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Suitable Low Income Flood Resilient Housing

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Abstract

Climate change is a critical issue for all of humanity. It is predicted that Thailand is likely to have an increasing frequency and intensity of rainfall and storms which, will result in a more severe flash flood problem. Slum residents in Chiang Mai are one of the groups of people who are vulnerable to flooding impacts of climate change. The objective of this study is to analyze the flood-resilient housing style of low-income people. Data from 3 slums (146 households) which encounter different kinds of floods every year, i.e. drainage floods (Ban Sanku: 21 households), river floods (Kampang Ngam: 64 households) and flash floods (Samunkee Pattana: 61 households), were collected. The study found that flood frequency, duration, depth and flow velocity caused damage to the houses, but only flood frequency, duration, and flow velocity were factors affecting the housing structure. If considering only damage to slums which frequently face shallow water depth, slow flow velocity and short duration, all 8 low-income housing styles (A-H) can be built. The high platform house with open space under the house is appropriate for slums located in flooding area where high-level, slow flow velocity floods occur frequently but for a short duration. It may be a permanent, semi-permanent or temporary structure (D-F). For the other slums facing high flood levels with high flow velocities for a short duration, all permanent housing styles are appropriate. If the objective is not only damage prevention but also living during a flood, permanent high platform houses with open spaces under the houses are recommended for all slums.

Keywords: Flooding; low-income housing; slum

Introduction

Slums are established and widespread in cities while the country is being developed. There is interdependence between slums and cities, which are the source of the slum dwellers' jobs, while these low-income people are important to the urban economy, especially by providing unskilled labour in various industries. Thailand's largest slums are located in major economic cities [1,2] including Bangkok, Nakhon Ratchasima, Nakhon Si Thammarat, and Chiang Mai [1]. Slum dwellers face many intractable problems such as overcrowding, poor housing, lack of land tenure, frequent flooding, sanitation, food shortage, poor infrastructure and public utilities, damaged or collapsed housing, and homelessness. In the future, slums are expected be prone to more frequent and severe flooding due to climate change impacts [2,3].

Chiang Mai is located in the north of the country and is rich in both natural and cultural attractions. In addition, the government has set Chiang Mai as the region's economic and development center, as it is highly developed and possesses high tourism rates, a strong economy, rapid growth and investment potential. At present, Chiang Mai's economy is ranked second in Thailand after Bangkok [4]. This city's growth has led to a rise in migration of people from surrounding areas seeking work, resulting in expansion of slums around the city. The Community Organization Development Institute's survey reveals that there are 132 slums with 25,459 households in Chiang Mai, which ranks third behind Bangkok and Nakhon Ratchasima; this number has an increasing trend for the future [1].

Chiang Mai is already affected by climate change, manifested in an increasing severity and frequency of thunderstorms and increasing rainfall, causing flooding. In the past 10 years, Chiang Mai has flooded many times and each flood brought damage to life, property and housing [5]. A study of the IPCC (Intergovernmental Panel on Climate Change) projected using the SRES model that there is a high possibility of more frequent and heavier rain in the coming years [6]. This result is consistent with Thailand's national climate change information [7] reports that average annual rainfall is likely to increase in all regions of the country. By the end of the century, rainfall is expected to increase by 15-25%; moreover, the rains will be heavier than in the past, increasing the risk of flash floods and other flood disasters [8].

Based on the available data, Chiang Mai slum dwellers therefore face an increasing flooding risk resulting from climate change. This study therefore analyzes low-income housing styles in slums which have been resilient to floods from 2001 to 2011, a period of frequent flooding [9]. The results can be used to develop recommendations to improve low-income housing styles to increase resilience to future floods. In addition, this study result may serve as a guideline for policy makers concerned with low-income housing.

