A COMMUNITY-BASED APPROACH TO FLOOD HAZARD AND VULNERABILITY ASSESSMENT IN FLOOD PRONE AREAS;

A Case Study in *Kelurahan* Sewu, Surakarta City - Indonesia

By:

Muhammad Zein

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Thesis submitted to the Double Degree M.Sc. Programme, Gadjah Mada University and International Institute for Geo-Information Science and Earth Observation in partial fulfillment of the requirement for the degree of Master of Science in Geo-Information for Spatial Planning and Risk Management

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GADJAH MADA UNIVERSITY
INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
2010

THESIS

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DISCLAIMER

This document describes work undertaken as part of a program of study at the Double Degree International Program of Geo-information for Spatial Planning and Disaster Risk Management, a Joint Education Program of ITC the Netherlands and UGM, Indonesia. All views and opinions expressed there in remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Zein, M

Abstract

*Keluraha*n Sewu of Surakarta City is located in a flood prone area. The largest flood inundation which occurred on the late December 2007 caused inundation on the entire village. Strengthening and raising public awareness of disaster-prone areas is necessary in order to reduce the vulnerability and risk. Community knowledge is very important to improve preparedness and mitigation to reduce impact due to flood. The research is focused on a local scale, and is based on community knowledge of, flood hazard, identify the element at risk, and assess the vulnerability of each of the elements at risk.

The primary data were obtained through interviewing 104 respondents who were purposively selected based on the structural types of household building, the distance from the river dike, and the elevation. General characteristics of community for social vulnerability to floods were observed. It was found that some of the communities lived on the riverbanks with unorganized housing, almost one-fifth of the communities consist of the elder and the youngest people, one-third of the communities were un-educated, and a half of people have low income. Moreover, the community has their capacity to deal with flood hazard through organizations and the local traditions.

Participatory Geographic Information System (GIS) was applied to get information about flood cause, depth, and duration. The information was processed using simple kriging in ILWIS software with Gaussian semivariogram model to establish flood depth and flood duration map. Eight *Rukun Tetangga* (*RT*) areas were found as the most prone area to flood hazard.

Physical and social vulnerabilities were examined and mapped. Four common structural types of household buildings from nine structural types of household buildings were found in study area. The relationships between flood depth and damage for these structural types were plotted into vulnerability curve. The most vulnerable building structure is the structural type with ground floor and bamboo wall. The least vulnerable building structure is the structure type with concrete and ceramic floor, concrete wall, and clay roof. Vulnerability of building contents is related to the level of income of a household. The higher the socio economic level of the head of household is, the more the value of household building contents is so that the greater the degree of loss of building contents is when facing flood. Vulnerability of outside property depends on the people preparedness and capability of facing flooding. Social vulnerability was generated with a combination of eight socio economic parameters of the household. The result indicates that only a few households have high vulnerability, most of households have moderate and low vulnerability for socio economy. That is why the people still live in the areas (flood prone areas) because their combination of social vulnerability is not so high. On the other hand, their capabilities such as social organizations and local traditions also help them to alleviate for recovery during an after flooding.

Keywords: *Kelurahan* Sewu, community, field survey, participatory geographic information system (PGIS), flood hazard, vulnerability assessment.

Acknowledgements

Alhamdulillahhi robbil 'alamin, praise belongs to Allah, the Lord of the Worlds Who in every century inspires. Nothing I can do without His Will, Guidance, and Permission.

I would like to express my gratitude to the Bappenas and The Netherlands Education Centre, for sponsoring me to pursue education in Gadjah Mada University (GMU) and ITC. I am grateful to my employer, Forestry Department for allowing to me to continue my study. Special thanks goes to Ir. Sugiharto, MM, Ir. Niam Zaini, M.Hum, Toni Rianto, S.Hut, MSc, Imam Safari, S.Hut and my officemates, for their support during my study.

My sincere thanks go to my supervisors, Dr. rer.nat. Muh Aris Marfai, S.Si., M.Sc and Drs Nannete C. Kingma for their support, patience and invaluable assistance during proposal writing, conducting fieldwork, and finishing my thesis. Special thanks for Dr. David Rossiter and Drs Michiel Damen who gave valuable idea and discussion during the fieldwork and the midterm. My grateful also goes to Dr.rer.nat. Junun Sartohardi, M.Sc and Nugroho Christanto, M.Sc for their ideas and discussion.

I especially thanks to my fieldwork team, Fetty Febrianti and Cecile De Millano, for accompanying me during my fieldwork in *Kelurahan* Sewu. I thank to my classmates Bona, Emba, Wahyu, Tandang, Komang, Eka, Dewi, Ganda, Diah, Toto, Sigit, Nina, Jaswadi, and Andi, who support, discussion and being such a good friend for me in Yogyakarta and Enscede.

My heartfelt thanks to my mother, my wife, my children, my brothers and sisters for yours love, pray and being there for me during my difficult time.

Yogyakarta, February 2010

Muhammad Zein

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Abbreviations

ADPC	Asian Disaster Preparedness Centre
Arisan	The activities of community to collect money to support the community
Bappeda	*Badan Perencanaan dan Pembangunan Daerah* Development and Planning Board
BPS	*Badan Pusat Statistik* Central Bureau of Statistics
Bakosurtanal	*Badan Koordinasi Survey dan Pemetaan Natsional* National Coordinating Agency for Surveys and Mapping
BBWS Bengawan Solo	*Balai Besar Wilayah Sungai Bengawan Solo* The Main Bureau of Bengawan Solo River
DEM	Digital Elevation Model
DPU	*Dinas Pekerjaan Umum* Public Work Office
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GPS	Global Positioning System
ILWIS	Integrated Land and Water Information System (software)
Karang Taruna	The youth organization
Kelurahan	Village
Kerja bhakti /Gotong Royong	Working together in the community to help each other
Kesbangpollinmas	*Badan Kesatuan Bangsa, Politik dan Perlindungan Masyarakat* Nation Unity, Politic and Community Protection Agency
NGO	Non Government Organization
PGIS	Participatory Geographic Information System
PKK	*Pembinaan Kesejahteraan Keluarga* Family Welfare Assistance
RBI	*Rupa Bumi Indonesia* Topographic Map of Indonesia
Ronda	The activities of community to patrol area neighborhood
Rp	Rupiah (Indonesia's currency)
RT	*Rukun Tetangga* sub area of *RW*
RW	*Rukun Warga* sub area of village
SPSS	Statistical Product and Service Solution (software)
UNCHS	United Nations Center for Human Settlements
UNDRO	United Nations Disaster Relief Organization
UN-ISDR	United Nations International Strategy for Disaster Reduction
UNS	Sebelas Maret University, Surakarta

1. Introduction

This chapter describes the general overview of the research, consisting of the background of the research, the research problems, the research objectives, the research questions, the benefit of research, the limitation of research, and the thesis structure. This chapter also describes the literatures used in this research. It started with the definition of flood hazard, vulnerability and participatory GIS.

1.1. Background

Indonesia is suffering from flood hazard. The flood hazard event occured frequently during the rainy season. Flood caused property damages and loss of life. The loss attained to quintillion of rupiah such as houses, livestock, yards, public facilities etc.

Some parts of Java Island were struck by flood and landslide on Wednesday, 26 December 2007. The incident was caused by heavy rainfall in that area. In Central Java Province, eleven districts and cities were struck due to this event. There were Karanganyar, Cilacap, Wonogiri, Sukoharjo, Sragen, Tegal, and Surakarta City. Spatial distribution of the 26 December 2007 event is shown in Figure 1-1. Based on Habitat for Humanitarian International Report (http://ochaonline.un.org), flood swept through four sub-districts (Jebres, Pasar Kliwon, Laweyan and Serengan) in Surakarta City, forcing more over 11,000 houses inundated.

The Surakarta City is located in Central Java. Geographically, the City is located between hills and mountains and it is considered as the natural intermountain basin, where the area is prone to flooding. Since the last 50 years, the big flood event, which occurred on 16 March 1966, was considered as the largest flood disaster. The flood which occurred after continuous rain in several days has caused about 13,000 people homeless (Daily Armed Forces, 1 May 1966 in Cahyono, 2008). Floods also caused damage to the agricultural land. This condition addresses a need of a reservoir to control water from the upper part of Surakarta. In the early 1970s, a reservoir was realized in the upper part of Surakarta, in Wonogiri District, called Gajah Mungkur reservoir.

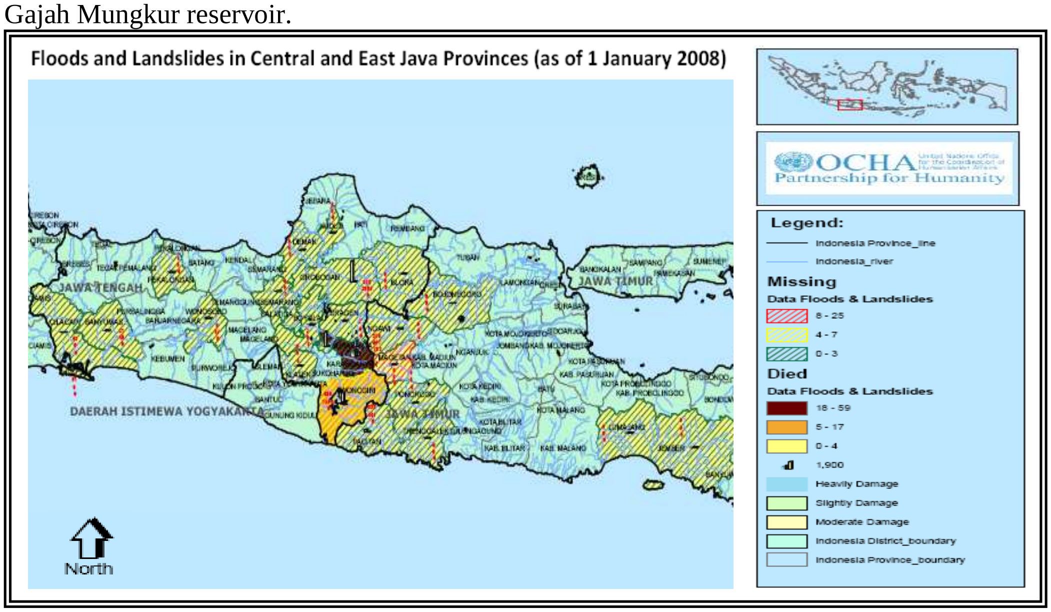


Figure 1-1. Floods and Landslide in Central Java and East Java Provinces
Source: http://ochaonline.un.org/MapCentre/ThematicMaps/tabid/3316/language/ fr-FR/Default.aspx

Several large flood events have been recorded; among them are a flood in Bengawan Solo 1863, a flood in Ngawi in1887, a flood in Surakarta in 1966, and in 1968 in Lamongan. The physical characters characteristics, such as geography, topography and river flow geometry, have an impact on the hazard susceptibility in Surakarta.

The population has in Surakarta City dramatically increased since last 5 years. In 2000 the population of city was about 550,251 people and in the year of 2005 the population was about 560,046 (Bappeda, 2008). Part of the population is located in flood prone areas. These areas usually lack governmental supervision in terms of the building permits and land use changes and as a result the rapid development of the settlement has increased the vulnerability and risk of the people and area.

Strengthening and raising public awareness of disaster-prone areas is necessary in order to reduce the vulnerability and risk. Community participation should be at the heart of natural disaster mitigation policy and practice. The community should be involved in the flood assessment because community members have experience to assess flood duration, depth and damage. Their knowledge is very important to improve preparedness and mitigation to reduce impact due to flood hazard.

The research is focused on a local scale, and is based on community knowledge of, flood hazard, identify the element at risk, and assess the vulnerability of each of the element at risk in flood prone areas of Surakarta City.

1.2. Research Problem

Usually flood hazard mapping and vulnerability assessment have been conducted by expert judgment. The community is rarely involved in the hazard mapping and vulnerability assessment. However, the best flood hazard mapping and vulnerability assessment must be based on the combination between expert judgment and community participation.
Mapping of flood and assessing vulnerability at micro level based on community knowledge have not been done yet in the study area. For that reason, this research intends to evaluate community characteristics related to flood hazard, to map the flood danger, identify the elements at risk, and assess the vulnerability of each of the elements at risk.

1.3. Research Objectives

The objective of this study is to evaluate the community characteristics, to map the flood danger, to assess elements at risk and vulnerability of flood, based on community approach.
More specific objectives are;

1. To evaluate the community characteristics for social vulnerability of floods.
2. To create a flood danger map based on the 2007 flood event which includes community knowledge.
3. To identify and classify the elements at risk, i.e. type of buildings, building contents, outside property, and socio economic people.
4. To assess the vulnerability related to elements at risk (structural type of buildings, building contents, outside property and socio-economy of people).

1.4. Research Questions

Research question has been formulated and it is shown in Table 1-1.

Table 1-1. Research questions and research objectives

No	Objectives	Research Questions
1	To evaluate the community characteristics for social vulnerability of floods.	What are the community characteristics in study area?
2	To create a flood danger map based on the 2007 flood event which includes community knowledge.	Where is the flood hazardous area?
3	To identify and classify the elements at risk, i.e. type of buildings, building contents and outside property and, socio economy of people.	What are the structural types of household building in study area? What are the building contents and Outside property in study area? What are socio economies of people at risk in study area? How is the spatial distribution of the elements at risk in study area?
4	To assess the vulnerability related to key elements at risk (structural type of buildings, building contents, outside property and socio-economy of people)	What is the physical and social vulnerability to flood in study area? What are the relationships between flood depth and damage in order to assess vulnerability for building structure and building contents? How is the spatial distribution of the physical and social vulnerability to flood in study area?

1.5. Benefit of the research

The research may give benefit for several purposes which relate to flood disaster management in local area as given below:

1. It provides necessary information related to community characteristics in relation to flood hazard in flood prone areas.
2. It represents the flood danger map based on the 2007 flood event which includes community knowledge.
3. It represents the elements at risk in relation to flood hazard in flood prone areas.
4. It provides information related to vulnerability as an important aspect for the local government in order to generate the policy and program for disaster mitigation.

1.6. Limitations of the research

In this research, the elements at risk are focused on physical aspects of household buildings including building structure, building contents, and outside property as well as the socio economy aspects of the people in study area.

Information and data related to flood extent and flood duration are obtained based on local community knowledge. The other factors, such as morphological and hydrological aspects, are not taken into consideration.

Because most of the respondents could no longer give any specific details related flood-depth and flood duration about the other flood events and they did not experience with the flood events, especially the flooding in 1966, this research only focused on the 2007 flood event which was the last greatest flooding that the respondents remember.

1.7. Thesis Structure

This research focused on four main activities. There are identifying the community characteristics, creating a flood danger map which are based on community knowledge, recognition of elements at risk based on data from fieldwork, and vulnerability assessment for elements at risk analyzed from social and physical point of view (see Figure 1-2).

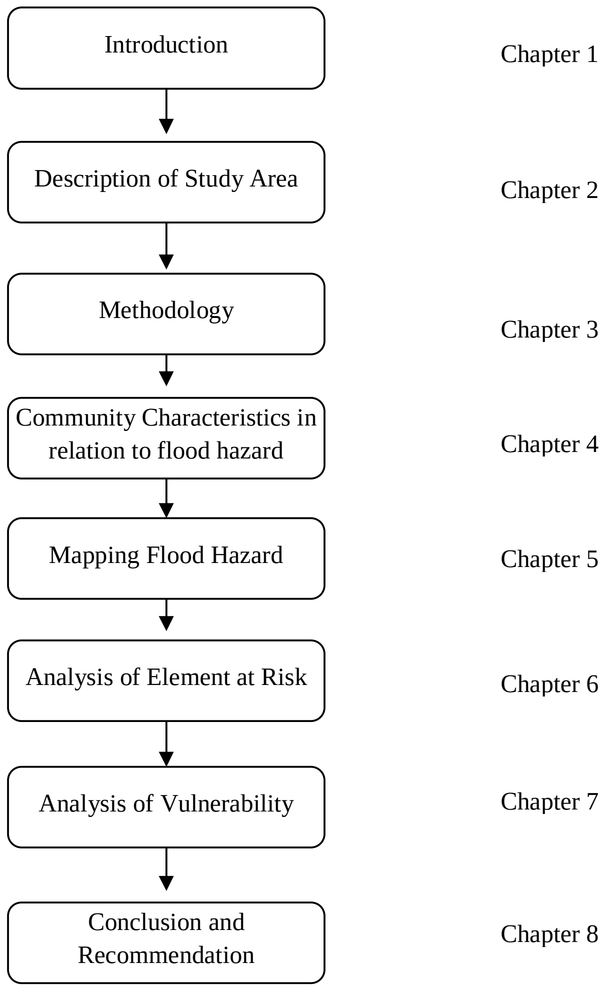


Figure 1-2. Outline of the research

The structure of this thesis consists of eight chapters as follows:

Chapter 1 – Introduction
This section will include the background of the research, the research problems, the research questions, the research objectives, the benefit of the research, the limitation of the research, and the thesis structure. Chapter 1 also describes the literatures used in this research. It started with the definition of flood hazard, vulnerability and participatory GIS.

Chapter 2 – Case Study Area: ***Kelurahan*** **Sewu, Surakarta**
This chapter describes the characteristic of the study area focused on the demographic and physical aspect.

Chapter 3 –Research Methodology
This chapter highlights the research methodology which divides into three stages: pre-fieldwork, fieldwork and post-fieldwork.

Chapter 4 – Community Characteristic in *Kelurahan* Sewu

This chapter describes about community characteristics that have relation to flood hazard for social vulnerability.

Chapter 5 – Mapping Flood Hazard in *Kelurahan* Sewu
This chapter discusses about flood hazard including flood depth and flood duration based on the community knowledge.

Chapter 6 – Analysis of Element at Risk in *Kelurahan* Sewu
This section presents the elements at risk including physical household building and socio-economy of people in study area.

Chapter 7 – Analysis of Vulnerability Assessment to flooding
This chapter explains both physical and social vulnerability considered with building structure, building contents, outside properties and the characteristic of the people at risk.

Chapter 8 – Conclusion and Recommendation
This chapter provides the conclusion and recommendations of this research.

1.8. Literature Review

1.8.1. Flood hazard

There are many different definitions of hazard. Blaikie et al. (1994) defines hazard as "the extreme natural events which may affect different places single or in combination at different times over a varying return period". On the other hand, according to Asian Disaster Preparedness Center (ADPC) (cited from Kafle and Murshed, 2006), "hazard is an event or occurrence that has a potential for causing injuries to life and damaging property and the environment". In order to know the important thing in definition of hazard, UN-ISDR (2004) in Alkema et al. (2009) proposes four elements which are a probability, a specific period of time, a specific area, and the intensity. Hazards related to geological and geo-morphological processes, such as earthquake, volcanic, eruptions, landslide and floods, are called geo-hazard. Rossi et al. (1994) define floods as extremely high flows of river, whereby water inundates flood plains or low laying area. Flood hazard can be measured by probability occurrence of their damaging values, conceived generally as flood risk, or by their impact on society, conceives usually as the loss of lives and material damage to society.

B.Merz et al. (2007) explain a flood hazard map as a map that shows the inundation area for a scenario with a certain return period in single or several flood scenarios. The maps illustrate the intensity of flood situations and their associated the exceedance probability. Whereas, the maps without the exceedance probability called flood danger maps which is illustrated historic or synthetic flood events.

Flood is called a natural disaster, when they occur in area occupied by human. The disaster can involve the loss of human life and property plus serious disruption to the ongoing activities of large urban and rural communities.

Based on floods occurrence, FEMA (Federal Emergency Management Agency) (1997) divided floods in six major classes. They are riverine flooding, alluvial fan floods, ice jam floods, dam break floods, local drainage and high ground water level and fluctuating lake level.

Most of floods in Indonesia belong to the riverine floods which occur in low-land floodplains. The floods are caused by high intensity and duration of rainfall making a body of water rise in the river so that overtop natural or artificial banks of a river.

1.8.2. Vulnerability

The widening of the concept vulnerability was described by Birkmann (2006), starting from definition only related to physical vulnerability until more complex definitions which are influenced by physical, economic, social and environmental factors. The conceptual difference of vulnerability arises from different point of view from many disciplines, such as civil engineering, geography, social science (Birkmann, 2006; Sagala, 2006; Marschiavelli, 2008).

Blaikie et al. (1994) define vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard, which includes a combination of factors. These factors determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or society.

Asian Disaster Preparedness Center (ADPC) (cited from Kafle and Murshed, 2006) stated vulnerability as a condition or sets of conditions that reduces people's ability to prepare for, withstand or respond to a hazard.

Pelling (2003) has introduced vulnerability as the exposure to risk and the inability to avoid or absorb potential harm. Three components of vulnerability according to Pelling are physical vulnerability as the vulnerability of the physical environment, social vulnerability as experienced by people and their social, economic, and political systems and human vulnerability as the combination of physical and social vulnerability.

According to UNDRO (1991) in Sagala (2006) vulnerability can be defined as the degree of loss of a given element at risk or a set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).

Kingma and Westen (2009) stated vulnerability in four types:

1. Physical vulnerability, the potential impact for physical environment or infrastructure of population.
2. Economic vulnerability, the potential impact of hazard on economic assets and processes.
3. Social vulnerability, the potential impacts of event groups.
4. Environmental vulnerability, the potential impacts of events on the environment.

Different types of losses can be analyzed using direct losses or indirect losses. The type of losses can be in term of human-social, physical, economic and cultural/environmental (see Table 1-2) The most frequently evaluated in the disaster study are fatalities, injuries, structural damage or collapse to buildings, and non-structural damage to contents (Kingma and Westen, 2009).

Table 1-2. Overview of types of losses

	Human-Social	Physical	Economic	Cultural Environmental
Direct losses	• Fatalities • Injuries • Loss of income or employment • Homelessness	• Structural damage or collapse to buildings • Non- structural damage and damage contents • Structural damage infrastructure	• Interruption of business due to damage to buildings and infrastructure • Loss of productive workforce through fatalities, injuries and relief efforts • Capital costs of response and relief	• Sedimentation • Pollution • Endangered species • Destruction of ecological zones • Destruction of cultural heritage
Indirect losses	• Diseases • Permanent disability • Psychological impact • Loss of social cohesion due to disruption of community • Political unrest	• Progressive deterioration of damaged buildings and infrastructure which are not repaired	• Economic losses due to short term disruption of activities • Long term economic losses • Insurance losses weaken-ing the insurance market • Less investment • Capital costs of repair • Reduction in tourism	• Loss of biodiversity • Loss of cultural diversity

Source: Kingma and Westen (2009)

In order to assess the vulnerability, several tools have been developed. Polsky (2007) divided eight steps approach to assess the vulnerability:

1. Define the study area together with stakeholders.
2. Get to know the place over time.
3. Hypothesize who is vulnerable to what.
4. Develop a casual model of vulnerability.
5. Find indicators for the elements of vulnerability.
6. Operationalize models of vulnerability.
7. Project future vulnerability.
8. Communicate vulnerability creatively.

1.8.3. Participatory GIS (Geographic Information System)

Working with small scale communities is very important to understand the vulnerability of a certain area. Local community provides necessary information and knowledge related to causes, effects, and the way to cope with the hazard. Socio-economic characteristics of community are the key factor influencing the mitigation action for flood hazard (Marfai et al., 2008).

According to Westen et al. (2009) local knowledge can provide some information including:

- Historical disaster events and the damages they have caused.
- Elements at risk and how they value them.
- The factors contributing to vulnerability.
- The coping strategies and capacities to face up to disasters.

Several tools were developed to assemble the information. They are Capacity and Vulnerability Assessment (CVA), Hazard, Vulnerability and Capacity Assessment (HVCA), and Damage, Needs and Capacity Assessment (DNCA).

2. Case Study Area: *Kelurahan* Sewu, Surakarta

This chapter explains about the general overview of the study area focused on the demographic and physical aspect.

2.1. General Information of Surakarta

Surakarta City is the center of politics, economy and culture in the Eastern part of Central Java Province. The popular name of the city is "Solo". Surakarta City is located about 65 km Northeast of Yogyakarta, and 100 km Southeast of Semarang. Bengawan Solo River borders the town in the Eastern part. This river is the longest river in Java Island. It flows through the Surakarta City to the Java Sea.

The geographic region of Surakarta is located between 110 º 45' 15"- 110 º 45' 35" E and 7 º 35' 00"- 7º 56' 00" S or in UTM 474412-485510 mE and 9168438-9160402 mN within the area of 44.04 km² (see Figure 2-1) with the boundaries as following

- North boundary : Boyolali Regency and Karanganyar Regency
- South boundary : Sukoharjo Regency
- East boundary : Karanganyar Regency and Sukoharjo Regency
- West boundary : Karanganyar Regency and Sukoharjo Regency

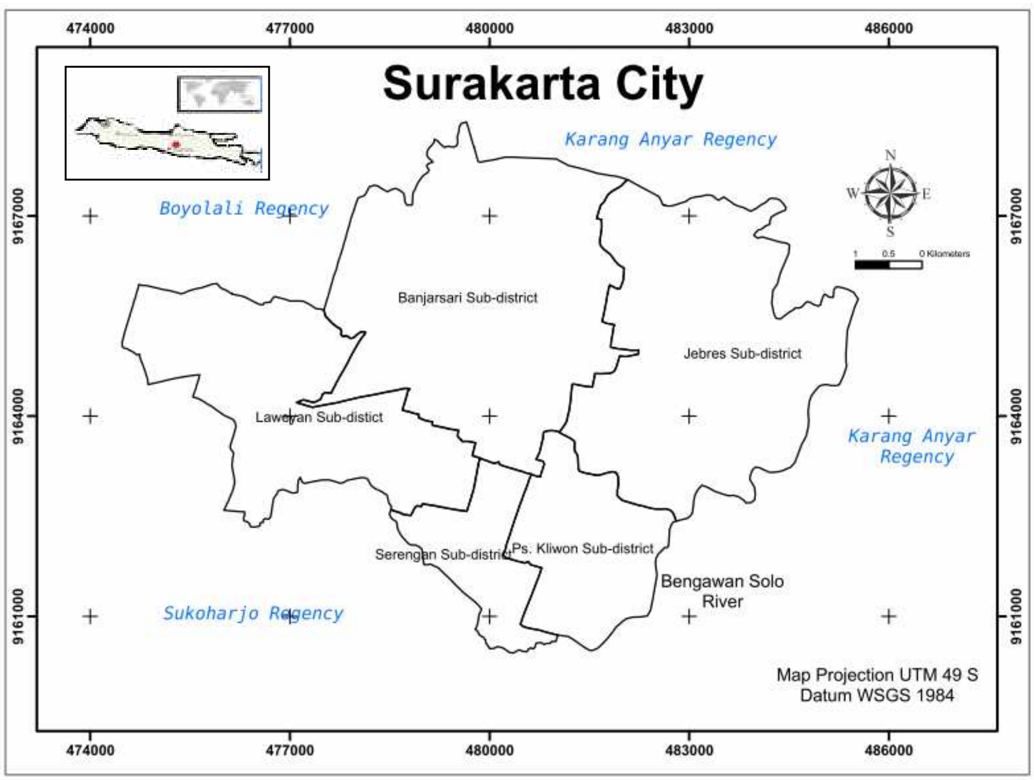


Figure 2-1. Surakarta City Map

Administratively, Surakarta is located in Central Java Province. The City is divided into 5 sub-districts, and 51 villages. The number of *RW* (sub area of village) was 595 and 2.669 *RT* (sub area of *RW*). Figure 2-2 shows the administrative ladder of Central Java Province.

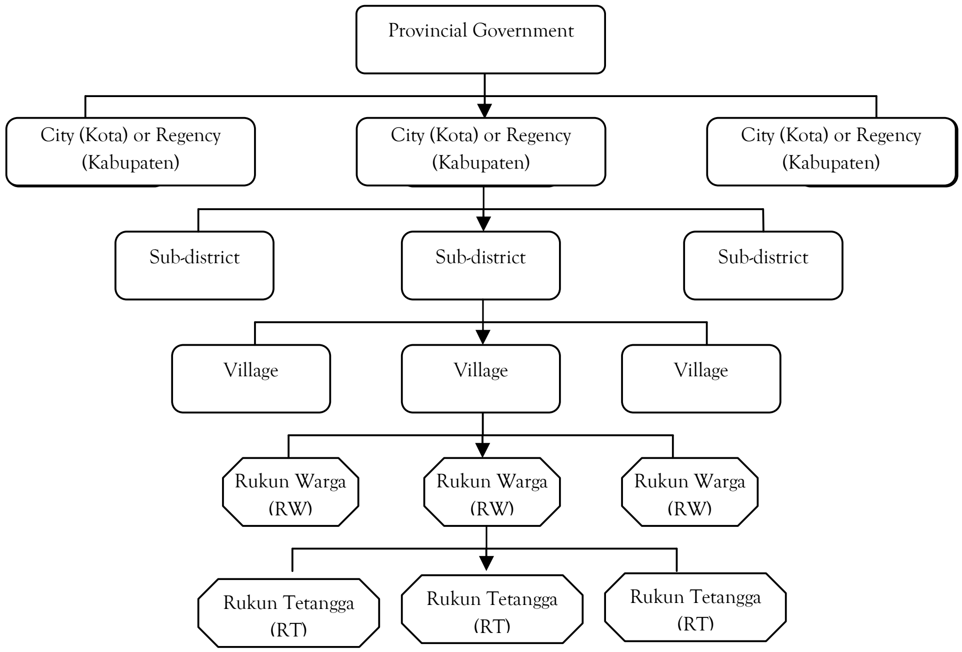


Figure 2-2. Administrative ladder of Central Java Province

Since the 15th century, the city has been expanding from its central palace. This city is considered as the most crowded city in the Province. Surakarta City consists of 5 sub-districts in which the overall number of population was about 564,000 inhabitants with population density 12.827 persons per square kilometers. Table 2-1 reveals the population of the Surakarta City. Bappeda (2008) stated an average population growth rate of Surakarta is about 0,354% per year.

Table 2-1. Population of Surakarta City

No	Sub-District	Area (km^2)	Inhabitant	
			Number	Density
1	Laweyan	8.64	109,447	12,667
2	Serengan	3.19	63,429	19,884
3	Pasar Kliwon	4.82	87,508	18,155
4	Jebres	12.58	143,289	111,390
5	Banjarsari	14.81	161,247	10,888
	Total	44.04	564,920	12,827

Source: BPS (2008)

Man power is the most important thing for the development dynamics. The total number of working population in Surakarta based on BPS (2008) was 401,411 people or 71.06 % of total population of Surakarta. Most of them work as workers of constructor (63,114 people) and Industry workers (74,655 people). The other workers work as farmers, farm workers, entrepreneur, retailer, transporter, and civil servant/police.

