THESIS

LAHAR FLOOD RISK ANALYSIS FOR SUPPORTING DETAILED SPATIAL PLANNINGAT THE CODE RIVER'S RIPARIAN ZONE IN YOGYAKARTA MUNICIPALITY

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

UGM

By :

EDI SUKOCO
11/325311/PMU/07247
(29740-AES)

Supervisor :

1. **Dr. Rini Rachmawati, S.Si., MT. (UGM)**
2. **Drs. Nanette C. Kingma (ITC)**

THE GRADUATE SCHOOL
GADJAH MADA UNIVERSITY
FACULTY OF GEO-INFORMATION AND EARTH OBSERVATION
UNIVERSITY OF TWENTE
2013

DISCLAIMER

This document describes work undertaken as part of program of study at Double Degree International Program of Geo-Information for Spatial Planning and Disaster Risk Management, a Joint Education Program of Faculty of Geo-Information and Earth Observation University of Twente – The Netherlands and Gadjah Mada University – Indonesia. All views and opinions expressed therein the sole responsibility of the author and do not necessarily represent those of the institute

Yogyakarta,26th March 2013

Edi Sukoco

THESIS

LAHAR FLOOD RISK ANALYSIS FOR SUPPORTING DETAILED SPATIAL PLANNING AT THE CODE RIVER'S RIPARIAN ZONE IN YOGYAKARTA MUNICIPALITY

Prepared by
EDI SUKOCO
11/325311/PMU/07247
(29740-AES)

was defended before the Board of Examiner
on 26th March 2013

Board of Examiners

Supervisor 1	ITC Examiner
Dr. Rini Rachmawati, S.Si., MT.	Dr. D.G. (David) Rossiter
Supervisor 2	External Examiner
Drs. Nanette C. Kingma	Dr. Dyah R Hisbaron, M.T., M.Sc.

This thesis was declared acceptable
to obtain the master degree
Date ......18 JUN 2013......

Program Director of Geo-Information for
Spatial Planning and Risk Management

Prof. Dr. H.A. Sudibyakto, M.S.
NIP. 19560805 198303 1 004

Approved by
Vice Director for Academic Affairs,
Development and Cooperation

UNIVERSITAS GADJAH MADA
SEKOLAH PASCASARJANA

Prof. Ir. Suryo Purwono, MA.Sc., Ph.D.
NIP. 19611119 198601 1 001

Abstract

Lahar flood is the threaten disaster in several area in Yogyakarta municipality i.e. Code river and Gadjah Wong river. This disaster is aftermath disaster following the periodically eruption event of Merapi Volcano. Especially Code river, based on the last eruption in October 2010, lahar flood strucked settlement along this river in the end of 2010 and early 2011. The lahar flood height in several points of settlement area along the Code river was reached approximately 0,5 to 1,4 m (pre research survey 2012).

In case of present Yogyakarta Municipality's Spatial Planning, Code river has been predetermined 50 m buffer zone for preserve area. The map of buffer zone can be seen in the annexes of Yogyakarta Spatial Planning regulation number 2 year 2010 about Spatial Planning of Yogyakarta Municipality. The result on literature study and indepth interview with several local agencies indicate that this regulation was not included lahar flood analysis in the zonation process of preserve area yet.

Conducted research on lahar flood risk analysis tries to propose method in zoning system improvement for supporting detailed spatial planning which should be compiled 3 years after the regulation above established. The four factors were analyzed i.e. hazard, vulnerability, capacity and amount. The risk calculation was done in two condition i.e. lahar flood event in 2011 and predicted impact after flood proofing activity.

The improvement on zoning area of present Spatial Planning Regulation of Yogyakarta Municipality Nr. 2 year 2010 is on zone mapping method by enhancing techniques in data collection for element at risk , lahar flood event to be combined in lahar flood risk calculation together with demographic data for social vulnerability assesment and capacity calculation. Deliniation of the actual riparian zone is proposed to be considered as one option to define buffer zone for preserve area in Code River. The final information is generated by overlaying existing zone , two risk map and zonation of preserve area according to the latest regulation Government Regulation No. 38 year 2011 about River.

Keyword : Lahar Flood, Spatial Planning, Risk Analysis

Intisari

Banjir lahar adalah bencana yang mengancam beberapa daerah di kota Yogyakarta seperti sungai Code dan sungai Gajah Wong. Bencana ini terjadi secara periodik setelah letusan Gunung Merapi. Khusus untuk sungai Code, setelah letusan Gunung Merapi pada bulan Oktober 2010, banjir lahar menerjang pemukiman sepanjang sungai pada akhir tahun 2010 dan awal tahun 2011. Ketinggian banjir lahar di beberapa titik kawasan permukiman di sepanjang sungai Code mencapai 0,5-1,4m (survei pra penelitian 2012).

Terkait dengan Tata Ruang Kota Yogyakarta saat ini, kawasan sungai Code telah ditetapkan sejauh 50 m zona penyangga untuk daerah perlindungan sungai. Peta yang menunjukkan daerah perlindungan ini dapat dilihat dalam lampiran Peraturan Tata Ruang kota Yogyakarta nomor 2 tahun 2010 tentang Rencana Tata Ruang Kota Yogyakarta. Hasil studi literatur dan wawancara mendalam dengan beberapa lembaga pemerintah menunjukkan bahwa peraturan ini belum memasukkan analisis banjir lahar dalam proses penentuan daerah perlindungan sungai.

Penelitian tentang analisis risiko banjir lahar ini mencoba untuk mengusulkan metode perbaikan sistem zonasi kawasan disekitar sungai untuk mendukung rencana rinci tata ruang yang harus disusun 3 tahun setelah peraturan di atas ditetapkan. Terdapat empat faktor dianalisis yaitu bahaya, kerentanan, kapasitas dan nilai rupiah dari lokasi yang terdampak banjir lahar. Perhitungan risiko dilakukan dalam dua kondisi yaitu peristiwa banjir lahar tahun 2011 dan prediksi dampak banjir lahar setelah usaha masyarakat untuk menahan banjir lahar.

Perbaikan terhadap zonasi kawasan pada Peraturan Tata Ruang Kota Yogyakarta No. 2 Tahun 2010 adalah metode pemetaan kawasan dengan memperbaiki teknik pengumpulan data untuk elemen beresiko, peristiwa banjir lahar yang akan digabungkan dalam perhitungan risiko banjir lahar bersama dengan data demografis untuk penilaian kerentanan sosial dan perhitungan kapasitas. Deliniasi dari batas kawasan penyangga yang sebenarnya (actual riparian zone) untuk dipertimbangkan sebagai salah satu pilihan untuk menentukan zona penyangga untuk melestarikan daerah di Sungai Code. Informasi terakhir dihasilkan dengan overlay zona yang ada, dua peta risiko dan zonasi kawasan perlindungan sesuai dengan peraturan Peraturan Pemerintah Nomor 38 Tahun 2011 tentang Sungai.

Keyword: Banjir Lahar, Tata Ruang, Analisis Risiko

Acknowledgement

Above of all, I am grateful and praise to the Lord Jesus Christ my saviour for His bless and establishing me to accomplish my research.

I wish to express my thanks to Badan Perencanaan dan Pembangunan Nasional (Bappenas) and Nuffic-Nesso for providing me a scholarship to pursue master degree in Joint Education Program between Gadjah Mada University (GMU) and ITC-UT. It was great educational environment to learn, work and know on something new both in Yogyakarta and Enschede.

I would like to convey my sincere thanks to my supervisor Dr. Rini Rachmawati, M.T. (GMU) and Drs. Nanette C. Kingma (ITC-UT) for their encouragement , excellent ideas and invaluable assistance throughout my research.

I gratefully acknowledge to the Lecturers and staff members in Geo-Information for Spatial Planning and Disaster Risk Management Program (GMU) and Applied Earth Science Department (ITC-UT) for their hospitallity and endorsement during my study, especially for Prof. Dr. H. Sudibyakto, Prof. Dr. rer.nat Junun Sartohadi.

I would like to deliver my thankfulness to all Geo-Info classmates batch 7 who provided abundant invaluable discussion, information sharing, and warm friendship for twenty four months . It was great time to get along with you all.

I also place on record, my sense of gratitude to one and all who, directly or indirectly, have lent their helping hand in this research.

My parents and family, it is great to have you and I am very grateful for all the prayers and support during this difficult time. Lastly, my special thanks to my lovely wife Annamaria Lilis Suryani and my beloved princess Lusia Intan Maharani, whose always made my day colorfull and toughened my heart to accomplish my research.

Contents

List of Figures

List of Figures

List of Tables

Abbreviation

AHP	Analytical Hierarchy Process
AI	Airbone Informatics
BAKOSURTANAL	Badan Koordinasi Survei Pemetaan Nasional / National Agency of Survey and Mapping Coordination
BM	Bench Mark
BNPB	Badan Nasional Penanggulangan Bencana / National Bureau for Disaster Countermeasure
BPN	Badan Pertanahan Nasional / National Land Agency
BPS	Badan Pusat Statistik / Central Statistic Bureau
DTM	Digital Terrain Model
DSM	Digital Surface Model
FEMA	Federal Emergency Management Agency
FGD	Focus Group Discussion
GIS	Geographic Information System
GMU	Gadjah Mada University
GPS	Global Positioning System
IDR	Indonesian Rupiah
LiDAR	Light Detection and Ranging
MCE	Multi Criteria Evaluation
NNI	Natural Neighbor Interpolation
NRCAN	Natural Resources Canada
PGIS	Participatory Geographic Information System
PU	Departemen Pekerjaan Umum / Public Work Agency
RTK	Real Time Kinematic
RW	Rukun Warga / sub area of village
SFAP	Small Format Aerial Photogrametry
SMCE	Spatial Multi Criteria Evaluation
USGS	United State of Geological Survey
UNDRO	United Nations Disaster Relief Organization
UNECE	United Nations Economic Commission for Europe

1. INTRODUCTION

Recent years, Yogyakarta province has struck by several disasters such as earthquake at Bantul regency in 2006 , the last Merapi volcano eruption in October 2010, landslides at Kulonprogo regency in early 2012 and lahar flood event at Code and Gajah Wong river in early 2011. Those disaster event were causing lots of loss to the settlements, agriculture areas, road facilities and moreover loss of life people living close to disaster prone area.

Code river is one of the big rivers in Yogyakarta province which is part of Opak Watershed (PU,2009) This river has upperstream of Boyong River at near top of Merapi Volcano. This river is passing through at the center of Yogyakarta city . It has several types of river pattern and some of them are meandering. The satellite image data shows that Code river has several spots with high possibility of suffering from lahar flood.

There were two different combination of floods happened in this area: lahar flood and localized (urban) flood. The lahar flood occurred because of the high-prolonged rainfall which brought volcanic material of Mt. Merapi eruption at the uppert stream of Code River.While the localized (urban) flood occurred due to the high-prolonged rainfall in Yogyakarta City and trapped water in bad drainage system in the area (Heryanti, 2012).

The lahar flood was happened in several subdistrict in Yogyakarta Municipality. After the Merapi volcano eruption in October 2010, lahar flood was inundated settlement close to Code river on Monday, 29th November 2010 (BNPB ,2010). This event also happened in May 1st 2011 (Kompas,2011). At that time, as it reported in several news paper, the rainfall at the top of Merapi reached upper limit and washed away the vulcanic material. The water height in several part of settlement along the Code river was reached approximately 0,5 to 1,4 m (pre research survey 2012). As it reported in national and local news paper, lots of inhabitants have to flee to the higher place and some of their properties were damaged.

In case of spatial planning of Yogyakarta municipality, Code river has been predetermined 50 m buffer zone for preserve area. The map of buffer zone can be seen in the annexes of Yogyakarta Spatial Planning regulation number 2 year 2010 about Spatial Planning of Yogyakarta Municipality (figure 1). However based on satellite image interpretation from

Quickbird image 2004 , it shows that there is no preserve area in those area. Landuse of the buffer zone mostly dominated by dense irregular settlement .

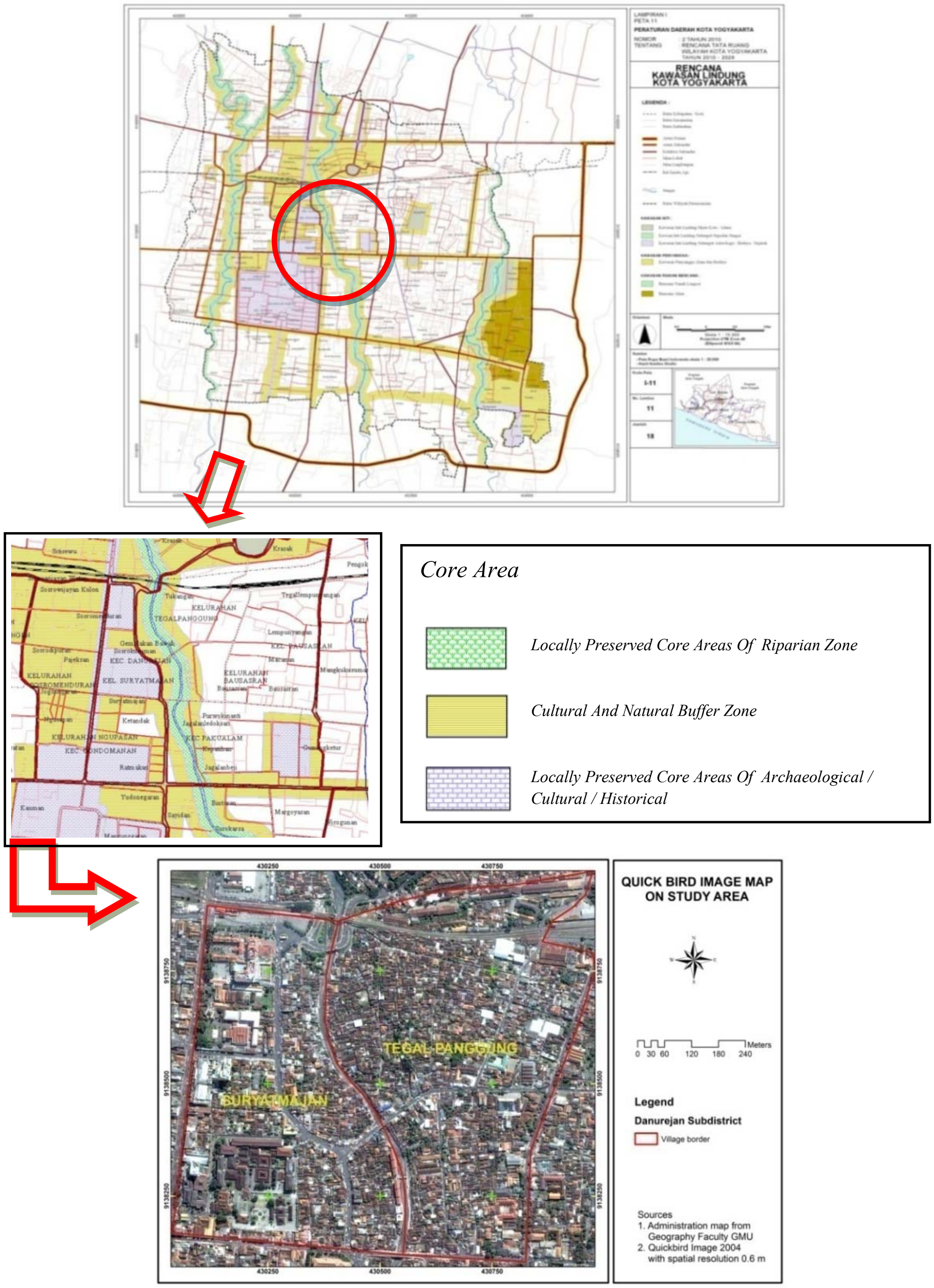

Figure.1.1 Preserve area in Spatial Planning Regulation (above) and Satellite image data (below)

Source : Spatial Planning Regulation no 2 year 2010 and 2004 Quickbird Image

Those dense settlements are populated by lots of inhabitants. It will bring social problem especially on disaster management. Inhabitants of this area has various composition on its gender, age, education level, income. It will lead to various condition of the social vulnerability. This factor is needed to be assessed as an input for lahar flood risk analysis.

Based on comparison on figures 1.1 ,it can be inferred that there has been a missing link between spatial planning regulation and existing landuse along Code river. Green colour in the Map legend of spatial planning product is the river preserve area. In pre-survey research in July 2012, along the river bank was already built flood dike protection after the last lahar event in 2011 . It seem that there is no green space area.

Additional information for the map above (figure 1.1), the coordinate system of the map is Universal Tranverse Mercator (UTM) zone 49.S. The ellipsoid reference is World Geodetic System 1984 (WGS 84). This parameter will be applied in all the map product in this research.

1.1 Research problem

Recent spatial planning of Yogyakarta municipality (number 2 year 2010) is constructed for small scale study (1: 10.000).This regulation is generated from provincial spatial planning which containing general regulation of objectives, policies , strategy, structure plan living area,spatial pattern plan , determination of strategic area, direction of spatial use, and the spatial use control provisions in district or municipality level. Further detailed spatial planning of municipality level has large scale of 1:5.000. It must regulate detail zonation of whole municipality area.

Detailed spatial planning from previous years (before 2010 Merapi eruption) which conducted by Yogyakarta municipality did not take into account the disaster aspect. In this case, lahar flood risk analysis along the river can be one of the input in constructing the regulation. In this research, risk analysis is generating risk zonation based on social and physical aspect.

1.2 Research Objective

General objectives of this research are analyzing the present spatial planning on its zoning system and relating to lahar flood risk analysis at riparian zone of Code river. For deep research guidance , the specific objectives are :

1. Assessing the present spatial planning regulation related to zoning system
2. Calculating lahar flood risk in riparian zone of Code river
3. Improving on present spatial planning zonation to support appropriate zoning system in detailed spatial planning which including lahar flood risk analysis

1.3 Research Question

Conducting further steps, all of those research objectives are formulated into several research questions on table 1-1 below :

Table 1.1 Research Question

No.	***Research Objectives***	***No***	***Research Question***
1.	Assessing the present spatial planning related to zoning system	a.	How is the zoning system of spatial pattern in present spatial planning?
		b.	How is the relation between existing spatial planning regulation with another regulations governing zone arrangement around the river?
2.	Calculating and assessing lahar flood risk in riparian zone of Code river	a.	How to improve on existing lahar flood hazard map?
		b.	What is the element at risk data (physical and social element) regarding to lahar flood and the improvement on better data presentation ?
		c.	How to map the level of social and physical vulnerability in research area?
		d.	What is lahar flood risk level in study area?
3.	Improving on present spatial planning zonation to support appropriate zoning system in detailed spatial planning which including lahar flood risk analysis	a.	How to improve zoning system at riparian zone of Code river regarding on lahar flood risk analysis ?
		b.	What is the advantage of improved method in zoning system to be applied in lahar flood risk based spatial planning at Code River and its surrounding area?

1.4 Benefit of the Research

Related to spatial planning and disaster management, this study on lahar flood at Code river could provide benefit for better development such as :

1. It can provide new information on actual riparian area which can be used as the basis of defining zoning system along the river
2. It offers a developed method of lahar flood risk mapping to assess existing condition of the river
3. It gives input for local government of new knowledge on spatial planning zoning system related to lahar flood risk

1.5 Limitations of the research

Modelling of flood hazard in Code river is not taken into account into this research. The used lahar flood hazard map is used from previous research in Code river which based on the last lahar flood event after Merapi eruption. This map was result of one dimensional modeling. To get the actual lahar flood extent and depth, the map was validated with Participatory Geographic Information System (PGIS). Combined with digital terrain model and digital surface model , this data is used to generate the physical vulnerability.