Low Income Housing's Background in Chiang Mai

Slum dwellers typically have income below the poverty line, which is 2,572 Baht/person/month [10]. They frequently live in crowded, dilapidated housing in unsanitary conditions, where crime and drugs are endemic. These characteristics are described as a slum [3,13]. Low-income houses are used effectively in terms of horizontal, rather than vertical, area [8]. Most are one-story houses requiring minimal building materials that are easy to find in their locations, particularly natural materials if their surrounding area has plenty of trees or is located near a forest. For urban slums, building materials are easy to find, sold in the area and inexpensive, such as plastic sheets, wood and tiles. Sometimes, they are creatively constructed from used materials. In selecting building materials. Other than the household's financial status, the land tenure is an important issue as it highly influences the owner's decision [12].

Most houses in the slums are built by the owners themselves [13]. Therefore, building materials and construction methods depend on their own skills and expertise. In spite of limitations such as small site, limited budget and short construction period, the low income houses meet the owners' basic needs. In certain cases, natural materials, such as clay floors, clay walls, wooden roof structures, straw roofs and wooden columns, as well as block and cement are used. Although low income houses are not designed by architects or engineers and are not constructed according to construction standards of residential buildings, they can be used for living and harmonize with the environment [11,13].

92 slums (70%) out of 132 slums are located in the business areas (Muang District) in Chaing Mai. This is consistent with various slum research stating that the rural people migrate to the urban areas for work and find or construct their houses near their work places, so the slums are generally situated in the urban areas where jobs are easy to find. The remaining slums in Chiang Mai are in other business areas and tourist attractions, i.e. Sankumpang District (14%), Sarapee District (12%), Sansai District (3%) and Samuang District (1%) [3] as shown in Figure 1.

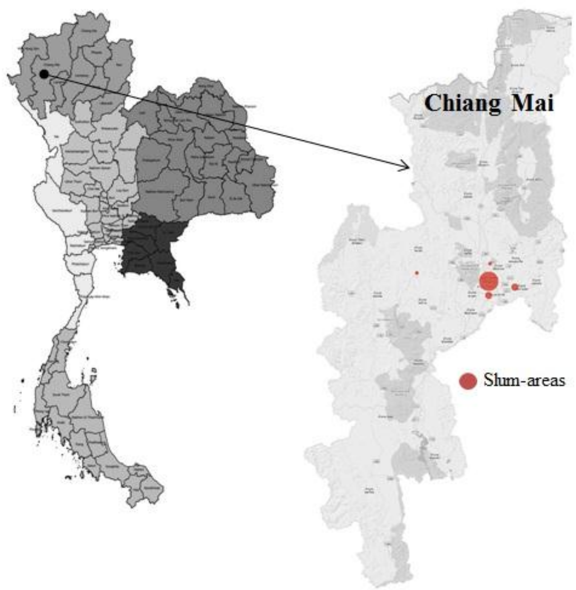

Figure 1 Slums' areas in Chiang Mai

Types of Floods

Floods are generally grouped into four categories [9,14].

1) Flash floods usually occur in the low plain area near an upstream mountain and are caused by heavy rain over the mountains for a long period, resulting in a large volume of accumulated water that the ground and trees cannot absorb as it flows downstream. The floodwater flows rapidly down to lower-lying areas, often causing structural damage, building collapse and fatalities.

2) Drainage floods usually occur in urban areas with poor drainage systems, in basins surrounded by buildings blocking the drainage, or in coastal areas during a high tide. In such areas, heavy rain falling for a long period, or an accumulated volume of water flowing down from higher elevations during a high tide will cause a drainage flood.

3) River floods are caused by a large amount of rain flowing into a river. When the water level in the river cannot be drained fast enough, it runs into homes, buildings and structures along the river banks.

4) A storm surge is a large wave inundating the shore due to the strength of wind caused by a tropical cyclone moving towards the shore. Normally, the storm surge's severity is high within 100 kilometers from the storm center, but it can sometimes impact at further distances, depending on the severity of the storm and geography of the coastal area.