Statistic data from BPS (2008) showed that almost all of total area of Surakarta occupied by building consisted of housing (62%), services (10%), establishment (7%), and manufacture (2%). The rest is covered by bare land (1%), dry land (2%), wet land (3%), cemetery (2%), and city park (1%) (see Figure 2-3).

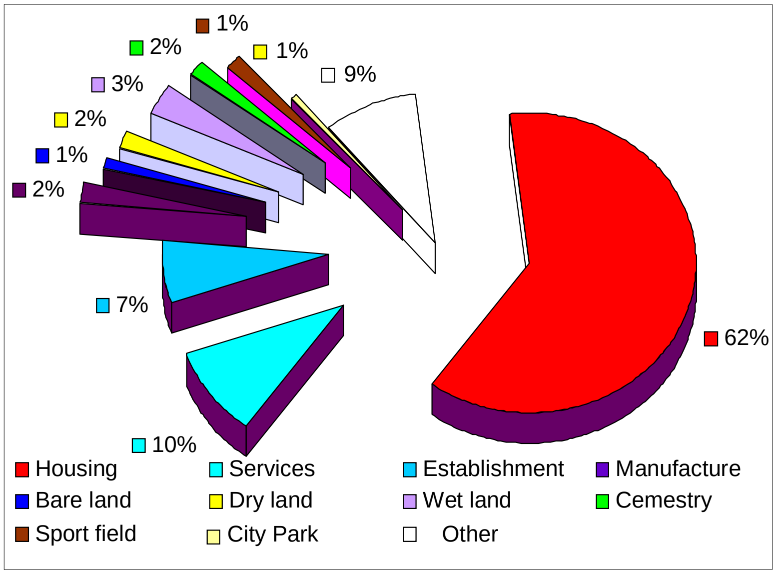


Figure 2-3. Percentage of Land utilization in Surakarta City
Source**:** BPS (2008)

In general, Surakarta City is a lowland area and it is located in intermountain basin between Lawu Mountain in the eastern part and the Merapi and Merbabu Volcanos in the western part. It is located within the Bengawan Solo River Catchment (see Figure 2-4).

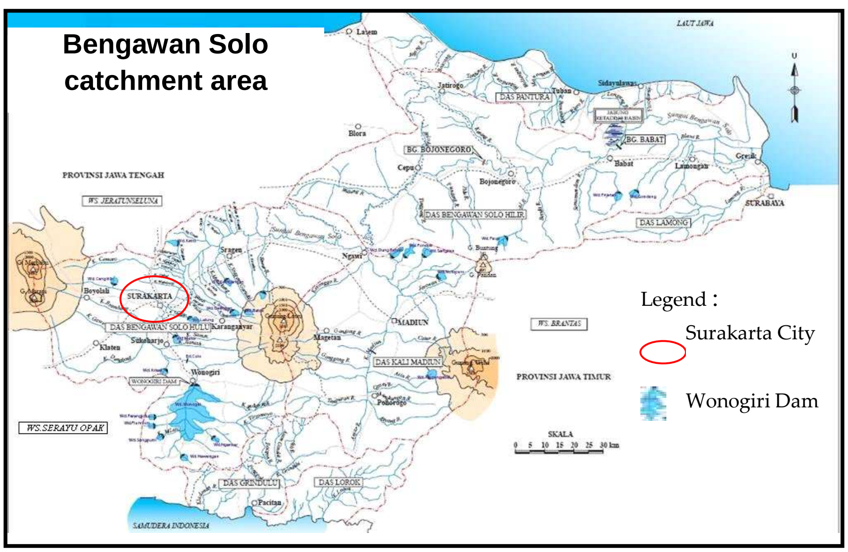


Figure 2-4. Bengawan Solo Catchment area
Source: BBWS Bengawan Solo (2009)

Based on DPU (2009), in Surakarta City, ten tributaries exist of the Bengawan Solo River. The function of these natural rivers is acting as primary channels draining rainwater runoff. They are Kali Pepe Hulu, Kali Anyar, Kali Gajah Putih, Kali Boro, Kali Pepe Hilir, Kali Jenes, Kali Pelem Wulung, Kali Brojo, Kali Tanggul and Kali Wingko, which empty into Bengawan Solo River as shown in Figure 2-5. The City has an elevation of about 80 till 130 above sea level rise and slope vary between 0 to 15%.

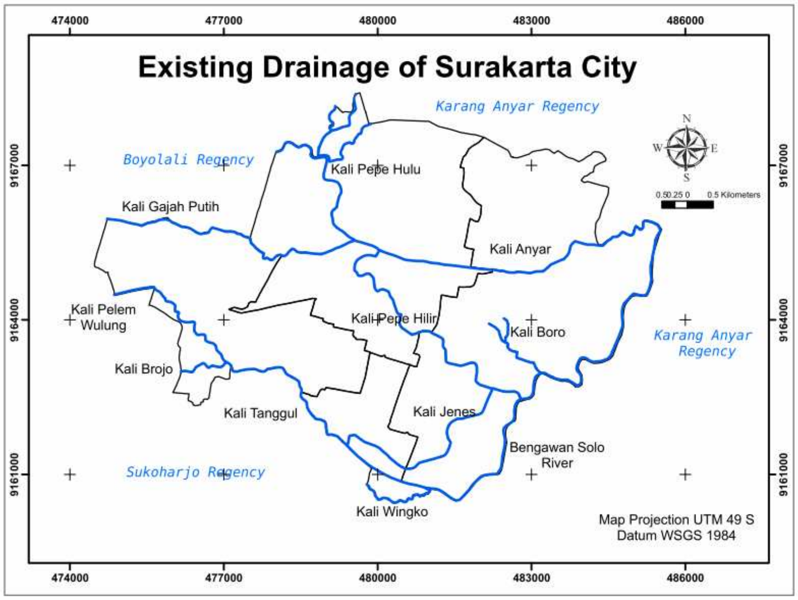


Figure 2-5. Existing Drainage of Surakarta City
Source: DPU (2009)

According to Setiyarso (2009) the climate type of Surakarta City, using Koppen Method, is tropical rain climate type Am. This climate region has characteristics that the wet months can compensate for the lack of rain in the dry months and has a temperature of the coldest month greater than 18°C. Based on Schmidt and Ferguson method, type of rainfall in Surakarta City is type D in which value Q equals to 60% up to 100%. Rainfall is varying with the lowest rainfall equal to 25.1 mm/year and the highest equal to 358.2 mm/year. The rainy season normally starts from November to April and the other months are dry season.

2.2. Flood Events in Surakarta

Historical record illustrates that some enormous floods have occurred in Surakarta i.e March 1966, March 1968, March 1973, February 1974, March 1975, January 1982, February 1993, December 2007, March 2008, and February 2009. The flooding occurred in 2007 was the greatest flood after the biggest one in 1966 (see Figure 2-6).

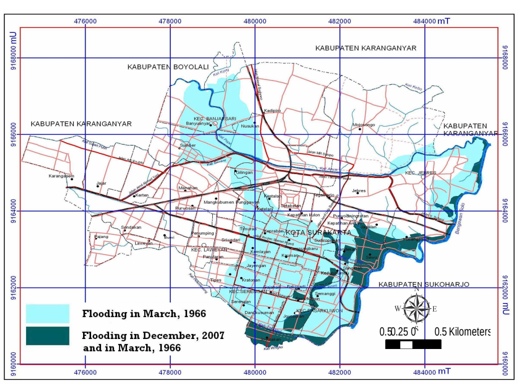


Figure 2-6. Surakarta flood area in 1966 and 2007
Source: Setiyarso (2009)

Flooding in December 2007 caused some damage and destroyed property. Based on report of the Unit Disaster Mitigation and Evacuation of Surakarta City, the damage was about Rp. 21,938,500,000 (EUR 1,534,161) including housing and public facility such as office, market, mosque/church, school, park, electricity, water facility, and industry. The water inundated approximately 6,626 buildings in 12 villages in Surakarta City shown in Table 2-2.

Table 2-2. House affected by the 2007 flood in The Villages of Surakarta City

No	Village	Outside riverbank		Riverbank	Total
		Minor Damage	Major Damage	Major Damage	
1	Pucangsawit	635	6	318	959
2	Sewu	71	2	1501	1574
3	Sangkrah	24	10	155	189
4	Semanggi	61	1	62	124
5	Joyosuran	305	0	22	327
6	Jebres	152	0	53	205
7	Gandekan	10	1	1093	1104
8	Jagalan	856	0	0	856
9	Sudiroprajan	51	0	10	61
10	Pasar Kliwon	7	0	0	7
11	Kedung Lumbu	10	0	0	10
12	Joyotakan	660	0	550	1210
	Total	**2842**	**20**	**3764**	**6626**

Source: Kesbangpollinmas (2008)

Hydro-meteorological observations during the flood in the late December 2007 revealed that the heavy rainfall was ranged in areas of Surakarta from 600 until 700 mm per month. Figure 2-7 shows the rainfall report in Pabelan station, Surakarta City.

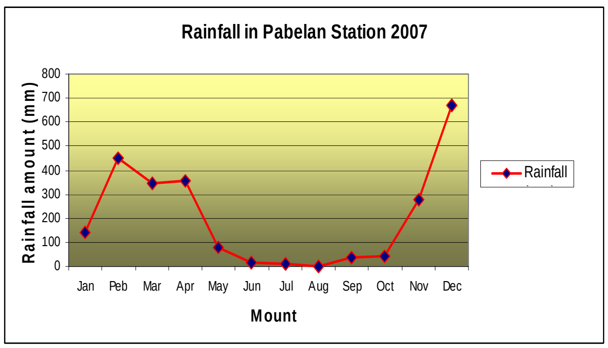


Figure 2-7. Rainfall report in Pabelan Station 2007
Pabelan Station (2007)

2.3. Characteristics of *Kelurahan* Sewu

The research is focused on the *Kelurahan* level. the *Kelurahan* Sewu, in Jebres sub-district in Surakarta, is selected for the study area. This area is located along the Bengawan Solo River (see Figure 2-8). *Kelurahan* Sewu in Surakarta City is the most frequently flooded area. It consists of 9 *Rukun Warga*, 35 *Rukun Tetangga* and 1,959 households (BPS, 2008). About 393 houses lie on riverbanks area, half of them (206 buildings) are illegal housing which is laid in state land and poor condition. Many people from the surrounding come to city to earn livelihoods without sufficient assets. They live in vacant land or along the riverbanks as squatters.

The administration boundaries of *Kelurahan* Sewu are:
North : *Kelurahan* Jagalan
East : *Kelurahan* Pucangsawit
South : Bengawan Solo River
West : *Kelurahan* Gandegan and *Kelurahan* Sangkrah

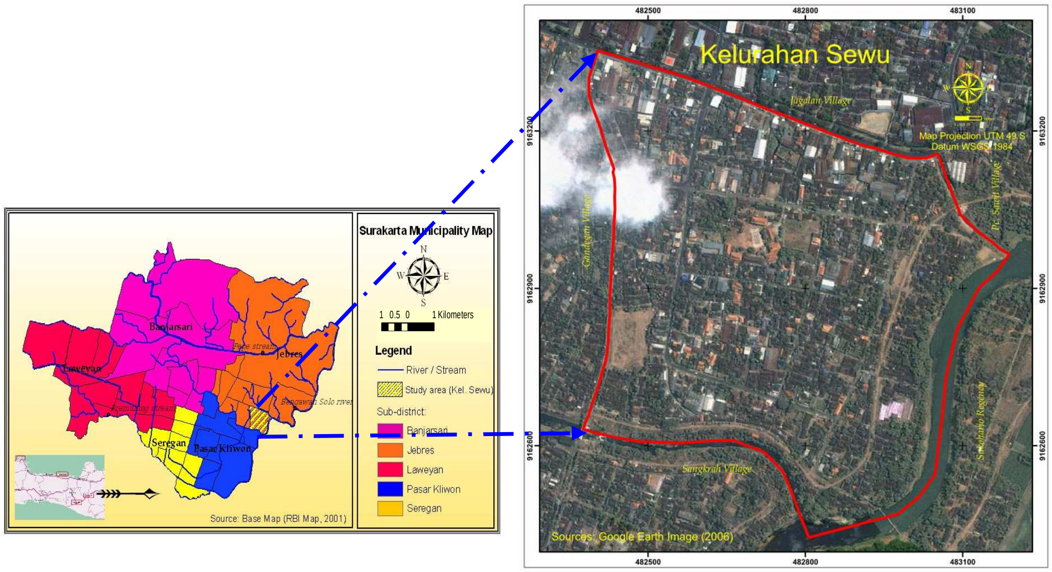
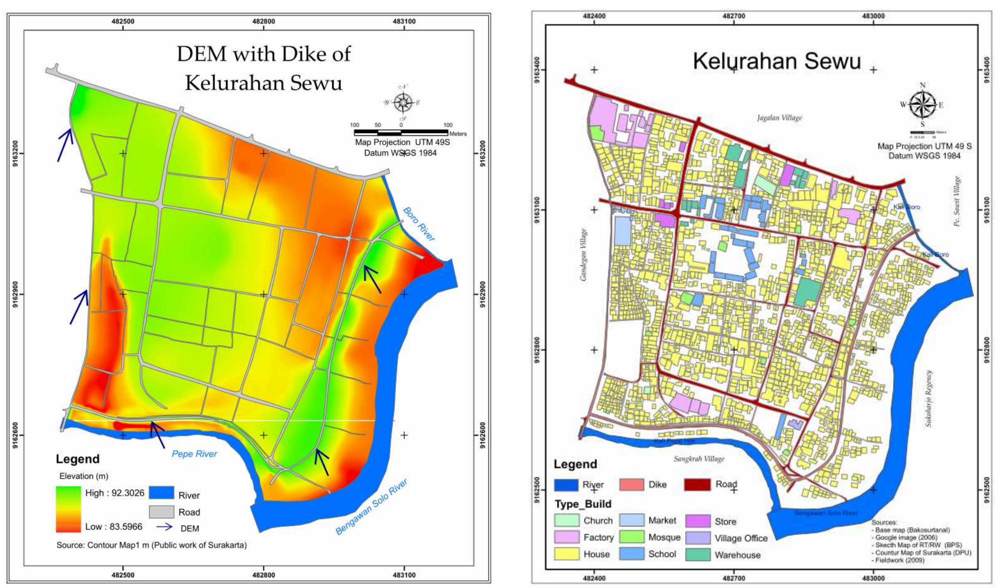


Figure 2-8. Study area

Kelurahan Sewu, with area of 0.485 km^2, has total of population approximately 8,461 inhabitants. The area consists of 4,144 men and 4,317 women (*Kelurahan* Sewu, 2009). The density of people is 17.45 per square kilometers. Geographically, *Kelurahan* Sewu is located in the eastern part of Surakarta City and most of this area is alluvial plain. The topography is relatively flat with altitude between 83 until 92 above the sea level (see Figure 2-9 a). Almost 60% land utilization of *Kelurahan* Sewu are covered by housing (29.79 ha) and the rest is covered by service (2.45 ha), enterprise (1.16 ha), industry (1.73 ha), cemetery (0.20 ha), sport field (1.00 ha), and others (12.17 ha) (see Figure 2-9 b).



(a) (b)

Figure 2-9. DEM with Dike elevation (a) and Land use of *Kelurahan* Sewu (b)

The community in the *Kelurahan* is regularly struck by flood. The largest flood inundation, which occurred on 27 December 2007, caused inundation of the entire *Kelurahan* Sewu (see Figure 2-10). The flood water ranged from 1 until 4 meter deep. From 2007 until 2009, there were 8 flooding events in *Kelurahan* Sewu (see Table 2-3).

Figure 2-10. Flooding on 27 December 2007 in *Kelurahan* Sewu, Jebres sub-district, Surakarta
Source: http://www.slide.com/r/FxKg2kWe7j9fZmuvBTBO1xmIguGSyOBo?map=2&cy=bb

There are some mitigation measures that were undertaken in the study area against flooding. Figure 2-11 shows some important places for mitigation action related to flood hazard in the study area.

Table 2-3. Flooding event 2007 – 2009 in *Kelurahan* Sewu

No	Date	Inundated (household)
1	26-28 December 2007	1753
2	29 December 2007	1175
3	05 February 2008	262
4	09 March 2008	753
5	22 March 2008	224
6	31 January 2009	1242
7	17 February 2009	283
8	25 February 2009	150

Source : *Kelurahan* Sewu (2009)

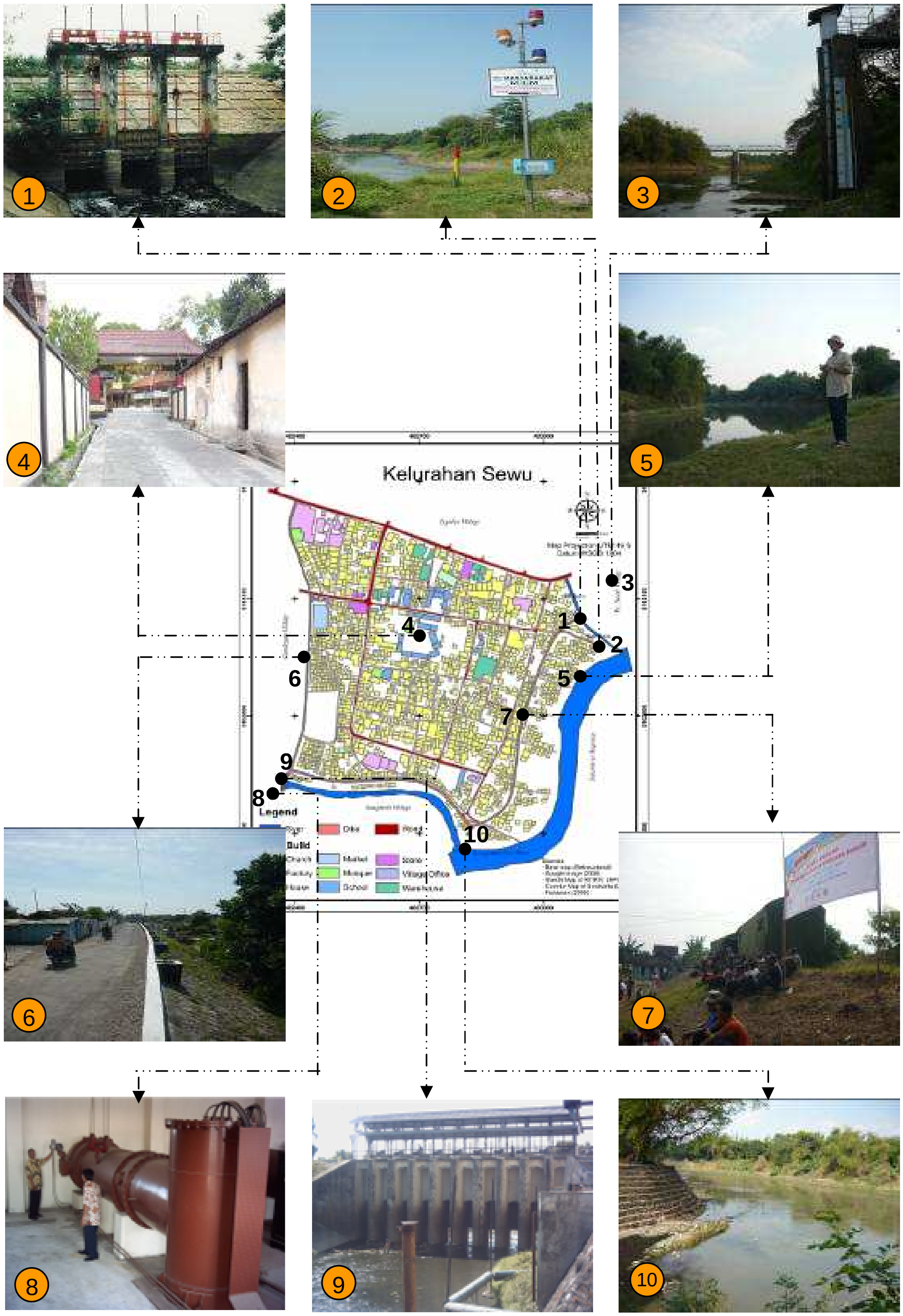


Figure 2-11. General overview of *Kelurahan* Sewu

Detail information about Figure 2-11 is described as follows:

1: Putat water gate is located at Kali Boro. This is one of the flood sources in *Kelurahan* Sewu. During the big flood in 2007, the water gate had damage. The gate could not close, when the water from Bengawan Solo River increased, they flowed through the gate to inundate the village.

2: An Early warning system is laid in *RW* III *RT* 3. This is one of the structural measures that was built after big flood 2007. It has the function to inform a critical level of water of the Bengawan Solo River in Putat area to the community when the water from the Bengawan Solo River increases. It consists of three levels of alertness. The green lamp/color is alert-I for getting ready, the yellow lamp/color is alert-II for preparedness, and the red lamp/color is alert-III for emergency.

3: Jurug Automatic Water Level Recorder (AWLR) station was established in 1969 by the Water Management Board. This station gives information about a level of water of Bengawan Solo River in Jurug. When the river levels reach the alarm point, the system automatically warns the staff who has been responsible to monitor the level of water. The alarm point consists of three levels of alertness. There are Alert-I which is river levels reaching 82.73 asl or 6.50 above river surface, Alert-II which is river levels reached 83.73 asl or 7.50 above river surface, and Alert-III which is river levels reached 84.73 asl or 8.50 above river surface (DPU Kota Surakarta, 2006).

4: Public Senior High School. During flooding in 2007, this school was used as the evacuation centre because it is located in high elevation. Besides this building, the people stayed in the mosque, dike, and church as the evacuation centre.

5: Bengawan Solo River, having length 548 km, is the longest river in Java Island. Flowing in the eastern part of *Kelurahan* Sewu, This River was flood source in 2007. During the flooding 2007, the water of Bengawan Solo River increased until 11.45 meter with debit 1,986 m^3/second whereas in the normal condition, the highest water level is 4 meter.

6: Dike I (inside) was established in 1910 by Netherland Government and Sunan Princedom. It serves as a dike to protect the city, facing directly into the shape of the river flow. When the dike was built, the eastern part of the dike was swamp, while the west was the residential solid. But now, the eastern part of the dike is the residential solid also.

7: Dike II (outside) was established in 1982 by Water Management Board. It has functioned as a dike retaining water from Bengawan Solo River so the water does not inundate the surrounding area. During the big flood of 2007, the water did not overtop this dike.

8: Demangan Pump House was established in 1910. There is a 3-pump with the capacity of 5.2 m^3/second. The pump will be actived when Demangan Water Gate is closed.

9: Demangan Water Gate is located on Kali Pepe Hilir. It was built in 1910 by Netherland Government and Surakarta Princedom. It has the function to repulse back water from Bengawan Solo River when the level of water increases. The gate will be closed when the level of back water from Bengawan Solo River is higher than the level of water from Kali Pepe Hilir.

10: River junction between Kali Pepe Hilir and Bengawan Solo River. Some parts of edge of Bengawan Solo River are laid gabion constructions to protect the land from landslide.

3. Research Methodology

This chapter introduces the methodology and the process of this research which is divided into three parts: pre-fieldwork, fieldwork, and post-fieldwork. Each stage describes in deep discussion.

This research is focused on four main activities. There are identifying the community characteristics, creating a flood danger map based on the 2007 flood event which includes community knowledge, recognition of elements at risk based on data from fieldwork, and vulnerability assessment for elements at risk analyzed from social and physical point of view. The general steps of this research is shown in Table 3-1.

Table 3-1. Research questions and methods

Sub objectives	Research questions	Methods
1	What are the community characteristics for social vulnerability of floods?	• To collect secondary data from local government • To do field observation • To interview community
2	Where is hazardous flood area?	• To apply Participatory GIS with brought the imagery, map of study area, GPS and interview household • To take point with GPS about water depth and duration of flood • To digitize the boundary • To classify the level of flood
3	What are the structural types of household building in study area?	• To perform field survey • To take point with GPS • To classify the building structure
	What are the building contents and outside property in study area?	• To perform field survey using questionnaire • To classify the building contents and outside property
	What is the socio-economy of people in study area?	• To perform field survey using questionnaire and observation • To record the socio economy of people at risk
	How is the spatial distribution of element at risk in study area?	• To plot the classified of the elements at risk spatially • To make a distribution of the elements at risk
4	What are the physical and social vulnerability to flood in study area?	• To perform field work survey using questionnaire • To classify the damage
	What are the relationships between flood depth and damage in order to assess vulnerability for building structure and building contents?	• To interview about element at risk using questionnaires about the damage • To classify the damage due to water depth • To analyze the data for each element at risk.
	How is the spatial distribution of the physical and social vulnerability to flood in study area?	• To plot the classified of the damage spatially • To classify the vulnerability • To make a vulnerability map

The research methods are represented in a conceptual framework as shown in Figure 3-1.

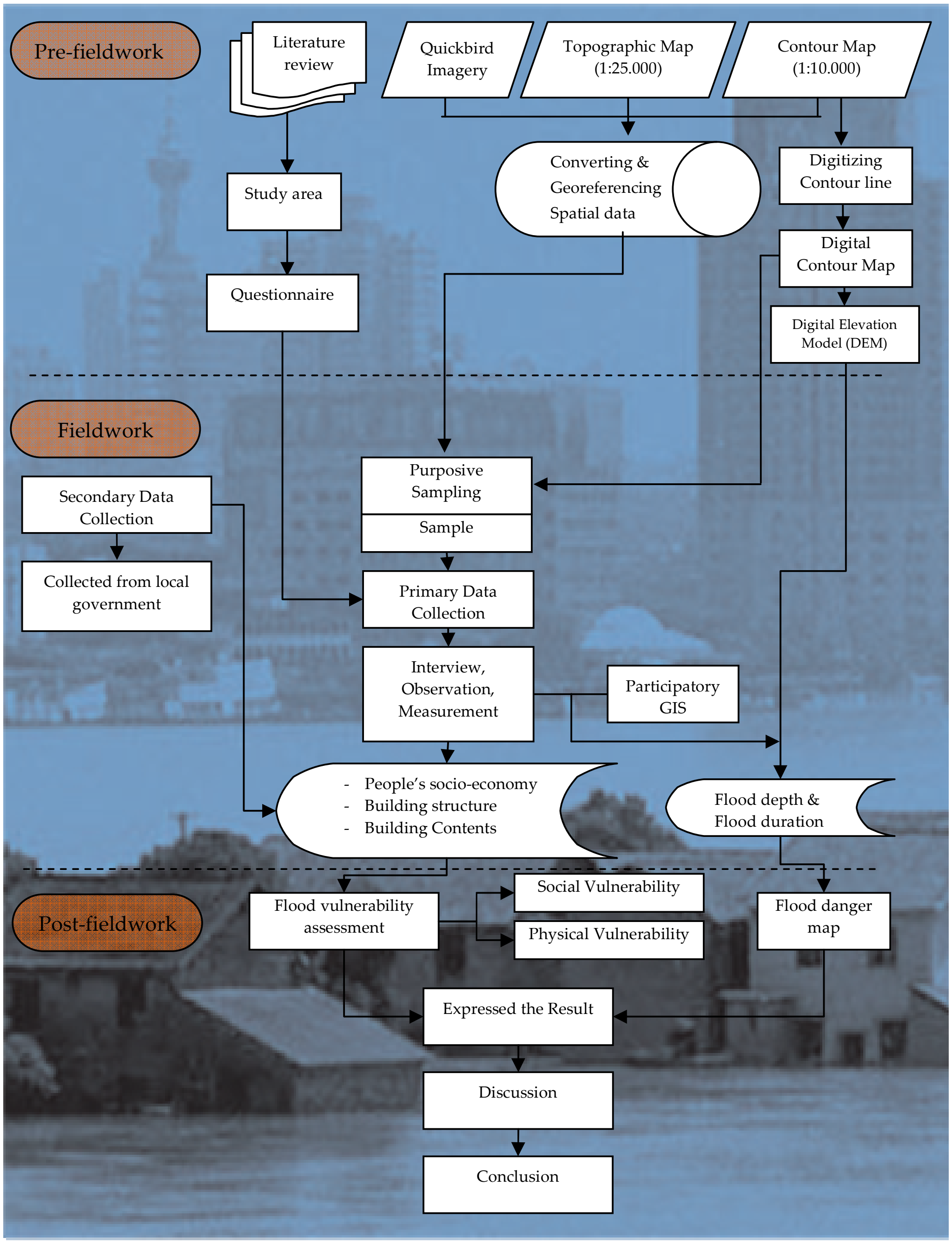


Figure 3-1. Research conceptual framework

This research consists of three stages: Pre-field work, fieldwork and post-fieldwork.

3.1. Pre-fieldwork

In the first stage, literature reviews have been collected including journals, reports, books, and previous studies that were related to information about data needs and methods. The information was used during field work and data analysis stage. The questionnaires have been generated in order to gather the primary data from the community. The study area have been selected using purposive multi stage area sampling which divides spatial extent of sampling into geographic areas (Dewi, 2007;Marfai et al., 2008). The landuse of the study area was identified from the imagery. This data was used to identify the types of buildings on the study area during the fieldwork.

3.1.1. Choosing study area

JOGLOSEMAR (Jogjakarta, Solo/Surakarta, Semarang) are the cities called The Golden Triangle in national development of Indonesia. The cities shall be developed economically by preserving its precious culture and nature, avoiding environmental damage (Dewi, 2007). Some parts of Surakarta City suffer flood every year in rainy season especially along the Bengawan Solo River. *Kelurahan* Sewu, one of the most prone areas to flood hazard in Surakarta City, was chosen a study area. In stage selection of *RW* and *RT* sampling, some criteria were taken. *RW* and *RT* were selected based on its distance from the Dike II (dike near the rivers) and their elevation. The method used and number of sample will be explained in more detail in Section Sampling Methods.

3.1.2. The Questionnaire

The questionnaires were used to interview the respondent in study area. The questionnaires are divided into four sections to collect information from local community (see Appendix 1). First section is respondent's information including a respondent's profile (age, sex, income, etc) and building information (building size, building age, administrative, owner, etc). Second section is focused on the element at risk including building structure (function, wall material, floor material, etc) and building contents as well as outside property (TV, refrigerator, sofa, table, car, motorcycle, etc). Section three is concerned with flood damages (flood source, water depth, duration, etc) while section four is about flood impact.