Analysis of element at risk that will be conducted is considering of physical aspect building such as landuse type and building height. Meanwhile, socio economy aspect of the community will deal with poverty, age, occupation,and education

1.6 Thesis Structure

There are 6 chapter constructing this thesis. Those chapters are

1. Chapter 1 explains about background of the research, research problem, research objectives, research question, benefits of the research ,limitations of the reserach and thesis structure.
2. Chapter 2 contains literature review of theoretical and definition which supporting the research.
3. Chapter 3 describes general information of study area

4. Chapter 4 deals with three stages overview of the research ie pre-fieldwork, fieldwork and analysis in the post fieldwork.
5. Chapter 5 presents present spatial planning assessment which include analysis on higher level than Spatial Planning of Yogyakarta Municipality i.e. national level (Government Regulation, Law), analysis of existing zone , and result of indepth interview with several local agencies.
6. Chapter 6 calculates lahar flood risk which consist of several steps i.e. improving the existing lahar flood hazard map, element at risk data base improvement, physical and social vulnerability assessment, capacity assessment, and lahar flood risk calculation.
7. Chapter 7 gives overview process of improvement on zoning system to support further detailed spatial planning
8. Chapter 8 provides conclusion and recommendation of the research

2. LITERATURE REVIEW

2.1 Flood Hazard

United State of Geological Survey - USGS (2012) defines flood as an overflow or inundation that comes from a river or other body of water and causes or threatens damage. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. Rossi et.al (1994) stated that flood 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. For the guidance of further research, second definition is seen as appropriate due to its broader coverage (ie probability, damaging values, risk) than first definition.

One of official agencies in United State of America, FEMA (1997) was classified types of floods into nine major classes : riverine flooding, overbank flooding**,** flash floods**,** alluvial fan floods, ice jam floods, dam break floods, local drainage ,high ground water level and fluctuating lake level.

In this study, the specific flood which will be used in further analysis is Lahar flood. Lahar is originally Indonesian term. According to Smith & Fritz (1989), they defined lahar as : "a general term for a rapidly flowing mixture of rock debris and water (other than normal stream flow) from a volcano. A lahar is an event; it can refer to one or more discrete processes, but does not refer to a deposit." The flow behaviour exhibited by lahars may be complex, and includes a debris flow phase, where sediment concentration is in excess of 60% by volume. Additionally, there are also precursor and waning stage hyperconcentrated-streamflow phases, where sediment concentration ranges from 20 to 60% by volume (Beverage and Culbertson, 1964 in Lavigne, 1999). Based on Lavigne research on lahar in Merapi Volcano, he stated that lahar is triggered by two main processes:

(1) eruption-induced lahars or primary lahars from the admixing of pyroclastic flows, or less frequently, from debris avalanches, with running water;
(2) rain-triggered lahars or secondary lahars from heavy rainfall upon recently erupted volcaniclastics, usually during the rainy season (from November to April).

2.2 Physical Vulnerability

In general, vulnerability can be defined as "The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage)" (UNDRO, 1991)

Meanwhile, physical vulnerability according to van Westen (2009) is "meaning the potential for physical impact on the built environment and population ". He also stated that "Vulnerability is analyzed per group of constructions (i.e. structural types) having similar damage performance".

It can be concluded that physical vulnerability is degree of loss of built environment ie. building , infrastructure resulting from occurence of natural phenomenom such as flood, earthquake, tsunami of given magnitude and scaled from 0 (no damaged) to 1 (total damage)

To assess physical vulnerability of buildings, several parameters can be used i.e. duration of flooding, flow velocity, flood depth, sediment concentration, and flood proofing . Due to limited resources, this research will only concentrate on flood depth as the parameter of the physical vulnerability.

2.3 Social vulnerability

Social vulnerability is "the ability or inability of individuals and social groupings to respond to, in the sense of cope with, recover from or adapt to any external stress placed on their livelihoods and well-being" (Kelly & Adger, 2000,p. 328). This definition highlights the social dimension of vulnerability, broadly understood as a state of well-being pertaining directly to individuals and social groups, and whose causes are related to social, institutional, and economic factors, as well as to climate impacts, in so far as social vulnerability is indeed not separate from exposure, and necessarily linked to specific climate impacts. This definition of social vulnerability highlights elements such as wealth, race, ethnicity, gender, and allows for diachronic consideration of the different states of well-being experienced by different populations living in different social, economic and environmental conditions (Grasso,2010).

In summary, social vulnerability is the capability level of individual or social group to face any disaster which can struck their livelihood. The elements of social vulnerability are the socio-economic factor such as wealth, race, ethnicity, gender, group age and education .

2.4 Risk

Risk is defined as the product of hazard and vulnerability (R = H * V), or – to put it another way – risk as the probability of an encounter between a specific hazard and an element vulnerable. This is interpreted as the probability of occurrence of loss of life or damage to objects,buildings and the environment as the result of an extreme natural phenomenon with a specific strength or intensity (Kohler, Jülich, & Bloemertz, 2004).

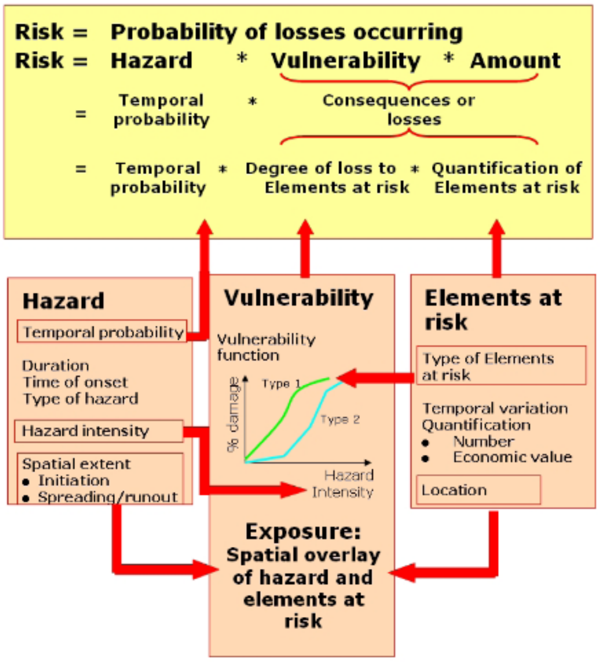

Figure 2.1 Basic function of risk calculation

Source : Introduction of Risk Assessment Guide Book (van Westen et.al.2009)

In figure 2.1, It shows relation and short explanation of risk and its elements (hazard, vulnerability and elements at risk). The last statement of "exposure : spatial overlay of hazard and element at risk" can be concluded that the risk is specific on the time and the affected elements

To relate risk with amount (A) of rupiahs, formula above is multiply with A factor : R = H x V x A (figure 2.1). Valued risk in currency can be obtained by calculating risk on building price, construction, land price or infrastructure value.

2.5 Riparian zone

Green and Haney (2000) stated that riparian buffer zones are vegetated areas along both sides of water bodies that generally consist of trees, shrubs and grasses and are transitional boundaries between land and water environments (figure 2.2). Xia et.al (2008) explained that ecological riparian zone is a transition zone between river ecosystem and land ecosystem interface, surface water and ground water, through which material, energy and information have been exchanged.

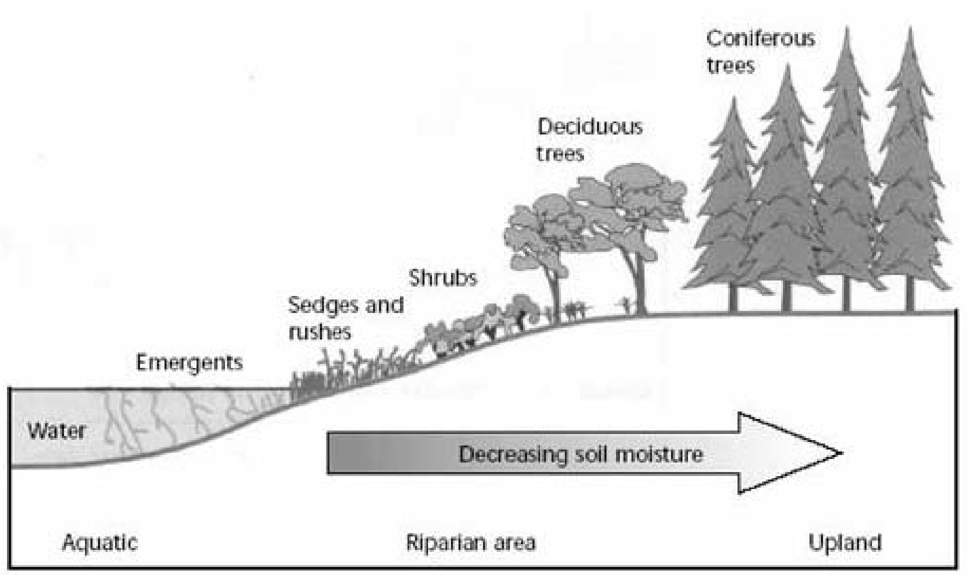

Figure 2.2 Illustration of riparian zone

Source : http://www.crd.bc.ca/watersheds/ecosystems/riparianzones.htm

In accordance to those term, riparian zone in Code river is zone between river edge and upland terrace on the both side of the river (figure 2.3). Case in Code River ,this zone is fully covering with irregular dense settlements. Green space or preseved area along the river bank is already occupied by city inhabitants. The existence of settlements is really not planned and most of them do not have the legal status of their land. In the beginning, they just built a semi-permanent house. Since there is no prohibition of the government, the it was already became a permanent building.

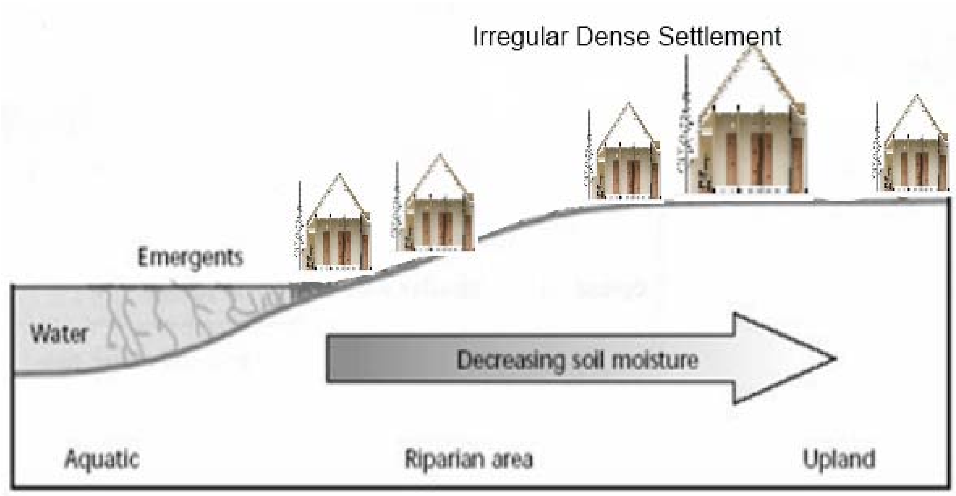

Figure 2.3 Illustration of Code river present situation
Source : edited image from
http://www.crd.bc.ca/watersheds/ecosystems/riparianzones.htm

2.6 Spatial Planning

Conyers and Hills (1984) defined planning as a continues process which involves decisions, or choices, about alternative ways of using available resources, with the aims of achieving particular goals at some time in the future. In this definition they gave accentuation on 4 major points of planning ie. decisions or choices, resource allocations, goals achievement and for the future.

According to UNECE (2008) spatial planning is a key instrument for establishing long-term, sustainable frameworks for social, territorial and economic development both within and between countries. Spatial planning has a regulatory and a development function. As a regulatory mechanism, government (at local, regional and/or national levels) has to give approval for given activity; as a development mechanism, government has to elaborate upon development tools for providing services and infrastructure, for establishing directions for urban development, for preserving national resources, and for establishing incentives for investment, etc

For further application, spatial planning is giving more balanced activitiy based on territorial proximity between urban and rural in social and economic development, competitivenes, information and knowledge acessibility, reducing the impact of natural disaster (flood, earthquake,landslides, tsunami etc.).

3. STUDY AREA

Yogyakarta City lies between 110°24'19"-110°28'53" east longitude and between 07°49'26"-07°15'24" south latitude, with an area of 32.5 km² or 1.02% from the area of Special Region Yogyakarta Province. The range between north and south is approximately 7.5 km and between west and east approximately 5.6 km. Yogyakarta City is located on Merapi Mount's Valley having an inclination of between 0-2% . The land is on the average of 114 meters above sea level. A number of 1,657 hectares lies on the height of less than 100 m and the rest (1,593 hectares) is located on 100-199 m height above sea level. Most of land contains regosol. There are 3 rivers flowing from north to south, i.e., Gajahwong River flowing through the east of the City, Code River through the middle and Winongo River through the west part (BPS,2009).

Location of further research is one of sub-district in Yogyakarta municipality named Danurejan sub district. This sub district is located almost in the center of Yogyakarta Municipality. It has 3 villages ie. Suryatmajan , Tegalpanggung and Bausasran. The last village is not crossed by Code river, therefore it will not included in the research area. Suryatmajan lie on the left side while Tegalpanggung on the opposite of the river (figure 3.1). Suryatmajan village has an area of 28.033 Ha and Tegalpanggung village has an area of 35.124 Ha.

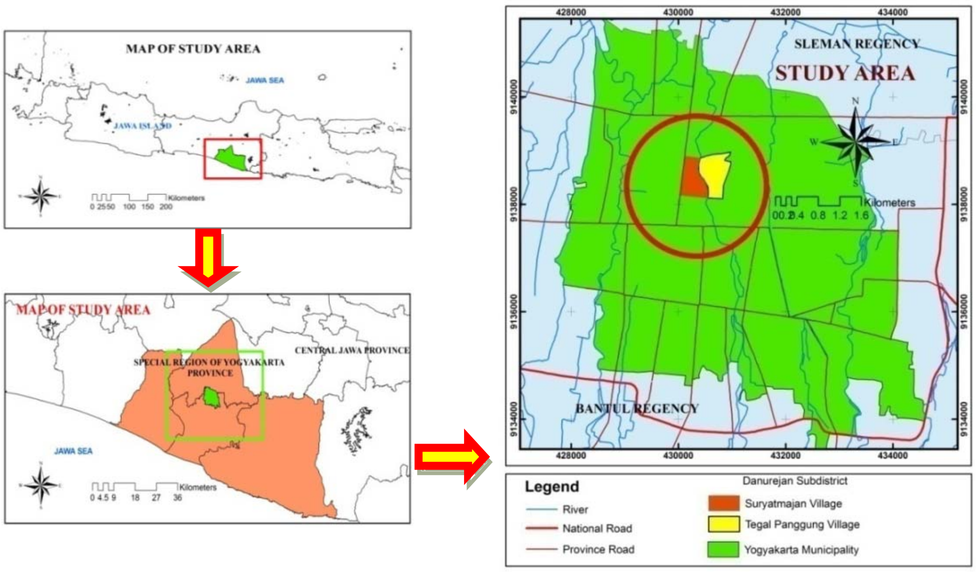

Figure.3.1 Study Area (Danurejan Subdistrict)

Source : Geography Faculty Gadjah Mada University

3.1 Demographic Condition

Based on data retrieved from Population and Civil Record Agency and Village office, those two villages are devided into several sub levels called RW (Rukun Warga). Tegalpanggung village has 16 RW and Suryatmajan has 15 RW. This level will be the basis of further analysis in determining the level of social vulnerability. Tabel 3.1 and 3.2 show population in each village.

Table 3.1 Population in Tegalpanggung village in 2011

Village	RW	Male	Female	Population	Area (Ha)	Population density
Tegal Panggung	I	474	461	935	1.57	595.53
	II	415	397	812	1.747	464.78
	III	443	447	890	1.821	488.71
	IV	516	492	1008	3.082	327.03
	IX	96	108	204	1.182	172.6
	V	339	400	739	2.5	295.61
	VI	441	448	889	2.093	424.8
	VII	392	393	785	6.381	123.01
	VIII	353	352	705	2.683	262.78
	X	140	134	274	1.821	150.45
	XI	146	139	285	2.031	140.3
	XII	195	183	378	1.045	361.65
	XIII	222	188	410	1.875	218.69
	XIV	296	277	573	1.825	313.93
	XV	270	277	547	2.269	241.11
	XVI	242	250	492	1.994	246.74

Table 3.1 above indicate that this area has dense populated area. Tegalpanggung is divided into 16 RW. The highest level of population density is in RW number 1, i.e 595.53 people per hectare. RW 7 has the lowest value of 123.01 people per hectare. This area is mostly occupied by Indonesian Railway Company as their office and ware house Population density data has been mapped on an administration map of the tegalpanggung village (figure 3.3) . Overal, it point male composition is higher than female composition.

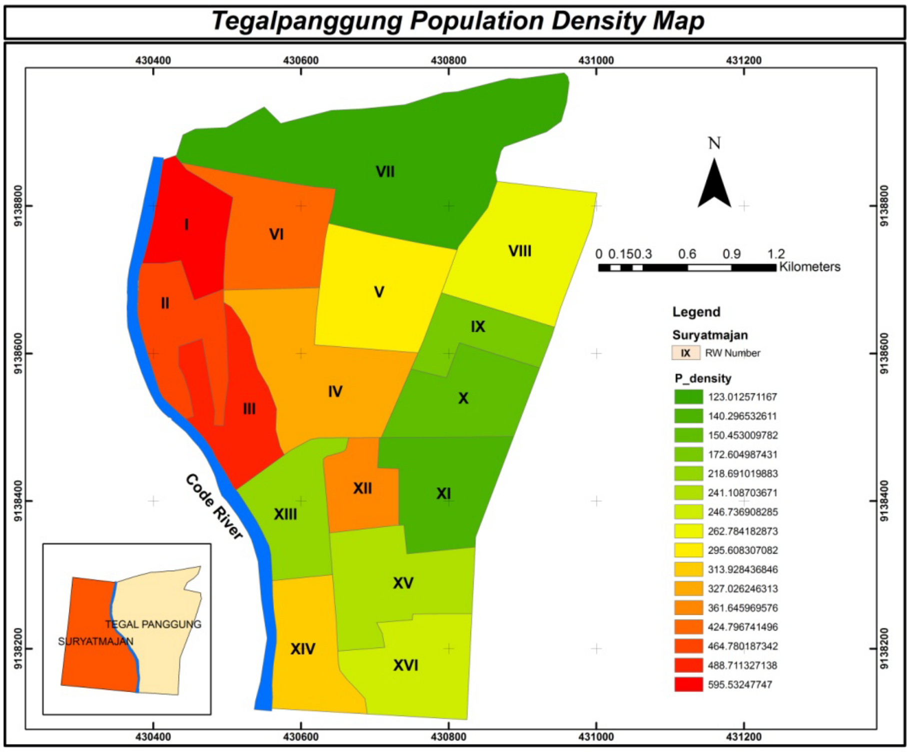

Figure 3.2 Tegalpanggung Population Density Map

Source: Data Analysis

Figure above shows population density per hectare. There are three RW located close to Code river which has the highest density level,namely RW I, II, III. Yellow color can be assumed that those area have moderate population density such as in RW V, VIII which value range from 245 to 297. Green color indicate low population level such as RW VII. This area has low value due to most of the area are owned by Indonesian railway company. Big building such as warehouse were dominated landuse. Similar condition to RW VII, RW XI has low value . Most of the buildings laid on this area were government office, and bussiness office.

Table 3.2 Population in Suryatmajan village in 2011

Village	RW	Male	Female	Population	Area__Ha_	Population density
Suryatmajan	I	146	136	282	4.443	63.48
	II	150	164	314	1.767	177.67
	III	112	114	226	3.174	71.20
	IV	155	161	316	0.568	555.89
	IX	206	196	402	0.567	708.96
	V	123	246	369	2.192	168.38
	VI	180	190	370	1.504	246.09
	VII	280	278	558	0.918	607.79
	VIII	189	203	392	1.042	376.28
	X	169	191	360	3.593	100.20
	XI	112	135	247	1.294	190.86
	XII	218	152	370	3.918	94.45
	XIII	256	250	506	1.153	438.84
	XIV	213	272	485	0.744	651.73
	XV	221	204	425	1.158	367.16

Compared to Tegalpanggung village, Suryatmajan has smaller area as well as its population. Satellite image in figure 1.1 shows more than half of its area is dominated by big building and identified as a bussiness building such as shopping centers, hotels, and government office. Due to its small area, population density in this village is higher than Tegalpanggung village. Table 3.2 shows RW number 9 has the highest population density ie. 708.96. This level has 113.43 point higher than the highest value in Tegalpanggung village. Overal, number of male in Suryatmajan is less than female. Figure 3.3 depictures the population density of Suryatmajan village in RW level.