Materials and methods

3 slums in Chiang Mai which experience different flood types: flash floods, drainage floods and river floods, were selected. The criteria included establishment over 10 years with more than 20 households per slum and flooding every year, to obtain adequate data for the study. The three selected slums were Kumpang Ngam, Samungkee Pattana and Ban Sanku. These locations, which differ in geographical location and encounter different flood characteristics, are shown in Figure 2.

Master plans for the three slums were drafted to investigate the geographical location, contours and drainage, using a survey and geographic information system (GIS). These master plans were used as a basis for collecting flood data and all housing information, i.e. structural (column, beam and roof structure), non-structural (floor, wall and roofing material) and building form (number of floors). Then, the data were grouped into patterns of housing in the slums.

The flood and housing damage data from 2001 to 2011 was collected from the residents (146 households) who had lived in the slums. It was collected by reviewing relevant authorities' documents and conducting interviews with residents in the three slums. Structured interviews, observation, digital photography and drawings were used to collect damage data. Afterwards, the flood data of each slum were summarized, including flood frequency (times/year), duration of flood (days), flood depth (meters) and flood flow velocity (m/s). The current cup-type meter was used to measure flow velocity in drainage channels in each slum area. This measured the baseline flow velocity which relates to the flood flow velocity.

Figure 2 Location of three study areas

All data were loaded into an SPSS database. The housing damage models were developed using ordinal logistic regression methodology, which is an extension of the general linear model to ordinal categorical data. Ordinal logistic regression was used to predict an ordinal dependent variable (housing damage) given one or more independent variables (flood characteristics and housing style). In addition, it was enabled to determine which of all independent variables had a statistically significant effect on housing damage. It was also be able to interpret the odds that one group of housing damage had a higher or lower value on any dependent variable compared to the others. Therefore, these models were used to calculate the probability of housing damage at different flood levels.

Results and Discussion

1) Slums' physical characteristics

Ban Sanku consists of 2 1households located 304 meters above the mean sea level, in a basin-like depression. In this slum, there are different area levels, with a flood plain area which is 301.5 meters above mean sea level. The contours of the slum are shown in Figure 3 (A). The dark colour represents low-lying areas, while the light colour represents elevated areas.

Samunkee Pattana consists of 61 households located in a low-lying plain around 307.75 meters above the mean sea level. The reference point is the electricity pole at the entrance of the slum on Chang Puak Road. Its location is considerably lower than the road level, and the survey reveals that this slum is about 0.75 meters lower than the reference point at the centre, and at the same level as the reference point in the western and southern areas, as shown in Figure 3 (B). The dark colour represents low-lying areas, while the light colour represents elevated areas.

Kumpang Ngam consists of 64households located in a flood plain with an average height of 304.475 meters. The reference point is at the slum name board. The average height of the slum is 0.225 meters lower than the reference point, and the lowest area is 0.8 meters lower than the reference point. The area at the middle and end of the slum is 0.4 meters higher than the reference point. The contour of the slum is shown in Figure 3 (C).