3.1.3. Data requirement

Spatial and non spatial data are registered in this research. Among the data are presented in Table 3-2.

Table 3-2. Required data and the data sources

No	Data requirement	Data sources
1	DEM (Digital Elevation Models)	Contour map (1:10.000) from DPU Surakarta
2	Landuse	Quickbird imagery obtained from Google Earth
3	Socio economy condition	Interview and secondary data (price of building contents, minimum wage, etc)
4	Flood source, frequency, duration and depth	Participatory GIS and interview
5	Topographic map (1:25.000)	Bakosurtanal
6	Elements at risk	Landuse map (1:5.000) and observation
7	Physical vulnerability	Fieldwork
8	Social vulnerability	Fieldwork and interview
9	Flood damage	Fieldwork and interview

The data were collected in hardcopy and softcopy from government official, community leader, previous research, NGO, etc. The digital data were processed using GIS software where the map projection is UTM (Universal Transvere Mercator) Zone 49S and the coordinate system is WGS (World Geographical System) 1984. Digital Elevation Model (DEM) was generated from contour map which was converted digitally through on screen digitizing and added the elevation of the dike. The DEM was processed using tools topo to raster in ArcGIS 9.2 software. Using Stitch Maps software, the Quickbird image of Surakarta City was copied digitally from Google Earth. This image was used to generate the landuse of *Kelurahan* Sewu. RBI (topographic map) from Bakosurtanal was used as GCP (Ground Control Point) in order to make georeference the image. A building footprint map was made by digitizing on screen the buildings in ArcGIS. However, when it was compared in the field during the ground check, the building footprint data were not accurate. There were missing buildings and had new buildings. Therefore, adding and omitting action should be done according to ground check. Most of data for analysis was collected through fieldwork. The Quickbird image, the base map, and the building footprint map have been used in the fieldwork, especially for the Participatory GIS.

3.2. Fieldwork

The second stage is fieldwork. Inventorying and measuring the elements at risk (physical and building contents, outside property as well as people's social-economic aspect), flood depth and duration, as well as estimation of the damage have been done in this stage. In order to do so, based on the landuse data from the imagery, the researcher inventoried building within *RT* sample in study area with the aim of determining sample. The *RT* sample is stratified based on the elevation and its distance to the river dike. The field survey was carried out from August until September 2009 in *Kelurahan* Sewu. Two main activities of fieldwork were done both primary data collection and secondary data collection. Primary data were performed using interview both households and key persons in *Kelurahan* Sewu like government official, community leader, NGO, etc. The data were gathered through the application of questionnaire that provided information about flooding and damage in *Kelurahan* Sewu. Secondary data were collected through gathering report and additional information from local government (Bappeda, Kesbangpollinmas, DPU), NGO (Speckham, Lestari, Idea), and Institutions (UNS, Balai Besar Wilayah Sungai Bengawan Solo, BPS).

3.2.1. Sampling Method

Purposive sampling method was used to select respondents in the study area. Figure 3-2 describes the sampling method. A hundred and four respondents were chosen and distributed proportionally by considering the geographic location of the area.

Several steps were taken to determine the sample using a purposive sampling method, in order to get representative sample points:

- The first step was establishing maps. Several thematic maps were built using ArcGIS software. There are Building footprint map, Contour map, and Administrative map. Building footprint map was generated from Quickbird image 2006. The contour map was digitized from a contour map which was gathered from Public Work Office of Surakarta and scanned. An administrative map, especially *RW* and *RT* boundary, was built based on the sketch map of *RT* boundaries collected from Badan Pusat Statistik (Central Bureau of Statistics).

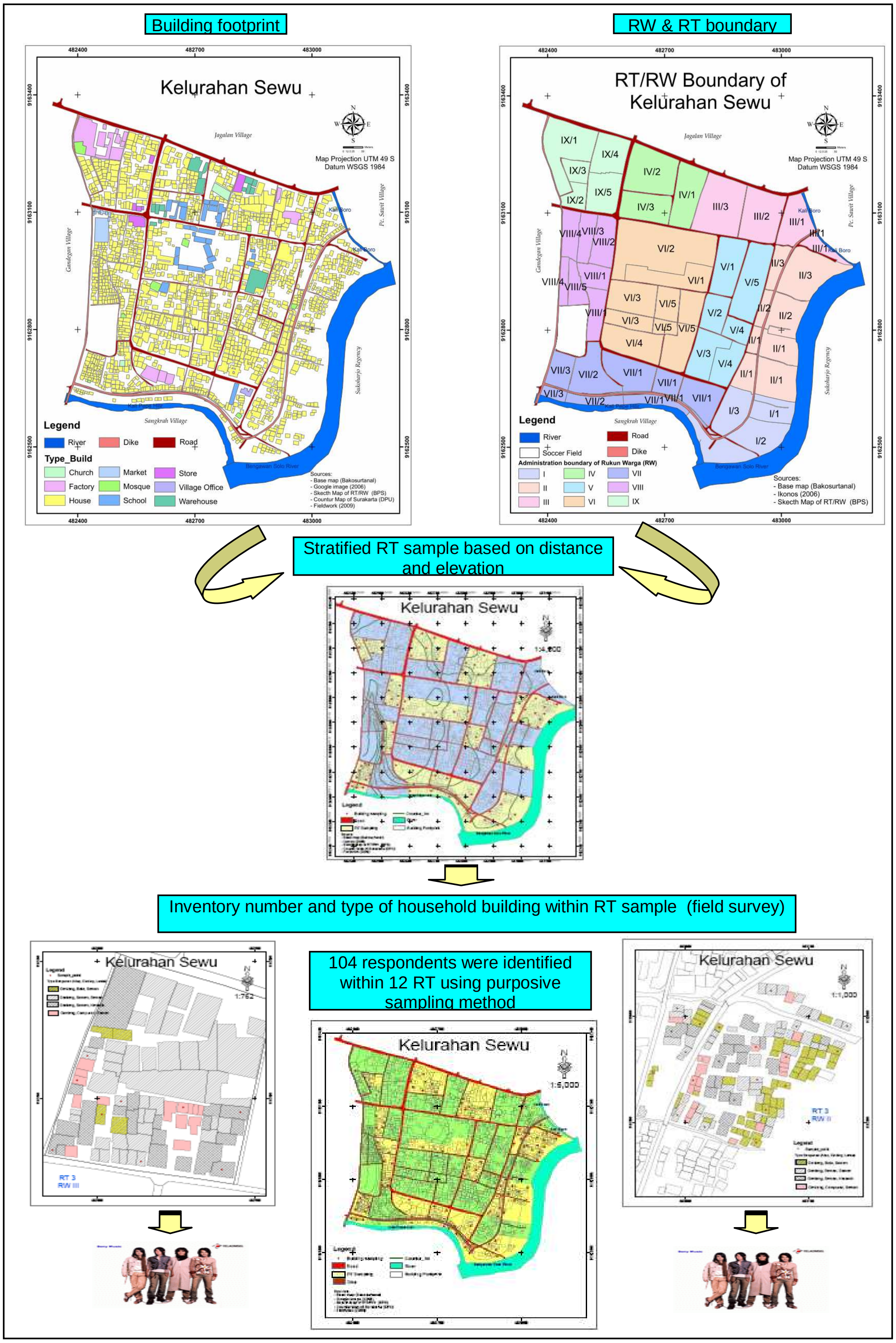


Figure 3-2. Sampling method illustration

- The second step was cross checking the maps in the field. The omitting and adding action were done to get an up-to date building footprint map as well as to change *RT* boundary based on the field. A GPS (Global Position System) was used to get accurate and detail information of buildings and boundaries.
- The third step was choosing *RT* sample. Based on information from government official, NGO and Flood map 2007 (see Figure 2-6); the 2007 flood inundated almost all the area of *Kelurahan* Sewu which consists of 9 *Rukun Warga(RW)* which is divided into 35 *Rukun Tetangga (RT)*. In order to get a representative sample, twelve *RT* samples were selected based on their distance from the Dike II (the dike near the rivers) and their elevations shown in Appendix 2.
- The fourth step was identifying the number and type of household buildings within *RT* sample. Building sample points were selected based on the spread of type of household building. In order to know how much samples will be taken, the number and type of household buildings must be identified in the field. 710 household buildings and 9 types of building were identified. The structural types of household building were defined by considering types of floor, wall, and roof material as follows:
  - ~ Structural type 1 (ground, bamboo, asbestos),
  - ~ Structural type 2 (concrete, concrete, zinc),
  - ~ Structural type 3 (concrete, mixed, zinc),
  - ~ Structural type 4 (concrete, brick, clay),
  - ~ Structural type 5 (concrete, concrete, clay),
  - ~ Structural type 6 (ceramic, concrete, clay),
  - ~ Structural type 7 (concrete, mixed, clay),
  - ~ Structural type 8 (concrete, wood, clay), and
  - ~ Structural type 9 (ground, bamboo, clay).
- The last was taking sample 15% of the sum total of household buildings within *RT* sample based on the types of building using purposive sampling method. 104 household buildings were selected as the household respondents (see Appendix 2). Figure 3-3 describes sample distribution of household building in each *RT*.

3.2.2. Fieldwork equipments

Several equipments were used to collect primary data. They are GPS (Trimble Geo XT), digital camera, MP4 recorder and tape measurement (see Figure 3-4). Trimble Geo XT GPS was used in this research for collecting information about geographic information of household building and some important places and correcting position of building footprint map based on the field. The geo-reference on GPS was set to UTM (Universal Transvere Mercator) Zone 49S and the coordinate system is WGS (World Geographical System) 1984. Digital camera was used to capture each household building and interview. MP4 recorder was employed to record information during interview. Tape measurement was applied to collect information about foundation height of household building and the flood mark in the field.

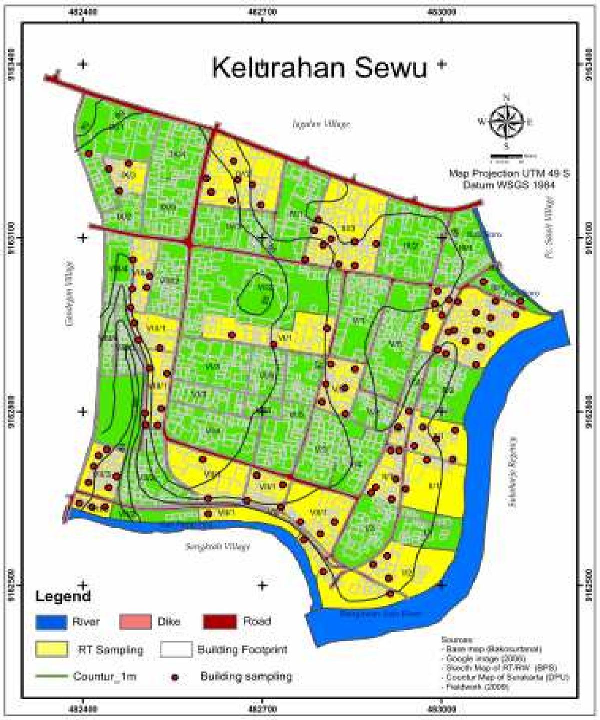


Figure 3-3. Spatial distribution of respondents

Figure 3-4. Fieldwork equipments

3.2.3. Building inventory and household interviews

Building inventory has been done in order to identify the elements at risk and to verify the answer of respondent. The activities were measuring the height of floor from street and observing the physical aspect of household building such as the number of floors, size of building, etc (see Figure 3-5). The information was collected such as Building_id, owners, building age, the ground floor height from surface, the ground floor height from street, the number of floors, and the size of buildings. Each of building was captured by a digital camera which described the condition of building. GPS has been used to record the position of the building.

Figure 3-5. Building inventory during fieldwork

The interview using questionnaire were done to gain information on the community perceptions related to the flood extent, flood depth, flood duration, socio-economy condition, and local knowledge related to flood hazards as well as assets and damages of each household building (see Figure 3-6). In-depth interviews were held with community leaders (head of village, leader of *RW* & leader of *RT*) in order to gain overview related to flood in the study area. During the interviews, all of the respondents gave a good response in answering the questions. Although almost all of respondent are Javanese, they can also speak Bahasa Indonesia. This condition made interview fluently. The good thing is that they had remembered the flood depth in their entire houses in 2007 because the water mark was still shown. In addition, the local community also gave documentary photos and video flood of the 2007 flood. There were no difficulties to interact with the community in *Kelurahan* Sewu.

Figure 3-6. Interview and measuring flood mark during the fieldwork

3.2.4. Participatory GIS

Participatory GIS is a very useful method to increase community awareness and decrease vulnerability as well as to understand disaster risk (McCall, 2008; Wigati, 2008). During the data collection in the field, the Quickbird image obtained from Google Earth (see Figure 3-7), map of study area and mobile GPS (Global Positioning System) were used to get the information about flood in the study area, especially for the cause, height and duration of flooding. The information about the flood extent was based on local community knowledge and was transferred into digital data for spatial analysis using ILWIS software. Later on, the data were used to generate flood depth map and flood duration map. Based on information from Participatory GIS, 71 points of flood depth and flood duration were added in order to identify in which the parts of area of *Kelurahan* Sewu were not inundated during flooding in the late December 2007.

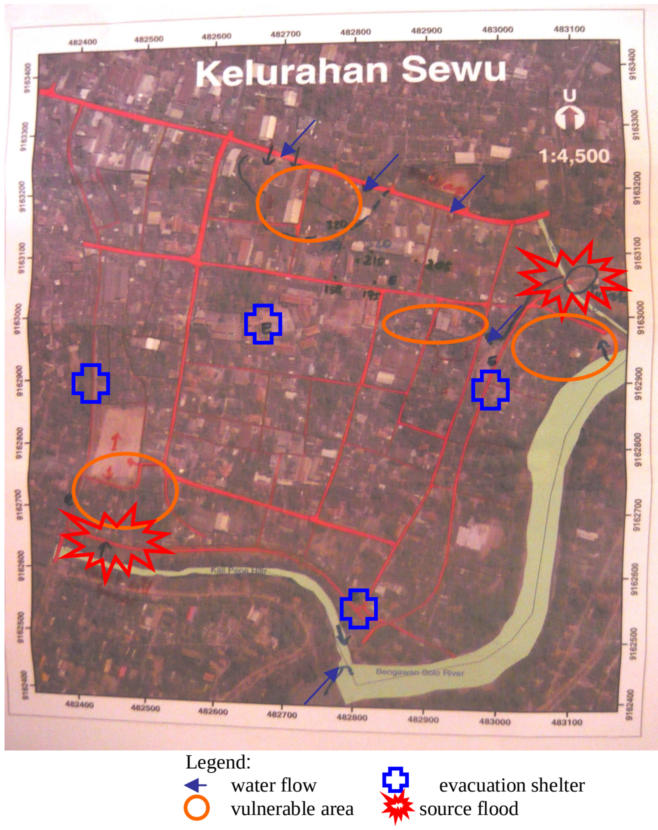


Figure 3-7. The Quickbird image obtained from Google Earth

3.3.Post-Fieldwork

All of the data from fieldwork were processed using ILWIS 3.31, ArcGIS 9.2, and SPSS 16 software. The data collected were analyzed in four parts: community characteristics of *Kelurahan* Sewu, flood hazard analysis, identification of elements at risk, and vulnerability assessment. Statistical analysis in SPSS was used for both descriptive statistics and cross tabulation to describe the social characteristic of the population in study area. ILWIS software was used to process flood depth and flood duration using interpolation in kriging with Gaussian semi-variogram model. ArcGIS software was used to analyze both elements at risk and vulnerability using spatial analysis. The result of this process, including community characteristics of *Kelurahan* Sewu, flood hazard mapping, the elements at risk and flood vulnerability assessment, will be discussed in the next chapters.

4. Community Characteristics in *Kelurahan* Sewu

This chapter describes about the general characteristics of the community, the community groups and also the local traditions of community in the study area. They are related with the community vulnerability and their capacity of flood hazard.

According to Wilkinson (1991) in Flint and Luloff (2005) the definition of community is stated into 3 basic concepts as a geographical expression, a system of social interactions and the source of mutual identity and object of local actors in associational action. In this research a community is related with the definition of a community as a system of social interaction among the people who live in *Kelurahan* Sewu.

Disaster occurred when certain hazard struck the vulnerable community (Smith, 1991 in Maiti, 2007). Several factors should be analyzed in order to know the risk and threats of community. Social, political and economic aspects are the factors that have effect to vulnerability of community. Cannon et al. (2004) divide three characteristics of community that have more vulnerability than others based on their proximity and exposure, poverty, and exclusion/marginalization. And also, they explain the capacities of community based on three categories such as physical and material, social and organizational, and skill and attitudes. On the other hand, Kuban and MacKenzie-Carey (2001) emphasize the characteristics of the people, who are the most vulnerable in community based on their lack of capacity to respond or to recover, as follows:

- Inadequate resources to plan or respond (e.g., single parents, the poor);
- Inadequate awareness (e.g., about opportunities or the availability of resources) ;
- Inadequate opportunity to express their unique needs (e.g., to avoid being ignored in the planning, response or recovery process) ;
- The presence of significant health problems (compounded by dependence on technology, living aids or medication) ;
- The lack of education to understand emergency-related messages;
- Limited access to community resources (e.g., the poor, transients, homeless) ;
- The lack of sufficient mobility to appropriately respond (e.g., seniors, the disabled) ;
- The lack of support networks (e.g., homeless) ;
- Cultural isolation from the bulk of the community (e.g., newcomers, indigenous people) ;
- Linguistic isolation from the bulk of the community (e.g., newcomers).

In order to know the community characteristics on the study area related to their vulnerability to flood hazard, the activities have been undertaken not only doing observation but also following Focus Group Discussion (FGD). The FGD was conducted by Cecile de Millano who is currently as PhD student from Groningen University. She focuses on understanding youth's resilience to flooding in *Kelurahan* Sewu. Those activities gave information about the knowledge, experience and perceptions of youths related to flood hazard issue in the study area.

4.1. General characteristics of community

Kelurahan Sewu comes from the word *penewu* which is name of the palace courtiers because many people in *Kelurahan* Sewu used to be palace courtiers. One-time, *Kelurahan* Sewu was a territory that consisted of villages with different geography. For instance, Mbeton region (now *RW* 1) was a harbor for trader boats and Ledok region (now *RW* 7 and *RW* 8) was a swamp which was used for a garbage disposal area. And now the most of the area is occupied by high density housing.

Some residents of *Kelurahan* Sewu live on the riverbanks inside the dike. This indicates that they are more vulnerable to flood hazard than the residents who live outside the dike. A half of them are living in an unauthorized residential with the public facilities and environment infrastructures are less than the standardized. Some respondents said that living and built a house on the riverbanks was cheaper than renting a house. Because they built an illegal house in the state land, they built their house with minimized condition seemingly unfit for habitation. The housing condition is crowded and unorganized, and also susceptible to floods. The visible physical characteristics of housing on the riverbanks area are (1) dense environment, the availability of land and housing needs are not balanced; (2) the average of the most residential is 30 m^2; (3) there is unavailability for drainage channel and garbage dumping; (4) The public facilities are limited like a meeting hall, public telephone, etc and (5) open space for public area is not available.

Based on *Kelurahan* Sewu (2009) the total of population in *Kelurahan* Sewu in June 2009 consisted of 49% men and 51% women from 8,461 inhabitants. This number of population increased with as many as 65 inhabitants since December 2007 (8,396 inhabitants) when flooding occurred in this area. Table 4-1 shows the distribution of population based on age and gender. It expresses that the children with the age of 0-4 years were 13.1% and the elder with the age of 60 years up are 8.1% from total of population. It indicates that about 21.2% people in *Kelurahan* Sewu are vulnerable to flood hazard in term of the age.

Table 4-1. The distribution of age and gender in *Kelurahan* Sewu

Age (years)	Men	Women	Total	Percentage
0-4	548	559	1107	13.1%
5-9	315	326	641	7.6%
10-14	297	407	704	8.3%
15-19	459	473	932	11.0%
20-24	475	542	1017	12.0%
25-29	345	347	692	8.2%
30-39	471	459	930	11.0%.
40-39	447	469	916	10.8%
50-59	426	411	837	9.9%
60+	361	324	685	8.1%
Total	**4144**	**4317**	**8461**	**100%**

Source:*Kelurahan* Sewu (2009)

In the term of education, approximately 32.6% of the people in *Kelurahan* Sewu have not been educated. Only 1.8% from 8,461 inhabitants have been educated in university. The rest are 14% in Senior High School, 35% in Junior High School, 7% in Elementary School, and

10% in unfinished Elementary School (see Table 4-2). Most of them are more likely oriented on fulfilling basic needs rather than education needs.

Table 4-2. The distribution of people education in *Kelurahan* Sewu

Education	Number of People	Percentage
University	150	1.8%
Senior High School	1148	13.6%
Junior High School	2968	35.1%
Elementary School	601	7.1%
Unfinished Elementary School	835	9.9%
Un-educated	2759	32.6%
Total	**8461**	**100%**

Source:*Kelurahan* Sewu (2009)

The number of working population in this area was 6,732 people who work as entrepreneur (22 people), construction workers (721 people), industry workers (3,159 people), retailers (255 people), transporters (73 people), civil servant (65 people), retired (70 people), and others such as shoemaker, tailor, etc. (2,367 people) (see Table 4-3) . It means that a half of people who live in *Kelurahan* Sewu have low income with dense population because most of them work as laborer like industry workers, construction workers, etc. The low income of the family causes inability to educate their children until Senior high school so the children have the same employment as their father does, as construction and industry workers.

Table 4-3. The livelihoods of people in *Kelurahan* Sewu

Livelihoods	Number of People	Percentage
Entrepreneur	22	0.3%
Construction workers	721	10.7%
Industry workers	3159	46.9%
Retailers	255	3.8%
Transporters	73	1.1%
Civil servant	65	1.0%
Retired	70	1.0%
Others	2367	35.2%
Total	**6732**	**100%**

Source:*Kelurahan* Sewu (2009)

4.2. Community Group in *Kelurahan* Sewu

Based on the result on focus group discussion (de Millano, 2009), it was found that the community in *Kelurahan* Sewu has several organizations that get together monthly (see Figure 4-1). The main organizations in Sewu community are:

– PKK (Family Welfare Assistance) that is the motherhood organization in a community related to social activities for women.

- *Karang Taruna* that is the neighborhood youth association which has members with the age of around 12 years old until one getting married or 25 years old. The organization does social activities for the youth not only in *Kelurahan* Sewu but also in the others areas.

- *Arisan Bapak-bapak* that is the fathers community that does some meetings and at the same time they collect money to support the community. The community collects small amount of money from the members and a lottery system used to draw name of the members who will receive the money collected by community. Thus, a small share of the money will be saved, which is used in times of need for instance when a community member is sick.

(a) (b) (c)

Figure 4-1. PKK in *RW* 9 (a) FGD with Karang Taruna *RW* 7 (b) and Arisan Bapak-bapak (c)

4.3. Local Traditions in *Kelurahan* Sewu

Another characteristic of the community in *Kelurahan* Sewu is a local tradition. This activity implemented in several forms in the community. The main forms of local tradition in *Kelurahan* Sewu are as follows:

- *Kerja bakti* or *Gotong Royong* is the tradition of working together in the community to help each one another for something goodwill. The activity is not done regularly, every two weeks or every month when they need it. For instance, the community conducts *kerja bakti* to clean the drainage when the rainy season will come and also after flood occur.

- *Ronda* is the activities of the community to patrol their neighborhood area. This activity is conducted in rotation by the time allowed for each member of society in the region *Rukun Tetangga (RT)*.Usually the activity is done at night to watch and guard the security of the neighborhood, but sometimes the activity is also done when flood occurs to control or see the height of the flood.

4.4. Discussion

The community characteristics in the study area are discussed in this chapter. The characteristics are related with the community vulnerability and their capacity in term to deal with flood hazard. It was revealed that some of the communities lived on the riverbanks with unorganized housing, almost one-fifth of the communities consist of the elder and the youngest people, one-third of the communities were un-educated, and a half of people who live in *Kelurahan* Sewu have low income. Moreover, the community has their capacity to deal with flood hazard through organizations and the local traditions.

5. Mapping Flood Hazard in *Kelurahan* Sewu

This chapter discusses flood occurrence that have occurred in the study area and some factors that caused the area get flooded. In addition it flood points are identified using Participatory GIS based on flood in 2007 where it was the worst flooding recently.

5.1. Flood events in *Kelurahan* Sewu

Kelurahan Sewu is the most flooded area in Surakarta City. Besides its location adjacent to Bengawan Solo River, the low topography is a factor that causes this area flooded. Although some enormous floods had occurred in this area (see Section 2.2), only a few data are available in *Kelurahan* Sewu office related to flood events, i.e. data of flooding in 2007 until 2009 (see Appendix 3). This condition occurs because the greatest flood in 2007 after the big one in 1966 made local government more alert with flood hazard so that they are more care with flood data. Based on this data, 8 *Rukun Tetangga* (*RT*) are the most prone area to flood hazard. There are *RW* I *RT* 1, *RW* II *RT* 3, *RW* III *RT* 1 and *RT* 3, *RW* IV *RT* 1, *RW* V *RT* 5, *RW* VII *RT* 2 and *RT* 3. The safer areas in *Kelurahan* Sewu are 11 *Rukun Tetangga* including RW VI RT 1, 3 and 5, RW VIII RT 2,3 and 4, RW IX RT 1,2,3,4, and 5. Figure 5-1 shows the spatial distribution of flood event in 2008 and 2009.

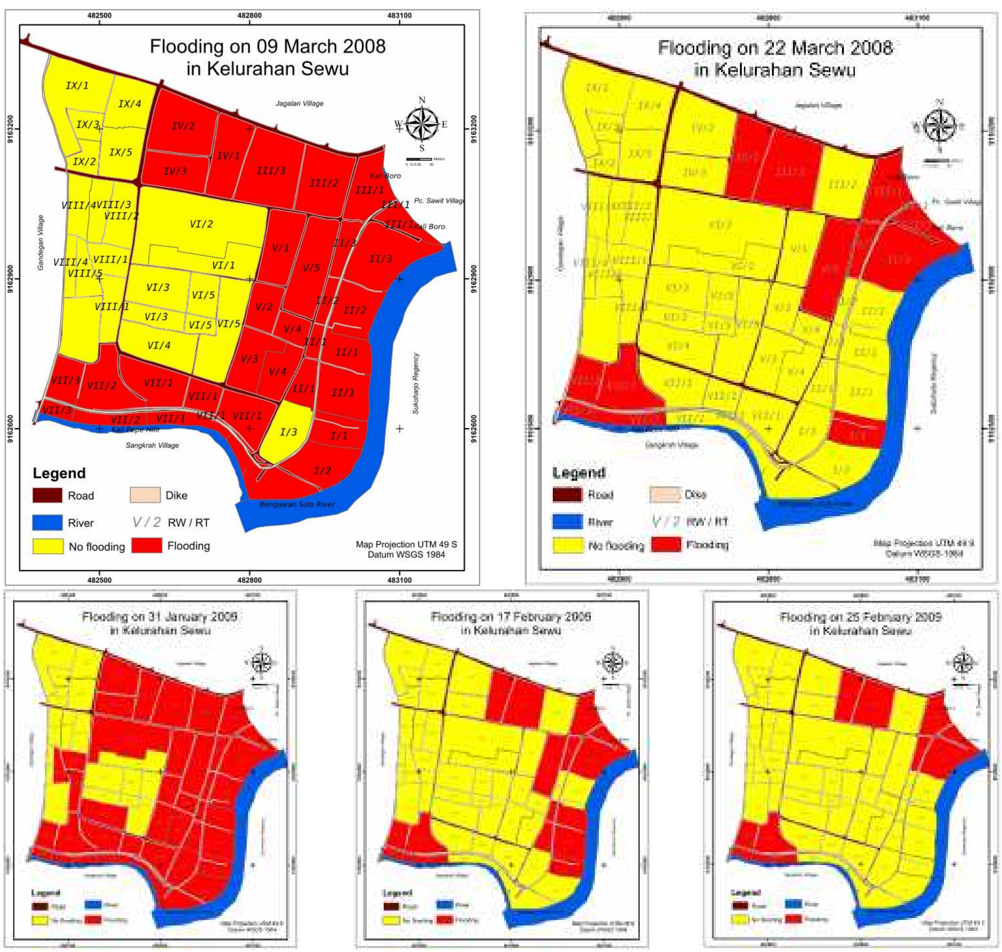


Figure 5-1. Spatial distribution of flood event in *Kelurahan* Sewu in 2008-2009

During the qualitative data collection (de Millano, 2009) two categories of flooding were identified in *Kelurahan* Sewu. The first is the seasonal flooding and the second is more dangerous flooding (like flooding in the late December 2007). In the seasonal flooding, the flood depth was 50-100 cm in which the duration was 12 hours until 3 days. This flood occurred around five times per year in rainy season. In the flood disaster, the water height reached 3-4 meters where the duration was more than 3 days. The occurrence of the flood disaster was not frequent. It happened in December 2007. Figure 5-2. illustrates the focus group discussion activity that provided information about flood characteristics in study area..

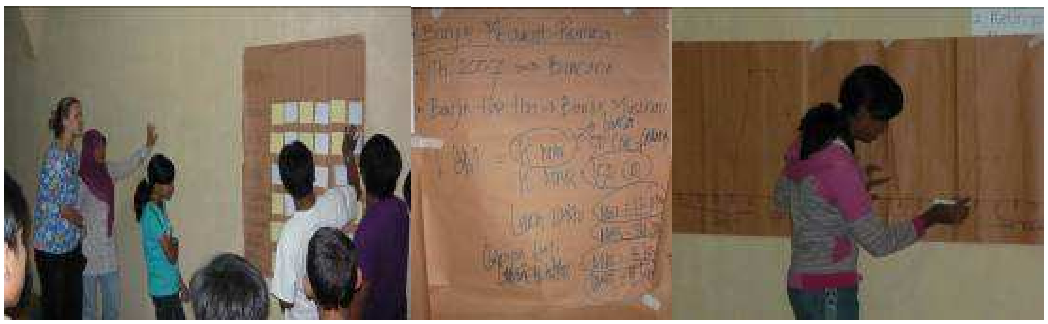


Figure 5-2. FGD activity in RW VII *Kelurahan* Sewu

5.2. Flood related fact in *Kelurahan* Sewu

A hazard is the probability of occurrence of a harmful natural event, within a specific period of time and within a given area (UNDRO, 1991). Several facts causing flooding in December 2007 in *Kelurahan* Sewu were found. The heavy rainfall in the upper part of Bengawan Solo River on 26 December 2007 caused the river to overflow. The rainfall amount was 124 mm/day on the average. Figure 5-3 shows rainfall totals from the Tropical Rainfall Measuring Mission (TRMM) from December 24, 2007 to January 2, 2008.