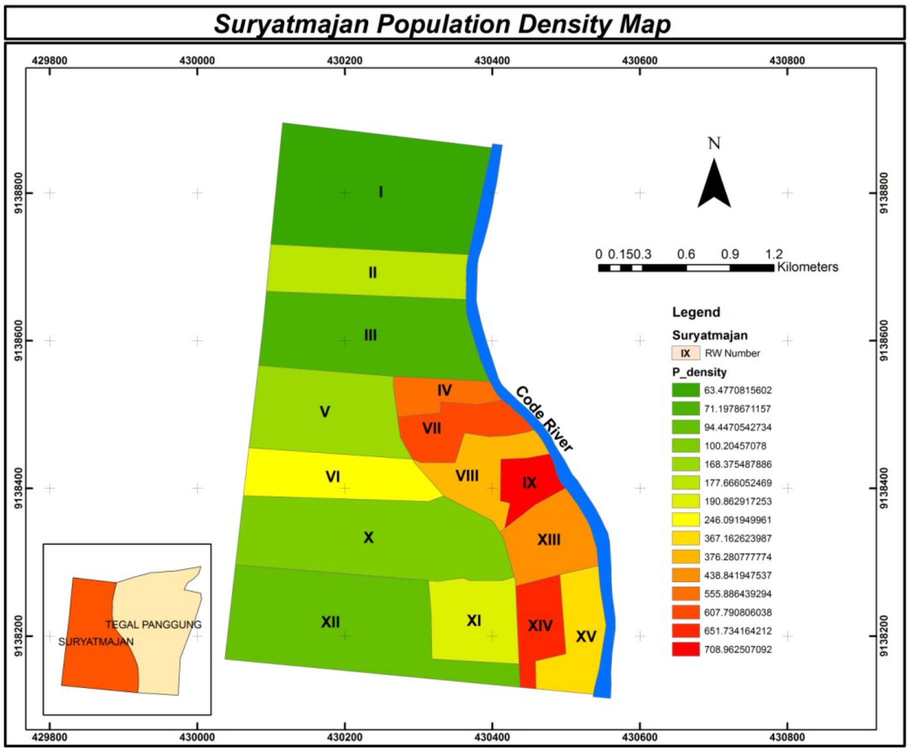

Figure 3.3 Suryatmajan Population Density Map

Source : Data Analysis)

According to figure 3.3, dense populated area were located near Code River i.e. RW IV, VII, VIII, IX, XIII, XIV and XV. Referring on figure 1.1 on earlier chapter, land use in those RW were mostly covered by irregular dense settlement.

3.2 Lahar Flood Event along Code River

As it mentioned in introduction, Code river is one of big river in Yogyakarta Municipality which has upstream on top of Merapi Volcano. This situation lead to the condiontion that area along Code river prone to lahar flood after Merapi eruption. In 2010 and early 2011, lahar flood inundated settlement in Code river . Based on information at National Disaster Management Agency's website, in 29th November 2010, lahar flood inundated more than 40 houses in Code River . In Sunday 1st May 2011, as it reported in National News paper at www. Kompas.com and www.tribunews.com, lahar flood was struck Code river again.,

4. RESEARCH METHODOLOGY

4.1. Methods

In this research methodology, it will disscuss about research stage which devided into three research stages i.e. pre fieldwork, fieldwork and post fieldwork analysis. Figure 4.1 below explains the flow chart of those three stages in detail.

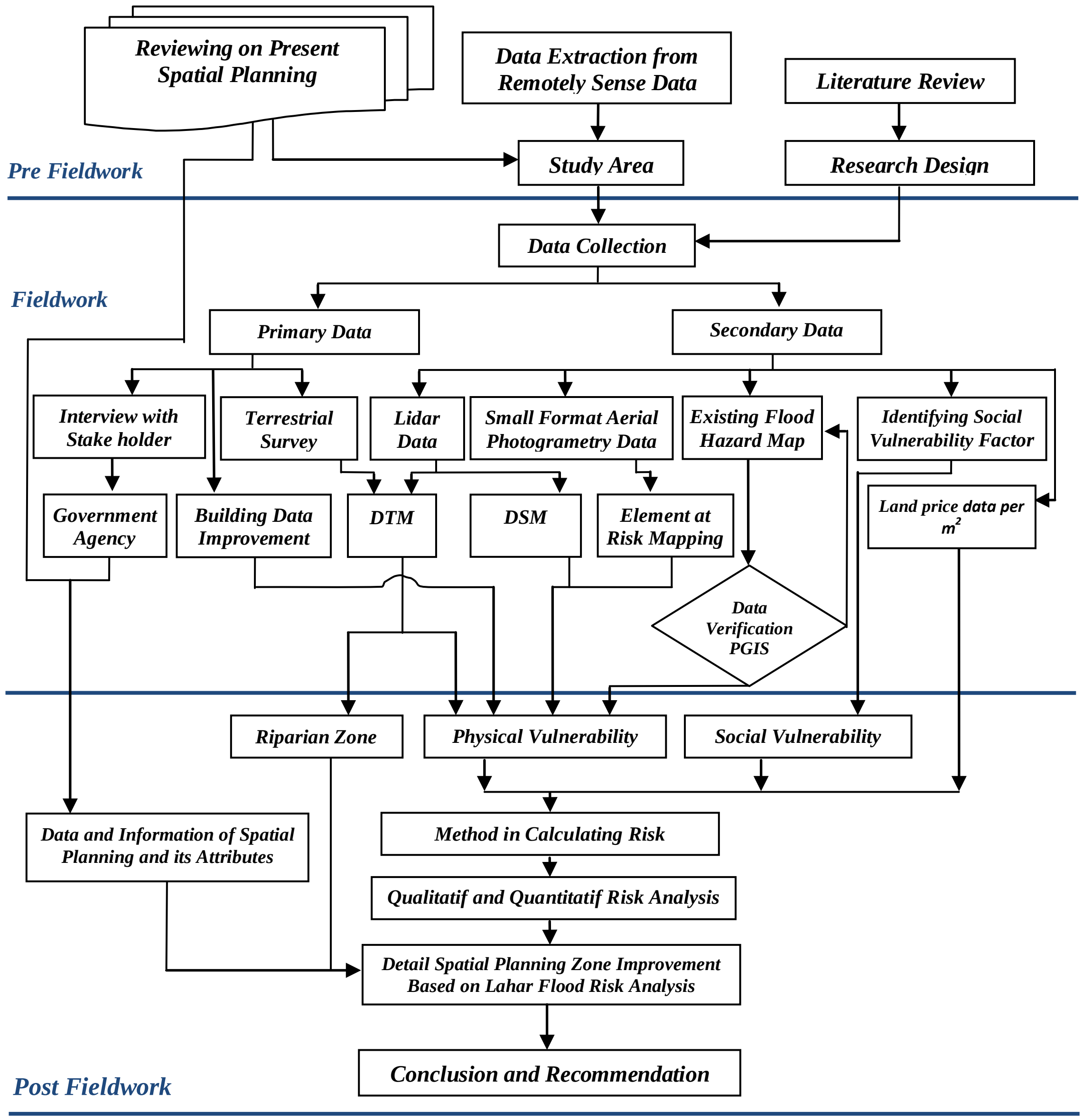

Figure 4.1. Research Framework

Each stage is planned to do some activities to seek answers from the research question established at the beginning of the study.

4.2 Pre Field Work

Firstly, the pre fieldwork stage deals with archive data inventory on existing database such as high resolution satellite image (Quickbird) . Next activities is reviewing present Spatial Planning of Yogyakarta municipality area year 2010 – 2029. Method in reviewing is compare and contras with higher level of regulation such as Government regulation and National Laws related to spatial planning to gain more comprehensif assessment. Result of reviewing regulation is became foundation on determining the studi area together with literature review on previous research (journal, books, report etc) . Some of result in this first step are objectives, research questions, and research design.

Table 4.1 Data Inventory in Pre Field Work.

No.	***Required data***	***Sources***	***Research Task***
1.	Spatial planning regulation and its properties	Local Planning Board of Yogyakarta Province	To review on present of spatial planning for generating planning information
2.	Quickbird satellite imagery	Geography Faculty of Gadjah Mada University	To define the study area
3.	Administratif boundary of the village	Geography Faculty of Gadjah Mada University	To define the study area
4.	Literature (books, journals)	Various resources	To design the research

In table 4.1, it gives information on data avaibility and theirs sources at the first stage of the research. The first required document to be assessed was Spatial Planning Regulation of Yogyakarta Municipality no. 2 year 2010 and other regulation on higher level (provincial and national level). Meanwhile, other required data was obtained from Gadjah Mada University and internet.

4.3 Field Work

Secondly, the next step is fieldwork on data collection of two villages (Tegalpanggung and Suryatmajan) along Code river.

There are two main data that will be collected i.e. primary and secondary data. Activity on primary data collection is interviewing stakeholder such as urban planner, local government to gain information of present spatial planning and its properties. Interview with local community also will be implemented to dig up about lahar flood disaster after Merapi eruption in 2010 especially on flood depth and flood extent. Another information that will be gathered is flood proofing effort based on their experience in 2010 to protect their properties from further disaster in the future. Building data improvement is to improve element at risk data such as landuse, building height etc. Digital terrain model data will be gathered by using Real Time Kinematic (RTK) GPS method and compared to Lidar data.

In secondary data collection, Small Format Aerial Photogrametry (SFAP) and LiDAR data were obtained from Geodetic department of Gadjah Mada University. SFAP data is combined with Ikonos image and used to generate building footprint constructing element at risk data base. Digital surface model is generated from LiDAR data. Social data in those two villages such as age, poverty, education, occupation, head of family are acquired from government agencies (Social and Man Power Agency, Population and Civil Record Agency) and mapped its spatial distribution. Quantifying risk is needed to calculate value of element at risk. Land price per m^2 is used to value the risk on Indonesian currency (Rupiah). This data is gained from National Land Agency of Yogyakarta Province. Lahar flood hazard maps and its atributes are retrieved from Gadjah Mada University (previous research on lahar flood in Code River).

4.4 Post fieldwork

The last step is post analysis fieldwork which will deal with lahar flood risk analysis and its correlation to the spatial planning of riparian zone in Code river.

Reviewing on recent spatial planning together with indepth interview (unstructural interview) with stakeholder i.e. Government (urban planner) will result data and information on its properties. In correlation to the study area, digital terrain model is used to define the actual riparian zone in Code River. Physical vulnerability value of settlement along Code River is defined based on element at risk data base, digital surface model from Lidar data, digital terrain model from combination of terestrial survey (RTK-GPS) and Lidar data, and lahar flood hazard map. Existing lahar flood hazard maps from previous research is verified using Digital Terrain Model (DTM) and Participatory GIS by interviewing local community (lahar flood depth and extent map after the last Merapi eruption in 2010) . Demographic data on those two village will be analyzed and placed on the map to have social vulnerability map based on some factors such as age, education, gender ,poverty, head of household.

Method in risk calculation will use the formula of R = H * V * A. There will be calculation on two different situation of landuse dynamic change. First risk calculation will only take account on 2011 lahar flood event. Second calculation, it will include the structural capacity of structural flood proofing effort after the 2011 lahar flood event . The result of risk calculation will obtain two categories i.e. qualitatif and quantitatif risk. The qualitatif risk will give information of risk level (high, moderate, low and no risk). Meanwhile, quantitatif risk calculation result is index of risk and its value in currency. Quantifying the lahar flood risk in Indonesian currency , the calculation will use land price data per m^2 (Rupiah/m^2).

Together with reviewing result of zoning system in present spatial planning, lahar flood risk analysis is going to be used as a tool to propose method in improving zoning system along the Code river's riparian zone for supporting further detail spatial planning.

Table 4.2 Tools and Software

No.	***Tools***	***Type***	***Function***
1.	Software	- ArcGIS - Ilwis v3.0 - Microsoft office	- To map risk element (Riparian zone, Physical vulnerability) - Calculating Risk and zoning system analysis improvement - To map social vulnerability - Data base improvement and research report
2.	Global Positioning System (GPS)	- Garmin 76 csx - RTK GPS (Javad Triumph)	- PGIS survey for locating flood extent and depth - Improving landuse data - To measure 3D point of terrain

Table 4.2 gives explanation on tools and software which used in this research. There were three software which will be become the main tools to map lahar risk factor and make research report. Global Positioning System is the tool for positioning. Two types of GPS were used i.e. navigation GPS (Garmin 76 csx) which has maximum accuracy of 5 meters and Geodetic GPS (Javad Triumph) which can give millimeter result in point positioning.

5. ASSESING PRESENT SPATIAL PLANNING

In national level of Indonesia's spatial planning regulation, as it regulated in Act number 26 year 2007 about Spatial Planning chapter III, it has five categories i.e. system, main function of the region, administrative boundary, region activity and region strategic value. Article 5 in this act explained all those categories i.e. :

1. Spatial planning based on system consists of the region and the urban internal systems.
2. Spatial planning based on the primary function region consists of protected areas and areas of cultivation
3. Spatial planning based administrative area consisting of national spatial planning, provincial spatial planning and district / municipality spatial planning
4. Spatial planning based region activities consist of rural spatial planning and regional urban spatial planning
5. Spatial planning based on strategic value of the region consists of national strategic spatial planning, the provincial strategic spatial planning, districts/ municipality strategic spatial planning

Furthermore, spatial planning based on administrative boundary can be devided into general and detailed spatial planning. Figure 5.1 below gives overview of the classification.

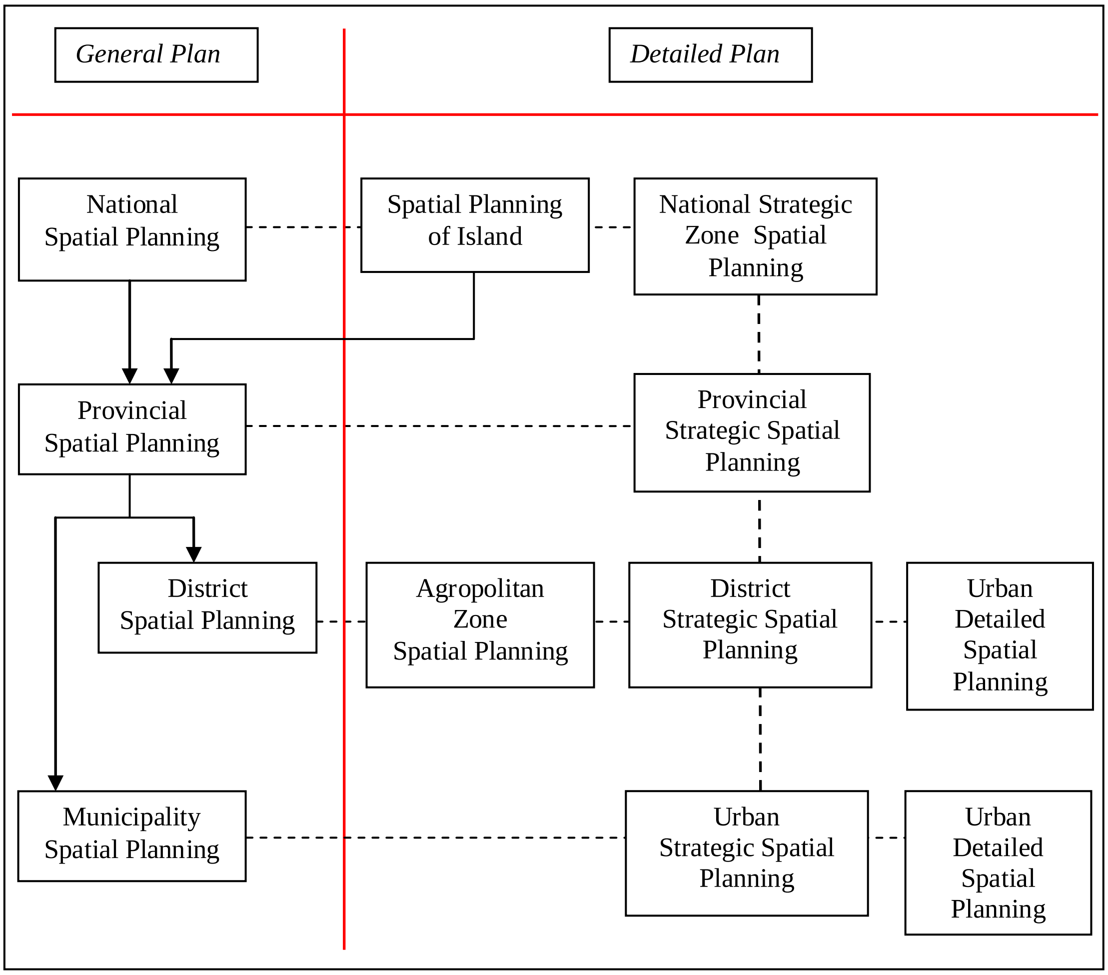

Figure 5.1 Overview of Spatial Planning Category

Source : Act number 26 year 2007 about Spatial Planning

Henceforth, the advanced rule of act above was Government Regulation No. 15 year 2010 about Implementation of Spatial Planning. In chapter 59, it stated that "Each spatial planning of district / municipality should assign part of the district / municipality needs compiled detailed spatial planning. Detailed spatial planning must be set at least 36 (thirty six) months since the establishment of the districts / municipality spatial planning."

In accordance with figure 5.1 above, Government Regulation of Republic Indonesia number 10 year 2000 about Map Accuracy Level for Regional Spatial Planning regulated the scale of each level. Especially for the municipality spatial planning, it has been written in article 32 and 34 that scale for the municipality spatial planning is 1 : 25.000 . The scale for Urban detailed spatial planning is 1 : 5.000 which contain elements of :

1. the shoreline;
2. hydrographic, such as sea including water elements in coastal area, rivers, canals, waterways, lakes, reservoirs or dams are described to scale to a minimum width of 5 meters;
3. settlements;
4. transportation networks, such as highways, arterial roads, collector roads, local roads, other roads, trails, railways, airports and ports;
5. administrative boundaries, such as national boundaries, provincial boundaries, district boundaries, municipality boundaries, subdistrict boundaries, village boundaries;
6. height point, and
7. geographic element names.

In term of the river regulation, the latest Government Regulation of Republic Indonesia about River number 38 year 2011 regulated the preserve zone of the river. The definition of the preserve zone of the river is " a buffer between river ecosystems and land, so that stream function and human activities are not mutually disturbed ". In article 8, the basis of the preserve zone are

a. river with no embankment in the urban area;
b. river with no embankment outside urban areas;
c. river with embankment in the urban areas;
d. river with no embankment outside urban areas;
e. river which affected by tide water;
f. lake flood exposure, and
g. springs.

Continuing the explanation, in chapter 11, the point c above was defined by minimum distance of 3 meters from the outside edge of the embankment foot along the river.

Moreover, the regulation that explanined implemententation of Act number 26 year 2007 was Government Regulation Number 15 year 2010 about Implementation of Spatial Planning. In chapter 61 (article 1) , it mentioned that the designing process of detail spatial planning involving :

a. preparation process of detail spatial planning;

b. the role of community involvement at the district / municipality in the preparation of a detail spatial planning, and
c. draft discussion of detail spatial planning by stakeholders at district / municipality level.

Article 2 in this chapter discussed more detailed on 5 stages of constructing detail spatial planning i.e.

a. Compiling preparation
    1. terms of reference preparation;
    2. used methodology and,
    3. detailed spatial planning budgeting activities.
b. Data collection at least include:
    1. Administration boundary data;
    2. Physiographic Data;
    3. Demographic data;
    4. Economic and financial data;
    5. Availability of facilities and basic infrastructure data;
    6. Space allotment data;
    7. land tenure, land use, and land utilization data;
    8. building intensity data, and
    9. topographic base map and thematic maps needs including land tenure map, land use map, space allotment map, and disaster-prone areas map on a scale maps at least 1:5,000.
c. Data processing and analysis of at least include:
    1. technical analysis of environment bearing capacity and carrying capacit determined through the strategic environmental assessment
    2. technical interregional linkage analysis of district / municipality;
    3. technical analysis of the linkages inter space components in district / municipality;
    4. area technical design
d. Formulation concept plan must be at least:
    1. refers to:
        a) spatial planning districts / municipality, and
        b) guidelines) and hint execution spatial planning sector
    2. take notice:

a) long-term development plan district / municipality and

b) medium-term development plan districts / municipality.