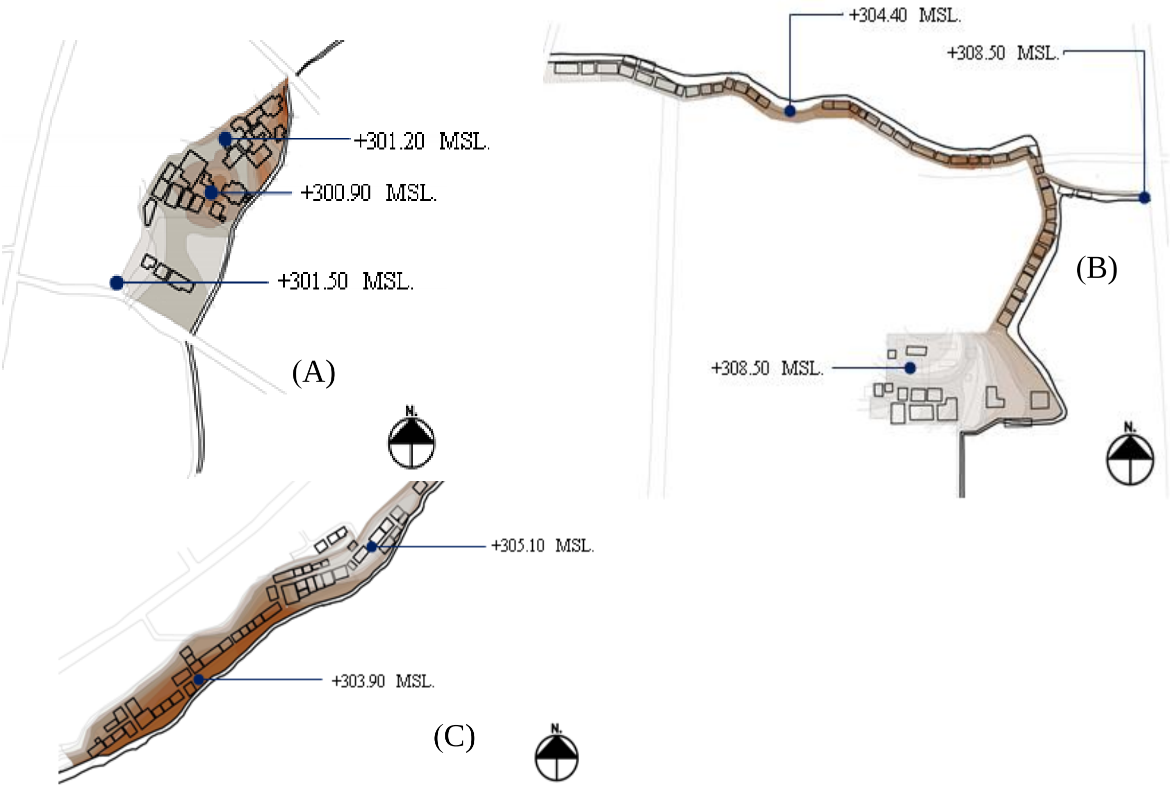

Figure 3 (A) Ban Sanku's geography and contour, (B) Samunkee Pattana's geography and contour and (C) Kampang Ngam's geography and contour

2) Housing styles in the three slums

From the survey, the housing styles in the 3 slums could be divided into eight styles (A-H) by house structure, construction materials and number of floors as detailed in Table 1. Styles A, D and G were permanent houses, referring to a house with strong structure, floors and walls built by reinforced concrete or wood in perfect condition; and roofed by double corrugated roofing tiles or galvanized iron sheets. Styles B, E and H are semi-permanent houses, with structures and floors built from reinforced concrete or wood, walls made from light-weight material such as galvanized iron sheet and plywood, and roofed by double corrugated roofing tiles or galvanized iron sheets. A small amount of blocks and wood may be used. C and F styles are non-permanent houses, referring to a house with a wooden structure, floors and walls made by various materials such as galvanized iron sheets, wood, bamboo sheets or others, and roofed by double corrugated roofing tiles, galvanized iron sheets or other material.

Table 1 Housing styles

Housing structure	Non-structure	Number of floors	Styles	Examples
All the structures made of reinforced concrete, steel or hardwood in good condition.	All the non-structures made of concrete, brick or wood in good condition.	1 floor	A	
		1 floor with high space under the house	D	
		2 floors	G	
All the structures made of reinforced concrete, steel or hardwood in good condition.	Some parts of the non-structures are not strong, not durable, made of waste materials.	1 floor	B	
		1 floor with high space under the house	E	
		2 floors	H	
The structures are not strong, not durable, made of waste materials.	The non-structures are not strong, not durable, made of waste materials.	1 floor	C	
		1 floor with high space under the house	F	