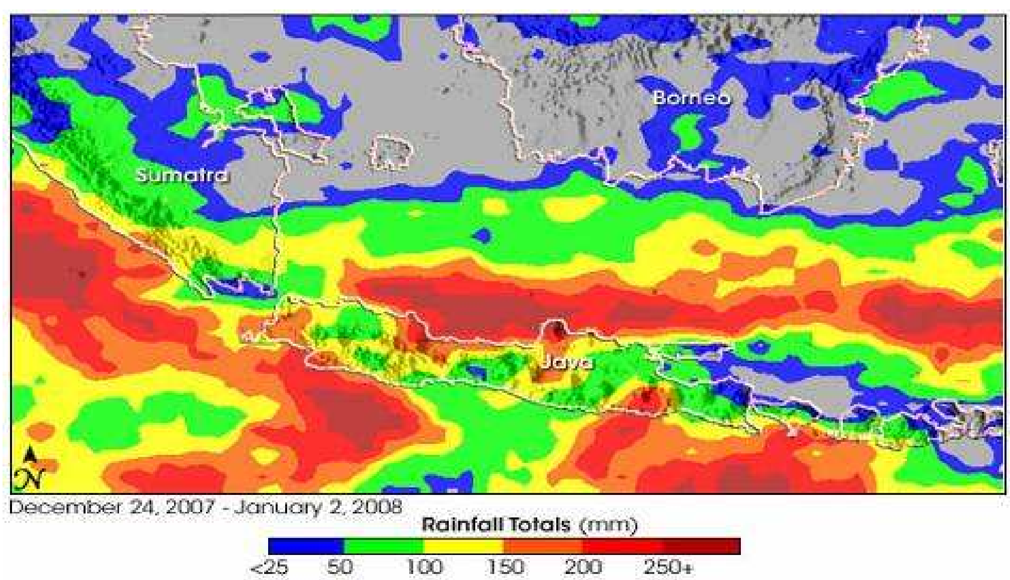


Figure 5-3. Rainfall totals in some parts of Indonesia from the TRMM-based
Source: NASA Earth Observatory (2008)

In the same time, 26 December 2007, the water level gauge in Jurug was recorded that the discharge of Bengawan Solo River was 1,986 m^3/second. The water level reached about 11 meters from river bed where the normal condition is 4 meters. In addition, Putat water gate laid in the north eastern part of *Kelurahan* Sewu got damaged. Although the water did not overflow the dike, it flowed through the gate and inundated *Kelurahan* Sewu.

Some structural measurements were laid in *Kelurahan* Sewu to protect the area of Surakarta City from flood but they did not protect *Kelurahan* Sewu from flood in the late December 2007 because Putat water gate had been damaged. A half of them were built by the Netherlands government when occupying this country, i.e. Dike I, Demangan pump house and Demangan water gate (see Figure 2-11). The others were built by Indonesian government such as Putat water gate, Dike II, gabion construction and early warning system. The early warning system was built after the flooding 2007 occured.

Flood in the study area during the late December 2007 was not only caused by persistent heavy rains, but also due to lack of drainage system, lack of flood control structures, and watershed degradation in the upper part of Bengawan Solo River basin. The primary flood control facility in Bengawan Solo River basin is the Wonogiri Multipurpose Dam located about 55 km upstream of Surakarta. The dam was completed in 1982 and controls flood runoff from uppermost 1,350 km^2 of basin. The reservoir provides 232 million m^3 of flood control capacity regulating peak discharge of 4,000 m^3/s to 400 m^3/s.

Flooding in December 2007 had inundated 1,574 houses in *Kelurahan* Sewu. From discussion with Mr. Harnarno who is an officer of *Kelurahan* Sewu, who has been responsible for disaster in this village, indicated that the area inundated was almost 90% of area of *Kelurahan* Sewu. More than 1,700 household were evacuated. The evacuation shelter was located in the School, the Church, the Mosque, the Hall mayor of Surakarta City, and also along the dike. Two houses laid on the riverbanks in *Kelurahan* Sewu were collapsed. Figure 5-4. displays the house before and after collapse during the flooding in the late December 2007.

Figure 5-4. The house collapse during flooding in December 2007
Source: Private document of head of *RT* 02/ *RW* II

In order to know the return period of flooding in the late December 2007, the data of discharge from 1966 to 2007 was calculated by using Gumbel method. The method obtains a simple statistical approach to calculate the probabilities of occurrence for different records.

Table 5-1 depicts the discharge of Bengawan Solo River taken from the water level gauge in Jurug (see Figure 2-11 point 3).

Table 5-1. The water height level and the peak discharge yearly of Bengawan Solo River from Jurug water level gauge from 1966 until 2007

Year	Date	Water height level (m)	Discharge (m^3/s)	Year	Date	Water height level (m)	Discharge (m^3/s)
1966	16-Mar	11.90	2,000	1987	20-Feb	6.72	821
1967	28-Feb	8.30	1,371	1988	16-Nov	7.20	909
1968	26-Mar	7.25	850	1989	5-Feb	7.40	947
1969	24-Mar	5.51	520	1990	22-Jan	5.97	689
1970	12-Mar	6.30	670	1991	19-Feb	7.10	903
1971	26-Mar	6.55	720	1992	5-Dec	7.00	700
1972	16-Feb	6.79	770	1993	3-Feb	9.16	1,249
1973	24-Mar	6.05	620	1994	12-Mar	8.80	1,146
1974	27-Feb	6.93	810	1995	12-Feb	8.80	1,146
1975	21-Mar	7.39	665	1996	13-Mar	6.45	582
1976	16-Jan	7.00	594	1997	9-Feb	7.20	744
1977	25-Jan	6.50	509	1998	20-Mar	7.00	700
1978	2-Feb	7.00	594	1999	20-Jan	7.40	789
1979	5-May	7.04	601	2000	9-Mar	8.80	1,146
1980	16-Apr	6.24	467	2001	10-Feb	7.05	711
1981	28-Mar	5.72	388	2002	10-Feb	8.45	1,051
1982	24-Jan	8.07	798	2003	22-Mar	8.10	960
1983	28-Feb	5.82	403	2004	28-Dec	7.90	909
1984	5-Feb	7.40	947	2005	5-Apr	6.10	517
1985	9-Mar	7.30	928	2006	25-Jan	6.95	689
1986	28-Mar	6.95	863	2007	26-Dec	11.45	1,986

Source: Balai Besar Wilayah Sungai Bengawan Solo in Setiyarso (2009)

Coto (2002) summarized steps to calculate the return periods using Gumbel method as follows:

- The discharge records have to be sorted from lowest to highest.
- A rank value (J) is assigned to the records, starting with a value 1 for the lowest record, until a value n (number of records) for the highest one.
- The probability of not-being exceeded is calculated with the formula $P= J/ n+1$, and the return period with $R=1/1-P$. The result of this calculation is shown in Table 5-2.
- For the graph of the results, a plotting position $Y(=-ln(-ln(P)))$ is calculated and then the discharges are plotted against it. Thus, a line of the best fit is conducted (see Figure 5-5).

Table 5-2. Calculation for return period using Gumbel method

Year	Sorted	Rank (J)	Left Prob (P)	Right Prob.	R	Y	Year	Sorted	Rank (J)	Left Prob (P)	Right Prob	R	Y
1981	388	1	0.02	0.98	1.02	-1.32	1999	789	22	0.51	0.49	2.05	0.40
1983	403	2	0.05	0.95	1.05	-1.12	1982	798	23	0.53	0.47	2.15	0.47
1980	467	3	0.07	0.93	1.08	-0.98	1974	810	24	0.56	0.44	2.26	0.54
1977	509	4	0.09	0.91	1.10	-0.86	1987	821	25	0.58	0.42	2.39	0.61
2005	517	5	0.12	0.88	1.13	-0.77	1968	850	26	0.60	0.40	2.53	0.69
1969	520	6	0.14	0.86	1.16	-0.68	1986	863	27	0.63	0.37	2.69	0.76
1996	582	7	0.16	0.84	1.19	-0.60	1991	903	28	0.65	0.35	2.87	0.85
1976	594	8	0.19	0.81	1.23	-0.52	1988	909	29	0.67	0.33	3.07	0.93
1978	594	9	0.21	0.79	1.26	-0.45	2004	909	30	0.70	0.30	3.31	1.02
1979	601	10	0.23	0.77	1.30	-0.38	1985	928	31	0.72	0.28	3.58	1.12
1973	620	11	0.26	0.74	1.34	-0.31	1984	947	32	0.74	0.26	3.91	1.22
1975	665	12	0.28	0.72	1.39	-0.24	1989	947	33	0.77	0.23	4.30	1.33
1970	670	13	0.30	0.70	1.43	-0.18	2003	960	34	0.79	0.21	4.78	1.45
1990	689	14	0.33	0.67	1.48	-0.12	2002	1,051	35	0.81	0.19	5.38	1.58
2006	689	15	0.35	0.65	1.54	-0.05	1994	1,146	36	0.84	0.16	6.14	1.73
1992	700	16	0.37	0.63	1.59	0.01	1995	1,146	37	0.86	0.14	7.17	1.90
1998	700	17	0.40	0.60	1.65	0.07	2000	1,146	38	0.88	0.12	8.60	2.09
2001	711	18	0.42	0.58	1.72	0.14	1993	1,249	39	0.91	0.09	10.75	2.33
1971	720	19	0.44	0.56	1.79	0.20	1967	1,371	40	0.93	0.07	14.33	2.63
1997	744	20	0.47	0.53	1.87	0.27	2007	1,986	41	0.95	0.05	21.50	3.04
1972	770	21	0.49	0.51	1.95	0.33	1966	2,000	42	0.98	0.02	43.00	3.75

Source: Balai Besar Wilayah Sungai Bengawan Solo in Setiyarso (2009)

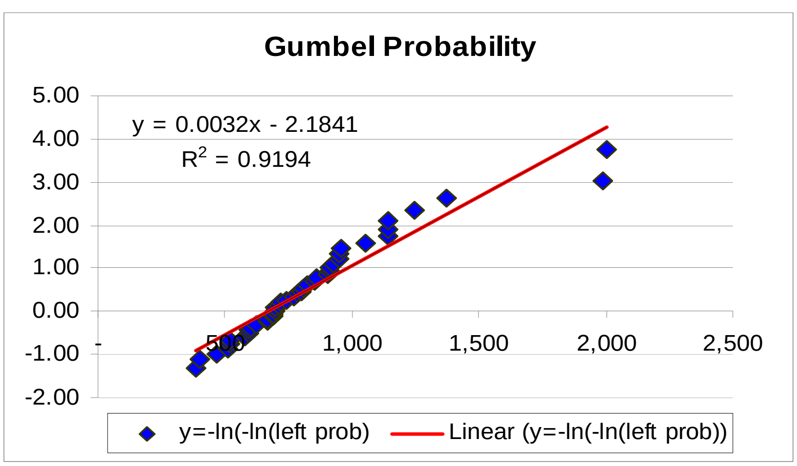


Figure 5-5. Gumbel probability graph

- From this graph the value Y for different discharge can be read and the return period can be calculated with the formula $P=e^{-e^{-Y}}$ (see Table 5-3 and Table 5-4).

Table 5-3. Return period of different discharges

Return Period (years)	Probability	Plotting position Y	Discharge (m^3/s)
5	0.8	1.5	1151.3
10	0.9	2.3	1385.8
25	0.96	3.2	1682.1
50	0.98	3.9	1901.9
100	0.99	4.6	2120.1

Table 5-4. Discharge with return period

Discharge (m^3/s)	Plotting position Y	Probability	RP	Return Period
2000	4.22	0.99	0.01	68.26
1986	4.17	0.98	0.02	65.29
1371	2.20	0.90	0.10	9.56
1249	1.81	0.85	0.15	6.64

5.3. Flood points using Participatory GIS

Applying Participatory GIS is really important to get information from community who live in flood prone area. Their knowledge has value-added for understanding disaster risk situations and designing community-based amelioration. Moreover, because there is a dike in the study area, the approach for mapping flood hazard related to the propagation of the inundation flow is difficult to be done in order to get accurate result based on reality. So the use of Participatory GIS is necessary to be conducted in order to determine the flood event in study area.

Participatory GIS was to gain information about the flood extent, flood-depth and flood-duration as well as the cause of flooding that occurred in *Kelurahan* Sewu. McCall and Minang (2005) stated that this method can help to obtain more reliable data outputs. The Quickbird image, obtained from Google earth image of 29 August 2006 covering the study area, was geo-referenced using WGS 84, UTM Zone 49S as reference system and gridded. The image was printed in scale 1:5,000 (see Figure 3-7). The Base map of Surakarta City with scale 1 :25.000 and the GPS mobile were also employed during the activity. The community leaders such as the head officer of *Kelurahan* Sewu, the leader of *RT* and *RW* were involved in gaining information about flood hazard in *Kelurahan* Sewu (see Figure 5-6). They described where the area in *Kelurahan* Sewu was prone to flood i.e. *RT* 2 and *RT* 3 in *RW* VII, *RT* 5 in *RW* V, *RT* 1 *RW* IV, *RT* 1 and *RT* 3 in *RW* III, *RT* 3 in *RW* II and *RT* 1 in *RW* I and also explained cause and situation of flooding in the late December 2007. They also said that the flood in the late December 2007 was the greatest one after flood in March 1966 where the water reached around 6 meters.

Figure 5-6. PGIS activity

There were 104 points of data of flood-depth and flood-duration gathered from respondents. In order to obtain more information about the flood extent of 2007 within each *RT* in *Kelurahan* Sewu, 71 points were added within several *RT* (see Figure 5-7). In addition, the water marks of flooding in 2007 still remained on the wall, so it was used to validate the information from the community related to flood-depth. The flood depth points were measured based on the ground floor as reference and then that point was added with the height of foundation for each building of house.

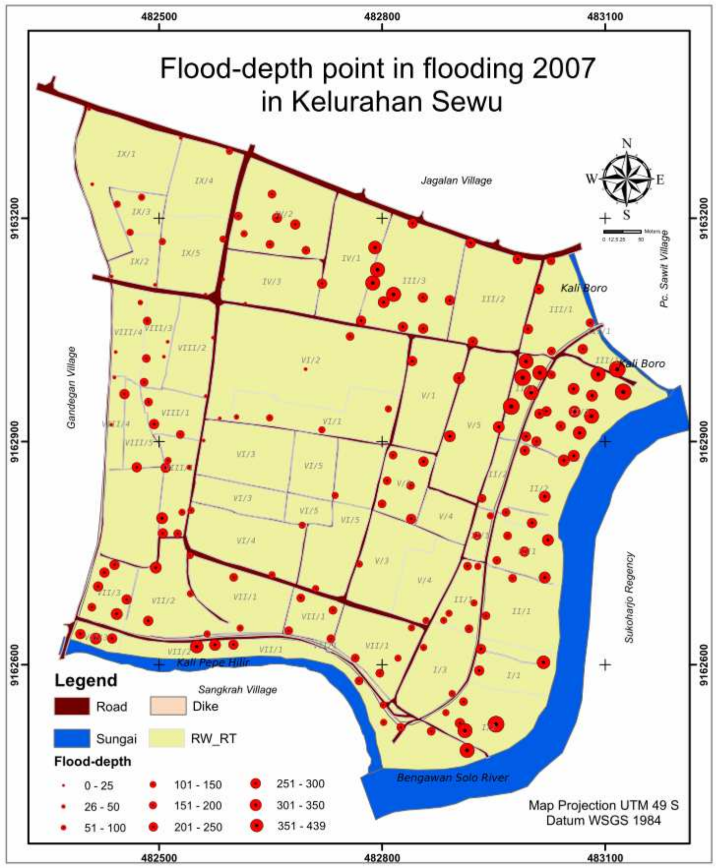


Figure 5-7. Flood-depth points

Although flooding in 2007 was about 2 years before this research conducted, the communities still remember well about the flood depth and the flood duration because it was the greatest flood which ever happened in their live.

5.4. Flood danger map

During the fieldwork activity, the information related flood events also asked from the respondents (see Appendix 1) in order to generate a flood hazard map. Unfortunately, most of the respondents could no longer give any specific details related flood-depth and flood duration about the other flood events and they did not experience with the flood events, especially the flooding in 1966. The respondents only remember the last greatest flooding, which is the flooding in the late December 2007. For this reason, the researcher decided to focus on a flood danger map based on the flooding event that occurred in 2007.

Totally, 174 points were calculated with One-sample Kolmogorov-Smirnov Test in SPSS software in order to know the distribution of point sample. The results of the flood height and the flood duration points have a normal distribution (see Table 5-5). This method compares the observed cumulative distribution function for a variable with a specified theoretical distribution, e.g. normal, uniform etc. in Guarin (2003). ILWIS software was used to generate the flood depth and the flood duration map. The points of flood depth and flood duration were imported into ILWIS format. Later on, the points were interpolated using a kriging method.

Table 5-5. The distribution test of points of flood-depth and flood-duration

One-Sample Kolmogorov-Smirnov Test		**Height of flood 2007**	**Duration of flood 2007**
N		174	174
Normal Parameters[a]	Mean	147.40	2.65
	Std. Deviation	92.534	1.426
Most Extreme Differences	Absolute	.082	.195
	Positive	.082	.161
	Negative	-.056	-.195
Kolmogorov-Smirnov Z		1.084	2.570
Asymp. Sig. (2-tailed)		.190	.000

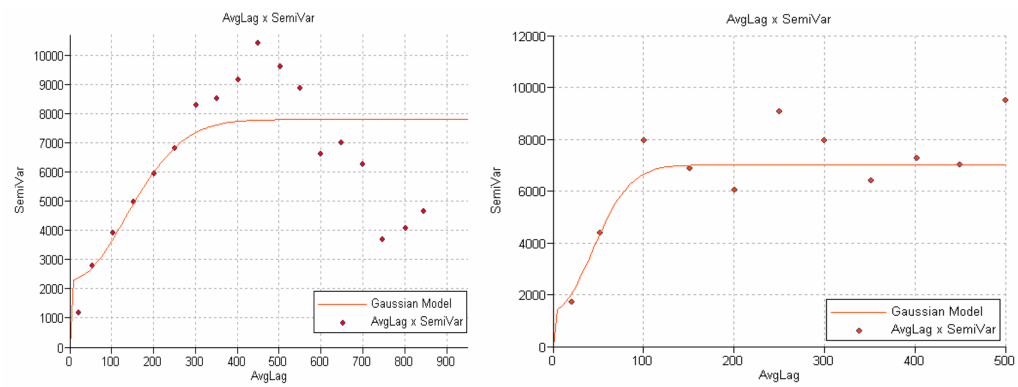
a. Test distribution is Normal.

Kriging is one of the geostatistical methods to interpolate the value of a random field and the goal is to infer the field at unobserved sites. Kriging provided reasonable result in regions because it consists of geostatistical method based on statistical models that include autocorrelation. In kriging the weight are based not only on distance between the measured points and the prediction location but also on the overall correlation among the measured points. The weighting factor is determined using semi-variogram model which represents the relationship between distance and squared differences of pairs of point values (ITC, 2001).

According to D.G. Rositter (personal communication, Nov 2007) in Wigati (2008), a Gaussian model is the best techniques for semi-variogram model to interpolate a phenomenon which physically must be very continuous e.g. the surface of a ground-water table.

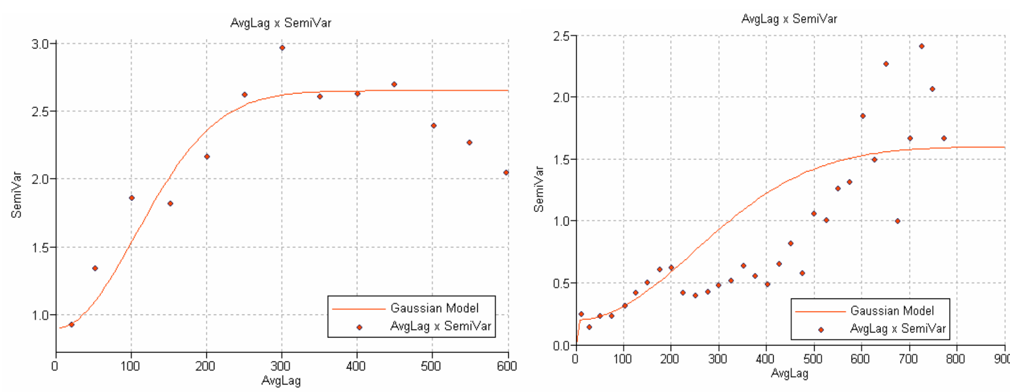
Four steps have been conducted to make kriging method including examining the input data, calculating experimental variograms, modeling variograms and kriging interpolation. Because Dike II laid along the riverbanks was not inundated during the flooding in the late December 2007 (see Figure 2-11 point 7), the interpolation for each map was divided into two interpolations area, outside Dike II and inside Dike II, with different semi-variogram model. From 174 points of data set, 126 points were used to interpolate outside Dike II and 48 points for inside Dike II.

The experimental semi-variogram output was obtained from the Gaussian model. In Flood depth data set, the best fitted for semi-variogram model outside Dike II was a sill of 7800, a range of 190, and a nugget effect of 2300 with the goodness fit (R^2) of 0.5 and for semivariogram model inside Dike II was a sill of 7000, a range of 60, and a nugget effect of 1400 with the goodness fit (R^2) of 0.1. The result of Gaussian semi-variogram model for flood depth data set shows in Figure 5-8. In Flood duration data set, the best fitted for semi-variogram model outside Dike II was a sill of 2.65, a range of 150, and a nugget effect of 0.9 with the goodness fit (R^2) of 0.7 and semivariogram model inside Dike II was a sill of 1.6, a range of 350, and a nugget effect of 0.2 with the goodness fit (R^2) of 0.5. The result of Gaussian semi-variogram model for flood duration data set shows in Figure 5-9.



(a) (b)

Figure 5-8. Graphs of Gaussian semi-variogram model of flood depth
(a) outside Dike II (b) inside Dike II

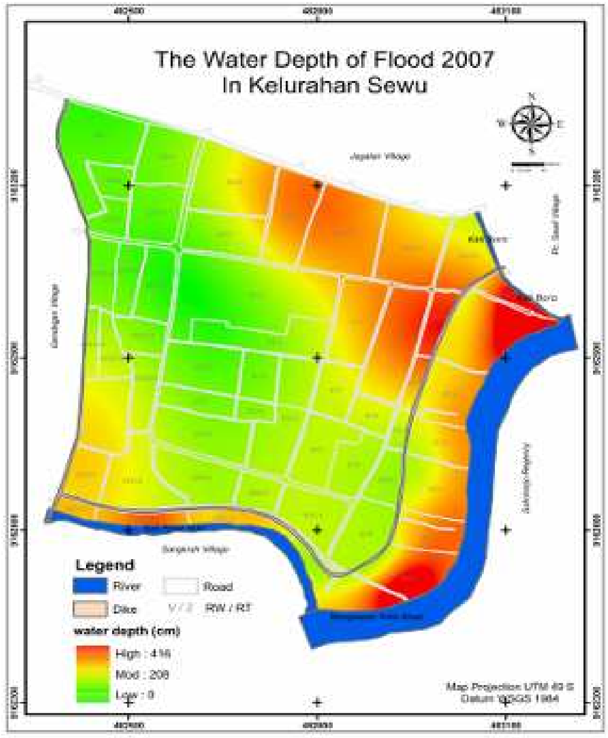


(a) (b)

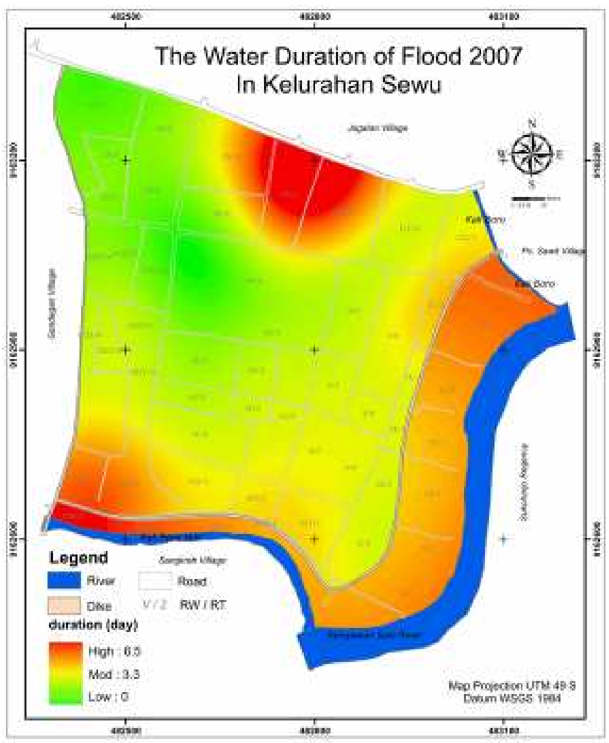
Figure 5-9. Graphs of Gaussian semi-variogram model of flood duration
(a) outside Dike II (b) inside Dike II

From the Graph of semi-variogram model, the inconsistency of measurement can be seen in the value of sqrt (nugget). It can be noted that for flood depth, the measurement/interview error is about 42 cm and the error for flood duration is around 0.7 day.

The simple kriging method for interpolation was performed on the four components of data set. This method was used because the trend component of data set is a constant and known mean and also the result of this method is smother and more aesthetically pleasing than ordinary kriging. Finally, the interpolations of the inside Dike II and the outside Dike II were combined on each flood depth map and flood duration map using glue operation in ILWIS software. The result of the interpolation map is presented in Figure 5-10. The maps display flood depth and flood duration map during the late December 2007 flood in *Kelurahan* Sewu. The maps show that during the late December 2007 the water height ranged from 0 until 4 meters, while the duration varied from 0 to 7 days. These maps will be used as a scenario for the further vulnerability assessments.



(a) Flood depth map



(b) Flood duration map

Figure 5-10. Interpolated map for flood depth (a) and flood duration (b) during the 2007 flood event in *Kelurahan* Sewu

The flooded area map of flood 2007 in *Kelurahan* Sewu (see Figure 5-11) was acquired after classifying inundated area based on the flood depth interpolation (see Figure 5-10 a). Comparing to Setiyarso (2009) who generated a flood hazard map using technical risk assessment in Surakarta City, the similarity in the result is the area of flooding, which is almost equal to flood area with the return period of 20 years (see Figure 5-12). Nevertheless, flooding in December 2007 in *Kelurahan* Sewu had a return period of 65 years (see Table 5-4). This difference is caused by the fact that the technical risk assessment did not consider the structural measure like the dike and the water gate which are located in the area. The generated map only considered the discharge of flood and the geomorphology of Surakarta City. It can therefore be understood that the size of the flood in the technical risk assessment is wider than the actual.

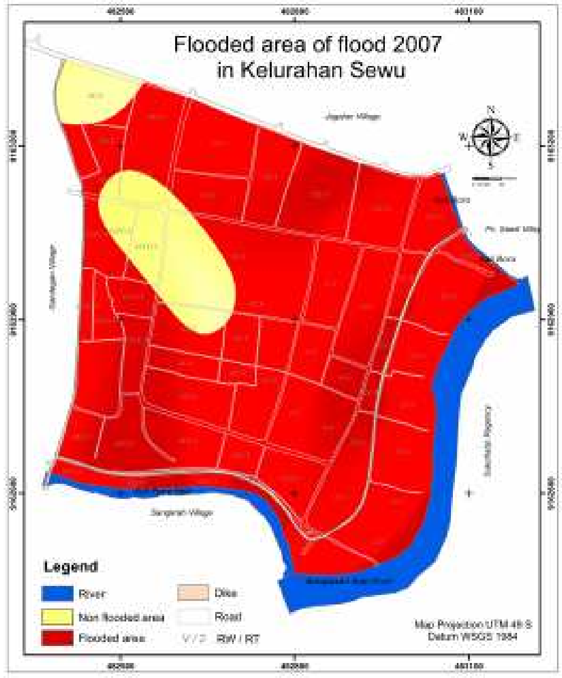


Figure 5-11. Flooded area of flood 2007

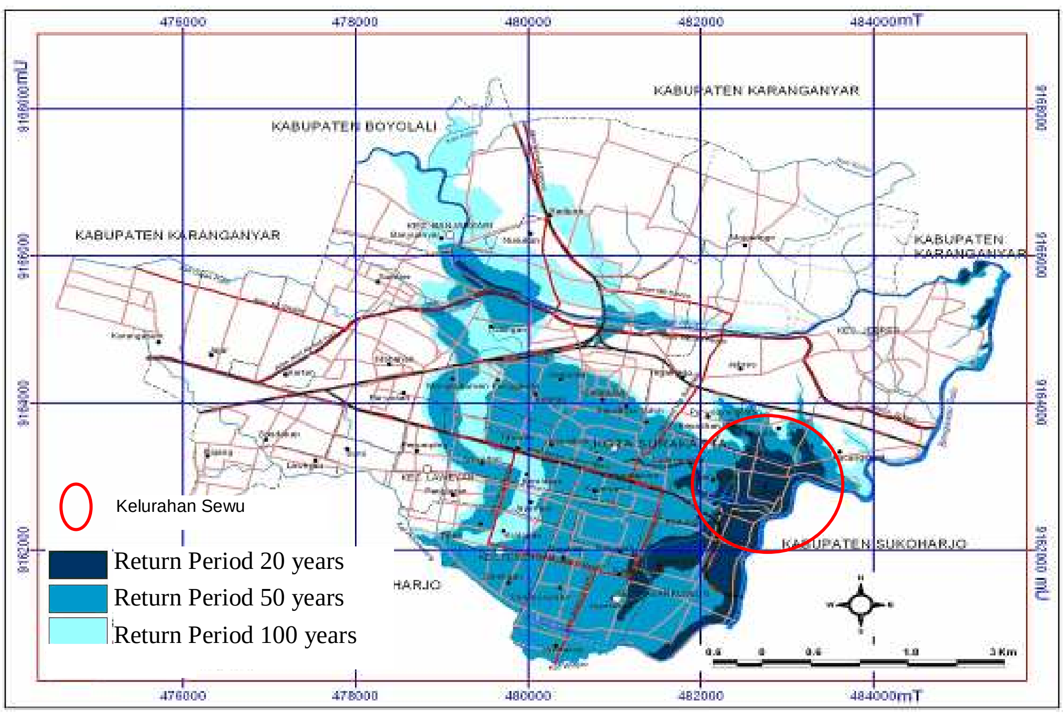


Figure 5-12. The technical risk assessment by Setiyarso (2009)

The detail description about flood event in the late December 2007 in *Kelurahan* Sewu shows in Figure 5-13. The documents were collected from the community during fieldwork.