3. formulate a detailed planning draft of area.

e. Preparation of the draft rules of the district / municipality detail spatial planning implemented accordance with the provisions of the legislation.

In accordance with government regulation above , especialy on chapter 61 article 2 point b, there are nine types of data which is needed to construct detail spatial planning. Further research will elaborate several data in lahar flood risk analysis to improve the technical method in zoning determination along Code river.

5.1 Existing Zone in Spatial Planning of Yogyakarta Municipality

Reviewing the present spatial planning of Yogyakarta municipality year 2010 – 2029 number 2 year 2010, its concern was on the zoning system in riparian zone especially in Danurejan Subdidtrict .

The existing zoning area as it was viewed in earlier chapter (figure 1.1), depicted Danurejan Subdistrict including in three zones of core area ie. Locally Preserved Core Areas Of Riparian Zone, Cultural And Natural Buffer Zone and Locally Preserved Core Areas Of Archaeological / Cultural / Historical.

Based on the definition in the regulation number 2 year 2010, Locally Preserved Core Areas Of Riparian Zone can be explained as " designated areas with the main function to protect the environmental sustainability covering natural resources and artificial resources along the river. ." Cultural And Natural Buffer Zone defined as "areas that are directly related to the core area, the use of urban space in the buffer zone is based on the linkage function and history of the buffer and core areas." The last zone, Locally Preserved Core Areas Of Archaeological / Cultural / Historical was defined as "an area that have cultural, historical, and other values that show the importance of the region to be preserved".

After knowing those three zone, it was important to obtain the width of two zones which only two out of three closed to the river (1st and 2nd zone). In this regulation ,it did not mentioned the width of the zone. GIS methode was used to generate the distance. The result (figure 5.2) was Locally Preserved Core Areas Of Riparian Zone zone has 50 meters width and the second zone was vary depend on the area (range from 35 meters to 75 meters).

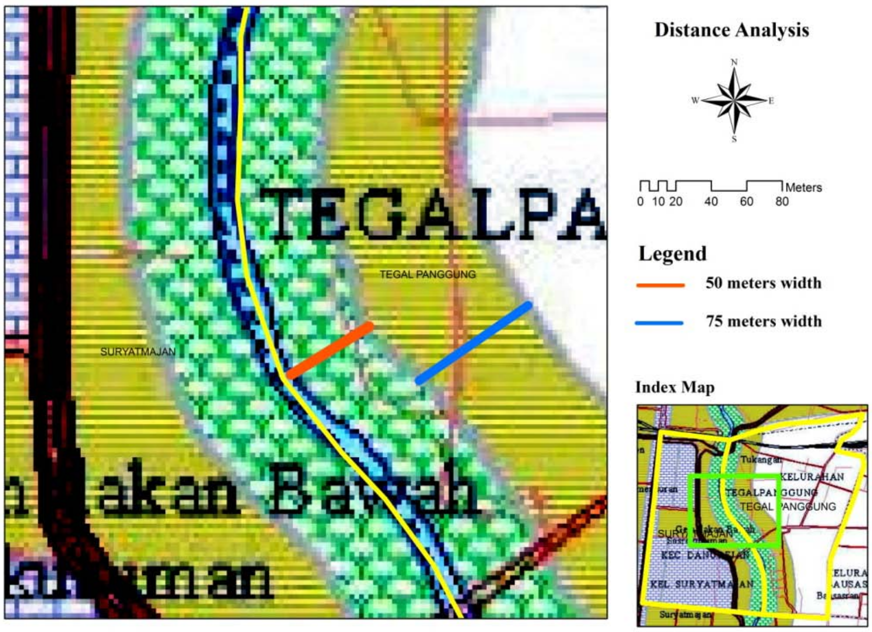

Figure 5.2 Distance Analysis

Source : Spatial Planning Regulation Of Yogyakarta Municipality number 2 year 2010 (clip image of figure 1.1) and GIS analysis

Concerning with those distance, to know what regulation underlying the process of making those distance is required for suitability assessment. Based on the list in the spatial planning regulation No. 2 year 2010, there were several regulations which become the basis of the zoning system in riparian zone i.e. : Presidential Decree No. 32 Year 1990 on the Management of Protected Areas, Government Regulation No. 35 year 1991 about River, , Government Regulation Number 26 Year 2008 on National Spatial Plan. All of those regulation regulate preserve area along the river. The latest Government Regulation No. 38 year 2011 about river regulate clearly about preserve area along the river in urban area.

Table 5.1 Preserve area based on existing regulation.

No.	Regulation	Article	Preserve area in settlement area (in Meter)
1.	Presidential Decree No. 32 Year 1990 on the Management of Protected Areas	16	10 - 15 meters
2.	Government Regulation No. 35 year 1991 about River	5	minimum 5 meters
3	Government Regulation Number 26 Year 2008 on National Spatial Plan	56	minimum 5 meters
4	Government Regulation No. 38 year 2011 about River	8 and 11	minimum 3 meters

In relation table 5.1 with existing Spatial Planning of Yogyakarta municipality No. 2 year 2010 (figure 5.2), it seem that the first and second zone need to be adjusted in detailed spatial planning especially following the latest regulation of minimum 3 meter preserve area outside the protection foot wall.

In addition, Act No. 4 year 1992 about Housing and Settlement and Act No. 26 Year 2007 on Spatial Planning regulated that the preserve area along the river should clear from the settlement and this area only intended for river consevation.

5.2 Interviewing Local Agency

To gain the information on regulation No. 2 year 2010, it was necessary interviewing related government agencies which in charge on constructing this regulation. The local agencies which was interviewed were Local Planning Board of Yogyakarta Province, Local Planning Board of Yogyakarta Municipality, Settlement and Regional Infrastructure Agency, Fire Prevention, Disaster and Public Protection Office. The interview was done in the fieldwork stage together with secondary data collection.

Several important information from the unstructural interview were obtained i.e. :

1. Lahar flood thread from Merapi Volcano eruption to the big river in Yogyakarta was not considered in river zoning system of Spatial Planning Regulation number 2 year 2010. The information on lahar flood can be used as one of sources in river zoning system
2. There is no building codes regulations arround the river banks especially related to lahar flood or any other disaster.
3. The preparation on detailed spatial planning following regulation No. 2 year 2010 is ongoing process. This process could use any information related to zoning system from local community, inter government agency, and university as a research center.

Those valuable information obtained from local agencies interviews reinforce one of the goals of this study i.e. improvement on zoning system along the Code river.

6. METHOD FOR CALCULATING LAHAR FLOOD RISK

In this chapter,it will describe about generating method for lahar flood risk calculation. Subsequently, there are four main topics that will be explained i.e. constructing 2011 lahar flood event map, element at risk data base , physical and social vulnerability, and risk method for lahar risk analysis.

6.1 Constructing 2011 Lahar Flood Event Map

There are several factors that will be analyzed in the constructing 2011 lahar flood event map such as retrieval of DTM data, extraction DSM and validation on existing flood hazard map using PGIS survey.

6.1.1 Retrieval of Digital Terrain Model (DTM) and Digital Surface Model (DSM) Data

Digital terrain model data extraction of the study area is carried in the fieldwork stage**.** Two method were used to know the pattern of the terrain in Suryatmajan and Tegalpanggung village. First method is using Real Time Kinematic Global Posistioning System (RTK-GPS). This method is choosen among the other of terrestrial method such as Total Station, Theodolite etc, due to its rapid data acquisition, centimetre accuracy and high flexibility to the study area which consist of dense irregular settlements. Reference point for the terrestrial survey (RTK –GPS) is National Agency of Survey and Mapping Coordination' s bench mark(BM) number N005 which located in Gadjah Mada University Boulevard. This BM has coordinate of 7° 46'25.6867" south , 110° 22' 36.4409" east with ellipsoid height 157.86 meter and UTM coordinate of E 431284.033 meter N 9140658.018 meter. BM N005 location has an ideal position for satellite data acquisition because of zero obstruction and placed in safe area. Figure 6.1 shows reference station of BM N005 in front of GMU's building Grha Sabha Pramana and Javad Triumph L1/L2 Geodetic GPS receiver.

Figure 6.1 Base station BM number N005
and Javad Triumph L1/L2 Geodetic GPS source fieldwork 2012

In implementation, real time kinematic survey use a set of Geodetic GPS, 1 base station and 2 rovers. These three GPS tools are the same ,but in RTK GPS measurement system is divided into two functions. Two rover retrieve the unknown data point which is considered to represent the terrain of study area (figure 6.2).

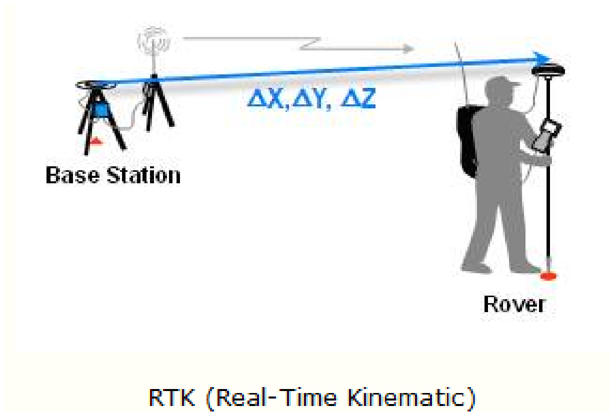

Figure 6.2 Illustration of RTK-GPS survey source NRCAN 2012
(http://www.geod.nrcan.gc.ca/edu/rtk_e.php)

Based on illustrattion on figure 6.2, those two GPS receivers are observing satellites simultaneously, then by using radio waves the correction data from the base station sent to the rover in real time for accurate positioning.

Limitations in data collection in the field is dense irregular settlement and not much open space left for the rover placement point. In most of the locations (figure 6.3),there are canopy blocked the sky view then satellite observations can not be done.

Figure 6.3 Blocked sky view

Source : 2010 SFAP data

During fieldwork stage, there were 304 points measured which will use as 3D points to generate digital terrain model data of two villages. Some of 3D points were removed from DTM calculation due to its low precision.The final 3D points were 290 points. Conducted 3D analyst in ArcGIS, Natural Neighbor Interpolation (NNI) was the method used to generate raster elevation data from 3D point. Compared to another interpolation method, NNI has the results close to the terrain of the study area.

Second method of DTM data extraction is LiDAR data. LiDAR is acronym for Light Detection and Ranging or Laser Imaging Detection and Ranging. A method is used to detect distance objects and determine their position, velocity, or other characteristics by analysis of pulsed laser light reflected from their surfaces (AI ,2012). This data was obtained from Geodetic department of Gadjah Mada University. This data contains 3D point coordinate data acquisition results in February 2011(four months after the last Merapi eruption). LiDAR provides a digital surface model data including buildings, trees and all objects on earth. The resulting distance between the point is one meter. Obtained LiDAR data were in a file with the extension *. xyz. There are two type of data ie. digital surface model (DSM) and digital terrain model (DTM). Figure 6.4 shows the raster image of DSM.

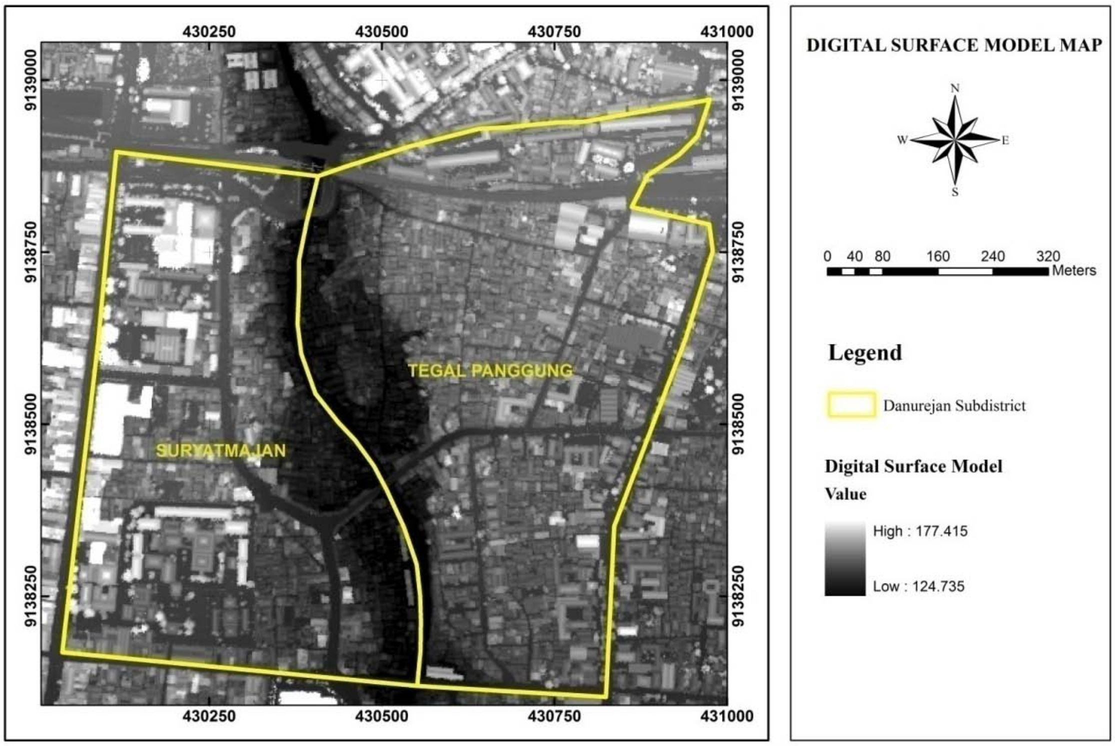

Figure 6.4 Digital Surface Model Map

Source : 2011 LiDAR data

The DTM data is filtered 3D point of DSM by removing data which is classified as non terrain data such as buildings, tress and other man-made objects.

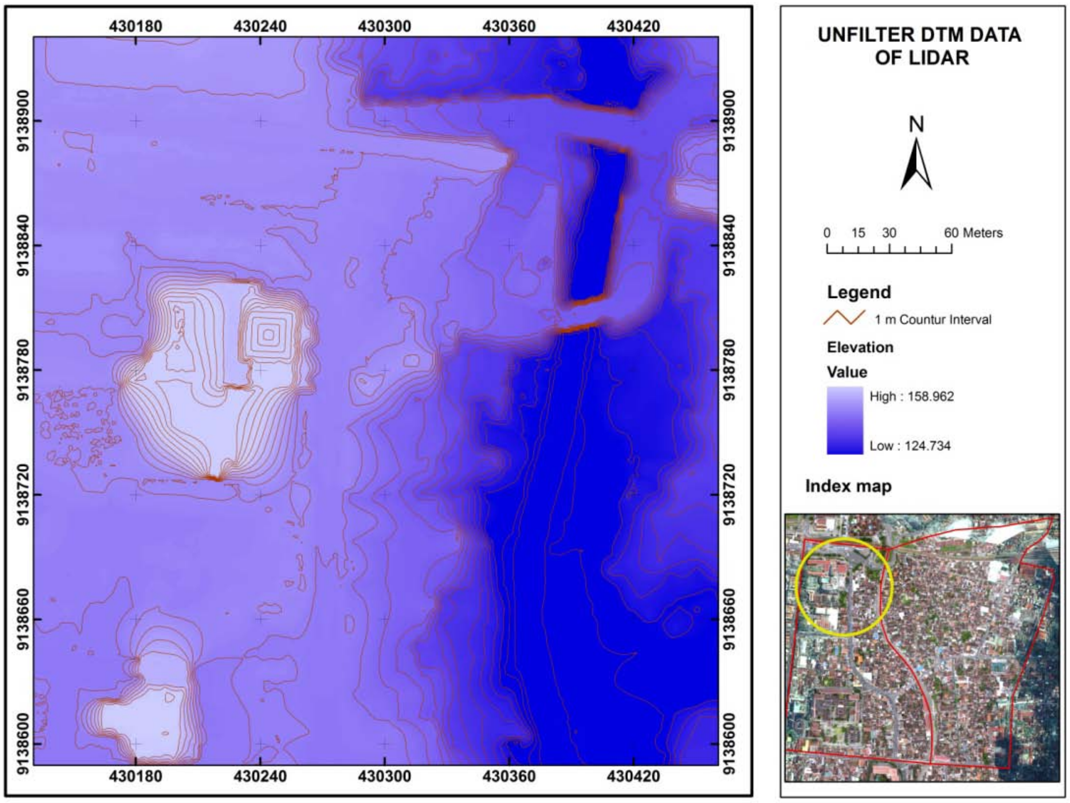

Figure 6.5 Unfilter DTM data of Lidar

Source : 3D analysis

Figure above shows raster elevation and contour line with 1 meter interval. The map shows the first 3D analysis filtering results derived from the 3D points using Natural Neighbor Interpolation. At the center of the map can be seen that there are contour lines that form a quadrilateral. This means that the obtained data need to be filtered. The results of measurements of RTK-GPS surveys was used to eliminate the points that do not represent the terrain. Raster elevation in Figure 6.5 use 3D the points of 269.570. Final raster elevation was based on 253.083 of filtered 3D points. The result will be used in defining the actual riparian zone of Code river and physical vulnerability calculation presented in the figure 6.6 below.

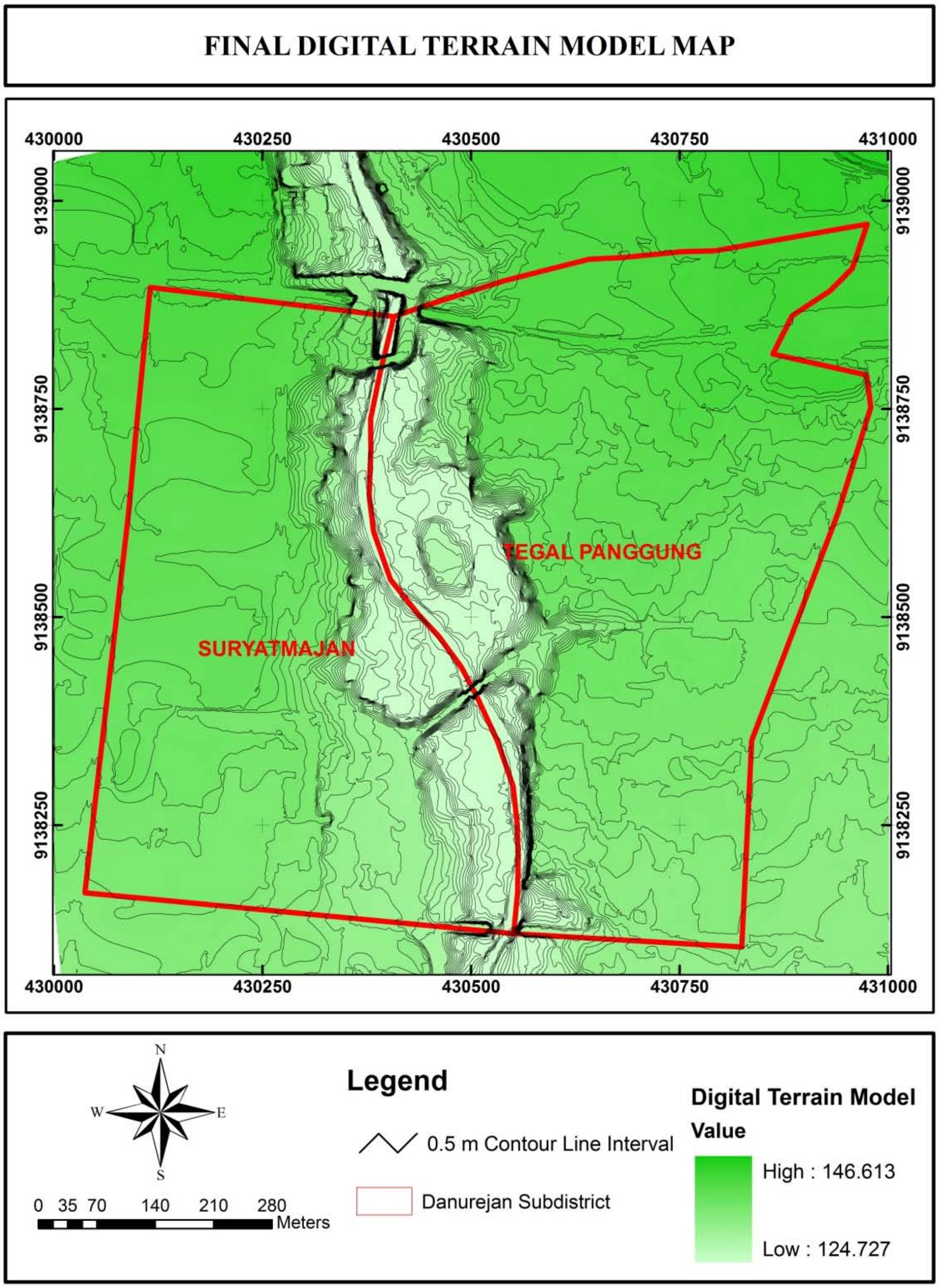

Figure 6.6 Final DTM Map

Source : 3D analysis

6.1.2 Constructing 2011 Lahar Flood Event

6.1.2.1 Previous Research

In this research, lahar flood predictiction map was derived from previous research by Agus Yasin in 2012. He made flood prediction by comparison bankfull discharge with predicted discharge using the PC raster modeling. Bankfull discharge is the maximum amount of water a specific channel can carry before water overflows the stream bank and causes flooding (E-how,2012). In case of Code river, this maximum of water was already flooded the settelement due to the flood plain area was occupied by the city dwellers. Bankfull discharge data of Code River was taken from 2007 (pre eruption) and 2011 (post eruption) which was measured using Manning's method. Yasin stated that those data were also drawn from prior research conducted by Widianto (2007) and Rahayu (2011) . Table 5.1 shows the bankfull discharge in 2007 and 2011.