From the survey conducted by observation and photography of housing styles in Ban Sanku, it was found that Ban Sanku had various housing styles in terms of useful area, structure and construction materials. 30% of all houses in this slum were in A style followed by G and H styles, but C and F styles were not found. In Kampang Ngam, most houses were permanent 1-floor (A) or semi-permanent 2-floor (H), followed by permanent 2-floor (G), but permanent 1-floor with a high space under the house (D) could not be found. For houses with a high space under the house, all of the owners were hill tribe people who lived in the cities, and the area under the house was a semi-public open space used as a living, working and cooking area. The toilet and bathroom were also on the ground. The toilet was a lavatory with septic tank and a bucket of water for bathing (Figure 4(. In Samunkee Pattana, all housing styles were represented. Most of them were in E style, followed by A and D styles as shown in Figure 4.

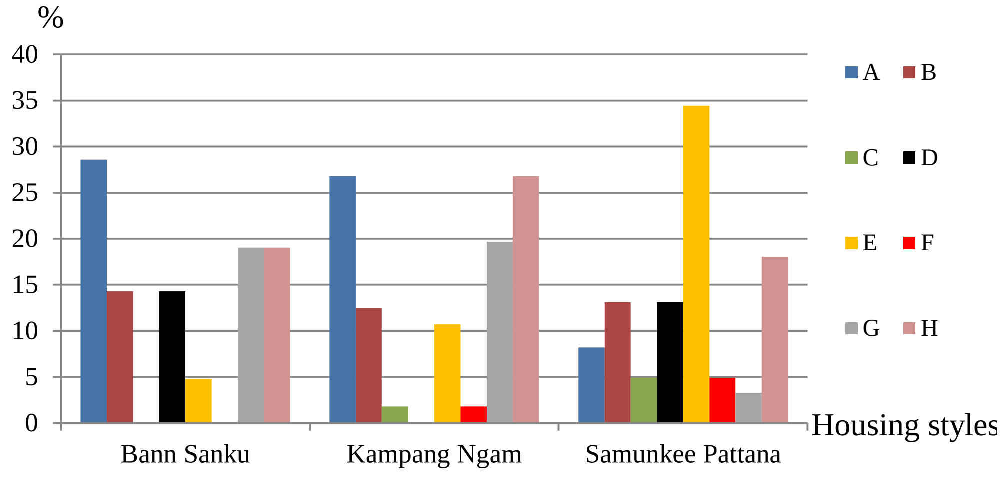

Figure 4 Housing styles

3) Flood information

According to the structural interview information and secondary data from 2001-2011, the three slums flooded every year at a shallow level (lower than 0.50 cm.) and livelihoods of residents were unaffected. For this study, only the more unusual floods of 2001, 2005, 2006, 2007 and 2011 were considered as shown in Table 4. Considering flood severity, which depends on four variables: flood depth, duration, flow velocity, and frequency [13,14], it was found that the flood characteristics of Samungkee Pattana are high flow velocity (as perceived by people in the slum) and short duration (not more than 1 day) but high frequency, i.e. over 15 times a year. In contrast, the flood characteristics of Ban Sanku are slow flood flow velocity, relatively high level of 0.7-1.10 meters, and longer duration (10-2 days). In Kumpang Ngam, the flood level is lower than 0.50 meters with a low flow velocity, with duration not more than 2 days, but occurring several times a year as shown in Table 2. It can be seen that Samungkee Pattana encounters the most severe flooding, followed by Ban Sanku and Kumpang Ngam. This difference in severity reflects the geographical location of each slum.