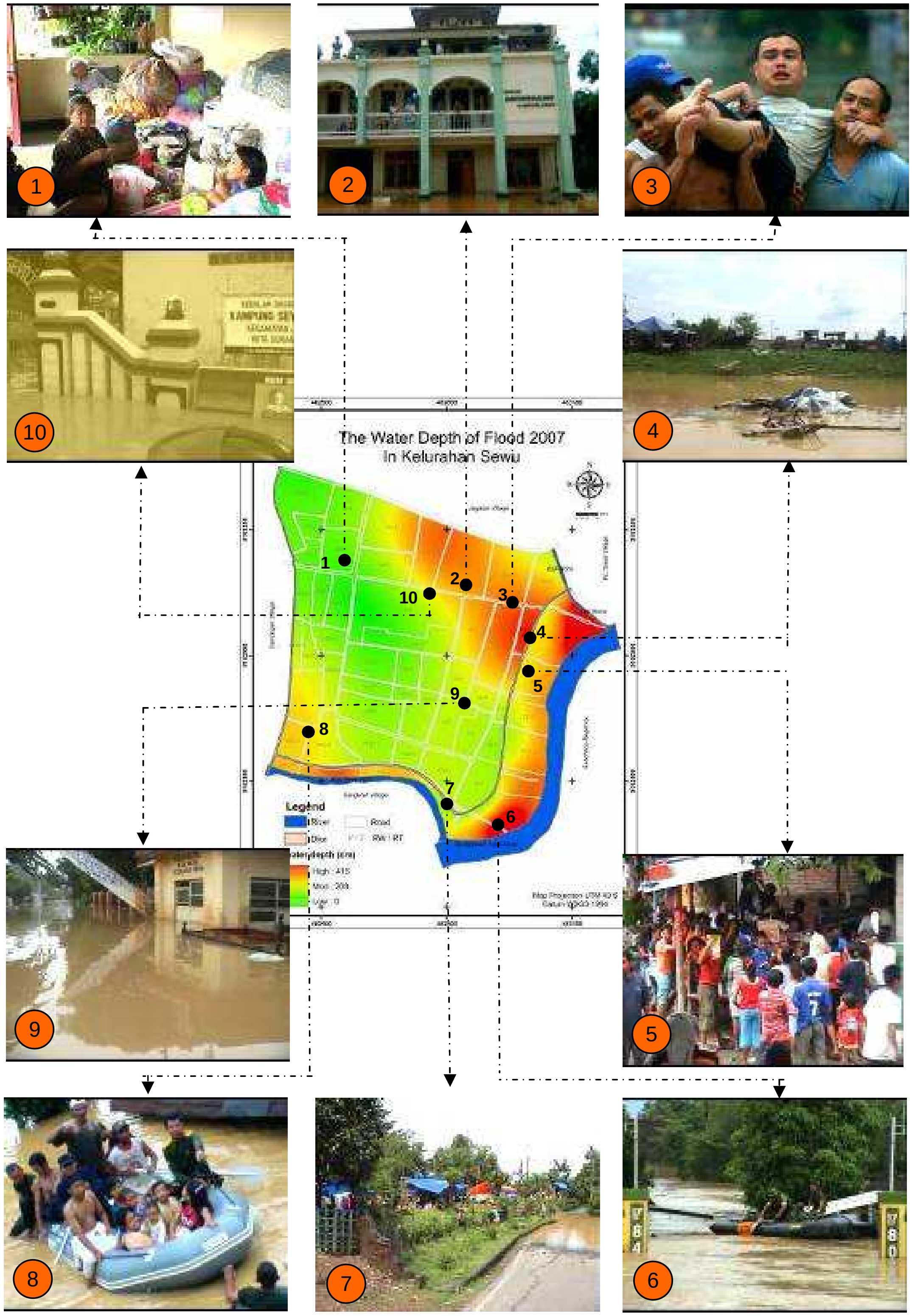


Figure 5-13. General overview of Flood event in the late December 2007

Detail information about Figure 5-13 is described as follows:

1: The elderly and the young people in the evacuation shelter. It is located in *RW* IX/*RT* 5. During flooding in 2007, this place was safe from flood so the inhabitants who had a house hit by flood in *Kelurahan* Sewu were evacuated to their family or neighbor in this region. This condition proved that the inhabitants were evacuated not only to the public infrastructure like the mosque, the school etc but also in their family and neighbor.

2: The Sawunggaling Mosque. It is located in *RW* III/*RT* 3. The mosque was one of the public infrastructures in *Kelurahan* Sewu as the evacuation shelter. Although the ground floor of the mosque hit by flood around 0.50 centimeters, the inhabitants who live in the surrounding area of the mosque still used the second floor as a place of evacuation.

3: Evacuating the deformity people. The local people of *Kelurahan* Sewu were not ready with the height of water during the flooding in the late December 2007. Usually flood only struck certain area in this village and the height of water was around 1 meter. That was why the deformity people evacuated after flood reached 1 meter as shown in this figure.

4: The evacuation shelter on Dike II. The local people who live in the riverbanks used Dike II as the evacuation shelter. They set up an emergency tent on Dike II and put their belongings such as the motorcycle, the television, the mattress etc on that place. This picture shows that Dike II did not inundated during the flooding in the late December 2007 where the height of water was around 1 meter below the top of the dike.

5: Relief on *RW* II/*RT* 2. This picture describes one of assistance activities provided by local government, NGO, etc who cared for with the victims of flood in *Kelurahan* Sewu. They gave assistance including the fresh water, foods, clothing etc.

6: Evacuating the adults who were trapped in their home**.** When the height of flood under 1.5 meters the elder, the young people, and the mother had been evacuated with their precious goods in the evacuation shelter, the adult men safeguarded the rest of property in their house which were placed in higher place in their house from a thief. Unfortunately, when the water level reached more than 1.5 meters, they were trapped in their house. Search and Rescue (SAR) team from The Indonesian National Army was sent to rescue them using a lifeboat with 40 horsepower engine. The SAR team was not only from military but also from PBP which is an organization in *Kelurahan* Sewu established in 2000 that has responsibility for disaster response and evacuation.

7: The evacuation shelter in the southern part of *Kelurahan* Sewu**.**

8: Evacuating the children and the mother with a lifeboat. The velocity of the water during the flooding in late December 2007 was very quick. It caused the people who live in certain areas in the village did not have time to evacuate. When the water level exceeded 1 meter, they were evacuated by a lifeboat.

9: *Poskamling RW* V/ *RT* 2. *Poskamling* means the environmental security posts. At nightfall, the residents who do *ronda* (see Section 4.3.) gather in this building to patrol and secure the environment. During the flooding in the late December 2007, the activity stopped for several days because the residents were busy to safeguard and clean their homes due to flooding.

10: The Public Elementary School no.25**.** It was one of the public infrastructures in *Kelurahan* Sewu hit by flood in late December 2007. This figure shows the flooding on the second day, 28 December 2007, with the water height around 1.50 meters when the flooding on the first day, 26 December 2007, was the water height around 50 centimeters upper the flooding on the second day. Because of this condition the students did not attend school for several days.

5.5. Discussion

This chapter has explained the flood events in *Kelurahan* Sewu, flood related fact, flood point using participatory GIS and flood danger map.

Flood events in *Kelurahan* Sewu consist of annual flooding and disaster flooding. The first flood also called seasonal flooding where the height of water was around 1 meter and the duration was less than 3 day. The second flood ever occurred in *Kelurahan* Sewu in 1966 and 2007. The characteristic of the flood was the water depth reached 4-6 meters with the duration more than 3 day. Some respondents said that many victims died in 1966 flooding.

Flooding in the late December 2007 in *Kelurahan* Sewu occurred not only because of heavy rainfall in the upper part of Bengawan Solo River basin and its location in lowland areas but also the Putat Watergate got damage and lack of drainage system. Gumbel statistical method was used to calculate return period based on different discharge from Jurug gauge.

Participatory GIS was useful to gained data and information related flood extent and cause of flood that occurred in *Kelurahan* Sewu. However, it must be explained more depth to the respondents who is uneducated and had educated only in basic level about the symbol, the direction, etc. The point's data collected from fieldwork is illustrated on the map related with flood depth and flood duration during flooding in the late December 2007. The map will be used as scenario for vulnerability assessment in Chapter 7.

6. Analysis of Elements at Risk in *Kelurahan* Sewu

This chapter explains about the characteristics of the elements at risk in Kelurahan Sewu. The elements at risk in this research emphasize the physical household building including structural type of building, building contents and outside property as well as the socio-economy of household related to risk. The information has been gathered from 104 respondents who live in the inside of dike or on the riverbanks and outside of the dike.

6.1. Information of household building structure

The data set related to the physical household buildings was collected through building inventory within *RT* sample. The data included the type of wall, floor, and roof, building function, and the number of floors. The specific data such as the height of foundation, age of building, and size of building were gathered through interviewing 104 respondents. Next, the data was inputted into ArcGIS software and presented their distribution spatially in a map. Data analysis using SPSS software has been conducted in order to acquire information about their frequency. Table 6-1 shows the result of building inventory within 12 *RT* sample.

Table 6-1. Building inventory within *RT* sample

Building Function	Number of buildings	Percentage (%)
Factory	17	2.26
House	710	94.41
Mosque	4	0.53
School	1	0.13
Store	6	0.80
Village Office	1	0.13
Warehouse	12	1.73
Grand Total	**751**	**100**

6.1.1. Building description from building inventory

6.1.1.1. Floor material

Based on building inventory activity in *Kelurahan* Sewu within *RT* sample, there were found three types of materials used for constructing floor such as ceramic, concrete, and ground (see Figure 6-1). The majority of the types of floor are concrete floor which means the floor made of a construction material composed of cement, water, and sand.

(a) (b) (c)

Figure 6-1. The types of floor (a) ceramic (b) concrete (c) ground

Close to 71% of buildings are using concrete material as their floor. Only about 28 percent are using ceramic material (see Table 6-2). Although after the flood struck ceramic floor was the most easy to clean up among the other floor materials, the low income of the households made them choose concrete material with refining the surface as floor material. Figure 6-2 depicts the most residents using ceramic floor live outside Dike II and the residents who live on the riverbanks most use concrete floors. Only a half percent of the buildings within *RT* sample use ground as the floor.

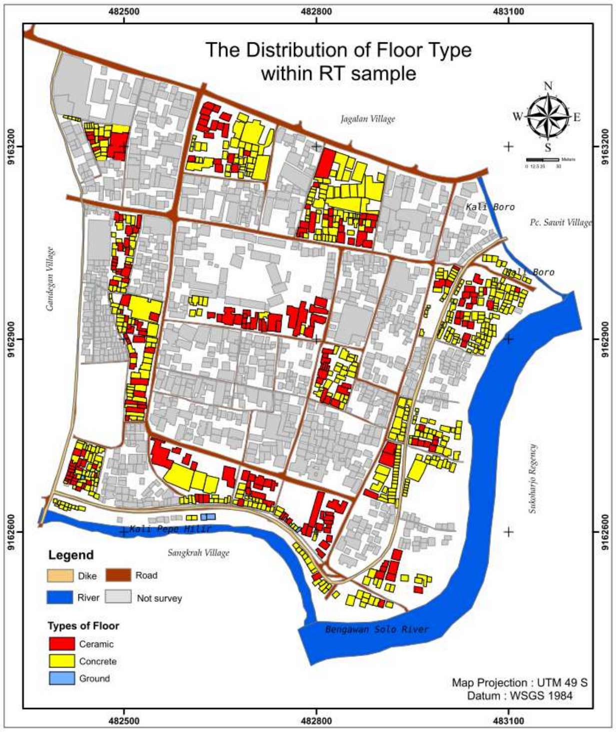


Figure 6-2. Distribution of floor types

Table 6-2. Floor types of building inventory

Type of floor	Number of buildings	Percentage (%)
Ceramic	216	28.76
Concrete	531	70.71
Ground	4	0.53
Grand	**751**	**100**

6.1.1.2. Wall material

Five types of wall material were found during the building inventory within *RT* sample in *Kelurahan* Sewu, such as bamboo, brick, concrete, mixed and wood (see Figure 6-3). Almost 65% of buildings use concrete as the wall. The concrete wall means a wall built with brick covered by cement and plaster. 17% of the buildings use brick as the wall. It is like concrete wall but do not covered by cement and plaster. Mixed wall, which is combination between concrete material in the lower part and the other material e.g. wood, plywood, zinc and bamboo sheet in the upper part, is 17 percent from the total building inventory. Only 1 percent of the buildings use bamboo sheet and wood as the wall (see Table 6-3). Figure 6-4 shows the spatial distribution of wall material within *RT* sample. Figure 6-4 illustrates that the residents who live on the riverbanks built their wall with brick and concrete material because these materials are more resistant to flood than the others.

(a) (b) (c) (d) (e)

Figure 6-3. The types of wall (a) bamboo (b) brick (c) concrete (d) mixed (e) wood

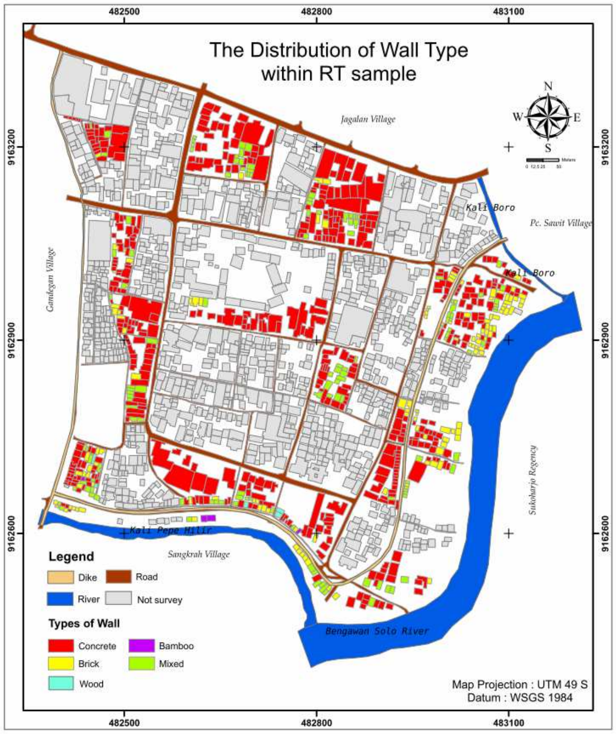


Figure 6-4. Distribution of wall types

Table 6-3. Wall types of building inventory

Type of wall	Number of buildings	Percentage (%)
Bamboo	4	0.53
Brick	125	16.64
Concrete	486	64.71
Mixed	131	17.44
Wood	5	0.67
Grand Total	**751**	**100**

6.1.1.3. Roof material

From 751 buildings in building inventory activity, only three types of roof material were found in *RT* sample such as asbestos, clay, and zinc (see Figure 6-5). Almost 99% of the buildings within *RT* sample use clay as the roof material. Because the high temperature of Surakarta City reaches 35-39 degree, the residents select this roof which more protects them from the outside heat compared with the other roofs. Some buildings still use asbestos and zinc as their roof material because the cost is cheaper (see Table 6-4). Spatial distribution of the types of roof within RT sample is shown in Figure 6-6.

(a) (b) (c)

Figure 6-5. The types of roof (a) asbestos (b) clay (c) zinc

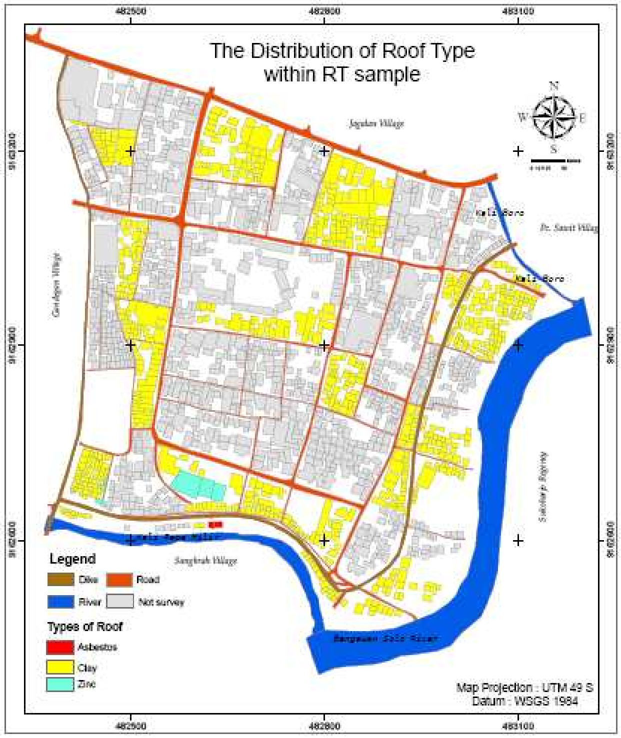


Figure 6-6. Distribution of roof types

Table 6-4. The roof types of building inventory

Type of roof	Number of buildings	Percentage (%)
Asbestos	2	0.27
Clay	742	98.80
Zinc	7	0.93
Grand	**751**	**100**

6.1.1.4. Common structural type of household buildings

According to UNCHS (Habitat) (2001), buildings in flood events can be a place of refuge or can be destroyed by flood. Therefore, assessing vulnerability of buildings based on their structural type should be carried out. Kelman and Spence (2004) mention that the damage of building includes wall failure, doors being forced open, glass breaking, roofs collapsing, or foundations being undermined. This research emphasizes to assess the vulnerability of buildings based on types of floor, wall, and roof material. From 751-building inventories, 9 types of buildings were identified based on the types of floor, wall, and roof using Pivot Table function in Microsoft Excel (see Section 3.2.1 Sampling Method). Table 6-5 shows the percentage of occurrence of structural types of building in *Kelurahan* Sewu.

Table 6-5. Percentage of occurrence of structural types in Kelurahan Sewu

No	Type of building structure	Materials			Total	Percentage (%)
		Floor	Wall	Roof		
1	Structural type 1	Ground	Bamboo	Asbestos	2	0.3
2	Structural type 2	Concrete	Concrete	Zinc	5	0.7
3	Structural type 3	Concrete	Mixed	Zinc	2	0.3
4	Structural type 4	Concrete	Brick	Clay	125	16.6
5	Structural type 5	Concrete	Concrete	Clay	265	35.3
6	Structural type 6	Concrete	Concrete	Clay	216	28.8
7	Structural type 7	Concrete	Mixed	Clay	129	17.2
8	Structural type 8	Concrete	Wood	Clay	5	0.7
9	Structural type 9	Ground	Bamboo	Clay	2	0.3
	Grand total				**751**	**100**

Sampling 15 % has been under taken in order to know the common structural type of household buildings in *Kelurahan* Sewu (see Appendix 2). Later on, this structural type will be used as a sample of respondents, 104 respondents. Figure 6-7 depicts that the common structural type based on types of roof, wall, and floor within 104 respondents are structural type 4 (concrete floor, brick wall, clay roof), structural type 5 (concrete floor, concrete wall, clay roof), structural type 6 (ceramic floor, concrete wall, clay roof), and structural type 7 (concrete floor, mixed wall, clay roof). The spatial distribution of structural types within *RT* sample is shown in Figure 6-8.

(a) Type 4 (b)Type 5 (c) Type 6 (d) Type 7

Figure 6-7. The common structural types in *Kelurahan* Sewu

Figure 6-9 reveals that the greatest structural type of respondents in *Kelurahan* Sewu is structural type 5, almost 35% from the total of 104 household building samples. The rest is 28% of structural type 6, 22% of structural type 7, and 15% of structural type 4.

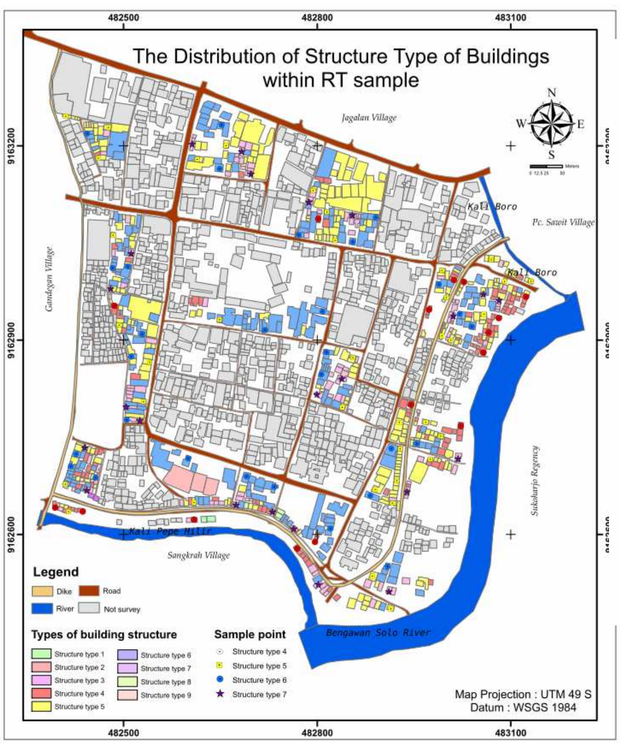


Figure 6-8. Distribution of structural types of household buildings

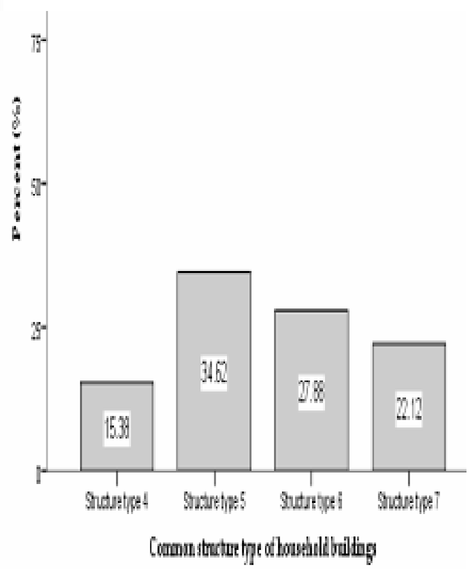


Figure 6-9. The frequency of common structural types of household buildings

6.1.2. Height of ground floor

The height of ground floor from ground surface varies from one household building to another. It indicates that the residents are aware of flood. It is one of the coping strategies from the residents to reduce the possibility of getting flooded. Most of the respondents constructed their buildings with the height of ground floor 1-25 cm; only 10 percent of household buildings did not raise the floor (see Figure 6-10). Some residents also constructed different floor levels inside their house (see Figure 6-11 b).

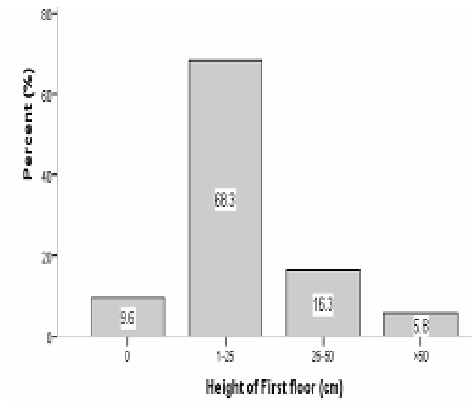


Figure 6-10. The height of ground floor

(a) (b)

Figure 6-11. The floor height measurement (a) The different floor level (b)

6.1.3. Number of Floors

Based on the data recorded from 104 household buildings, almost 92% of the respondents stay in single storey buildings, only 8% have buildings with two storeys (see Figure 6-12). Some respondents said that during flooding in the late December 2007 they put their precious belongings like electronics, mattress etc to neighbors who have two storeys. Generally the residents who have two storeys are located outside the dike, the respondents who live on the riverbanks only have single storey buildings. Spatial distribution of household building based on the number of floors is represented in Figure 6-13.

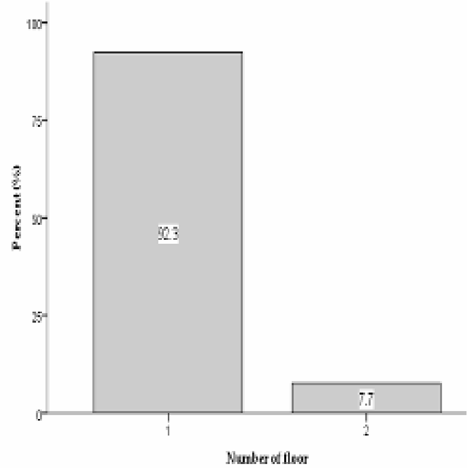


Figure 6-12. The number of floors of household buildings

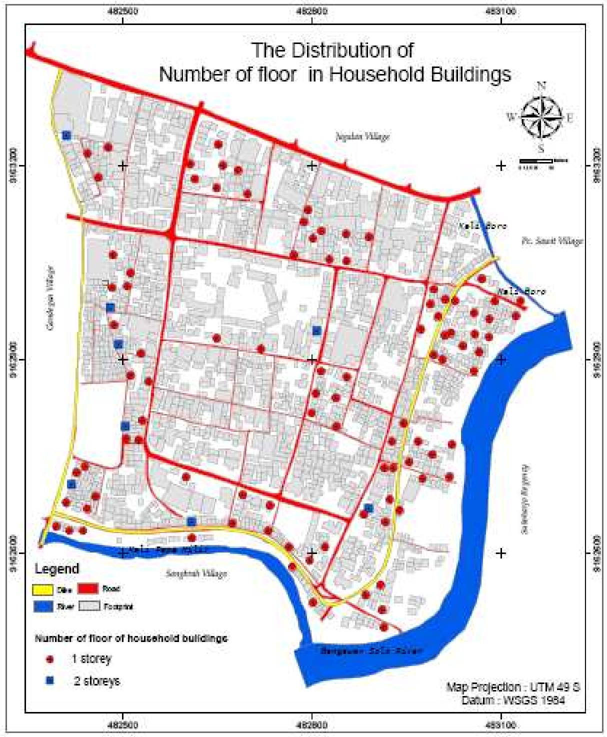


Figure 6-13. Distribution of household buildings based on the number of floors

6.1.4. Building Age

The data recorded during fieldwork show that mostly the age of respondents' buildings in *Kelurahan* Sewu is more than 15 years lying outside the dike, 20 percent of the buildings are between 10-15 years old, and more than 10 percent buildings are standing less than 10 years (see Figure 6-14). The older the buildings are the more vulnerable they are to flood. Figure 6-15 shows the spatial distribution of household buildings based on their ages. Most respondents who have old buildings are located outside the dike, while the residents living on the riverbanks have buildings with the varied ages. From this condition we can assume that the bare land of the riverbanks made people build houses without permission or illegal houses. It occurred in the last 15 years.

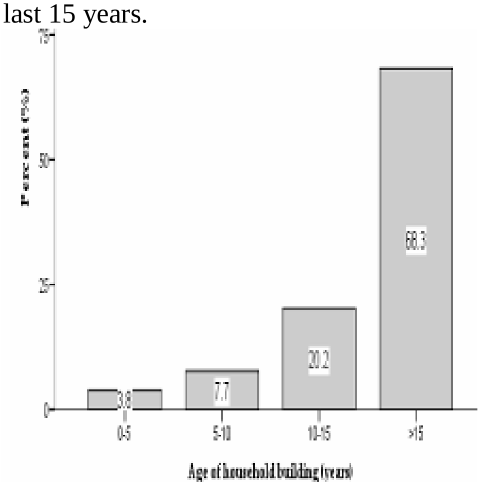


Figure 6-14. The age of household buildings

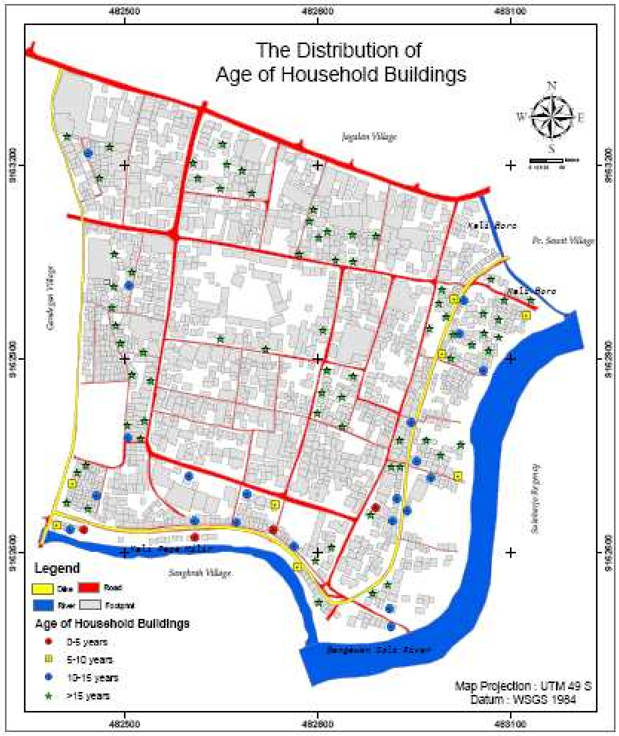


Figure 6-15. Distribution of household buildings base on their age

6.1.5. Building Size

A half of the respondents in *Kelurahan* Sewu live in small houses with the widths of less than 50 m^2. They are located not only on the riverbanks but also outside the dike in unorganized residential area. 36 percent of respondents have buildings with size of 51-100 m^2, most are located in the outside of the dike. The rest is about 10 percent of respondents who live in houses with size of more than 100 m^2 (see Figure 6-16). The spatial distribution of household buildings based on the size is depicted in Figure 6-17.