Table 6.1 Bankfull Discharge 2007 and 2011

No. Sta	Bankfull Discharge (m3)		No. Sta	Bankfull Discharge (m3)	
	2011	2007		2011	2007
1	61.31	118.01	26	304.6	534.1
2	163.58	212.06	27	112	313.1
3	14.5	60.1	28	53.61	99.14
4	38.48	111.36	29	128.26	241.88
5	87.61	240.1	30	120.95	280.94
6	2.51	16.55	31	76.5	209.37
7	187.9	440.72	32	48.77	181.16
8	46.82	95.03	33	45.87	201.18
9	79.22	95.87	34	86.05	415.92

Highlighted yelow color, Number 30-34 is a section of Danurejan Subdistrict which was experienced lahar flood in early 2011. Furthermore, result of PC raster model's predicted discharge were 1,422,130 m3/day, 2,171,967 m3/day, 2,969,264 m3/day, and 3,515,760 m3/day for extreme rainfall event of 5, 20, 50, and 100 year return period respectively.

Next step of the calculation was to predict flood which is needed conversion m3/day to m3/hour by dividing 3600. The results were 68.9 m3/s, 105.3 m3/s, 143.9 m3/s and 170.4 m3/s. Table 6.2 below shows predicted discharge and bankfull discharge of Code River pre and post eruption in 2010

Table 6.2 Response of Code river to predicted discharge

Source : Yasin 2012

No. Sta	Pre-eruption					Post-eruption				
	Bankfull Discharge	5 year 68.91	20 year 105.25	50 year 143.88	100 year 170.37	Bankfull Discharge	5 year 68.91	20 year 105.25	50 year 143.88	100 year 170.37
34	415.92	347.01	310.67	272.04	245.55	86.05	17.14	-19.20	-57.83	-84.32
33	201.18	132.27	95.93	57.30	30.81	45.87	-23.04	-59.38	-98.01	-124.50
32	181.16	112.25	75.91	37.28	10.79	48.77	-20.14	-56.48	-95.11	-121.60
31	209.37	140.46	104.12	65.49	39.00	76.5	7.59	-28.75	-67.38	-93.87
30	280.94	212.03	175.69	137.06	110.57	120.95	52.04	15.70	-22.93	-49.42

Table 6.2 above gives comparison in section Danurejan between predicted discharge and bankfull discharge (2007 and 2011). Yelow colour indicates Danurejan section (30-34) prone to lahar flood. Based on calculation above, Yasin said that 2010 eruption gives significant impact to predicted flood due to sedimentation in the Code river. Those data, especially on yellow color, can be mapped to know the section is prone to flood. Figure 6.7 below shows Danurejan section in blue color is an area that includes flood prone area.

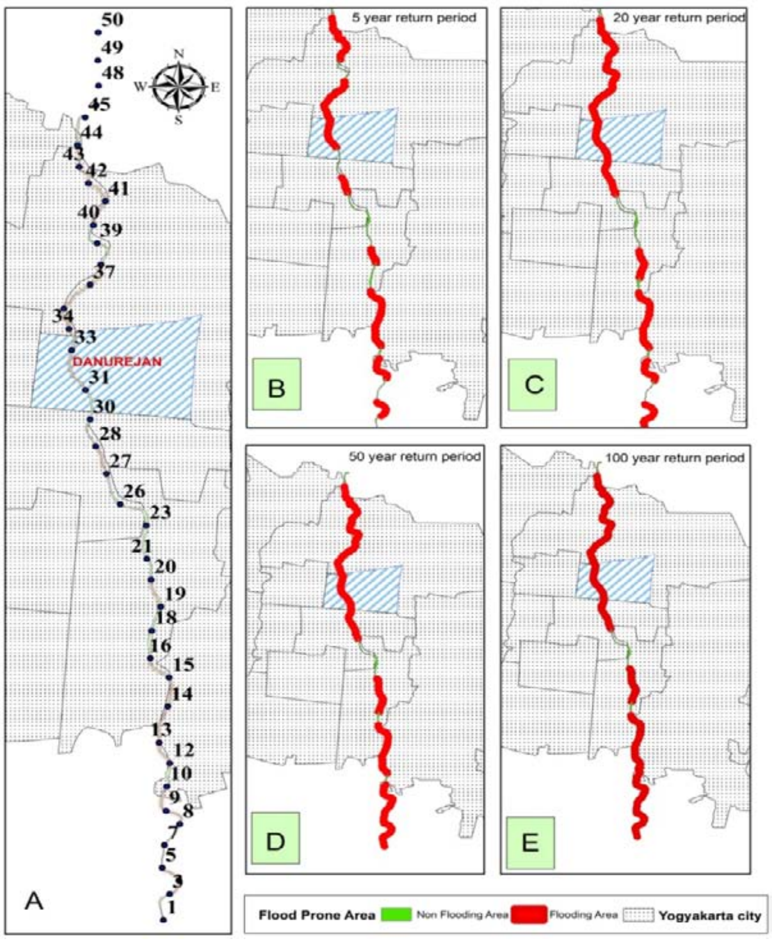

Figure 6.7 One Dimensional Lahar Flood Prone map after Merapi 2010 eruption.

Source: Yasin (2012)

6.1.2.2 PGIS Study and 3D analysis to Define the 2011 Flood Extent

The map above (figure 6.7) was a result of one-dimensional flood prediction model. It depicted the possibility of lahar flood prone area and did not figured the real flood extent which was strucked settlements. For the purposes of this research, the map of 20 year return period was choosen to vaildate its extent and depth using Participatory GIS. Those data were collected by interviewing community along Code river and seeking the remnant of the lahar flood.

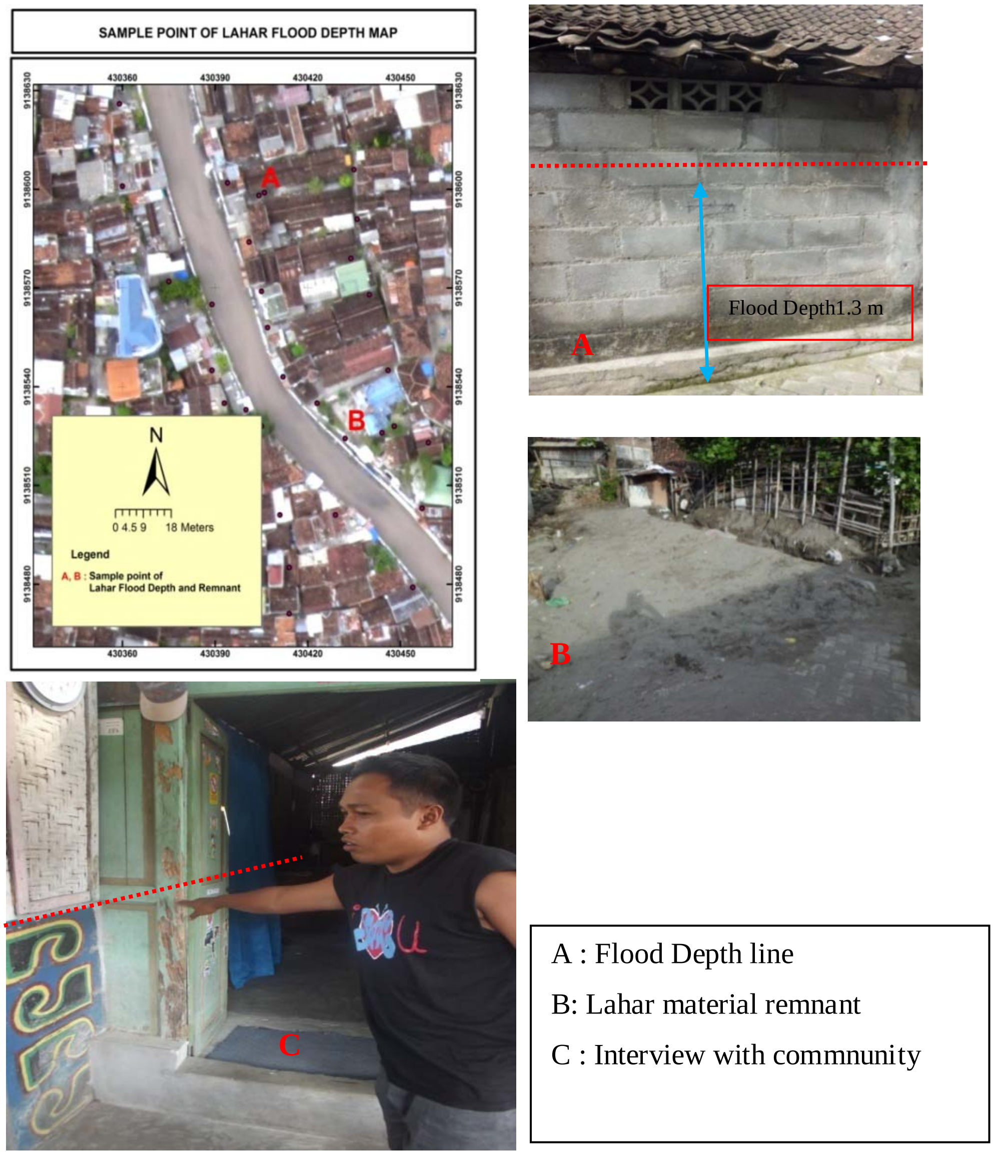

Figure 6.8 PGIS survey

Source : fieldwork survey 2012

Figure 6.8 above shows the remnant of the lahar flood in Code river. In figure A, there was a surface line remnant of the lahar flood on the building wall. This data was measured and marked in the GPS garmin 76csx as a one of source data to reconstruct the lahar flood depth. Figure B explains that the type of the flood was lahar flood due to its vulcanic material came along with the flood current. Based on the interview with the community , the vulcanic material after the lahar flood strucked their settlement was much larger than those in the picture. In another place, the community was showed the level of lahar flood depth in their house (figure C).

The first attempt to construct lahar flood depth was used data from the lahar flood extent and verified digital terrain model. The assumption was that if we have data of lahar flood extent then the very end of the lahar flood having a depth of 0 meters and the area closer to the river will be interpolated its depth by subtracting the value of height with height values at a depth of 0 meters. This assumption was taken due to Code river has a shape close to V letter.

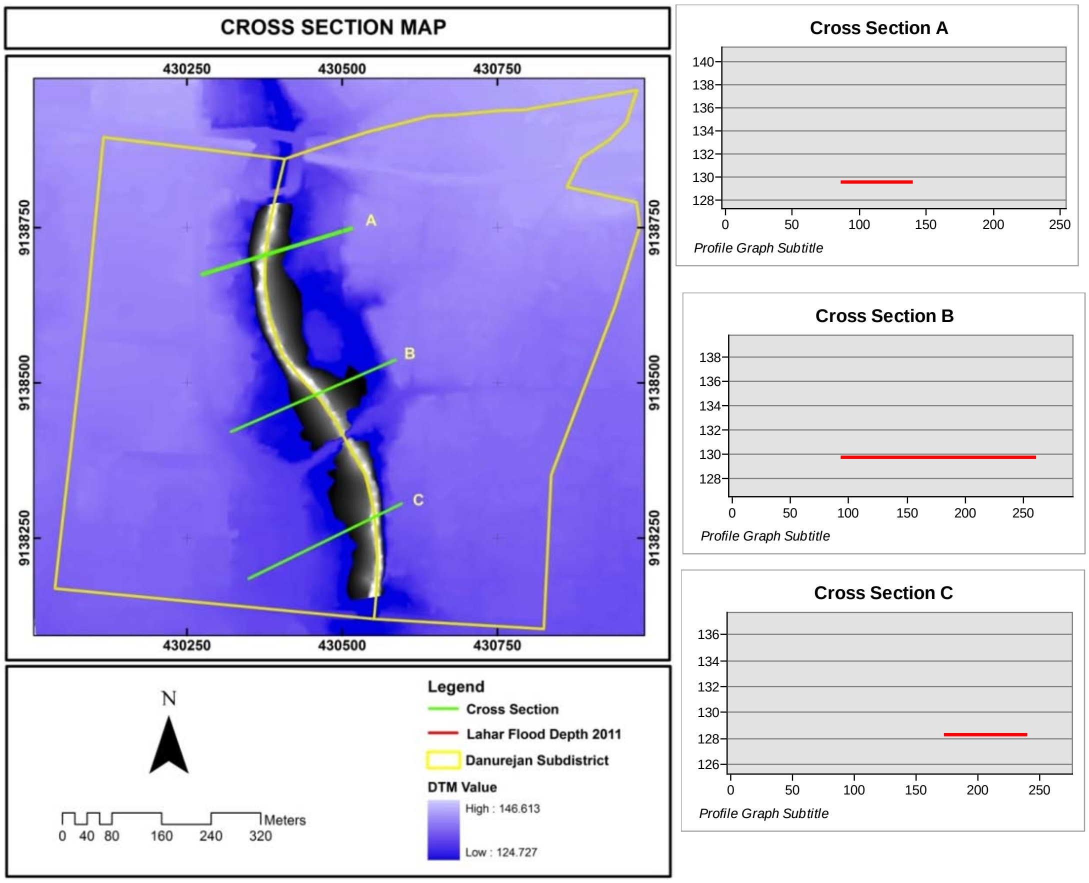

Figure 6.9 Cross Section Map

Source :3D Analysis

Figure 6.9 above shows the cross section at Code river based on verified digital terrain model. It represents the V shape. The assumption was worked on an area without any houses or man- made buildings ie. terraces, embankment etc., but some of area did not represent well enough of the flood depth. Those data were validated with lahar flood depth from community interview result. Final lahar flood extent and depth were presented in figure 6.10 and 6.11 below.

