools, electrical posts - also contributed to the increase in the value.

The total number of flood victims transferred to relief centres was still high in the 2000 era. However, the trend of transferred victims in the 1970s and 1980s was still higher compared to recent years. This could be due to the socio-economic condition of the people at that time which was still around poverty level and the aspect of adaption to floods was not a major issue. Very few people could repair house structures, build houses on stilts and so on. The 1967 flood in Kelantan is among the worst affecting 636,700 people (Figure 1). As a result, the government reinforced the early warning system by installing more of them particularly in the Kelantan Upstream [14].

In terms of casualties, at times it increased and this depended significantly on the parents' attitude and awareness in ensuring their children's safety. In conclusion, based on Kelantan Department of Irrigation and Drainage records, it is clear that the Kelantan basin is frequently flooded. Although floods are regarded as common occurrences by the Kelantanese people, sometimes they can be disastrous when a major flood occurs. When compared with areas frequently hit by floods in Malaysia, it is found that the Kelantan River Basin is a watershed that most frequently hit by floods with a high magnitude and this should be addressed

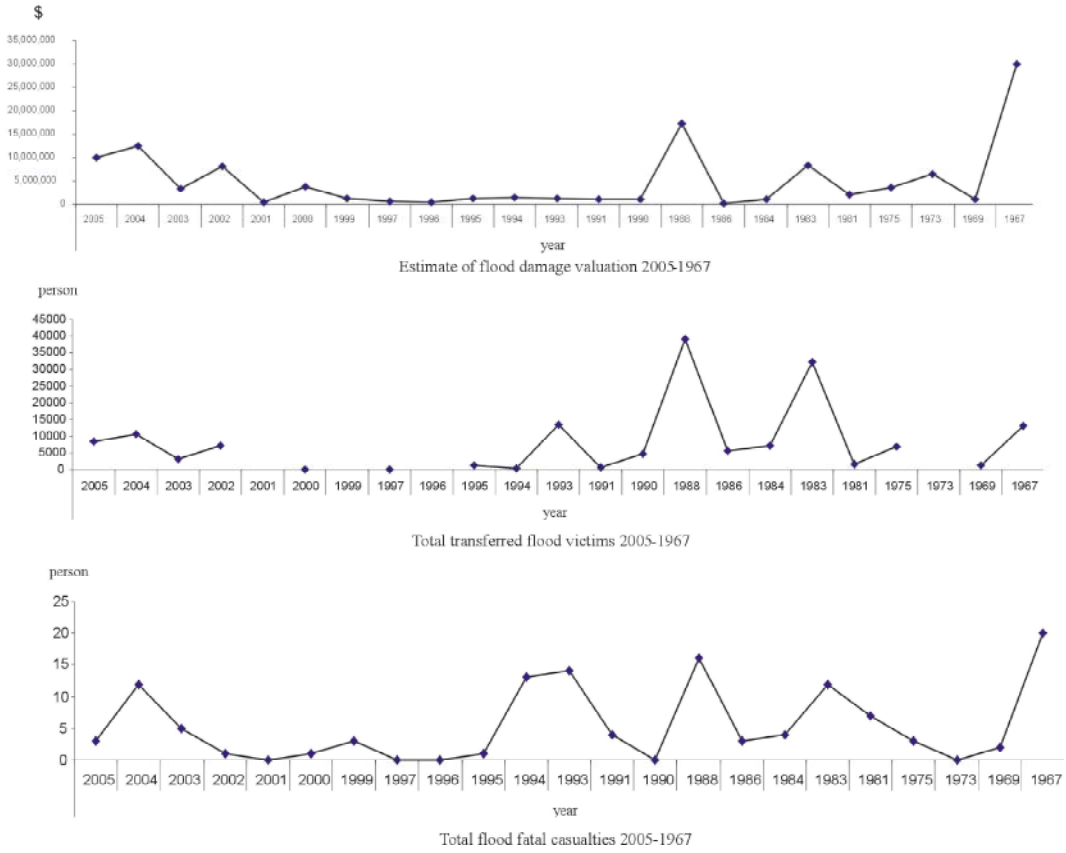

Fig. 1: Estimated damage, victim and casualties due to floods in Kelantan River Basin

immediately by the government to abate the destruction and death due to floods in the country in future. However, when compared with flooding episodes, the situation is the same as in the Kelantan River Basin as floods bring destruction to property, crops, livestock and so on [15].

For example, the incidence of flooding in Bangkok in November 2011, floodwaters have inundated many areas of industry, Don Muang airport and close to 40 percent of downtown Bangkok. The flood disaster has caused 800 deaths and losses reached USD45 billion, which cause millions of people to leave their houses. Floods in 2000 in Hydrabad and Ahmedabad have resulted in a loss of 340 million U.S. dollars. Flooding in the Susquehanna River Basin, Harrisburg United States in January 1996 floods had caused 19 deaths and the destruction of an estimated value of 700 million U.S. dollars. In addition, floods have also caused diseases such as malaria, pneumonia, measles and yellow fever [16].

As Malaysia neighbor, Indonesia is a country often hit by the disaster, including landslides, floods, drought and so on. Since 1998 to 2003 there were about 647 disasters in Indonesia and 85 percent were floods that have killed 1066 people and the total loss was estimated at 191.32 million rupiah. In addition, a number of flood events that occurred in the developing countries between the years 1960-1990 caused the death of about 65,000 people worldwide. Of the total of about 51,000 people or 78 percent of deaths occur in Bangladesh, China, Colombia, India and Pakistan. For example, flooding in Bangladesh in 1974 has resulted in 29,000 people died between 1970-1990 and estimated economic loss has reached 50 thousand million U.S. dollars [17].

Hence with the availability of this study, it is expected that the government or parties involved are able to take appropriate action such as improvements in the country's development policy, both in terms of enforcement of land use changes in the drainage basin of high risk and so on. This is because many flood disasters cause negative effects than positive. The embodiment of this disaster is also apparent in the diminishing household economic development benefits felt by most of the population in the Kelantan River Basin depite improved national economy.

CONCLUSIONS

At last, the total amount of heavy rain in the Kelantan River Basin area has caused the increase in the overflow rate for the Kelantan river tributaries, causing severe floods. Normally, each of the flood episodes has serious socio-economic effects on government and the people involved. Thus, when flood frequently happen the value of damaged properties in Kelantan River Basin also increased. Therefore, one of the methods to mitigate floods and reduce damages is to implement an integtrated flood management system, whereby cooperation and involvement of all stakeholders (society, private sector, NGOs and government) are crucial in reducing the negative impacts of floods. Hence, any future research should focus on the psychological impact especially towards the flood victims and treatment to psychological disorders due to frequent flood disaster.

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