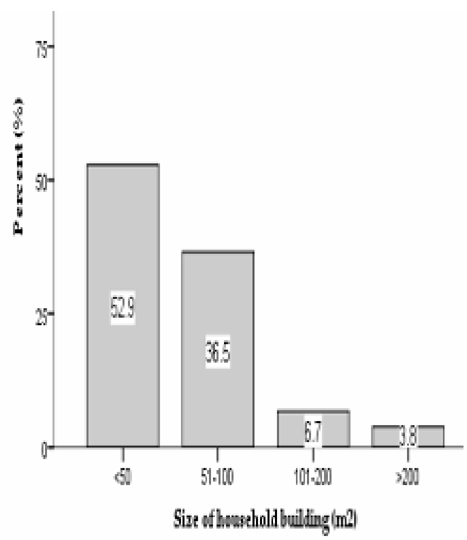


Figure 6-16. The size of household buildings

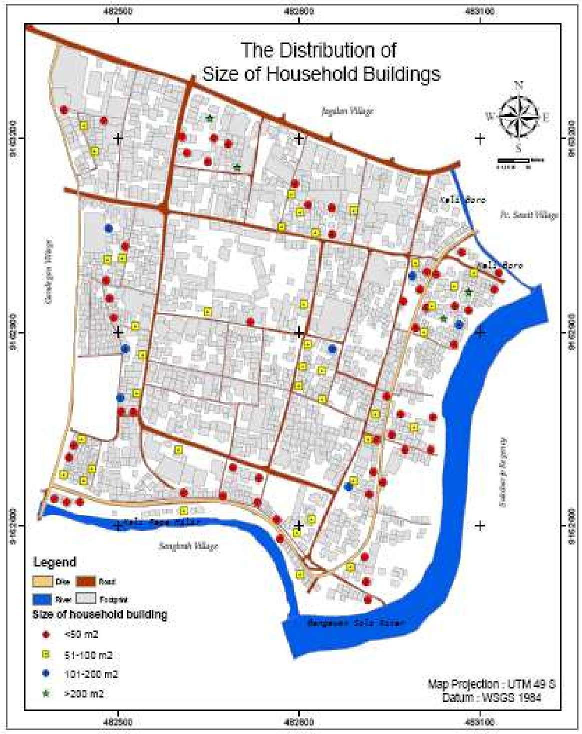


Figure 6-17. Distribution of household buildings based on the size

6.2. Building Contents and Outside Property

One of the approaches to the calculation of direct economic losses from floods is with estimating the potential losses due to a specified severity of flood events based on generalized relationships between certain flood characteristics and physical damage (Smith and Ward, 1998). The direct economic losses are caused by the direct physical damage to property which is related with the value of resident assets (Blaikie et al, 1994; Pelling, 2003; Sagala, 2006). In this section, the value of assets is analyzed into two parts such as the building contents of households and their outside property.

Information related to building contents and outside property have been gathered during fieldwork activity. The building contents (see Figure 6-18 a) are all household assets inside the house including major appliances and furniture. The outside property (see Figure 6-18 b)are all household assets outside the house including the animal, car, bicycle, motorcycle and pedicab (see Appendix 1). 104 respondents provided information about their assets during interview process. Fortunately, the respondents allowed the researcher to look at around their houses for verification and quantification of their property and also taking the pictures. The good degree trust of respondents was because of the effect of flood in the late December 2007 in which they received a lot of assistance from outside parties during and after flooding. This condition makes their attitude more open and trust other people especially related with the flood.

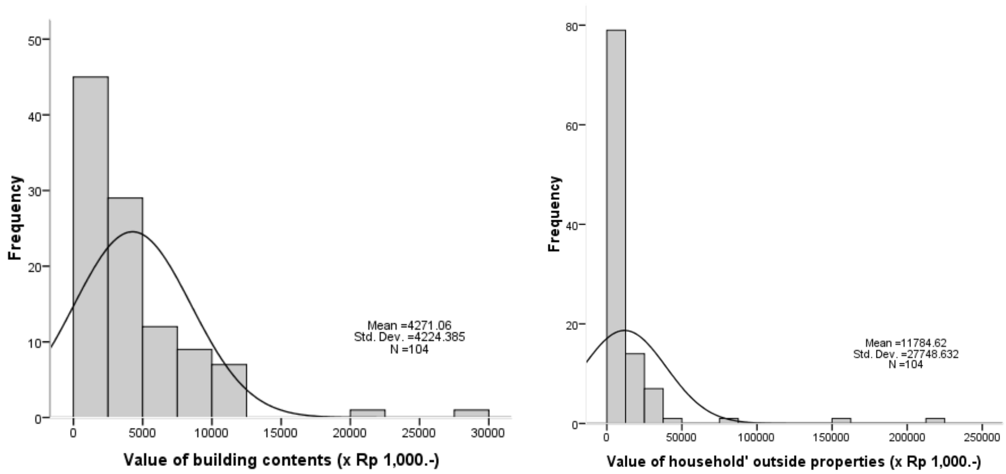
(a) (b)

Figure 6-18. Building contents (a) Outside property (b) in *Kelurahan* Sewu

During the flooding in the late December 2007, most of the households lost their property. The flood events occurred 3 times consecutively. In the first flood, 26 December 2007, the community did not expect that the height of flood reached 3 until 4 meters so that their belongings which were placed in the higher place about 1.5 meter in their houses were struck by flood. In the second flood, 28 December 2007, the height of water was 50 cm below the first flood but the velocity of water was faster. The community did not think that the flood would come again, so they cleaned up their belongings and dried them in open space. The arrival of flood was so fast, and their energy had been drained because of cleaning their belonging so that they did not have time to save their property which were eventually swept away by flood. In the third flood, 30 December 2007, the water height was not too high. There were no missing properties on this flooding.

Figure 6.19a shows the total value of building contents for all the respondents. It indicates a very high range from Rp. 530,000 for minimum value until Rp. 28,950,000 for maximum value. The most total values of building contents are less than Rp. 1,785,000. The average of total value of building contents is Rp. 4,271,000.

Total value of outside household property is from Rp. 0 until Rp. 220,400,000. It means that some respondents do not have any outside property and the others have cars as valuable property. The most value of outside property is Rp. 7,700,000 on the average of Rp. 11,784,000 (see Figure 6-19b).



(a) (b)

Figure 6-19. Total value of building contents (a) and outside property (b)

Total assets are meant the value of building contents plus the value of households' outside property. The assets of household building are correlated with its vulnerability due to flooding. The higher assets of household building have, the more vulnerable they are to flood hazard. Figure 6-20 depicts the total assets of the respondents in *Kelurahan* Sewu in which the most value of total asset is Rp. 9,299,000. Total assets have a high range from Rp. 600,000 until Rp. 229,850,000 with the average of the total assets Rp. 16,055,000.

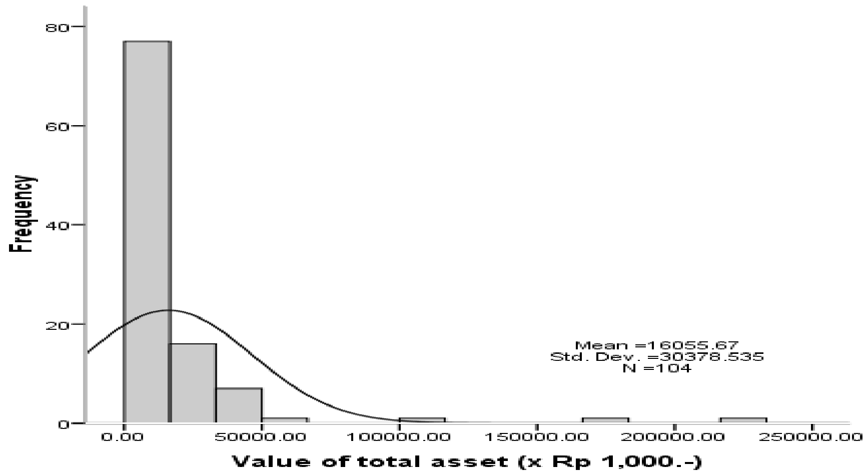


Figure 6-20. Total asset of respondents in *Kelurahan* Sewu

6.3. Information of Socio-economy of people at risk

Social, economic and political processes are the factors that generate people vulnerable to hazard. The people in community are proner than others to damage, loss and suffering due to flood depending on their characteristics which are class, caste, ethnicity, gender, disability, age, or seniority (Blaikie et al., 1994, Birkman, 2006). Bankoff et al. (2004) add such as sexual orientation, parenthood, location, mobility, and renters where they are associated with poverty, powerlessness, weakness, limited capacity and lack of resources of the people. In this research, the elements at risk in socio-economy of the respondents are emphasized on age, gender, occupation, income, educational level, period of stay, housing status, ownership of household building, and size of family. The other factors are ignored because of limited time and lack of data.

6.3.1. Age distribution

Based on the recorded data from fieldwork, the age of respondents is varied from less than 20 years (5%), 21-30 years (6%), 31-40 years (18%) 41-50 years (35%), and more than 50 years (36%) (see Figure 6-21). From the difference of age, it was found the difference of perspective of the people in order to cope the flood. For instance, one of the respondents who has the age of more than 50 years said that based on his experience if the water of flood meets on the intersection road in RW 5/RT 2, the big flood will occur so he should evacuate to the safer place.

In addition, the ages of family members were analyzed in order to know the distribution of the elder who have the ages of more than 65 years and the youngest who have the ages of less than 4 years. The elder and the youngest are more vulnerable due to flood hazard related to their mobility, access to resources and financial capacity. The data taken from 104 respondents were found 383 family members who consisted of 10 people or 3 percent at the ages of less than 4 years, 124 people or 32 percent at the ages of 4 until 24 years, 234 people or 61 percent at the ages of 25 until 65 years, and 15 people or 4 percent at the ages more than 65 years (see Figure 6-22).

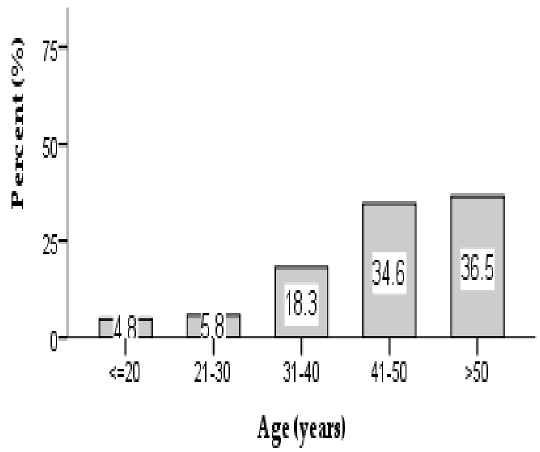


Figure 6-21. Age of respondents

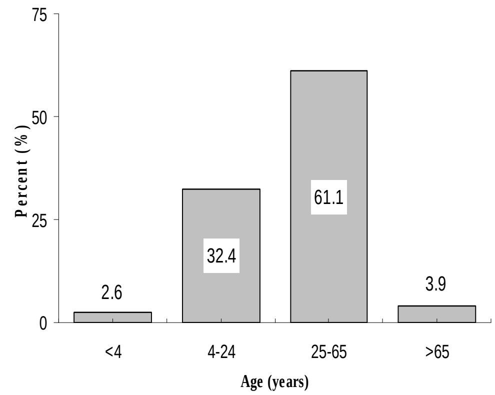


Figure 6-22. Age of family members

6.3.2. Gender distribution

Figure 6-23 shows the gender distribution of respondents in which the men more dominated rather than the women. This is because most respondents worked as retailer, tailor, shoe maker, etc. who work in their houses so during the interview activity the men still stayed in their houses.

In order to know the distribution of gender in *Kelurahan* Sewu, 383 family members were taken into account. The graph reveals that the gender distribution of family members between the men and the women is not very different. Almost 50% of family members were women who are vulnerable to flood hazard.

During the fieldwork, pregnant women were also taken into account, but nobody was pregnant in the family members of respondents.

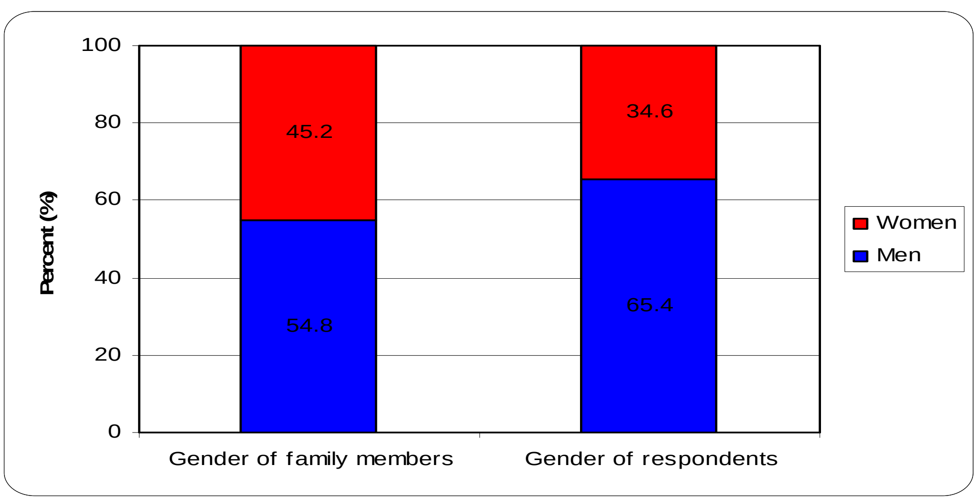


Figure 6-23. Gender distribution

6.3.3. The Livelihood

Almost 40% of the respondents work as laborers with minimum income such as industry workers, construction workers, etc. About 26 percent of the respondents work as a retailer and 15 percent is the other consisted of shoe maker, tailor, home industry (see Figure 6-24). Their products are sold to *Pusat Grosir Surakarta* (PGS) market which is a central of distributor market in Surakarta City located 1.5 km from *Kelurahan* Sewu and also to Klewer market which is located in the center of Surakarta approximately 3 km from the village. The remainder work as a housewife, transporter, civil servant, entrepreneur and retired (see Figure 6-25). The livelihood considers the ability of people to deal with the impact of the hazards to which they are exposed. During the flood in the late December 2007, the people whose houses were struck by flood did not go to work or work at home.

Figure 6-24. Livelihood of respondents

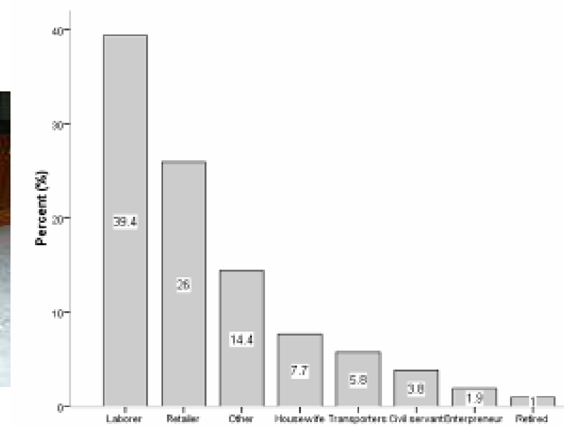


Figure 6-25. Distribution of livelihood of respondents

6.3.4. Income

Data recorded during fieldwork show that around 50 percent of the respondents have income less than Rp. 750,000. It can be assumed that almost a half of the respondents have a low-income because their income was less than the Regional Minimum Wage of Surakarta City which is about Rp. 723,000. They mainly worked as a tailor, pedicab driver, laborer, and home industrialist. 30 percent of households have income range Rp. 750,000 until Rp. 1,500,000 and only 20 percent have income more than Rp. 1,500,000 (see Figure 6-26). The medium income source usually comes from the retailer, driver, and retired, and the high income source is from the civil servant and entrepreneur.

Income represents ability of people to pay for services and resources that may not be readily available after a hazard impact. The rich are more easily able to find alternative shelter and to continue with their income-earning activities after disaster rather than the poor. Low-income households are more affected due to flood because they usually stay in the old buildings using low quality construction materials and methods and less well maintained.

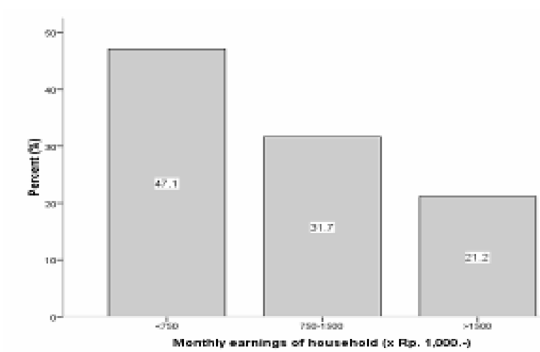


Figure 6-26. Income of respondents

Table 6-6 shows correlation between the income level of the respondents and their value of the building contents. It is important to note because the value of building contents usually associated with the income of households. It was found that low value of building contents is showed by people who have low income. On the other hand, the people who have high income have the high value of the building contents.

Table 6-6. The correlation between income and value of building contents

Level of income	N	Minimum	Maximum	Mean	Std Deviation
Low	49	530	4780	1920.61	1100.81
Moderate	33	630	7260	3705.45	1765.65
High	22	3870	28950	10355.55	5276.62
Total	104	5030	40990	15980.61	8143.08

The results of cross tabulation between income levels and expenses per day obtained the result that nearly 60% of respondents who have low incomes have monthly expenses exceed their income, while moderate and high-income around 20%. This described their financial condition to deal with flood events.

6.3.5. Educational Level

The majority of household obtained basic educational levels, around 63 percent of the respondents in *Kelurahan* Sewu were educated in elementary school and junior high school. Close to 32 percent were in senior high school and 2 percent were un-educated. Only 4 percent have education in university (see Figure 6-27). Educational level contributes to an explanation of people capacity to cope and deal with flood impact such as life expectancy and illiteracy. The educational level affects the ability of people to receive training and information about mitigation.

6.3.6. Period of stay

Figure 6-28 depicts that almost 62 percents of households live in *Kelurahan* Sewu over 20 years. The others have been living in the village about 11 percent since 1990-1995, 12 percent since 1995-2000, and 14 percent since 10 years recently. The longer people domicile in the area is, the higher their cultural knowledge, social network are which can assist them in order to reduce impact due to flood.

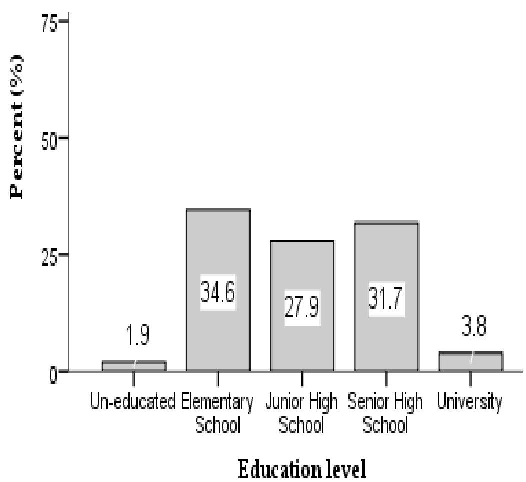


Figure 6-27. The educational level of respondents

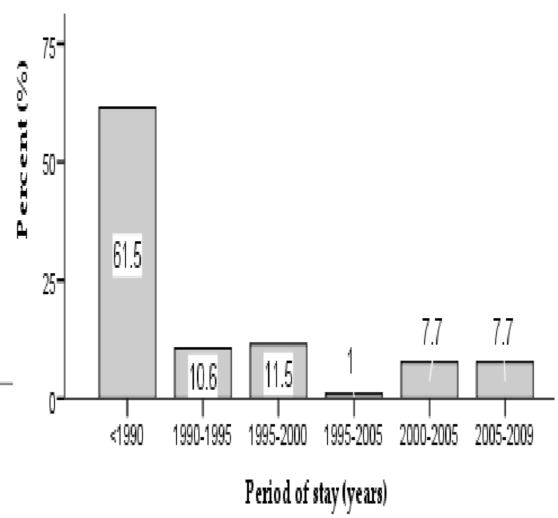


Figure 6-28. Period of stay in the village

6.3.7. Housing Status

The majority of the respondents in *Kelurahan* Sewu have their own houses, only 16 percent are rent the houses (see Figure 6-30). Figure 6-29 illustrates that most of the rent houses are located outside the dike, whereas the houses on the riverbanks have status as their own houses. Housing status is related with the action of people to cope flood like making coping mechanism or maintaining their houses.

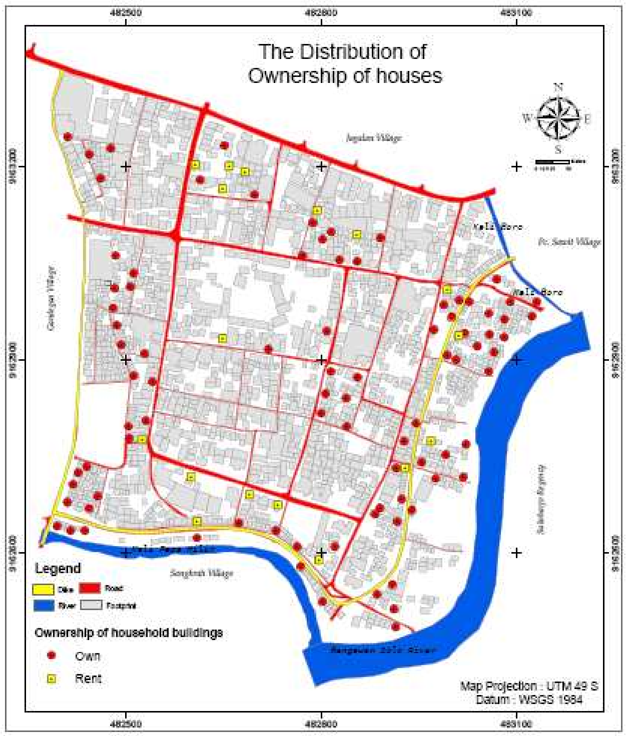


Figure 6-29. Distribution of ownership of houses

6.3.8. Size of Family

Based on the data gathered from fieldwork, close to 60 percent of total respondents are dominated by households with 3 until 4 family members. About 24 percent have more than 5 family members and only 16 percents of respondents have family members consisting of 1 until 2 persons (see Figure 6-31). Some of the respondents who have married still joint they parents in their houses so that it made one house consist of more than 2 households. The more their family members are the more vulnerable they are.

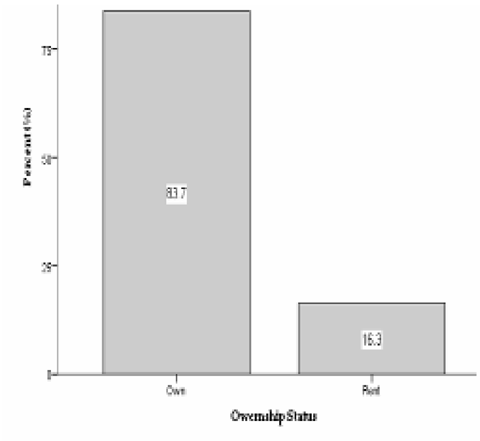


Figure 6-30. Ownership of household buildings

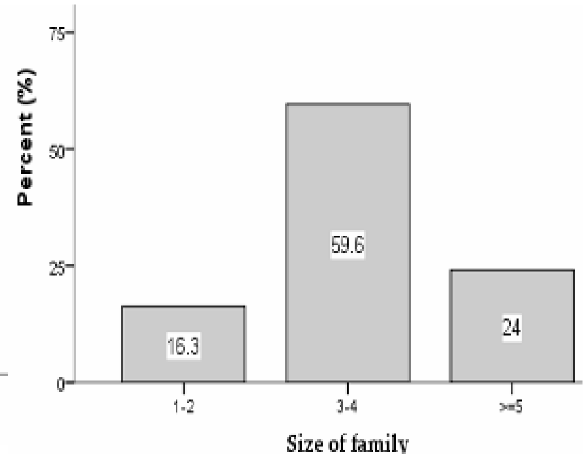


Figure 6-31. Size of family

6.4. Discussion

This chapter has explored the elements at risk related to flood hazard in the study area. The elements at risk is emphasized structural types of household buildings, building contents, outside property, and socio-economic of household.

Four common structural types of household buildings were found during the building inventory within *RT* sample. They were classified based on material of floor, wall, and roof. The four structural types were used to select respondents for interview using purposive sampling method as well as to assess the vulnerability of structural types of household buildings in vulnerability assessment in chapter 7. Although ceramic floor is easier to clean after flooding than the other materials, most household used concrete floor which is the floor made of a construction material composed of cement, water, and sand as well as refining in the surface. This condition occurred because most of them are low income; concrete floor is cheaper than ceramic floor and quite sturdy deal to flood. Majority of the household also use concrete material as their wall. It is related to the strength of this material to impact due to flood. Clay tile was the most widely used as roof material in the study area.

Based on the analysis of value of household building contents, most households have total values Rp. 1,785,000. The most of households have outside property value in the household building less than Rp. 7,700,000 Those value indicate the value of household building contents and the value of outside household property that could be damage due to flood.

Socio-economic of household in the study area related flood hazard is discussed in this chapter include age, gender, livelihood, income, educational level, period of stay, housing status, and size of family. The characteristics are deal with their weakness and capability to cope with flood hazard. About 10 percent of family members in the household building sample consist of the elder and the youngest where almost a half of total family members within the respondents are women. Almost a half of the respondents have low income level where they work as construction worker, industry worker, etc. Most of respondent only have basic educational level. On the other hand most of them live in the study area more than 20 years and stay in their own house so they have more widely social network and cultural knowledge about the study area and also they can maintain their own house to reduce the impact from flooding.

7. Analysis of Vulnerability Assessment to Flooding

This chapter focuses on the structural vulnerability to flooding related to the structural type of building, building contents and outside property based on damage assessment from the respondents. Subsequently, the section continues discussing social vulnerability of people in the study area regarding the socio-economic characteristics.

7.1. Vulnerability of Structural type of household building

Many parts of a building are considered in assessing physical vulnerability of a building such as the structural column, wall, floor, roof, door, window, ceiling, etc. This research examines the structure of household buildings based on the damage to floor, wall, and roof materials where the vulnerability of structural type of household buildings is determined on the basis of degree of damage for each material (floor, wall, roof) from the height of flood depth that occur in the study area and also the velocity of water related to building location.

The value of vulnerability for structural type of household building is expressed on scale between 0 (no loss at all) and 1(total loss) in order to quantify the expected damage reduction for several categories of elements at risk. This concept is established based on the definition of vulnerability from UNDRO (1991) that is mentioned before in Section 1.8.2.

Merz et al. (2004) explain several factors influenced flood damage such as water depth, contamination, flood duration, flow velocity and resistance factors like types of building, preventive measures, preparedness and warning. This research determines water depth and velocity (related to the location of the element inside or outside the dike) as the damage factors. It is important to derive a vulnerability factor from the most important vulnerability indicators contributing impact on the degree of damage produced during the flood event (Messner and Meyer, 2004).   .

During the fieldwork, the respondents reveal that the parts of household building structure that can be damaged during flood were floor, wall and roof materials. Structural damage is not only caused by the water depth and velocities but soaking and the weight of standing water, known as hydrostatic pressure also influential. The approach to estimate flood damage was conducted during fieldwork, estimating the damage from repairing and replacement cost and determining the damage based on Nothing Happening (NH), Half Collapse (HC), and Collapse (C) (see Appendix 1). In the first approach, the damage was expected to be in financial value using local currency or the cost for repairing or replacing the damage. Unfortunately, most of the respondents had not repaired the damage in their houses and some respondents could not remember the cost to repair and replace the damage due to flood. In the second approach, the damage is determined based on criteria as shown in Table 7-1.

Table 7-1. Description for damage class

Damage class	Damage description
Nothing Happening (NH)	If the materials do not get damage due to flooding
Half Collapse (HC)	If the materials get half damage due to flooding and need some reparations (painting, plastering, etc) but no structural damage
Collapse (C)	If the materials get structural damage due to flooding and need to be replaced

Adopted and modified from Sagala (2006)

The respondents were asked to define the damage based on these criteria. This approach is used to generate vulnerability assessment of structural type of household buildings in the study area.

Vulnerability scale for structural types of household building was established based on the damage information of floor, wall and roof materials (see Table 7-2) and the combination function of vulnerability scale shown in Appendix 5. The scale is adopted from Maiti (2007) who conducted research for flood structural damage using a floor-wall-roof combination as elements at risk. Figure 7-1 presents examples of damage to structural type of household building due to flooding.

Table 7-2. Vulnerability scale of structural type of household building

Vulnerability	Description
0 (No Damage or Nothing happening to wall, floor and roof materials)	If the materials (wall, floor, roof) do not get damaged due to certain level of flood depth.
0.2 (> Nothing Happening and < Half Collapse of wall, floor and roof)	If any one material (wall, floor, roof) or a half portions of that gets Half Collapse (half damaged) and the other two do not get damaged (Nothing Happening) due to certain level of flood depth.
0.4 (> Half Collapse and < Nothing Happening to wall, floor and roof materials)	If any two material (wall, floor, roof) or a half portion of those get Half Collapse (half damaged) and the other one does not get damaged (Nothing happening) due to certain level of flood depth.
0.5 (Half Collapse of wall, floor and roof materials)	If the three materials (wall, floor and roof) or a half portions of those get Half Collapse (half damaged) simultaneously due to certain level of flood depth.
0.6 (>Half Collapse and < Collapse or total damage of wall, floor and roof materials)	If any two materials (wall, floor, and roof) or a half portions of those get Half Collapse (half damaged) and the other one gets full damaged or total Collapse due certain level of flood depth.
0.8 (> Collapse or total damage and < Half Collapse of wall, floor and roof materials)	If any two materials (wall, floor and roof) or a half portion of those get total Collapse (total damage) and the other one gets Half Collapse (half damaged) due certain level of flood depth.
1 (Collapse or total damage of wall, floor and roof materials)	If full portions of the three materials (wall, floor, and roof) got total Collapse or total damaged simultaneously due to certain level of flood depth.

Figure 7-1. Examples of damage to structural of household buildings
(a) & (c) peeling plaster on the concrete walls (b) deteriorated paint on the concrete wall (d) warped on the plywood wall (e) cracked on the concrete floor (f) cracked on the brick wall

Althought *Kelurahan* Sewu have 9 structural types of buildings based on the inventory buildings as mention in Section 3.2.1, however only structural type 4, 5, 6, and 7 are dominant in this area (see Table 6-5). Levels of damage and flood depth data were plotted into the curve which illustrates the average vulnerability for each common structural type of household buildings in the study area. For this stage, the flood depths are measured from the height of water inside the house. Vulnerability curve for the four common structural types of household buildings are explained as follows:

a. Structural Type 4

Houses with structural type 4 are made from the combination of concrete floor-brick wall-clay roof material (see Figure 6-7 a). This structural type is not so vulnerable to water. However, the brick wall is prone to damage when the mud leaving the mark on the brick wall can not be cleaned. When the structural type is located in the area that is prone to water with high velocity like inside the dike, cracks will occur on the brick wall (see Figure 7-1 f) because the wall is not very sturdy and solid like concrete wall. This structural type starts getting damage from flood depth around 13 cm. It has half damage when flood water increases until around 200 cm. The materials of structural type 4 are almost entirely damaged from flood depth around 342 cm (see Figure 7-2)

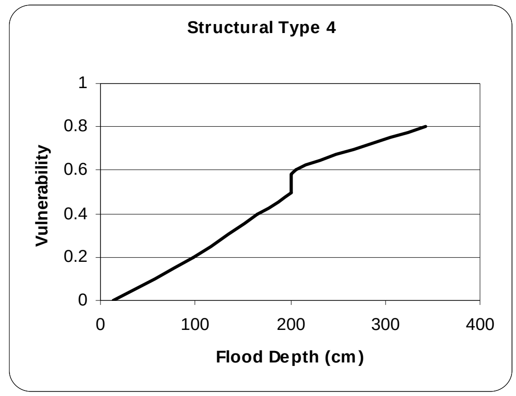


Figure 7-2. Vulnerability curve of structural type 4

b. Structural Type 5

Houses with structural type 5 are made from the combination of concrete floor-concrete wall-clay roof material (see Figure 6-7 b). This structural type is less vulnerable to water than structural type 4. The combination between concrete floor and concrete wall makes this structural type sturdy and solid to water. Some people only spent their money to repair holes (see Figure 7-1 a,c,e) due to the impact of flood water. This structural type starts getting damaged when it attached to water around 40 cm. When water increases inside the house around 271 cm, it has half damage (see Figure 7-3).