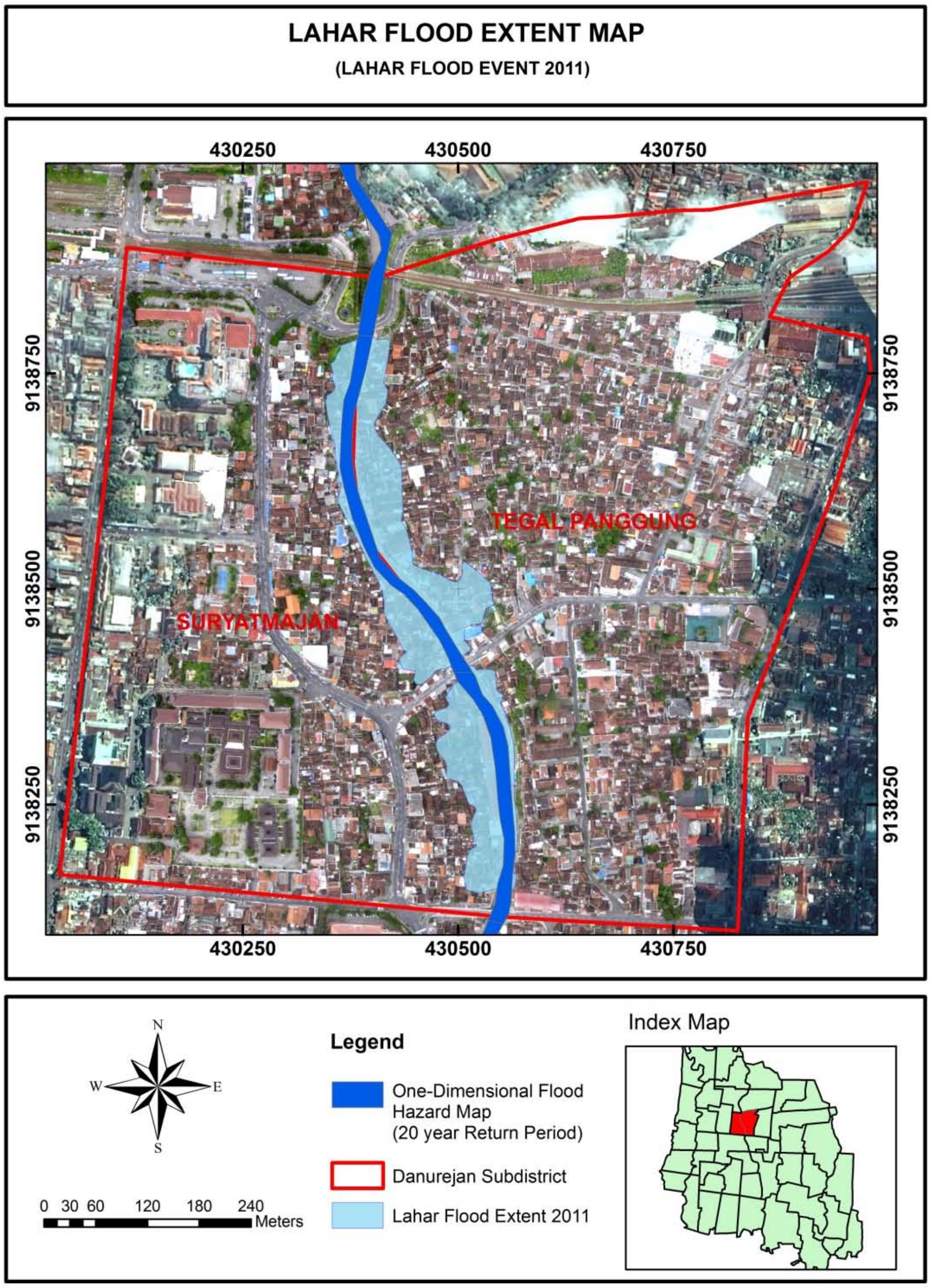

Figure 6.10 Final Lahar Flood Extent Map in 2011Event

Source : PGIS survey 2012 and 3D Analysis

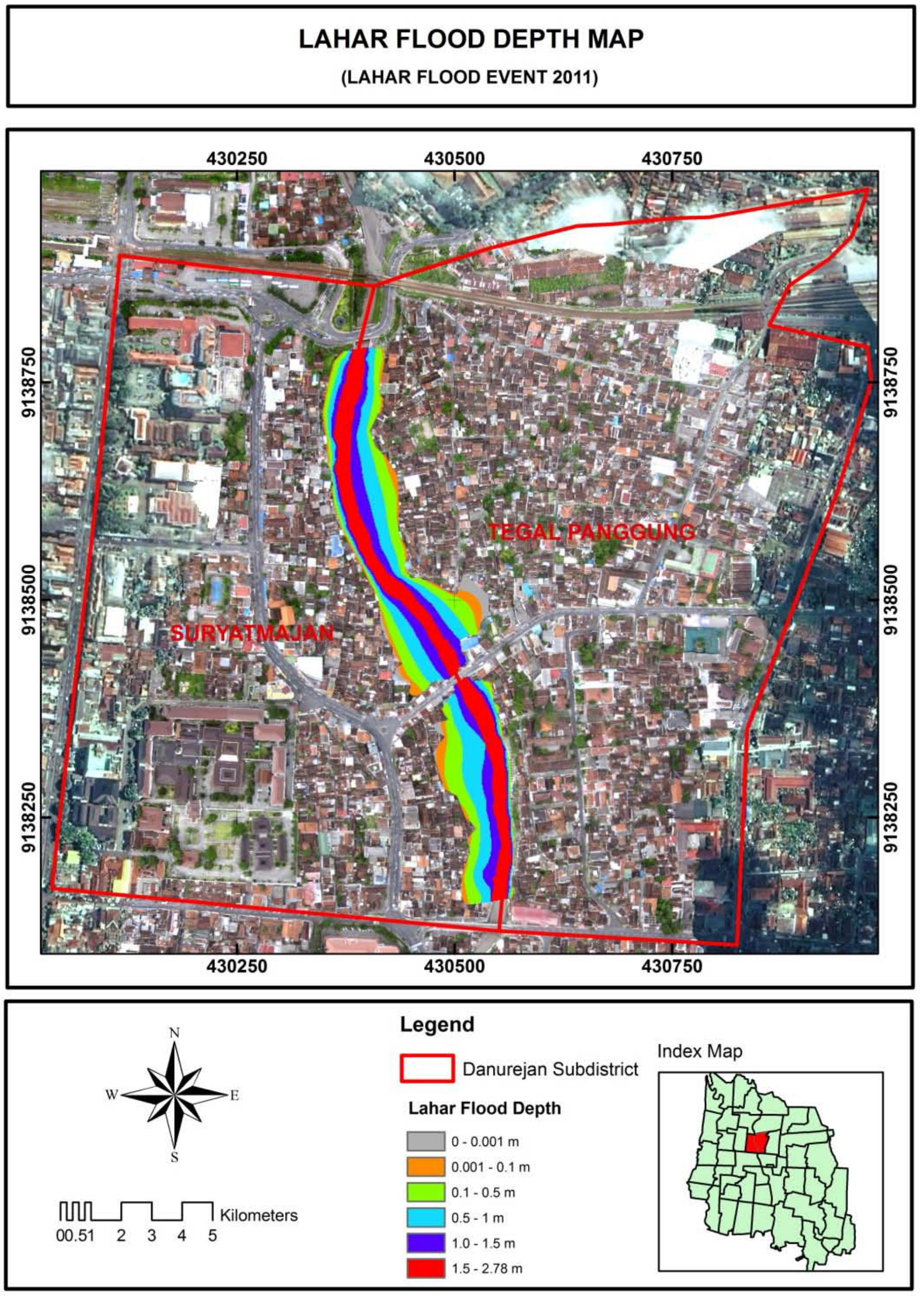

Figure 6.11 Final Lahar Flood Depth Map in 2011 Event

Source : PGIS survey 2012 and 3D Analysis

The result in figure 6.10 and 6.11 above was constructed based only on 2011 lahar flood event,since it was no data of two-dimensional lahar flood map on the Code river which represent lahar flood in diferent return period.

6.2 Element at Risk Data Base

In this stage, building as a element at risk was generated from Small Format Aerial Photogrametry (SFAP) data which was captured two months after eruption on December 2010. This data was obtained from Geodetic department of Gadjah Mada University. Acquired data images from a photo shoot with a pocket camera (Canon DIGITAL IXUS 120 IS) were placed under remote control aircraft. Raw data of the image has resolution of 12 megapixel. Orthophoto rectification of the image was use reference point from National Mapping Coordinating Agency' s bench mark (BM) number N005 which located in Boulevard of GMU. Resulted spatial resolution of the SFAP image is 20cm or 400cm^2 per pixel. It has higher spatial resolution than commercial satellite imagery available at this time (GeoEye 0.5 m, Quickbird 0.6 m, IKONOS 0.8m, WorldView 0.5 m). 20 cm resolution is advantages for generating building footprint. As mention in the earlier chapter, the study area is mostly consist of dense irregular settlement.

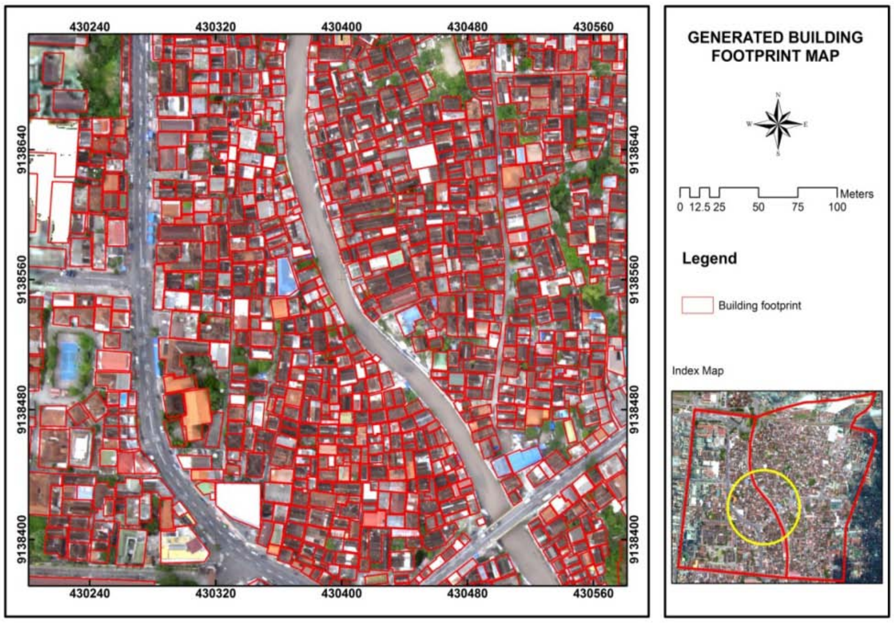

Figure 6.12 Building data extraction

Source : Data Analysis

Figure 6.12 shows building footprint result from on screen digitation using ArcGIS . Next step is interpreting the landuse of each building based on interpretation key especially size , shape, pattern, site ,association and assissted with previous knowledge and experience.

Another interpretating key which is used is height ,in this case is building height. Building height was extracted using raster calculator in ArcGIS by raster elevation of DSM minus finalized raster DTM . Interpretation results were used as landuse database and saved in shape file (figure 6.13).

Attributes of Building_1

FID	Shape *	Id	Landuse	Area_m2	Area_Ha
0	Polygon	0	APARTMENT	783.368632	0.078337
1	Polygon	0	ELEMENTARY SCHOOL	646.151199	0.064615
2	Polygon	0	ELEMENTARY SCHOOL	901.618657	0.090162
3	Polygon	0	SQUATTER	35.374366	0.003537
4	Polygon	0	BUSINESS	68.631484	0.006863
5	Polygon	0	SQUATTER	83.581149	0.008358
6	Polygon	0	SQUATTER	119.069375	0.011907
7	Polygon	0	SQUATTER	95.436009	0.009544
8	Polygon	0	SQUATTER	81.028826	0.008103
9	Polygon	0	SQUATTER	57.215697	0.005722
10	Polygon	0	SQUATTER	40.331604	0.004033
11	Polygon	0	SQUATTER	60.585555	0.006059
12	Polygon	0	SQUATTER	41.981194	0.004198
13	Polygon	0	SQUATTER	34.873186	0.003487
14	Polygon	0	SQUATTER	33.441069	0.003344
15	Polygon	0	MOSQUE	60.390396	0.006039
16	Polygon	0	SQUATTER	24.737431	0.002474
17	Polygon	0	SQUATTER	57.124071	0.005712
18	Polygon	0	SQUATTER	57.089035	0.005709
19	Polygon	0	SQUATTER	56.558408	0.005656
20	Polygon	0	SQUATTER	42.272996	0.004227
21	Polygon	0	SQUATTER	111.17085	0.011117
22	Polygon	0	SQUATTER	69.018746	0.006902
23	Polygon	0	SQUATTER	27.488353	0.002749
24	Polygon	0	SQUATTER	39.590281	0.003959
25	Polygon	0	SQUATTER	27.70291	0.00277
26	Polygon	0	SQUATTER	35.109729	0.003511
27	Polygon	0	SQUATTER	36.422745	0.003642
28	Polygon	0	SQUATTER	44.216489	0.004422
29	Polygon	0	SQUATTER	31.875493	0.003188
30	Polygon	0	SQUATTER	36.018648	0.003602

Record: 0 Show: All Selected Records (0 out of 3063 Selected)

Figure 6.13 Landuse database in ArcGIS

Source : Data Analysis

Entered landuse attribute data in the database is the result of visual interpretation of the SFAP data. There are some buildings that are not too obvious its landuse classification but then classified by the type of landuse around it, or by the shape and size of the building. The first classification result of the buildings that have been digitized, yielding 18 landuse classification are mostly squatters. Furthermore, these results are validated with a building field check that were deemed to be doubtful classification.

In practice, there are several things that become the focus of the validation in the field, namely :

- renewing type of land use and correction on visual landuse classification
- updating the existence of the building based on current condition

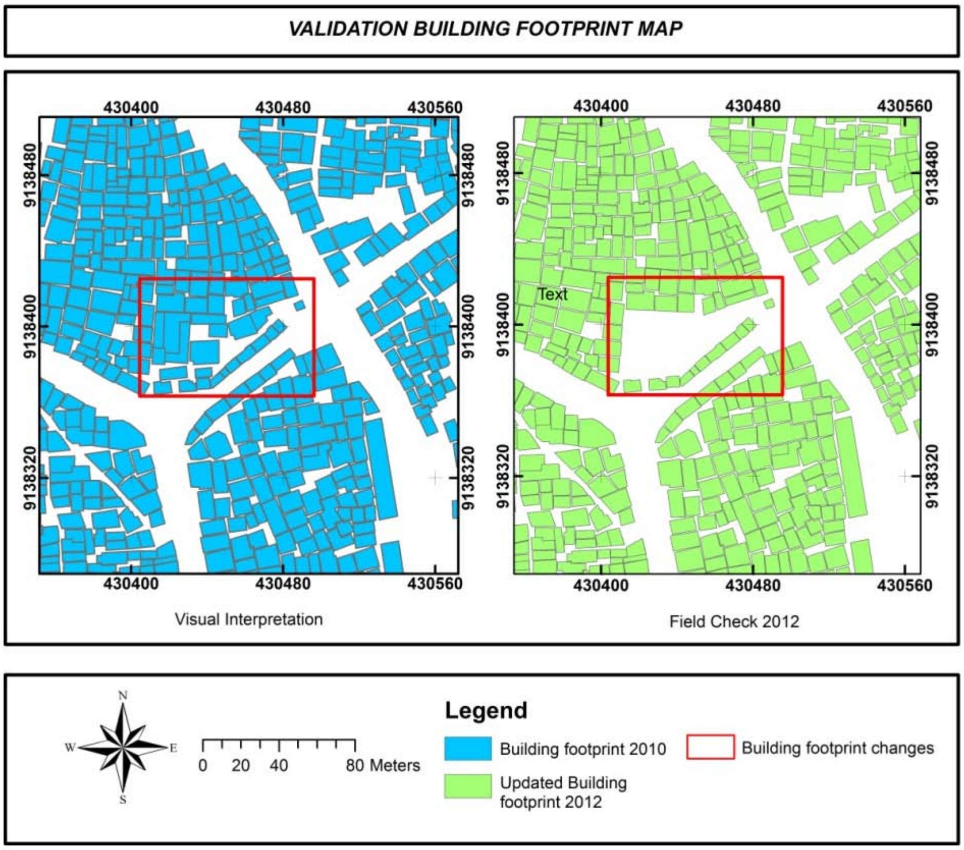

Figure 6.14 Validation of Building Footprint Map

Source : Data analysis

Figure 6.14 shows a change in existing land use along the river Code. In the SFAP image taken in December 2010 on the left side picture, there are some houses that are in the red box. Validation and checking the field in 2012, those building were no longer exists. According to interviews with local people, their home is exposed to the eviction because of their land is belongs to one of the big hotels near the area. In addition to the changes in land use, there are additional categories of land use classification. It was found 8 new landuse classification and some of buildings were incorrect landuse misinterpretation.

Correcting landuse classification is one of important factor to define the value of physical vulnerability. To reduce number of class and better data presentation , the classification of landuse was reclassified into five classes (see table 6.3) i.e. Commercial (bussiness, shop, market, mall, hotel, bank, money changer, pharmacy), Industrial (railway company, warehouse), Institutional (elemetary school, government office, tourist center, private school, government pawnshop, post office, kindergarten, maternity hospital, house of reprensentatif), Public (pulic service, outpost), Religious (mosque, public religious), residential (squatter, apartement,student boarding house).

Table 6.3 Sample of Landuse Reclassification after groundcheck

Source : fieldwork 2012

No.	Main Landuse	Landuse
1	Residential	Apartment
2	Institutional	Elementary School
3		Elementary School
4	Residential	Squatter
5	Commercial	Business
6	Residential	Squatter
7		Squatter
8		Squatter
9		Squatter
10		Squatter
11		Squatter
12		Squatter
13		Squatter
14		Squatter
15		Squatter
16	Public Religious	Mosque
17	Residential	Squatter
18		Squatter
19		Squatter
20		Squatter
21		Squatter

The final classification and building footprint were deivided into two years i.e. 2010 and 2012 (figure 6.15).

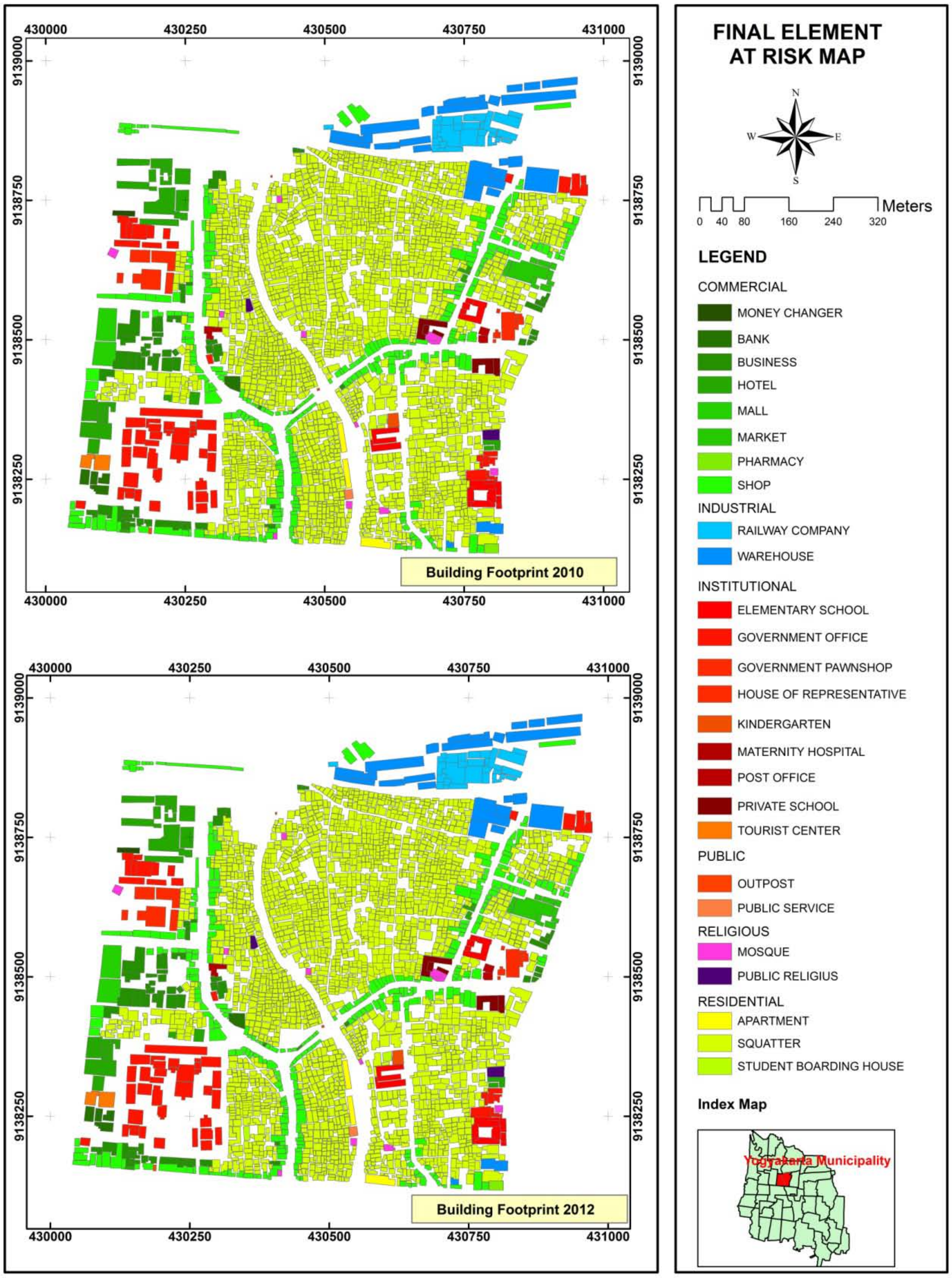

Figure 6.15 Final Element at Risk Map

Source : Data analysis and fieldwork 2012

To calculate the physical vulnerability, number of floor need to be extracted from elevation data. The building floor data was derived from digital surface model (DSM) and digital terrain model (DTM). In practice, number of floor was DSM minus DTM. Result of this calculation was devided into several classification of floor height as shown in table 6.4 below.:

Table 6.4 Number of Floor Classification

Height	***Number of Floor***
≤ 3.5 m	*1*
3.5 – 6.5 m	*2*
6.5 – 9 m	*3*
9 – 12 m	*4*
12 - 15 m	*5*
15 – 18 m	*6*
18 – 21 m	*7*
21– 24 m	*8*
24 – 27 m	*9*
27 – 30 m	*10*
30 – 33 m	*11*
>33 m	*12*

Those classification was generated from fieldwork survey together with building data improvement on its landuse.