Table 2 Flood characteristic in each slum

Slums	Years	water depth (m)	Duration (days)	flow velocity (m/s)	Frequency (number/year)
Ban Sanku	Normal year	0.4	5	1.2	3
	2001	1.4	10	1.2	4
	2006	0.7	7	<1.2	3
	2011	0.9	10	<1.2	2
Kampang Ngam	Normal year	0.3	3	1.6	5
	2005	0.55	3	<1.6	4
	2011	0.7	4	1.6	4
Samungkee Pattana	Normal year	0.5	3	3.4	15
	2001	0.65	1	>3.4	10
	2006	1.15	1.5	>3.4	15
	2011	0.7	1	3.4	15

4) Relationship of flood characteristics and housing damage

Each slum flooding affects each house unequally, depending on the physical characteristics and contour of the building site. For this reason, some houses were undamaged, some suffered partial damage (non-structural), while some houses were structurally damaged. 520 database entries from the slums were collected to describe housing damaged by usual and unusual flooding from 2001-2011: 84 from Ban Sanku (21x4), 244 from Samukee Pattana (61x4), and 192 from Kampang Ngam (64x3). The data were grouped in an SPSS database. Housing damage and flood flow velocity were grouped as ordinal data. Housing damage data were grouped into 4 levels: 0 (no damage), 1 (non-structural damage), 2 (structural damage), and 3 (house destroyed). Flow velocity data was grouped into 3 levels: 1 (0-1.5 m/s), 2 (<1.5-3.0 m/s), and 3 (<3.0 m/s). After analysis using ordinal logistical regression methodology, the relationship of flood characteristics and housing damage was tabulated (Table 5).

In Table 3, each independent variable had significantly between 0.00-0.07 which was acceptable for this study i.e. 0.00 (depth), 0.02 (frequency), 0.07 (flow) and 0.008 (type). This implies that the independent variables (depth, frequency, flow velocity, and house style) were related to housing damage. The flood duration had little relationship with housing damage (0.26), but was retained in the model because information from the literature review revealed that prolonged flooding was an important cause of damage [14]. The results of the model fitting test showed that there was 99% confidence, which is significantly higher than the baseline. Therefore, the models are suitable for predicting housing damage with other flood characteristics and housing styles.

Table 3 Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[Damage = 0]	2.726	.548	24.727	1	.000	1.652	3.801
	[Damage = 1]	4.344	.583	55.582	1	.000	3.202	5.486
	[Damage = 2]	6.088	.641	90.135	1	.000	4.831	7.344
Location	Depth	3.048	.333	83.846	1	.000	2.396	3.700
	Duration	0.029	.116	1.227	1	.268	-.099	.357
	Frequency	0.058	.112	5.275	1	.022	-.477	-.038
	[Flow=1]	0.211	.843	.063	1	.802	-1.863	1.441
	[Flow=2]	0.853	.486	3.082	1	.079	-.099	1.806
	[Flow=3]	0[a]	.	.	0	.	.	.
	[TYPE=1]	-0.041	.344	.014	1	.906	-.715	.634
	[TYPE=2]	-0.030	.374	.006	1	.936	-.762	.702
	[TYPE=3]	1.809	.549	1.230	1	.267	-.467	1.684
	[TYPE=4]	-0.750	.658	.823	1	.364	-1.886	.693
	[TYPE=5]	-0.302	.406	.554	1	.457	-1.097	.493
	[TYPE=6]	1.425	.616	6.955	1	.008	.417	2.832
	[TYPE=7]	-0.060	.406	3.412	1	.065	-1.545	.046
	[TYPE=8]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

For example, the equation predicted that style A at level 1 flow velocity will probably cause damage levels 0, 1, 2 and 3, as in equations (1) - (4). In the case that style A encountered a different type of flood, the equation could be used to calculate the probability of housing damage. For other housing styles (B-H), equations could be established as detailed in Table 4. There are 32 total equations for predicting housing damage probability.