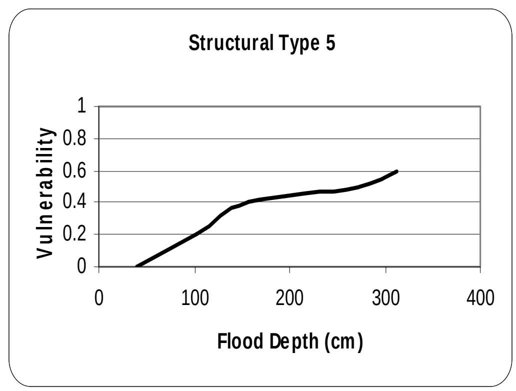


Figure 7-3. Vulnerability curve of structural type 5

c. Structural Type 6

Houses with structural type 6 are made from the combination of ceramic floor- concrete wall-clay roof material (see 6-7 c). This structural type is not vulnerable to water, which has a strong ceramic floor and a solid concrete wall. Some respondents spent their money for repainting or re-enforcing some holes on the wall. Ceramic floor is easier to clean after flood event and it is sturdier than concrete floor. So, the respondents do not spend much money to repair or replace this material (see Figure 7-4).

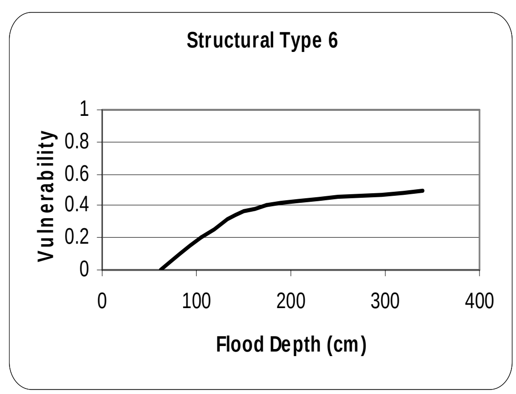


Figure 7-4. Vulnerability curve of structural type 6

d. Structural Type 7

Houses with structural type 7 are made from the combination of concrete floor-mixed wall-clay roof material (see Figure 6-7 d). Mixed wall is meant combination between brick or concrete material in the lower part and the other material e.g. wood, plywood, zinc and bamboo sheet in the upper part. This structural type is very prone to water. Plywood and bamboo sheet wall material absorb the water easily. When they dry the materials change their composition or shape like to splitting, warping, swelling or getting rotten. This structural type starts getting damage when it exposes to water. Subsequently, when water reaches until about 100 cm, the structural type gets half damaged. The materials of structural type 7 are totally damaged when flood water increases to 219 cm or more (see Figure 7-5).

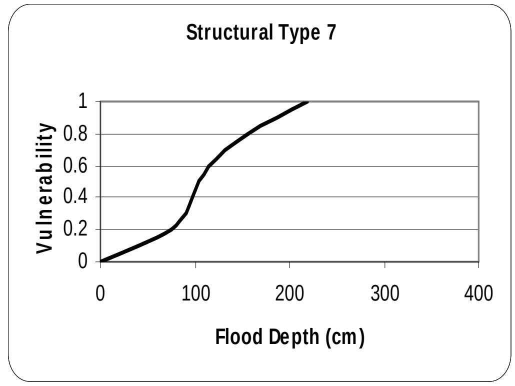


Figure 7-5. Vulnerability curve of structural type 7

Figure 7-6 depicts comparison of the vulnerability curves for four common structural types in the study area. It is found that houses with structural type 7 are the most vulnerable among all common structural types of household buildings in *Kelurahan* Sewu. There is similarity of vulnerability curves for two types of material for structural type 5 and 6 where they are the least vulnerable among all the common structural types of household buildings in *Kelurahan* Sewu.

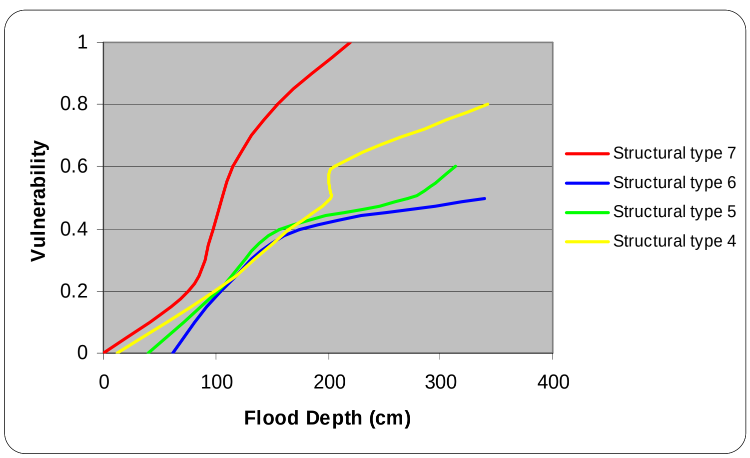


Figure 7-6. Comparison of vulnerability curves for all structural types

Based on the analysis above, for analysis all structural types of building, it can be concluded that structural type 1 (ground, bamboo, asbestos) and structural type 9 (ground, bamboo, zinc) are the most vulnerable among all structural type of building in *Kelurahan* Sewu although the numbers are less than one percent (see Table 6-5). Both of the structural types are more vulnerable than structural type 7 because the structural types consist of ground floor material which is easily eroded by flood water and bamboo sheet wall material which is very easily absorbing flood water and change their composition or shape. Structural type 3 (concrete, mixed, zinc) and structural type 8 (concrete, wood, clay) have materials nearly the same with structural type 7 so that their vulnerability is same as structural type 7. Structural type 2 has materials nearly the same with structural type 5 so this building is less vulnerable to flood hazard. Figure 7-7 depicts the uncommon structural types of household building in *Kelurahan* Sewu.

(a) Type 1 (b) Type 2 (c) Type 3 (d) Type 8 (e) Type 9

Figure 7-7. The uncommon structural types of household building in *Kelurahan* Sewu

In order to get the final vulnerability assessment, the position of household building from the dike should be taken into account. It relates to the influence of water velocity against the building. The buildings which are located inside the dike are more susceptible from high velocity of flood than the buildings which are situated outside the dike. Therefore, in order to make higher the vulnerability class of household buildings inside the dike, the researcher adjusted the value of vulnerability of household buildings inside the dike to be one class higher than the value of vulnerability of household buildings outside the dike. The researcher decided to put value 0.4 (based on the value of interval class of vulnerability see Table 7-4). Then, the vulnerability value from the structural types of household building which were located inside the dike is added with the value 0.4 so that the building inside the dike is more vulnerable than the building outside the dike which is not added (see Table 7-3).

Table 7-3. Final vulnerability value of building structure

Value of vulnerability of building structure	**Combine if function**	**Final vulnerability value**
0	If(vuln="0"and location="outside_dike"), "0")	0
	If(vuln="0"and location="inside_dike"), "0.4")	0.4
0.2	If(vuln="0.2"and location="outside_dike"), "0.2")	0.2
	If(vuln="0.2"and location="inside_dike"), "0.6")	0.6
0.4	If(vuln="0.4"and location="outside_dike"), "0.4")	0.4
	If(vuln="0.4"and location="inside_dike"), "0.8")	0.8
0.5	If(vuln="0.5"and location="outside_dike"), "0.")	0.5
	If(vuln="0.5"and location="inside_dike")	0.9
0.6	If(vuln="0.6"and location="outside_dike")	0.6
	If(vuln="0.6"and location="inside_dike")	1
0.8	If(vuln="0.8"and location="outside_dike")	0.8
	If(vuln="0.8"and location="inside_dike")	1
1	If(vuln="1"and location="outside_dike")	1
	If(vuln="1"and location="inside_dike")	1

The final vulnerability map for structural type of household buildings in *Kelurahan* Sewu is shown in Figure 7-8. This map was acquired after classifying the value in different categories such as no vulnerability, low vulnerability, moderate vulnerability, and high vulnerability (see Table 7-4).

Table 7-4. Final vulnerability class for structural types of household buildings

Vulnerability Class	Value of Vulnerability
No Vulnerability	0
Low Vulnerability	0.1 – 0.3
Moderate Vulnerability	0.4 – 0.7
High Vulnerability	0.8 – 1

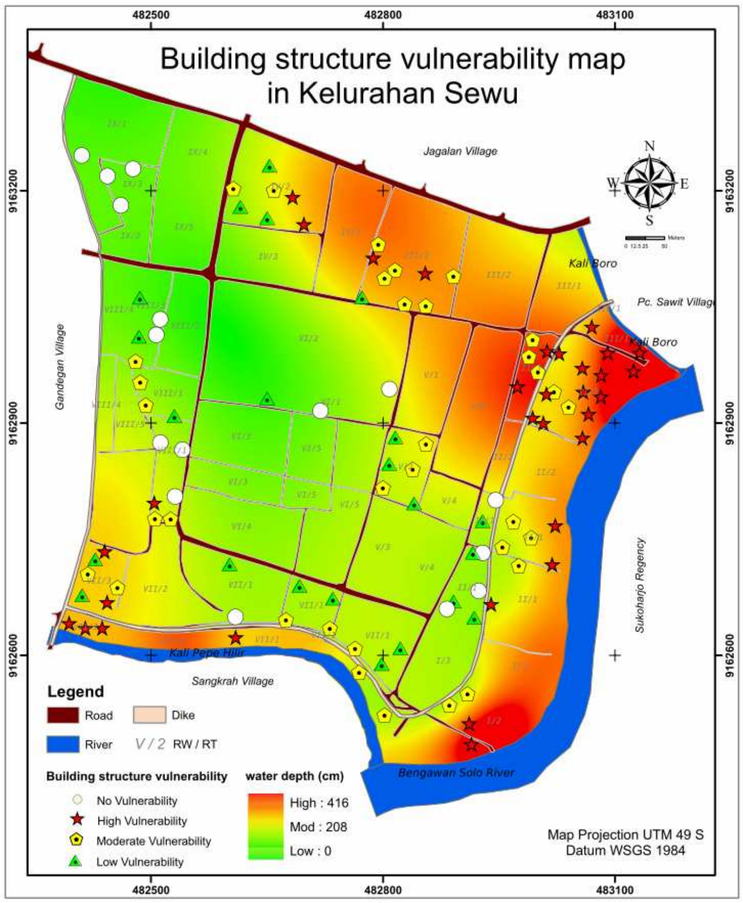


Figure 7-8. Vulnerability Map of structural household buildings

7.2. Vulnerability of Building Contents and Outside Property

7.2.1. Vulnerability of Building Contents

The damage of building contents was recorded from interviews to 104 respondents including the cost for repairing and replacement as well as the damage itself (see Appendix 1). Similarly to the damage to structural household building, most respondents could not estimate the money their spent to repair and replace the damage of building contents because they had not repaired the damage for their belongings or they could not remember the cost for repairing and replacing the damage of building contents due to flood. The respondents still remember the damage to their belongings and mention the kinds of their belongings affected by flood. Figure 7-9 shows the damage of building contents when flood occurred in the late December 2007.

(a) (b) (c) (d)

Figure 7-9. The damage of building contents: (a) electronic device do not work (b) wooden furniture may become so badly warped (c) furniture and electronic device had damage (d) the document was soaked

Table 7-5 depicts the common damage on the household building contents due to flood in the late December 2007. Only 15 respondents did not suffer any damage on their belongings. Most damage of household building contents were wet clothes and dirty or smelly furniture. The other forms of damage were loss of kitchen utensils, wet pillows and mattresses, broken electronic devices and loss of some documents.

Table 7-5. Damage cases on building contents within 104 respondents

Damaged appliances	Cases	%	Damaged Furniture and document	Cases	%
~ Clothes become wet and soaked	81	40	~ Dirty and smelly furniture	79	46
~ Loss of kitchen utensils	60	29	~ Pillows and mattresses get wet and dirty	65	38
~ Electronic devices do not work any more	48	24	~ Loss of some documents	14	8
~ No Damage	15	7	~ No Damage	15	9
Total	204	100	Total	173	100

The methodological approach to estimate vulnerability of building contents is developed based on consistency of circumstance and the way of living existing in the study area that was gathered through interview and observation during fieldwork. Therefore some assumptions were also established before defining the loss functions i.e.:

- The list of building contents is made based on the income level and socio economic condition such as low income, medium income and high income.
- The list of building contents considered the major furniture and appliances that are located in bedrooms, dining/lounge rooms and kitchens.
- Three socio-economic levels were assumed to have different value of building contents (see Table 6-5). Therefore, the item was divided into three lists. Although one item can be presented in all socio-economic classes, the price of item varies according to the income level. The price for item was obtained from shops in Surakarta City (see Table 7-6). The price present in Table 7-6 is an average rate in some shops in Surakarta City.

Table 7-6. Contents estimation based on the income level of the household building

Item	Low Income (1) (x Rp 1,000)	Moderate income (2) (x Rp 1,000)	High income (3) (x Rp 1,000)
TV	500	1000	1500
Stove	50	300	1000
Refrigerator		1200	2000
Video/DVD		500	1000
Tape/Radio	300	300	1000
Computer set			4000
Washing machine			1500
Air Conditioner			1500
Carpet		150	350
Dinning Set		300	500
Iron	100	150	200
Chairs	50	100	150
Curtain	50	100	150
Bed	100	500	1000
Electric fan	80	150	200
Rice cooker	100	150	400
Telephone		200	200
Sofa		1000	3000
Table	150	200	500
Cupboard	500	750	1500
Total	**1980**	**7050**	**21650**

Note: 1 euro = Rp.14,300

The height position of the major building contents was taken into account during the fieldwork (see Appendix 1). Majority of respondents placed the electronic equipments with a height of more than 1 meter, especially television is around 1.5 meters. The other appliances and furniture was not raised. This information is used to estimate the item vulnerability of buildings contents in Appendix 3.

Based on the result in Table 7-5, the damage of household building contents was classified into five classes: No Damage, Slightly Affected, Moderately Affected, Highly Affected, and Destroyed (see Table 7-7).

Table 7-7. Damage stage of building contents

Damage Class	Damage Code	Description
No Damage	0	No water inside the dwelling
Slightly Affected	1	Minor losses particularly clothes, shoes, chair, table and cupboard get dirty and smelly due to soaking wet and people does not need repairing and replacement cost.
Moderately Affected	2	Moderate losses particularly clothes, chair, table, and mattresses get rotten due to soaking wet and people need cost to repair.
Highly Affected	3	Almost total loss of the contents, especially furniture, equipment, kitchen utensils, cupboards etc. and people needing repair cost and some replacement cost.
Destroyed	4	Total loss of the content, mainly electronic devices, furniture, kitchen utensils etc. and people needing cost to replace.

Adopted and Modified from Guarin (2003)

The damage of building contents was considered with different flood depth. The relationship between the damage level from the respondents and flood depth was plotted into the graph (see Figure 7-10).

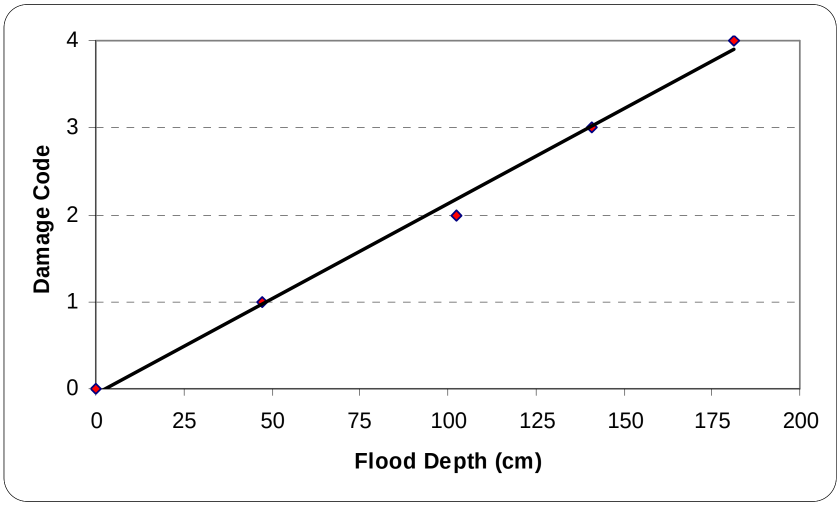


Figure 7-10. Damage estimation of building contents correlated with flood depth

From the graph, the values of flood depth for five classes of damage were obtained as shown in Table 7-8.

Table 7-8. Correlation between damage stage of building contents and flood depth

Damage class (code)	Flood depth (cm)
No Damage (0)	0
Slightly Affected (1)	< 45
Moderately Affected (2)	< 85
Highly Affected (3)	< 130
Destroyed (4)	>130

For each flood depth, the vulnerability for each item of building contents, which is depicted in Table 7-6, was calculated. The damage information gathered from respondents was taken into account as the percentage of expected damage. Then, the percentage of expected damage was multiplied by the value of each item. After that, the vulnerability value (from 0 to 1) for each flood depth was calculated by summing up the subtotals and dividing by the total price of the list (see Appendix 3). The summaries of the calculation for the vulnerability of building contents are shown in Table 7-9.

Table 7-9. Vulnerability value for household building contents

List	< 45 cm	<85 cm	<130 cm	>130 cm
1	0.12	0.23	0.67	1
2	0.22	0.45	0.82	1
3	0.23	0.43	0.84	1

Based on the result Table 7-9, Vulnerability value of building contents for each household building in *Kelurahan* Sewu was created.

The vulnerability map for household building contents in *Kelurahan* Sewu is shown in Figure 7-11. This map was acquired after classifying the value in different categories such as no vulnerability, low vulnerability, moderate vulnerability, and high vulnerability (see Table 7-10).

Table 7-10. Vulnerability class for household building contents

Vulnerability class	Value of Vulnerability
No Vulnerability	0
Low Vulnerability	0.1 – 0.3
Moderate Vulnerability	0.4 – 0.7
High Vulnerability	0.8 – 1

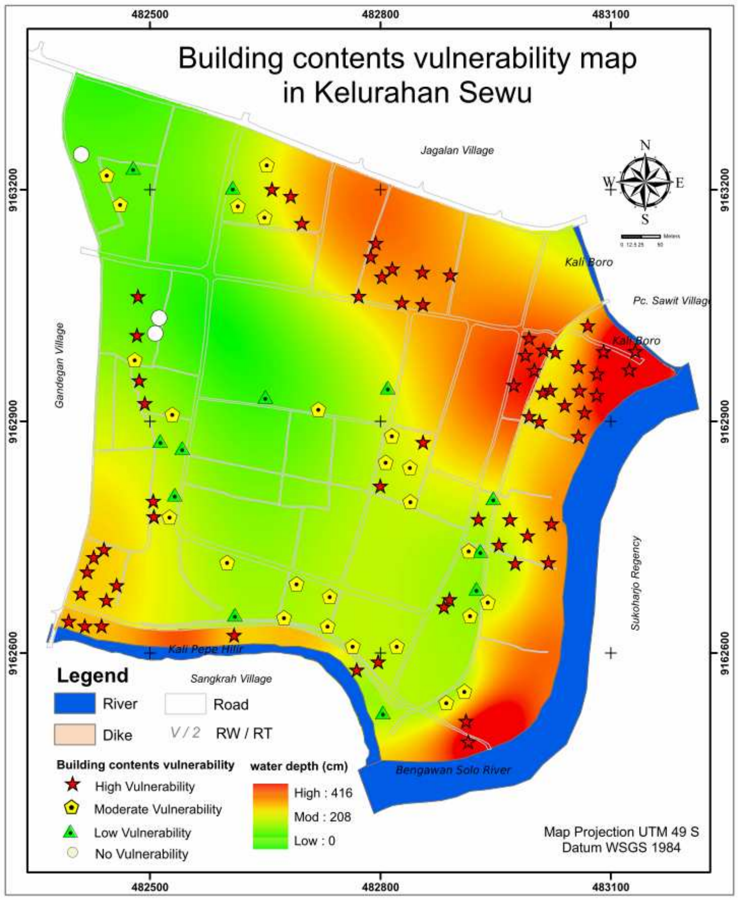


Figure 7-11. Vulnerability map of household building contents

7.2.2. Vulnerability of Outside Property

The damage value of outside property was recorded from interviews to 104 respondents including the cost for repairing and replacing as well as the kind of damage itself (see Appendix 1). During the flood in the late December 2007, there were twelve damage events to outside property due to flood based on being reported from the respondents (see Figure 7-12). From 104 respondents, 92 respondents did not suffered losses of outside property. The common damages within 12 damage events happened to the animal (3 respondents) and the motorcycle (6 respondents) and the rest happen on bicycle (2 respondents) and car (1 respondent). During the interview, the damage also was estimated by the respondents into the value of damage in Rupiah. The damage value of outside property shows a very high range from Rp. 50,000 until Rp. 2,000,000. All the damage happened to the buildings which are located on the outside of the dike. It means that some of the respondents whose houses are outside the dike did not expect the height of flood.

Figure 7-12. Damage of outside property

Vulnerability of outside property is calculated from value of outside property divided with total value of outside property. The vulnerability values of the outside property on 12 damage events have a very high range from 0.0025 to 0.5 (see Table 7-11).

Table 7-11. Vulnerability value of outside property within 12 damage events

No	Respondent Code	Water Depth (cm)	Outside Property Value (x Rp 1,000)	Damage Value (x Rp 1,000)	Vulnerability Value
1	61	70	30500	75	0.0025
2	102	140	15500	50	0.0032
3	48	113	10000	100	0.0100
4	50	199	10200	200	0.0196
5	21	330	22000	500	0.0227
6	5	126	2200	100	0.0455
7	6	95	10000	500	0.0500
8	47	120	1000	75	0.0750
9	56	210	27000	5000	0.1852
10	17	190	220400	50000	0.2269
11	20	160	2200	500	0.2273
12	10	128	4000	2000	0.5000

Table 7-11 shows that there is no correlation between the value of outside property and the value of damage as well as water depth. This condition shows that the damage to outside property depends on their preparedness and capability to deal with flooding. Because of that, a vulnerability function cannot be generated due to lack of data and the damage does not affect many respondents in the study area. Spatial distribution of the damage of outside property during the flood event in the late December 2007 is shown in Figure 7-13.

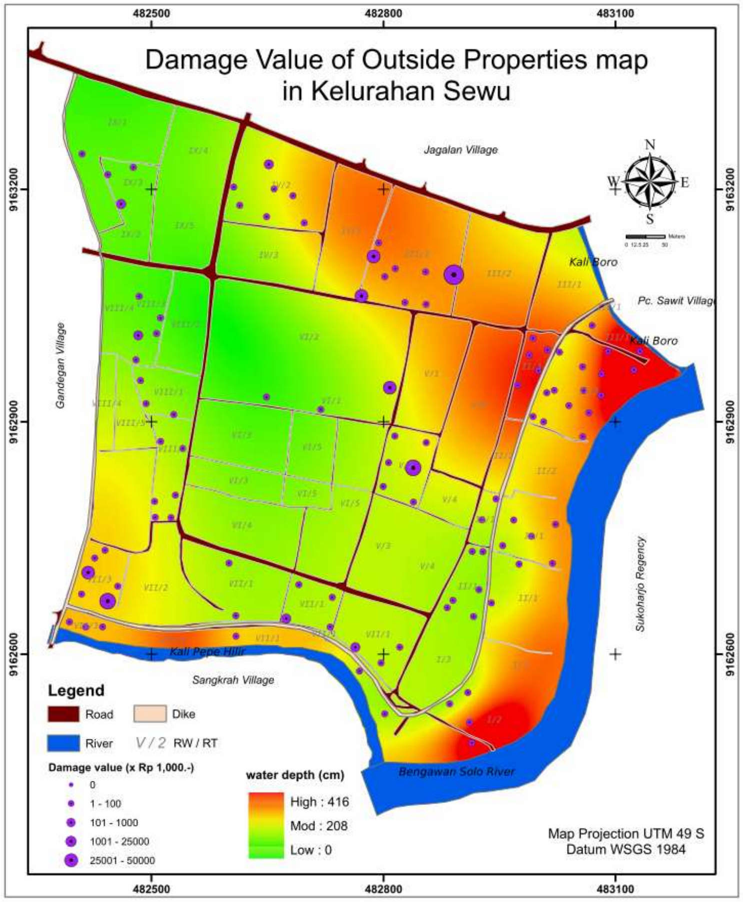


Figure 7-13. Damage value map of outside property

7.3. Social Vulnerability of People

According to Blaikie et al. (1994) social vulnerability means the probability of identifiable persons or groups lacking the capacity to anticipate, cope with, resist and recover from the impact of a hazard. Several factors that generate people more vulnerable than others are explained in Section 6.3, such as class, gender, age, etc. The elements at risk information gathered from 104 respondents were collected during the fieldwork emphasized on age, gender, livelihood, income, educational level, period of stay, housing status, ownership of household building, and size of family. This information is used to assess social vulnerability of people in the study area.

This section explores quantitative method of assessing the vulnerability of the households in the study area due to flood hazard. Dwyer et al. (2004) explained that vulnerability cannot be determined by one factor but a combination of many factors will influence people to more vulnerable due to a certain hazard. They gave an example when an elderly person would increase their vulnerability not only because of age but also if the accompanying condition that he or she lives alone, on being disabled, and low income. However, if he or she lives with another person, has health insurance, and has a very high level of savings their vulnerability may decrease. Therefore, the weighting factors should be taken into account to combine the vulnerable factors.

The eight socio economic factors including age, gender, livelihood, income, educational level, period of stay, housing status, and size of family have been analyzed in order to estimate and identify the most vulnerable factors when they are combined. From those socio economic factors, it is assumed that the most important socio-economic vulnerability factor is income level because it is reasonably straightforward in the way to affect the vulnerability. It is not only related with financial capacity of a household to recovery but also financial preparedness and mitigation related to flood hazard. The second most important factors are livelihood and period of stay. They are linked with the aspect of the abilities to recover from flood hazard. People working at home is more difficult to recover than those who work in other places as well as those who have long lived in the area to recover faster than new people because they have wider social network and cultural knowledge in the area. The next most important factors are size of family and gender. They are related with the way when they face with the flood hazard. People living alone will be less likely to have an immediate support network when he or she faces with flood hazard. Women are more vulnerable than men because they need help for being evacuated from men during flooding. The lower weighting factors for socio-economic vulnerability are age, educational level, and housing status because those factors are very influenced by the other factors as mentioned before. The weighting matrix of social vulnerability of household is shown in Table 7-12.

Table 7-12. The weighting matrix of social vulnerability of household

Social vulnerability factors		**Low**	**Moderate**	**High**
	Weight	**1**	**2**	**3**
Income	0.11	High income	Moderate income	Low income
Livelihood	0.05	Not working at home		Working at home
Period of stay	0.05	>10 years	5-10 years	< 5 years
Size of family	0.03	2-4 persons	1 persons	>=5 person
Gender	0.03	% women of < 33% in family members	% women of 33%-66% in family members	% women of 66%-100% in family members
Age	0.02	4-65 years	<4 years	>=65 years
Educational level	0.02	Senior high school, Bachelor	Elementary school, Junior high school	Un-educated
Housing status	0.02	Owner		Renter

$$V_{social}=(0.11x3)+(0.05x3)+(0.05x1)+(0.03x2)+(0.03x2)+(0.02x3)+(0.02x3)+(0.02x1)$$

= 0.79 → example of the social vulnerability calculation

This approach is adopted from Villagran (2006) where the method is applicable for the housing sector at the local level. This method is required parameters which are directly related to the type of vulnerability. It is simple, understandable and applicable in order to measure vulnerability at the local level. In this research, the social vulnerability of a household is generated through eight parameters as mentioned above.

The classification in terms of low, moderate, and high classes is introduced in term of socio-economic condition that is related to degree of vulnerability. The value of classification is given value 1 for low, 2 for moderate and 3 for high as shown in Table 7-12

Each parameters/factor is given weighting based on the importance for vulnerability as seen in Table 7-12. The weighting was created by using the Analytical Hierarchy Process (AHP) in ILWIS tools based on the most important factors. The eight factors were pooled together and weighted to obtain a single estimate across all effects. Income was given the highest weight (0.11 equal to 36% from total weighting). Length of stay and livelihood were given equal weights (0.05 equal to 18% from total weighting). Size of family and gender were given equal weight (0.03 equal to 8% from total weighting), and age, educational level, and housing status were given equal weights (0.02 equal to 4% from total weighting). The value of vulnerability for social vulnerability is expressed on scale between 0 and 1 so that if the total weighting factor (0.33) is multiplied with the highest classification (3), the result should be 1.

The overall social vulnerability for each household is obtained as a result of added score of each parameter that multiplied by the classification before (see the example of calculation above). The vulnerability class is presented in low, moderate, and high (see Table 7-13). The interval class is obtained from the higher score in weighting minus the lower score divided by the number of classes. The result of social vulnerability for 104 households has been displayed in a map using ArcGIS tools (see Figure 7-14).