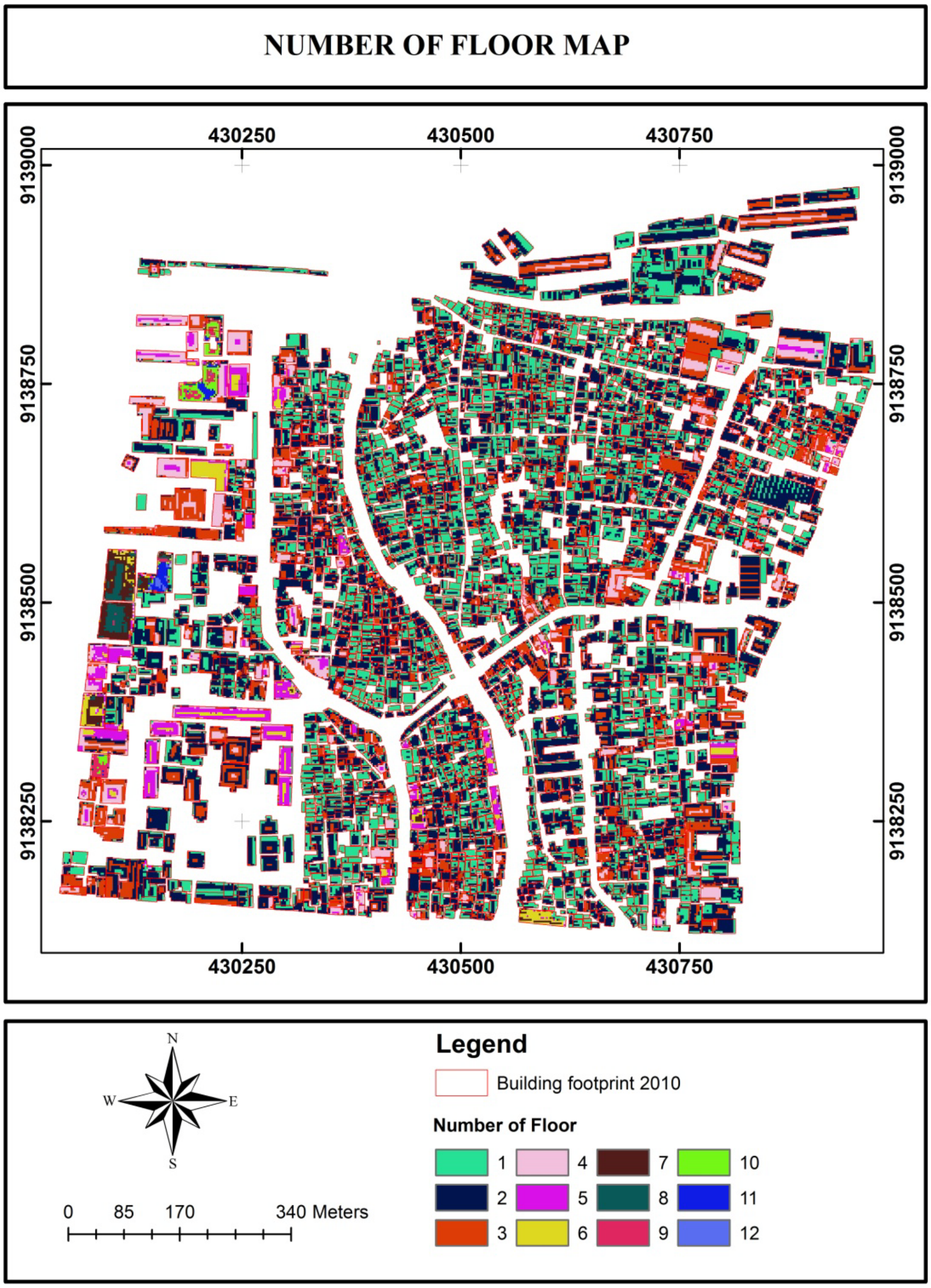

Figure 6.16 Number of Floor Classification result

Source : DSM and DTM data processing

In figure 6.16, each building can be contained two or more classifications. Therefore, it will be choosen the predominant value of floor.

6.3 Physical and Social Vulnerability

In this subchapter, physical and social vulnerability will be discussed. The physical vulnerability calculation based on two condition before and after lahar flood proofing activity. Meanwhile, the social vulnerability only took into account 2011 demographic data with the consideration that the study area is only 63 Ha. The population changes was only in small percentage.(no more than 0.5%) .

6.3.1 The First Physical Vulnerability Calculation

The first physical vulnerability will be calculated based on lahar flood depth , lahar flood extent in 2011,building footprint 2010, and number of floor from elevation data (DSM and DTM). Figure 6.17 gives overview of physical vulnerability calculation based on 2011 lahar flood event.

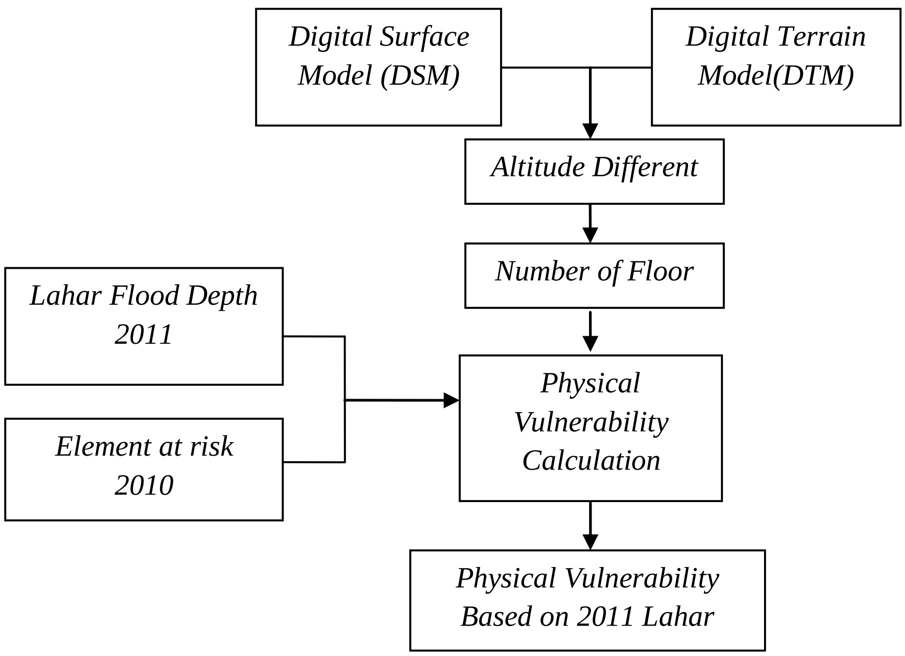

Figure 6.17 Flow chart for calculating physical vulnerability 2011.
Source : Data Analysis

To know vulnerability value, the research will use the classification of an earlier study conducted by Elena Badila Coto (2002) in Turrialba City Costarica. This classification was used because of the research only emphasis on landuse type instead of building material and building content. The Coto's research develop vulnerability value based on landuse type and flood water depth. Once again, the assumption were used to adjust with lahar flood depth in Code river. In her research,she said that the vulnerability or loss functions relate floodwater depth and degree of loss on a specific type of element at risk.

Furthermore ,the value ranging from 0 to 1 are assigned to each of the different types of buildings, in relation to four different flood water depth intervals i.e. < 10 cm, 10 – 50 cm, 50 – 100 cm and 100 – 150 cm. (see table 6.5). In her research, there were some assumptions regarding four classifications i.e. :

- The water depth inside each plot is assumed to be unique and uniformly distributed (only one depth value for each plot
- A complete loss is assumed for floodwater depths larger than 1.5m, on single floor house

Moreover, there are some object that are customized or adjusted to the conditions around the Code river i.e. landuse classification in table 6.5 were not all used in the calculation of vulnerability index. The value of vulnerability in table 6.4 has a correction factor of 0.7 for the building which have more than 1 floor. In the calculation, those buildings must be multiplied by 0.7. Used building footprint data in the first calculation was building frootprint from small format aerial photogrammetry in December 2010.

Table 6.5.a Vulnerability values for different landuse categories, in relation to four different floodwater depth interval adopted from Elena Badila Coto (2002)

Landuse type or Category	Vulnerability Value			
	< 10 cm	10 -50 cm	50 – 100 cm	100 – 150 cm
Residential	0.15	0.35	0.50	0.80
Elementary education	0.02	0.30	0.45	0.60
High education	0.02	0.30	0.50	0.70
Fire brigade and police	0.00	0.10	0.40	0.50
Government Office	0.00	0.25	0.60	0.80
Bank/Financial	0.00	0.15	0.45	0.60
Rehabilitation Center	0.05	0.25	0.50	0.65
Elderly's rest house	0.05	0.10	0.35	0.60
Church	0.00	0.05	0.20	0.30

Table 6.5.b Vulnerability values for different landuse categories, in relation to four different floodwater depth interval adopted from Elena Badila Coto (2002)

Landuse type or Category	Vulnerability Value			
	< 10 cm	10 -50 cm	50 – 100 cm	100 – 150 cm
Cemetery	0.20	0.30	0.35	0.40
Hotel, rest., bar	0.01	0.30	0.50	0.85
Commercial	0.10	0.40	0.60	0.80
Work shop/garage	0.00	0.10	0.30	0.50
Warehouse	0.00	0.20	0.40	0.50
Gas station	0.00	0.20	0.40	0.60
Industrial	0.00	0.20	0.40	0.60
Empty area	0.00	0.00	0.00	0.00
Sport fields and parks	0.00	0.05	0.10	0.15
Gymnasium and stadium	0.00	0.15	0.25	0.30
Parking and bus station	0.00	0.01	0.05	0.05

The customization of the landuse from table above were resident in the research will be squatter and church became mosque. Other than two classification remain the same. After knowing the number of floor, lahar flood depth and landuse classification, vulnerability map can be constructed.

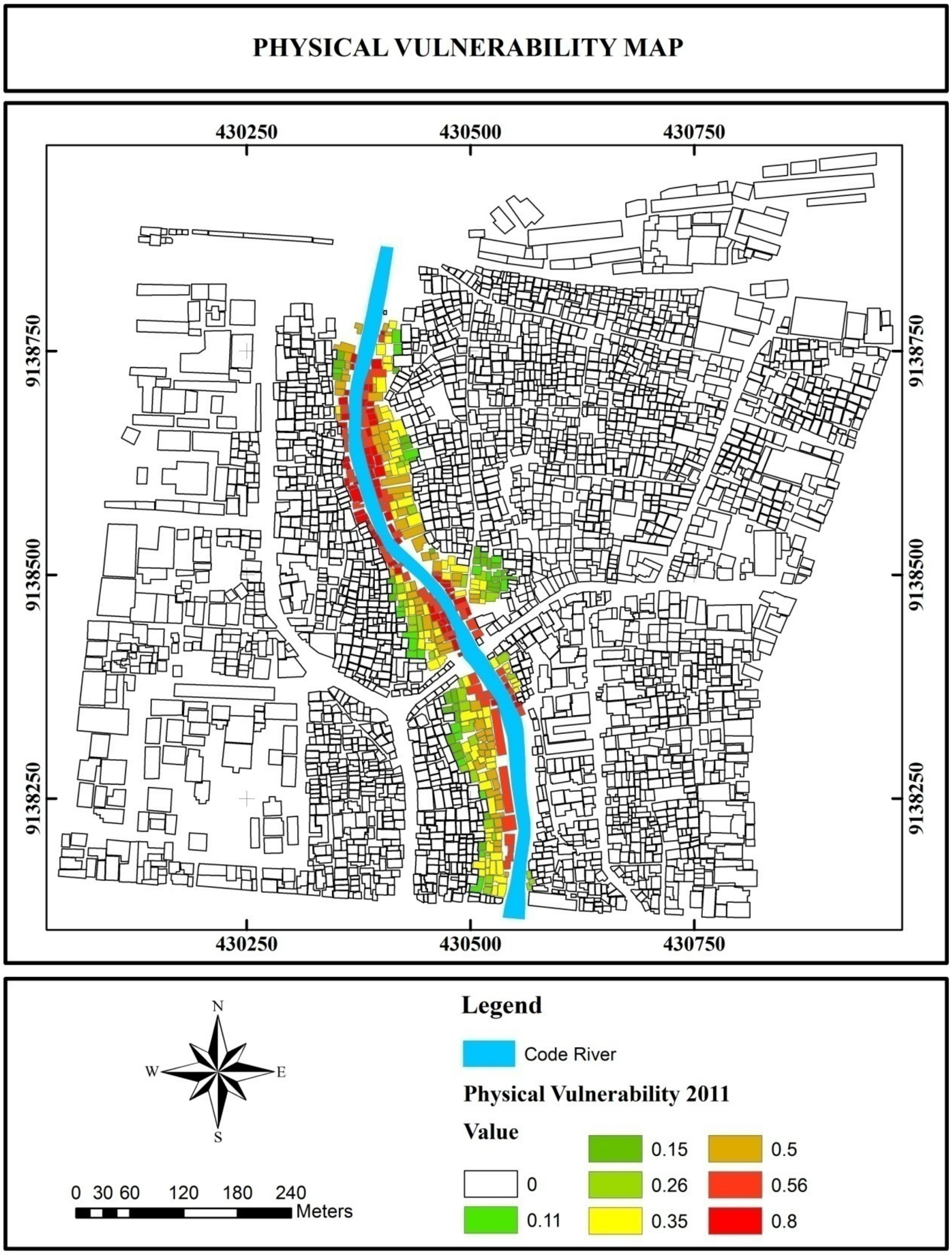

Figure 6.18 Physical Vulnerability Map based on 2011 Lahar Flood event

Source : Data processing

Figure 6.18 shows the result on the first physical vulnerability calculation based on the last lahar flood in 2011. To qualify the vulnerability value, final calculation was categorized into four class ie :

No Vulnerability	*Vulnerability Value = 0*
Low Vulnerability	*Vulnerability Value ≤ 0.10*
Moderate Vulnerability	*Vulnerability Value ≤ 0.35*
High Vulnerability	*Vulnerability Value ≤ 1*

Those classifications were adopted from vulnerability category by Elena Badila Coto (2002)

6.3.2 PGIS Survey for Structural Flood Proofing Activity

In this subsection, it will disscused about lahar flood proofing activity which is done by local community and government to protect their environment from further lahar flood disaster. The last event gave community information to make some proofing actions i.e. deepening the river basin, heightening first floor or building second floor of their houses, heightening the embankment wall, preparing water pump to suck the water if the lahar flood starts to flood the houses, and preparing early warning system to face further disaster.

Furthermore, conducted PGIS survey was only assessed the structural flood proofing activity on heightening of the embankment wall at the egde of Code river.

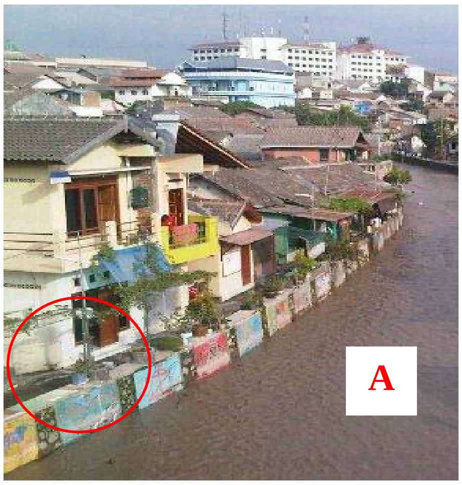

Figure A source *http://www.kotajogja.com*
Code river in 2009
Figure B and C show lahar flood proofing action. The community was heightened the embankment up to 1.2 meter (source Fieldwork 2012)

Figure 6.19 Structural Lahar Flood Proofing
Source : Fielwork 2012 using PGIS method

Collected information of the interview result that the heighthening of the embankment wall was diferent in some point and adjusted the height of the wall to the last lahar flood depth. As in figure 6.19, It was only 1.2 meters, another places it can reach up to 2 meters.

6.3.3 The Physical Vulnerability Calculation After Construction Lahar Flood Wall Protection

The second set-up is the changes that the community made to face the lahar flood i.e. heightening the embankment wall (figure 6.18). Points of heigthening wall were mapped in previous sub sections. Those data were used to reduce the lahar flood depth in 2011. This vulnerability calculation gave possible value of vulnerability in the future. Figure 6.20 below shows the flowchart in calculating the physical vulnerability after structural effort to raise the lahar flood protection wall.

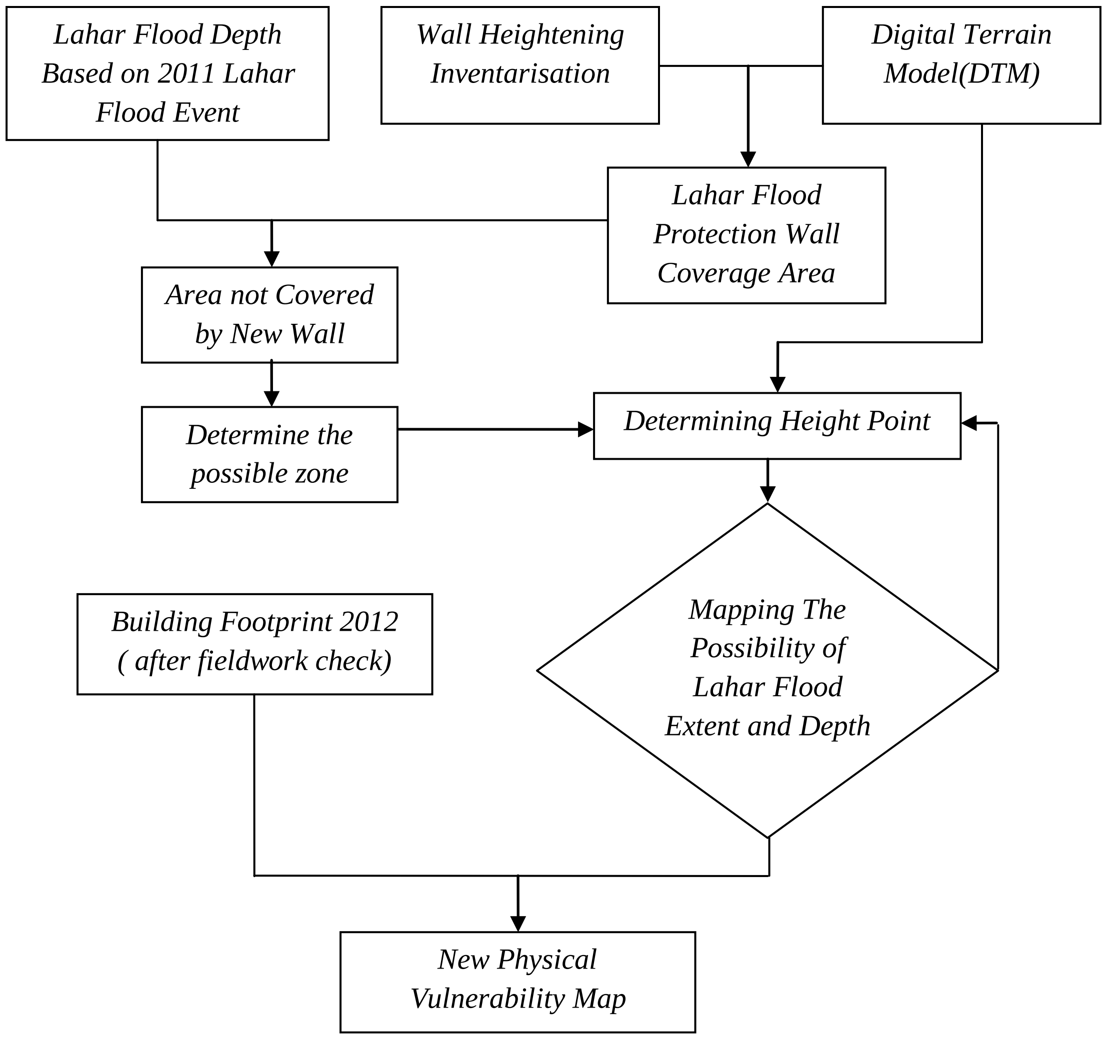

Figure 6.20 Flow chart for calculating physical vulnerability after the structural effort.
Source : Data Analysis

According to flowchart in figure 6.20, it gives overview of the process in second set-up of the physical vulnerability calculation. The first step was calculated the lahar flood protection coverage area using data from wall height inventarization points and digital terrain model map. The outer limits of the protection wall area coverage is obtained by adding the wall height value to the height values at the river edge . Next step was seek the point on the DTM raster and mapped the coverage area .