$$P_0T_A\ 1 =/(1+EXP(-(2.726-3.048X_1-0.029X_2-0.058X_3-(-0.041)-(0.211((\quad (1)$$
$$P_1T_A\ 1 =/(1+EXP(-(4.344-3.048X_1-0.029X_2-0.058X_3-(-0.041)-(0.211((-P_0T_A \quad (2)$$
$$P_2T_A\ 1 =/(1+EXP(-(6.088-3.048X_1-0.029X_2-0.058X_3-(-0.041)-(0.211((-P_0T_A-P_1T_A \quad (3)$$
$$P_3T_A = 1- P_0T_A - P_1T_A - P_2T_A \quad (4)$$

Which P_0T_A is the probability of 0 level damage to style A
P_1T_A is the probability of 1 level damage to style A
P_2T_A is the probability of 2 level damage to style A
P_3T_A is the probability of 3 level damage to style A
X1 is flood depth (meters)
X2 is duration (days(
X3 is frequency (number/year(

Table 4 Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	792.779			
Final	562.703	230.076	12	.000

Link function: Logit.

5) Suitable low-income housing style

The equations were entered with the variables being the characteristics of the most severe floods in each community, including 2001 data for Ban Sanku, 2006data for Samukee Pattana and 2011 data for Kampang Ngam. It is found that the housing style D was most likely to cause zero level damage when compared with the other styles in every type of flood. C and F have the potential to cause level 2 damage, as shown in the data in Table 5.

Table 5 Opportunity to damage the 0-3 level of style A-H

Slums	Damage levels	Housing styles							
		A	B	C	D	E	F	G	H
Ban Sanku	0	0.141	0.140	0.025	0.250	0.176	0.037	0.143	0.136
	1	0.312	0.310	0.090	0.377	0.342	0.124	0.314	0.307
	2	0.367	0.369	0.704	0.192	0.302	0.659	0.362	0.377
	3	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
Kampang Ngam	0	0.758	0.756	0.330	0.864	0.803	0.420	0.761	0.750
	1	0.182	0.184	0.383	0.106	0.151	0.365	0.180	0.188
	2	0.049	0.049	0.221	0.025	0.038	0.169	0.048	0.050
	3	0.011	0.011	0.066	0.005	0.008	0.046	0.011	0.011
Samungkee Pattana	0	0.164	0.162	0.030	0.285	0.203	0.043	0.167	0.158
	1	0.333	0.332	0.105	0.383	0.359	0.143	0.335	0.328
	2	0.353	0.354	0.336	0.252	0.318	0.380	0.350	0.357
	3	0.150	0.152	0.529	0.080	0.120	0.434	0.148	0.156

Considering the housing styles that were slightly damaged by flooding, since the flooding suffered by Kampang Ngam was not severe (frequent but short duration and low height), all housing styles (A-H styles) could be built. However, in Ban Sanku styles D, E and F were more suitable, while styles A, D and G styles were appropriate for Samunkee Pattana. This was because Ban Sanku frequently encounters high-level floods for a long duration so the houses require a high space underneath and permanent construction materials to ensure flood resiliency. The height of the house should depend on past flood levels, owner's needs, and budget. If building a 1-story or 2-story house on the ground, water resistant materials are needed. Samunkee Pattana suffered the greatest impact from frequent, high-level, heavy flooding although it was for a short duration. In this slum, the structural part of the houses was affected. Therefore, the house structures must be strong, such as styles A, D and G. If considering housing styles which were slightly damaged by floods, coupled with their capacity of residence (during a flood), style D with water resistant building materials such as brick, cement blocks or zinc panel was the most suitable style.

Conclusions

The flood characteristics differ according to each slum's geography, but floods in these slums will not be heavy as they are located mainly in the cities or business districts with high building density; water flow in these areas is reduced by many water barriers. In the slums frequently facing floods with low water level, low flow velocity and short duration, all housing styles (A-H) can be built, while styles A, D and G are appropriate for the slums frequently facing floods with high water levels and long duration but low flow velocity. However, style D is recommended for all slums as it can resist the damage from a flood and is appropriate for living in during a flood.

Acknowledgement

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