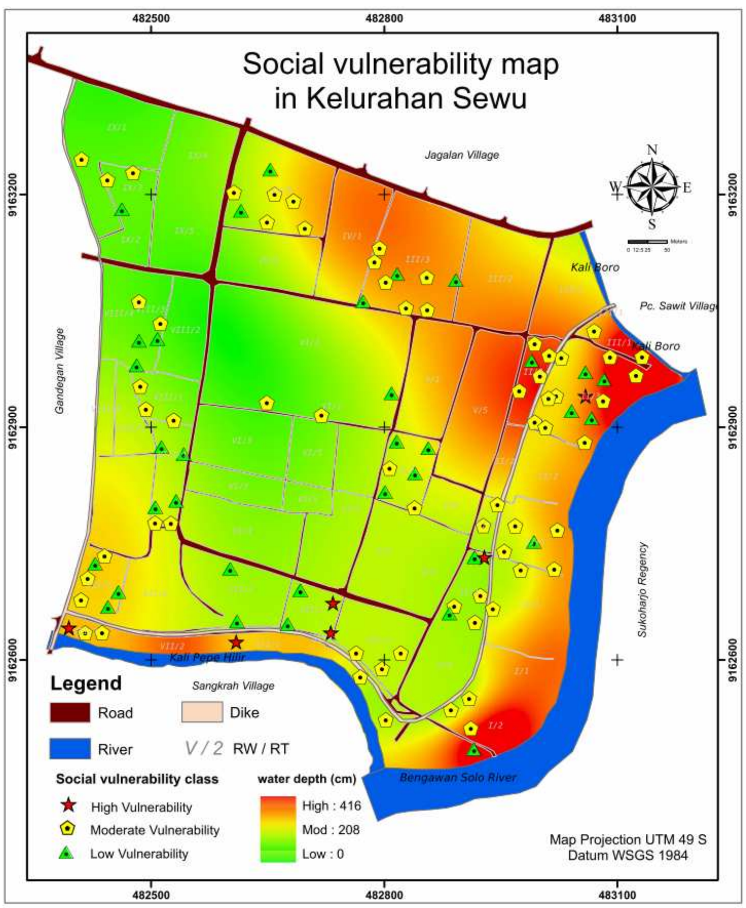


Figure 7-14. Social vulnerability map

Table 7-13. Vulnerability class for social vulnerability

Social Vulnerability class	Value of Vulnerability
Low Vulnerability	0.34 – 0.55
Moderate Vulnerability	0.56 – 0.77
High Vulnerability	0.78 – 1

7.4. Discussion

The vulnerability assessment has been discussed in this chapter. The assessments include vulnerability of structural type of household building, vulnerability of building contents and outside property as well as socio-economic vulnerability of people within a household.

It is found that the structural type 7, which consists of the combination of concrete floor-mixed wall-clay roof material, is the most vulnerable to flood among four common structural types of household buildings in the study area. However, the most vulnerable to flood among all structural types of building in *Kelurahan* Sewu is structural type 1 and 9 although there are not many. These types are made from the combination of ground floor-bamboo wall material. The structural type 6 is the least prone to flood. It is made from the combination of ceramic floor-concrete wall-clay roof material. It shows the relationships between the vulnerability of structural type of building and the flood-depth to the structural types of the household building.

Vulnerability of building contents is strongly linked with socio economic level of the head of household. The higher the socio economic level of the head of household is, the more the value of household building contents is so that the greater the degree of loss of building contents is when facing flood. Three lists of asset related to the three socio economic level were employed to assess vulnerability of household building contents in the study area. The relationships among socio economic level, flood depth, and losses are described clearly in this section.

In analysis of vulnerability of outside property, there were only 12 households suffering damage and loss of outside property. Therefore, although the respondents remembered the value of losses and translated into rupiah, the vulnerability function of outside property can not be generated caused very few of events. It can be assumed that the damage and losses of outside property depends on the people preparedness and capability of facing flooding.

Eight parameters including income, livelihood, period of stay, size of family, gender, age, educational level, and housing status have been weighted to generate social vulnerability of the households in *Kelurahan* Sewu. The combination of these factors can be especially valuable for estimating and identifying the most vulnerable household in the study area. It was found that only a few households have high vulnerability, most of households have moderate and low vulnerability for socio economy. It is likely that only a few households have average moderate and high vulnerability on each parameter, while the other households have a high vulnerability on one parameter. It can be summarized that why the people still live in this areas (flood prone areas) because the reason is not only because of owner property, cheap house, and better access to economic activity but also their combination of social vulnerability to flood hazard is not so high. In addition, their capabilities such as organizations and local traditions as described in the previous chapter also support.

8. Conclusion and Recommendation

This chapter contains the concluding part of this research related with the objectives of this thesis. Finally, this chapter suggests some recommendations of the further research.

8.1. Conclusion

The main objective of this study is to evaluate the community characteristics, to map the flood danger, to assess elements at risk and vulnerability of flood based on community approach in *Kelurahan* Sewu, Surakarta City-Indonesia. Following discussions are based on the specific objectives introduced in the first chapter of this thesis.

The first sub objective is to evaluate the community characteristic for social vulnerability of floods. To obtain this objective, the activities have been undertaken not only collecting secondary data and observation in the field but also following Focus Group Discussion (FGD). It was found that some of the communities lived on the riverbanks with unorganized housing and some of them are standing on the state land, illegal house. Although the comparison between women and men in *Kelurahan* Sewu looks balanced, the age distribution showed that one-fifth of them are vulnerable to flooding consisting of the youngest with the age of below 4 years and the elder with the age of over 65 years. A half of the people in the study area have low income, and one-third of them are uneducated. On the other hand, the community has their capacity to deal with flood hazard through social organizations and local traditions. Social organizations exist in this area such as PKK (the motherhood organization), Karang Taruna (Neighborhood youth association), and Arisan Bapak-bapak (the fathers' community). Local traditions exist in this area such as *kerja bakti* or *gotong royong* and *ronda*. Both of them can help community to alleviate for recovery during and after flooding.

The second sub objective is to create a flood danger map based on the 2007 flood event which includes community knowledge. In order to respond this objective, the representative sampling method has been generated based on structural type of household buildings considering the distance with the dike near the river and the contour. Participatory GIS was employed to get information about flood depth, flood duration and cause of flood based on community knowledge and experience. Both of those processes were found to be useful in this research. First, the sampling method provided a very accurate way of generating a comprehensive sampling frame for selected respondents. Second, Participatory GIS served an accurate flooding map in the study area.

It is found that flooding in *Kelurahan* Sewu have occurred a long time. There were two characteristics of flooding in *Kelurahan* Sewu, the seasonal flooding and the flood disaster. The seasonal flooding has characteristics that the flood depth was 50-100 cm and the duration was 12 hours until 3 days. The flood disaster has characteristics that the water height reached 4 meters and duration was more than 3 days (like the greatest flood occurring in 2007 after the big one in 1966). 8 *Rukun Tetangga (RT)* are the most prone area to seasonal flooding in *Kelurahan* Sewu such as *RW* I *RT* 1, *RW* II *RT* 2, *RW* III *RT* 1 and *RT* 3, *RW* IV *RT* 1, *RW* V *RT* 5, *RW* VII *RT* 2 and *RT* 3 (see Figure 5-1).

Flooding in the study area is strongly related to the occurrence of heavy rainfall not only in this area but also in the upper part of Bengawan Solo River basin as well as due to lack of drainage system, lack of flood control structures, and watershed degradation in the upper part of Bengawan Solo River basin. Flooding in the late December 2007 inundated almost all area of *Kelurahan* Sewu (see Figure 5-11) where it was recorded the rainfall amount of 124 mm/day and the discharge of Bengawan Solo River of 1,986 m^3/second. In addition, Putat Water gate got damaged so the water from Bengawan Solo River flowed through the gate to inundate the village. The return period of flood has been calculated based on the data of discharge from 1966 to 2007 using Gumbel method. The result shows that flooding in the late December 2007 is equal to return period 65 years.

Finally, a flood depth and a duration map for the 2007-flood event in the late December 2007 have been generated using kriging interpolation of the points data set with Gaussian semi-variogram model. The interpolation was divided into two interpolation area, inside Dike II and outside Dike II, because the water has not been overtopped Dike II during the flooding in the late December 2007. The maps show that the water height ranged from 0 until 4 meters and the duration varied from 0 to 7 days. When the result is compared with the technical risk assessment map, it seems the same with the return period 20 years. It is because the technical risk assessment map did not consider structural measures like the dike and the water gate which are laid in this area.

The third sub objective is to identify and classify the elements at risk, i.e. type of buildings, building contents, outside property, and socio-economy of people. To answer this sub-objective, taking building inventory and interviewing respondents have been conducted to identify and design the detail classifications of elements at risk such as structural type of household building, household building contents and outside property as well as the people at risk. The structural types of household building are classified into four based on the common structural type of household building in the study area. The building contents including appliances and furniture inside the house and the outside of property which are all household assets outside the house are grouped into one element based on its value. The people at risk are identified through socio-economic aspects such as age, gender, livelihood, income, educational level, period of stay, the housing status, and the size of family.

The fourth sub objective is to assess the vulnerability related to elements at risk (structural type of buildings, building contents, outside property and socio-economy of people). To achieve this objective, several approaches have been carried out. The vulnerability of structural type of buildings is determined by the materials of the house including floor, wall, and roof materials. From four common structural types of household buildings in *Kelurahan* Sewu, the most vulnerable to flooding is structural type 7 which is made from the combination of concrete floor-mixed wall-clay roof material. The houses with structural type 4 which is made from the combination of concrete floor-brick wall-clay roof material are the moderate vulnerable. The least vulnerable to flood is structural type 5 (the combination of concrete floor-concrete wall-clay roof material) and structural type 6 (the combination of ceramic floor-concrete wall-clay roof material). However, the most vulnerable among all structural types of buildings in study area is structural types 1 and 9 which are made from combination ground floor and bamboo wall. From vulnerability curve, it clearly shows that the first 200 cm is the crucial height of flooding. The mixed wall (structural type 7) almost gets totally damaged in this height while brick and concrete material (structural type 4, 5, and 6) start to get half damage.

The vulnerability of building contents in the study area varies from 0 to 1. This value means the percentage of losses of household building contents related with the height of water and the socio-economic level. The estimation of housing contents was supported by local knowledge and particular conditions of the study area.

The vulnerability functions of outside property cannot be generated caused very few of damage events. It can be assumed that the damage and losses of outside property depends on the people preparedness and capability of facing flood.

The vulnerability of social economy of people in *Kelurahan* Sewu has been analyzed by using several parameters such as age, gender, livelihood, income, educational level, period of stay, housing status and size of family. Subsequently, each parameter was weighted based on its impact on social vulnerability. The combination of these factors can be especially valuable for estimating and identifying the most vulnerable household in the study area. The result of combination of socio economic factors shows that only a few household have high vulnerability, most of households have moderate and low vulnerability for socio economy. It can be summarized that why the people still live in this areas (flood prone areas) because their combination of social vulnerability is not so high.

8.2. Contribution of this research

This research provides contribution as follows:

~ The methodology of this research can be adopted by local government to deal with data collection for disaster management because it is simple, applicable and cheap method.

~ The vulnerability assessment of structural type of building, building contents, outside property and social vulnerability of people provide valuable information to local government in order to make policies related to flood risk management in the study area or the other similar areas in order to reduce the impact of flood hazard.

~ The result of this research shall support the flood disaster management program in *Kelurahan* Sewu in order to mitigate the negative impact of flooding

8.3. Recommendation for further research

Recommendations for future research are as follows:

~ In order to enhance the accuracy of the research on flood hazard assessment, further research in the study area should also take into account the community based on risk assessment with the technical risk assessment that considers structural measure like dike and watergate.

~ Since the flood depth and flood duration maps for the flood in the late December 2007 were established in this research, further research may generate flood hazard maps with different return periods (e.g. 5, 10, 100 years event) in order to establish flood hazard zone in the study area.

~ Damage functions for assessment of loss of outside property should be developed with different approach from damage event.

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Appendix

Appendix 1. The Questionnaire

Interview No:

VILLAGE HOUSEHOLD SURVEY 2009
Geo Information for Spatial Planning and Disaster Risk Management. UGM - ITC

Purpose: This survey is intended to study "A Community-based Approach to Flood hazard and Vulnerability assessment in flood prone area, a case study in Kelurahan Sewu, Surakarta City, Indonesia"
(Adopted and modified from Marschiave (2008), Sagala (2007) and Mayasih (2008))

Interviewer: ………………………………	Respondent's name: ……………………
Date: ………………………………………	Time of interview: ………………………
Building No: …………RT………RW……	GPS:Lat……………….Long:……………

1. Respondent's Information

1.1. Respondent's profile

(1) Age: ………years; (2) Sex: ☐ Female ☐ Male ;

(3) Position in household: ☐ Father ☐ Mother ☐ ..……….…………….

(4) Literacy : ☐ literacy ☐ illiteracy

(5) Education* : ☐ES ☐ JHS ☐ SHS ☐ B ☐ GS

(6) When did you start living here? ☐ 2005-2009 ☐ 2000-2005 ☐ 1995-2000 ☐ 1990-1995 ☐ before 1990

Where are you stay before here? …………………………. Province ……………..

(7) Ethnic : ☐ Javanese ☐ Sundanese ☐ Others

(8) Job : ☐ Government officer ☐ Military ☐ Businessman ☐ Farmer ☐ Labour ☐ …..

(9) Income : ☐ < Rp. 750.000,- ☐ Rp. 750.000,- s/d Rp. 1.500.000,- ☐ >Rp. 1.500.000,-

(10) Expenses per day:

- Food : ☐ < Rp. 10.000,- ☐ Rp. 10.000,- s/d Rp. 20.000,- ☐ >Rp. 20.000,-
- Transportation: : ☐ < Rp. 10.000,- ☐ Rp. 10.000,- s/d Rp. 20.000,- ☐ >Rp. 20.000,-
- Others : ☐ < Rp. 10.000,- ☐ Rp. 10.000,- s/d Rp. 20.000,- ☐ >Rp. 20.000,-

* ES = Elementary School, JHS = Junior High School, SHS = Senior High School, B = Bachelor, GS = Graduate School

(12) Household Member:

No	Name	Sex*		Age (year)				Education*					Job*				
		M	F	<4	4-24	25-65	>65	ES	JHS	SHS	B	GS	GO	M	B	F	O
1.																	
2.																	
3.																	
4.																	
5.																	

M = Male, F = Female, ES = Elementary School, JHS = Junior High School, SHS = Senior High School, B = Bachelor, GS = Graduate School, GO = Government Officer, M = Military, B = Businessman, F = Farmer, O = Others

- Pregnant woman : ☐ yes ☐ no

1.2. Building information

(13) Building size : ☐ ≤ 50m^2 ☐ 51m^2 - 100m^2 ☐ 101m^2 - 200m^2 ☐ > 200m^2
(14) Ownership : ☐ Own ☐ Rent
(15) Building age : ☐ 0-5 years ☐ 5-10 years ☐ 10-15 years ☐ > 15 years

2. Elements at Risk

2.1. Building structure

Floor material	Ceramic	Concrete	Ground	Mixed	…………..
Roof material	Clay	Asbestos	Mixed	…………..	
Wall material	Concrete	Brick	Wood	Bamboo	Mixed
Number of floor	1	2	3	4	>4
Height of the ground floor (m)					
Height foundation (m)					
Height from road (m)					

2.2. Building contents

2.2.1. Appliances (Major)

Item	Raised or on ground level (m)				Number of Item	Value (x Rp.1,000)		
TV	0,5-1	1-1,5	1,5-2	>2		500	1000	1500
Stove	0,5-1	1-1,5	1,5-2	>2		50	300	1000
Refrigerator	0,5-1	1-1,5	1,5-2	>2			1200	2000
Computer set	0,5-1	1-1,5	1,5-2	>2				4000
AC	0,5-1	1-1,5	1,5-2	>2				1500
Tape/Radio system	0,5-1	1-1,5	1,5-2	>2		300	300	1000
Washing machine	0,5-1	1-1,5	1,5-2	>2				1500
Video/DVD	0,5-1	1-1,5	1,5-2	>2			500	1000

2.2.2. Furniture (Major)

Item	Raised or on ground level (m)				Number of Item	Value (x Rp.1,000)		
Carpet	0,5-1	1-1,5	1,5-2	>2			150	350
Sofa	0,5-1	1-1,5	1,5-2	>2			1000	3000
Dinning set	0,5-1	1-1,5	1,5-2	>2			300	500
Iron	0,5-1	1-1,5	1,5-2	>2		100	150	200
Chairs	0,5-1	1-1,5	1,5-2	>2		50	100	150
Curtain	0,5-1	1-1,5	1,5-2	>2		50	100	150
Bed	0,5-1	1-1,5	1,5-2	>2		.100	500	1000
Electric fan	0,5-1	1-1,5	1,5-2	>2		80	150	200
Cupboard	0,5-1	1-1,5	1,5-2	>2		500	750	1500
Table	0,5-1	1-1,5	1,5-2	>2		150	200	500
Rice cooker	0,5-1	1-1,5	1,5-2	>2		100	150	400
Telephone	0,5-1	1-1,5	1,5-2	>2			200	200

2.3. Outside properties (valuable properties)

Item	Number of Item	Value (x Rp.1,000)		
Animal			200	500
Car			20000	100000
Motorcycle		2000	10000	15000
Bicycle		200	1000	2000

3. Flood and its Damage

3.1. Flood occurrences

What is the highest of water level during flood on Dec 2007? (cm)	
How long was the flood duration (Dec 2007)?	
What is the maximum height of water level ever happened in this location? (cm)	
When? (dd/mm/yy)	
How long?	days

3.2. Flood history

Time	Frequency		Water level	Duration	Cause of Flood			Victim
2009	Single	Multiple	cm	days	Excessive rainfall	Dam break	………	……. Death
2008	Single	Multiple	cm	days	Excessive rainfall	Dam break	………	……. Death
1966	Single	Multiple	cm	days	Excessive rainfall	Dam break	………	……. Death

3.3. Damages and losses (Flooding 2007)

3.3.1. Building structure

What is the maximum damage to building structure within the last 10 years?
How much the cost to repair the damage?

Item	Damage			Cost (in rupiah)	
				Repairing	Replacement
Floor	NH	HC	C		
Wall	NH	HC	C		
Door	NH	HC	C		
Window	NH	HC	C		
Roof	NH	HC	C		

Note: C = Collapse HC = Half Collapse NH = Nothing Happen

3.3.2. Building contents

What kinds of building content have been damaged caused by flood in the last 10 years?
How much the cost to repair the damage?

Item	Damage				Cost (x Rp 1000)
Appliances	Clothes become wet and soaked	Electronic devices do not work anymore	Loss of kitchen utensils	No Damage	
Furniture	Dirty and smelly furniture because of mud	Pillows and mattresses get wet and dirty	Loss of some documents	No Damage	

3.3.3. Damage to outside properties

- What kind of damage has been happened to outside properties in the last 10 years? ....
- How much is the cost to repair the damage? ……………………………………………

4. Flood Impact

- What are common diseases that appear after the flood?
  ☐ Skin diseases ☐ Fever ☐ diarhea ☐ …………………
- How high the water do you things away in case of flood? (cm) ………………………………………………………………………………………………
- Where do you place you things when flood strike? ………………………………………………………………………………………………
- During the flood, where do you live?
  - Shelter, location: ……………………………………………………..

  - Family, location: …………………………………………………….
  - Others: ……………………………………………………………….
- Can you continue to work during the flood? Why?
  ……………………………………………………………………………………………
- Have you considered moving from this area (gateway from flooding)?
  Yes / No
  If yes, to which area? Why?
  ……………………………………………………………………………………………
- What is the reason living in this area?
  ☐ Cheap ☐ Own Properties ☐ Ancestral properties ☐ Better access (to business centre, educational place, place to work, etc) ☐ Other…………………

-----Thanks for your help and cooperation-----

Note :
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Appendix 2. Sample point determination

No	Position	Administrative		Type of Household Building Structure				Number of Sample (15 %)
		RW	RT	Roof	Wall	Floor	Total	
1	A long the dike near the river Elevation/Contour <=86 asl	I	2	Clay	Brick	Concrete	8	1
				Clay	Concrete	Concrete	11	2
				Clay	Concrete	Ceramic	8	1
				Clay	Mixed	Concrete	12	2
							39	**6**
		II	1	Clay	Brick	Concrete	21	3
				Clay	Concrete	Concrete	51	8
				Clay	Concrete	Ceramic	10	2
				Clay	Mixed	Concrete	10	2
							92	**15**
		II	3	Clay	Brick	Concrete	48	7
				Clay	Concrete	Concrete	51	8
				Clay	Concrete	Ceramic	20	3
				Clay	Mixed	Concrete	20	3
							139	**21**
		VII	1	Asbestos	Bamboo	Ground	2	0
				Clay	Bamboo	Ground	1	0
				Clay	Brick	Concrete	15	2
				Clay	Concrete	Concrete	9	1
				Clay	Concrete	Ceramic	34	5
				Clay	Mixed	Concrete	13	2
				Clay	Wood	Concrete	3	0
							77	**10**
		VII	3	Clay	Bamboo	Ground	1	0
				Zinc	Concrete	Concrete	2	0
				Zinc	Mixed	Concrete	1	0
				Clay	Brick	Concrete	17	2
				Clay	Concrete	Concrete	14	2
				Clay	Concrete	Ceramic	20	3
				Clay	Mixed	Concrete	12	2
				Clay	Wood	Concrete	2	0
							69	**9**
2	Rather far from the dike near the river Elevation/Contour 87-88 asl	III	3	Clay	Brick	Concrete	4	1
				Clay	Concrete	Concrete	23	3
				Clay	Concrete	Ceramic	19	3
				Clay	Mixed	Concrete	14	2
							60	**9**
		V	2	Clay	Concrete	Concrete	12	2
				Clay	Concrete	Ceramic	14	2
				Clay	Mixed	Concrete	12	2
				Clay	Wood	Concrete	1	0
							39	**6**
		VI	1	Clay	Brick	Concrete	3	0
				Clay	Concrete	Concrete	3	0

No	Position	Administrative		Type of Household Building Structure				Number of Sample
		RW	RT	Roof	Wall	Floor	Total	(15 %)
				Clay	Concrete	Ceramic	20	3
				Clay	Mixed	Concrete	1	0
							27	**3**
		VIII	1	Clay	Brick	Concrete	7	1
				Clay	Concrete	Concrete	17	3
				Clay	Concrete	Ceramic	20	3
				Clay	Mixed	Concrete	11	2
							55	**9**
3	Far from the dike near the river Elevation/Contour >88 asl	IV	2	Clay	Brick	Concrete	1	0
				Clay	Concrete	Concrete	14	2
				Clay	Concrete	Ceramic	12	2
				Clay	Mixed	Concrete	17	3
							44	**7**
		VIII	3	Clay	Brick	Concrete	3	0
				Clay	Concrete	Concrete	14	2
				Clay	Concrete	Ceramic	18	2
				Clay	Mixed	Concrete	4	1
							39	**5**
		IX	3	Clay	Brick	Concrete	1	0
				Clay	Concrete	Concrete	19	3
				Clay	Concrete	Ceramic	7	1
				Clay	Mixed	Concrete	3	0
							30	**4**
	Grand total						**710**	**104**

Sources : Administrative boundary (Central Bureau of Statistics), Contour map (Public Work Office), Building footprint map (fieldwork)

Appendix 3. The victims and the flood depth in flood event 2008-2009

NO	Administrative		09 Mar 08		22 Mar 08		17 Feb 09		25 Feb 09		31 Jan 09	
	RT	RW	The Victims	The flood depth (cm)	The Victims	The flood depth (cm)	The Victims	The flood depth (cm)	The Victims	The flood depth (cm)	The Victims	The flood depth (cm)
1	1	I	125	10-60	21	1-10	18	40	0	0	167	30-100
2	2	I	80	30	0	0	0	0	0	0	174	20-50
3	3	I	0	0	0	0	0	0	0	0	153	20-50
4	1	II	52	20-30	0	0	5	20	0	0	347	60-150
5	2	II	76	10-30	0	0	0	0	0	0	282	40-150
6	3	II	162	30-190	62	168	100	100	101	50-110	522	50-150
7	1	III	135	30-200	12	39	10	50	5	10-20	238	30-80
8	2	III	90	30-90	0	0	0	0	0	0	140	30-80
9	3	III	201	30-160	23	74	14	50	2	6-10	296	30-150
10	1	IV	140	30-160	25	78	41	50	3	6-10	149	20-80
11	2	IV	75	20-60	0	0	0	0	0	0	134	30-100
12	3	IV	35	20-60	0	0	0	0	0	0	144	20-75
13	1	V	110	30-100	0	0	0	0	0	0	152	20-50
14	2	V	32	10-30	0	0	0	0	0	0	203	20-50
15	3	V	40	5-20	0	0	0	0	0	0	428	20-60
16	4	V	87	30-80	0	0	0	0	0	0	137	20-50
17	5	V	223	80-150	52	142	50	50	0	0	377	30-150
18	1	VI	0	0	0	0	0	0	0	0	0	0
19	2	VI	0	0	0	0	0	0	0	0	50	20-50
20	3	VI	0	0	0	0	0	0	0	0	0	0
21	4	VI	0	0	0	0	0	0	0	0	14	10-20
22	5	VI	0	0	0	0	0	0	0	0	0	0
23	1	VII	50	30-60	0	0	0	0	0	0	81	30-40
24	2	VII	42	30-60	9	31	5	50	6	30-60	44	10-30
25	3	VII	132	60-150	35	139	40	100	25	40-60	133	30-100
26	1	VIII	0	0	0	0	0	0	0	0	14	20-50
27	2	VIII	0	0	0	0	0	0	0	0	0	0
28	3	VIII	0	0	0	0	0	0	0	0	0	0
29	4	VIII	0	0	0	0	0	0	0	0	0	0
30	5	VIII	0	0	0	0	0	0	0	0	36	20-50
31	1	IX	0	0	0	0	0	0	0	0	0	0
32	2	IX	0	0	0	0	0	0	0	0	0	0
33	3	IX	0	0	0	0	0	0	0	0	0	0
34	4	IX	0	0	0	0	0	0	0	0	0	0
35	5	IX	0	0	0	0	0	0	0	0	0	0
	Total		1887		239		283		142		4415	

Source: *Kelurahan* Sewu (2009)

Appendix 4. Vulnerability analysis of building contents

Item	Low Income (List 1)							Moderate Income (List 2)							High Income (List 3)						
	Value	<45		<85		<130		Value	<45		<85		<130		Value	<45		<85		<130	
		I_V	E_D	I_V	E_D	I_V	E_D		I_V	E_D	I_V	E_D	I_V	E_D		I_V	E_D	I_V	E_D	I_V	E_D
Appliances																					
TV	500	0	0	0	0	0	0	1000	0	0	0	0	0	0	1500	0	0	0	0	0	0
Stove	50	0	0	0	0	1	50	300	0	0	0	0	1	300	1000	0	0	0	0	1	1000
Refrigerator								1200	0.25	300	0.75	900	1	1200	2000	0.25	500	0.75	1500	1	2000
Video/DVD								500	0	0	0	0	1	500	1000	0	0	0	0	1	1000
Tape/Radio	300	0	0	0	0	1	300	300	0	0	0	0	1	300	1000	0	0	0	0	1	1000
Computer set															4000	0.25	1000	0.5	2000	1	4000
Washing machine															1500	0.25	375	0.5	750	1	1500
Air Conditioner															1500	0	0	0	0	0	0
Furnitures																					
Carpet								150	1	150	1	150	1	150	350	1	350	1	350	1	350
Dinning Set								300	0.25	75	0.75	225	1	300	500	0.25	125	0.75	375	1	500
Iron	100	0	0	0	0	1	100	150	0	0	0	0	1	150	200	0	0	0	0	1	200
Chairs	50	0.5	25	0.75	37.5	1	50	100	0.5	50	0.75	75	1	100	150	0.5	75	0.75	112.5	1	150
Curtain	50	0	0	0.25	5	0.5	10	100	0	0	0.25	25	0.5	50	150	0	0	0.25	37.5	0.5	75
Bed	100	0.5	50	0.75	75	1	100	500	0.5	250	0.75	375	1	500	1000	0.5	500	0.75	750	1	1000
Electric fan	80	0	0	0	0	1	80	150	0	0	0	0	1	150	200	0	0	0	0	1	200
Rice cooker	100	0	0	0	0	1	100	150	0	0	0	0	1	150	400	0	0	0	0	1	400
Telephone								200	0	0	1	200	1	200	200	0	0	1	200	1	200
Sofa								1000	0.5	500	0.75	750	1	1000	3000	0.5	1500	0.75	2250	1	3000
Table	150	0.25	37.5	0.5	75	1	150	200	0.25	50	0.5	100	1	200	500	0.25	150	0.5	250	1	500
Cupboard	500	0.25	125	0.5	250	0.75	375	750	0.25	187.5	0.5	375	0.75	562.5	1500	0.25	375	0.5	750	0.75	1125
Total expected damage	1980		237.5		450		1330	7050		1562.5		3175		5812.5	21650		4925		9325		18200
Vulnerability			**0.12**		**0.23**		**0.67**			**0.22**		**0.45**		**0.82**			**0.23**		**0.43**		**0.84**

Note: I_V = Item vulnerability, E_D = Expected Damage

Appendix 5. Function of vulnerability scale of structural type of household building

Vulnerability	Combine if function in Microsoft Excell
0 (No Damage or Nothing happening to wall, floor and roof materials)	If(and(floor="NH",wall="NH",roof="NH"),"0")

0.2 (> Nothing Happening and < Half Collapse of wall, floor and roof)	If(and(floor="HC",wall="NH",roof="NH"),"0.2")
	or
	If(and(floor="NH",wall="HC",roof="NH"),"0.2")
	or
	If(and(floor="NH",wall="NH",roof="HC"),"0.2")

0.4 (> Half Collapse and < Nothing Happening to wall, floor and roof materials)	If(and(floor="HC",wall="HC",roof="NH"),"0.4")
	or
	If(and(floor="NH",wall="HC",roof="HC"),"0.4")
	or
	If(and(floor="HC",wall="NH",roof="HC"),"0.4")

0.5 (Half Collapse of wall, floor and roof materials)	If(and(floor="HC",wall="HC",roof="HC"),"0.5")

0.6 (>Half Collapse and < Collapse or total damage of wall, floor and roof materials)	If(and(floor="C",wall="HC",roof="HC"),"0.6")
	or
	If(and(floor="HC",wall="C",roof="HC"),"0.6")
	or
	If(and(floor="HC",wall="HC",roof="C"),"0.6")

0.8 (> Collapse or total damage and < Half Collapse of wall, floor and roof materials)	If(and(floor="C",wall="C",roof="HC"),"0.8")
	or
	If(and(floor="HC",wall="C",roof="C"),"0.8")
	or
	If(and(floor="C",wall="HC",roof="C"),"0.8")

1 (Collapse or total damage of wall, floor and roof materials)	If(and(floor="C",wall="C",roof="C"),"1") or If(and(floor="C",wall="C",roof="C"),"1") or If(and(floor="C",wall="C",roof="C"),"1")