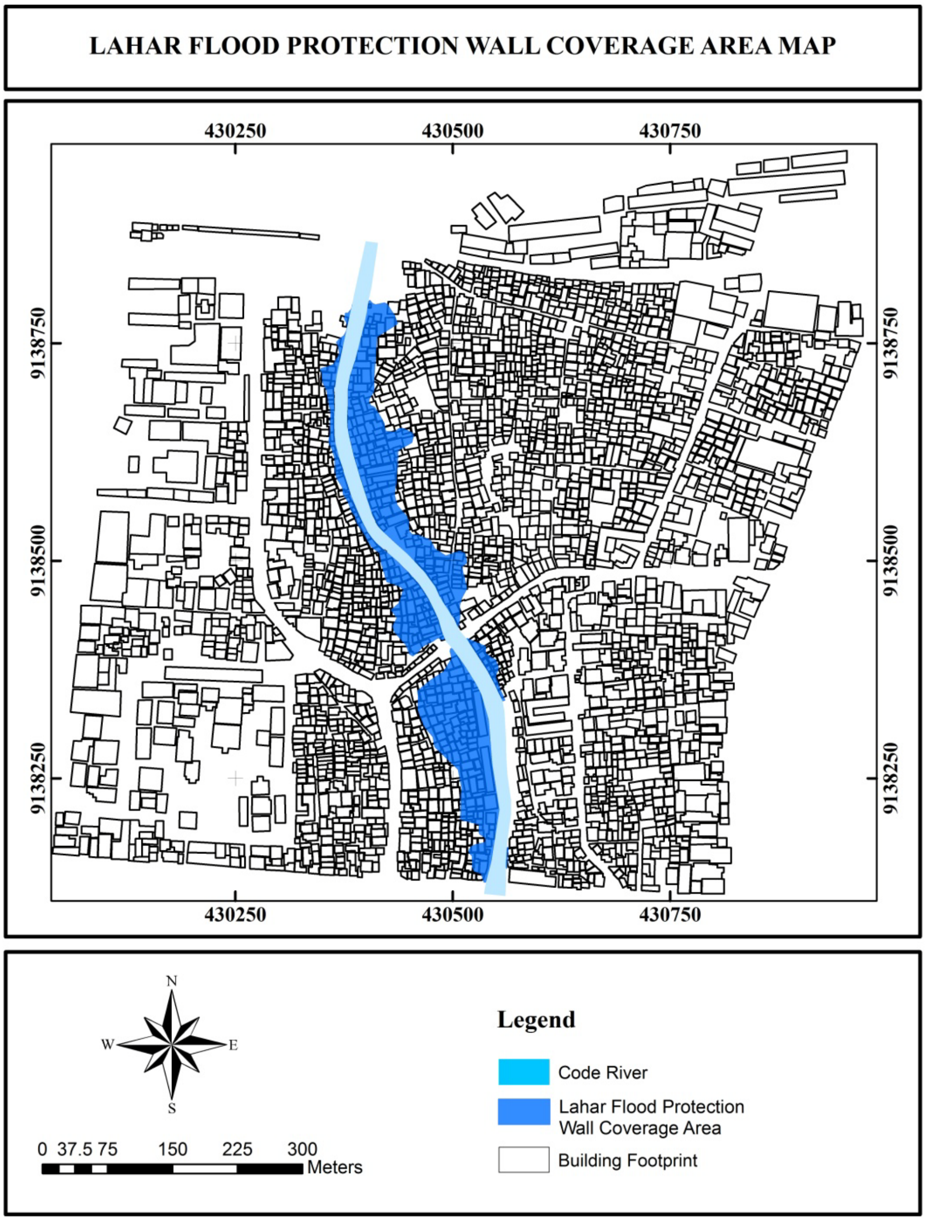

Figure 6.21 Lahar Flood Protection Wall Coverage Area Map

Source : Data processing

Figure 6.21 shows the result of lahar flood protection wall coverage area map which considering only on wall height not the wall strength. This result were overlaid with lahar flood depth from the event in 2011. In figure 6.21 below, some part of the area were not covered by the protection wall. Most of the area included in third zone which has highest value of 50 cm lahar flood depth. This value was used to seek the possibility lahar flood extent using the same method as the wall protection coverage area calculation.

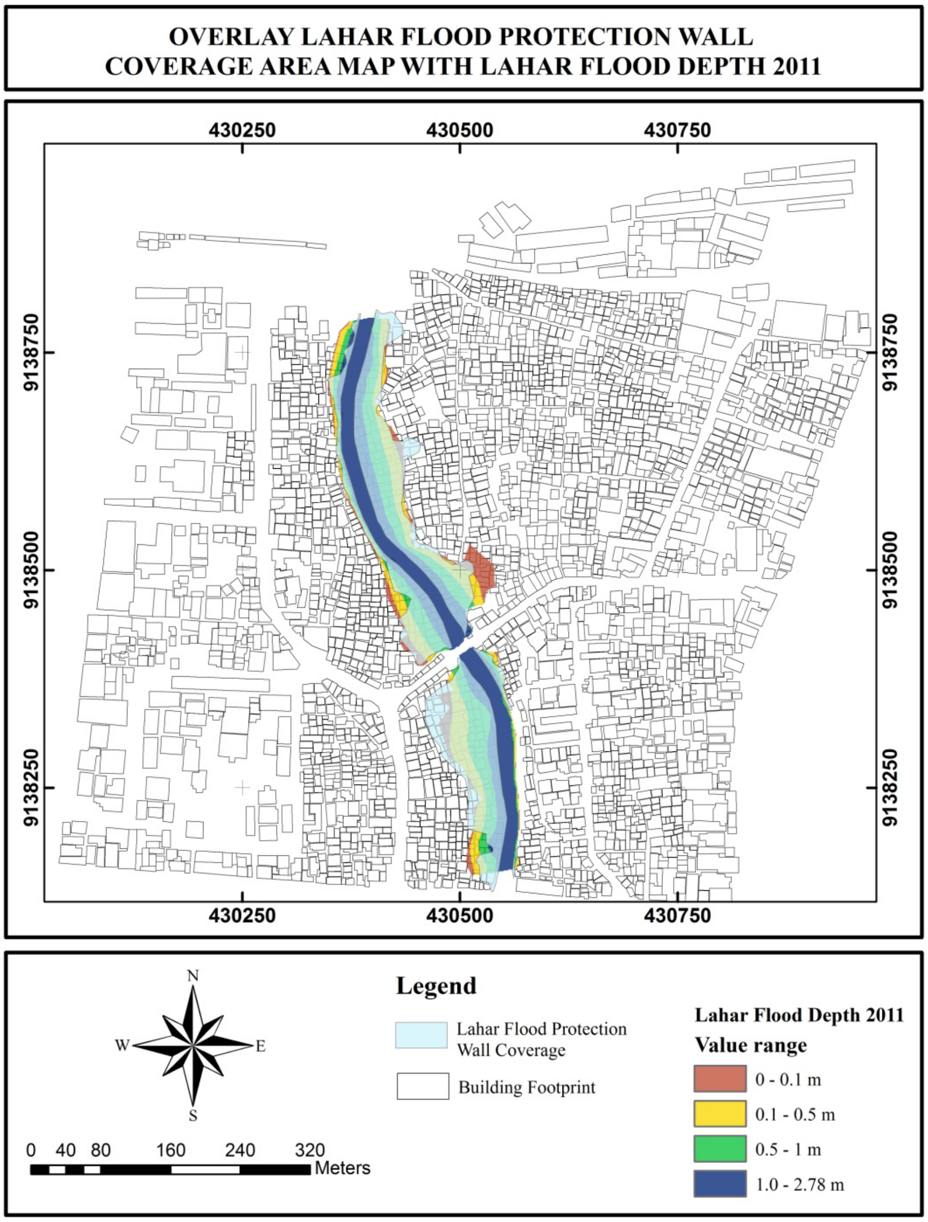

Figure 6.22 Process For Obtaining Predicted Lahar Flood Depth

Source : Data processing

In figure 6.22, it depicts the process of generating lahar flood depth possibility after structural proofing activity based on the lahar flood protection wall coverage area and lahar flood depth in 2011 event.

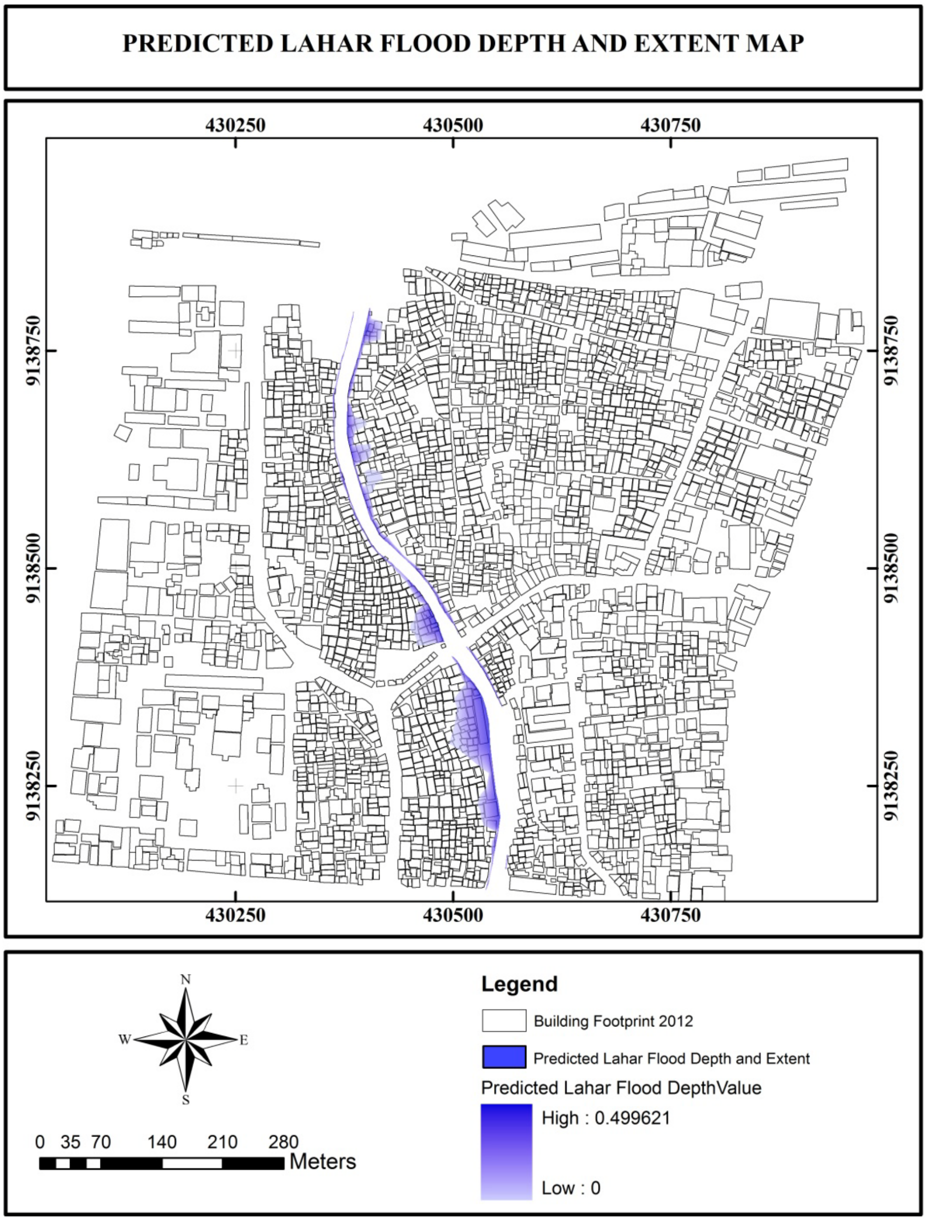

Figure 6.23 Predicted Lahar Flood Extent and Depth Map

Source: Data Analysis

The map in figure 6.23 above shows some part of Code river left side would have experience another lahar flood in the near future with similar magnitude as the 2011 event. Based on observation on fieldwork stage, the dark blue color at south of the bridge was relatively low and flat area compare to another with the elevation range 126 m to 127.5 m. In the next step, the vulnerability value was recalculated according to classification on table 6.5 using new data of building footprint 2012 and predicted lahar flood depth. Following figure below is the result of predicted vulnerability.

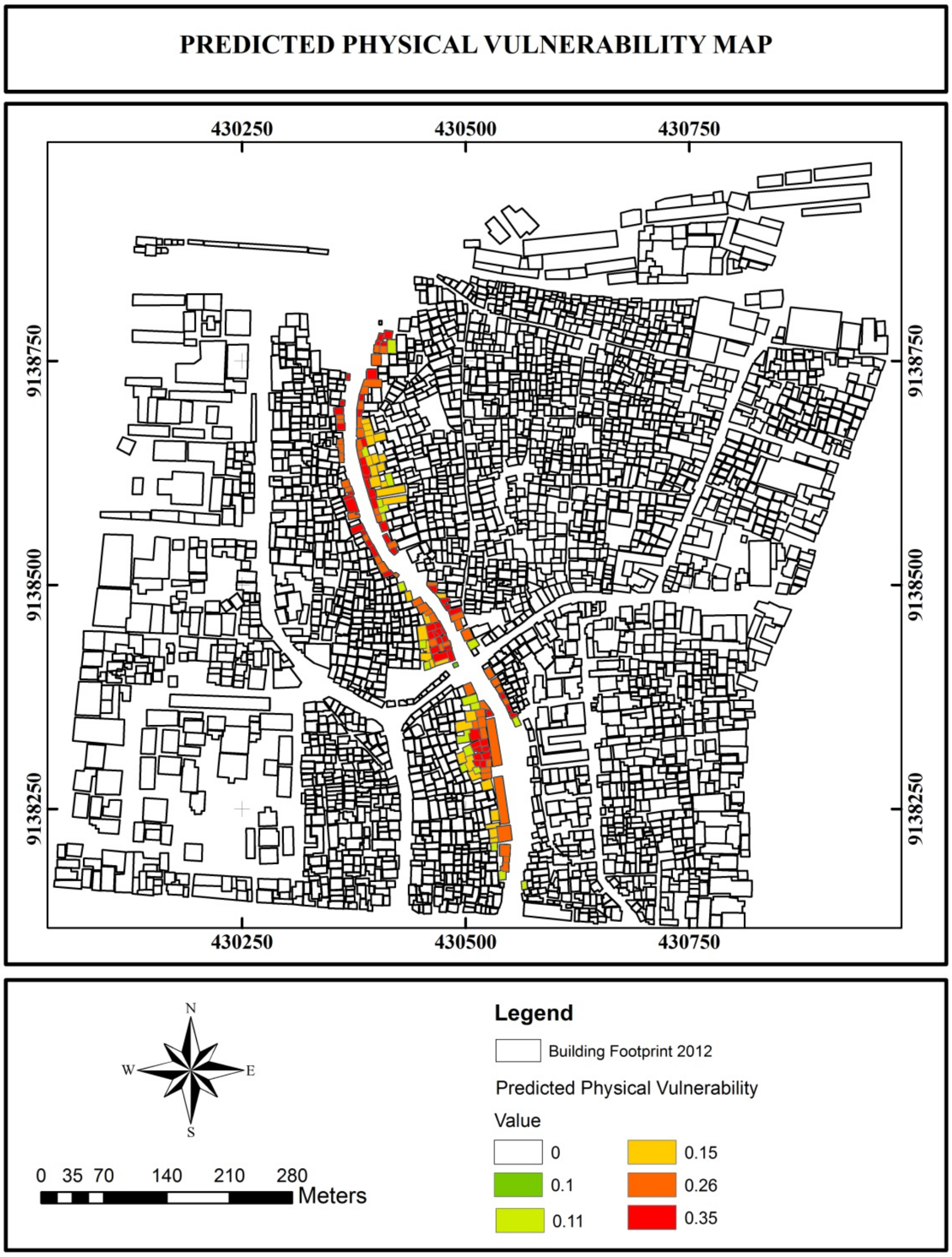

Figure 6.24 Predicted Vulnerability Map

Source : Data Analysis

The predicted vulnerabilty result in figure 6.24 above was built based on scenario for 20 year return period which predicted could happend again in the near future. Compare to 2011 lahar flood event, it shows that less element at risk would have suffer or damage by the lahars.

6.3.4 Social Vulnerability

The calculation of social vulnerability used spatial multi criteria (SMCE) in Ilwis software. According to Ilwis 3.0 user help, " the SMCE window is an application that assists and guides a user in doing Multi-Criteria Evaluation (MCE) in a spatial way. The input for the application is a number of raster maps of a certain area (so-called 'criteria' or 'effects'), and a criteria tree that contains the way criteria are grouped, standardized and weighed".

Table 6.6 Demographic Data Of Suryatmajan Village

Source : Population and Civil Record Agency and Data Analysis

DEMOGRAPHIC DATA (IN %)							
Village	**RW (Sub Village)**	**Age 0-4 year**	**Age over 65 year**	**Poverty**	**Female Head of Family**	**Unemploy**	**Literate**
SURYATMAJAN	I	4,02	5,22	36,84	13,89	21,631	80,50
	II	5,00	5,00	82,47	24,47	12,102	76,11
	III	3,56	5,33	57,97	23,19	9,735	78,76
	IV	5,10	4,78	36,84	23,23	12,342	79,75
	IX	6,35	5,65	67,77	18,32	12,935	75,87
	V	3,59	9,56	8,96	21,74	9,756	76,83
	VI	4,00	6,40	21,05	28,33	12,703	80,27
	VII	8,14	5,13	76,10	37,80	15,412	73,48
	VIII	5,24	6,73	50,86	29,27	11,990	79,59
	X	4,85	28,41	63,89	25,00	13,056	77,78
	XI	4,10	6,56	42,86	39,39	11,336	78,95
	XII	5,52	2,33	2,44	37,80	11,081	84,05
	XIII	7,75	6,20	43,13	23,31	13,043	76,09
	XIV	5,39	6,22	43,66	30,77	15,258	74,43
	XV	6,68	6,45	89,13	27,59	15,765	72,71

The percentage of the element in social vulnerability of Suryatmajan village shows in table 6.6 above. As it depicted in chapter 3, Suryatmajan village devide into 15 RWs (sub village). There are 6 element which assessed in Spatial Multi Criteria Evaluation i.e. Age 0-4 year, Age 65 years, Illiterate, Poverty, Female Head of Family and Unemploy level.

Table 6.7 Demographic Data Of Tegalpanggung Village

Source : Population and Civil Record Agency and Data Analysis

DEMOGRAPHIC DATA (IN %)							
Village	**RW (Sub Village)**	**Age 0-4 year**	**Age over 65 year**	**Poverty**	**Female Head of Family**	**Unemploy**	**Literate**
TEGAL PANGGUNG	I	5,82	4,83	49,24	26,40	17,11	71,37
	II	6,59	5,86	49,79	22,22	14,29	74,88
	III	7,57	5,05	97,60	21,71	14,27	74,27
	IV	5,83	6,80	31,25	22,95	13,79	76,49
	IX	6,54	9,81	29,82	21,49	9,80	78,43
	V	5,69	7,45	63,41	27,40	13,53	80,11
	VI	4,79	6,13	81,60	24,90	16,54	74,47
	VII	5,56	4,92	76,42	25,44	15,41	74,01
	VIII	5,03	5,45	52,26	25,17	14,04	76,60
	X	6,50	7,22	26,39	27,85	13,87	78,47
	XI	4,91	7,37	88,00	21,79	15,09	73,68
	XII	7,40	4,85	39,64	27,83	13,49	76,72
	XIII	6,10	5,61	92,52	18,92	14,15	74,88
	XIV	7,29	7,81	56,00	24,46	13,44	73,12
	XV	6,10	6,47	93,90	26,67	15,17	74,22
	XVI	5,54	6,14	71,11	23,18	12,20	77,44

Table 6.7 gives demographic data of Tegal Panggung village. This area has 16 RWs(sub village). Similar with Suryatmajan, 6 criteria will be assessed in Spatial Multi Criteria Evaluation.

First step in SMCE for social vulnerability was grouped the same spatial criteria in table 6.6 and table 6.7 into one group. Those groups were standardized to the range value of 0 to 1 (the vulnerability value range). In this research, used method for standardizing the value was maximum method which translated maximum value has the higher value of vulnerability and goal method which. It is also mentioned in user's help that there are 3 weighthing methods in SMCE ie. direct weighting, pairwise comparison and rank ordering. The second methode was selected to use. In pairwise comparison, it was explained by Saaty (1980) as the Analytical Hierarchy Process (AHP) that we must indicate for each pair of factors which factor is the most important one. Subsequently we must indicate in qualitative terms to what extent a factor is more important than another. The pairwise comparison method converts these comparisons of all pairs of factors to quantitative weights for all factors. Several factors were used to generate social vulnerabilty such as : age, income, social structure (see figure 6.25). The administration based level for those factor was Rukun Warga (RW) or neigborhoods (one level below village administration). The data used in this stage only from the year 2011. Due the study area was not large only two villages (63.157 Ha) and almost 1/3 of the area was office and bussiness center, the changes in several year of its inhabitans composition was found too small to be included in. It was assumed that there was no changes in 5 years.

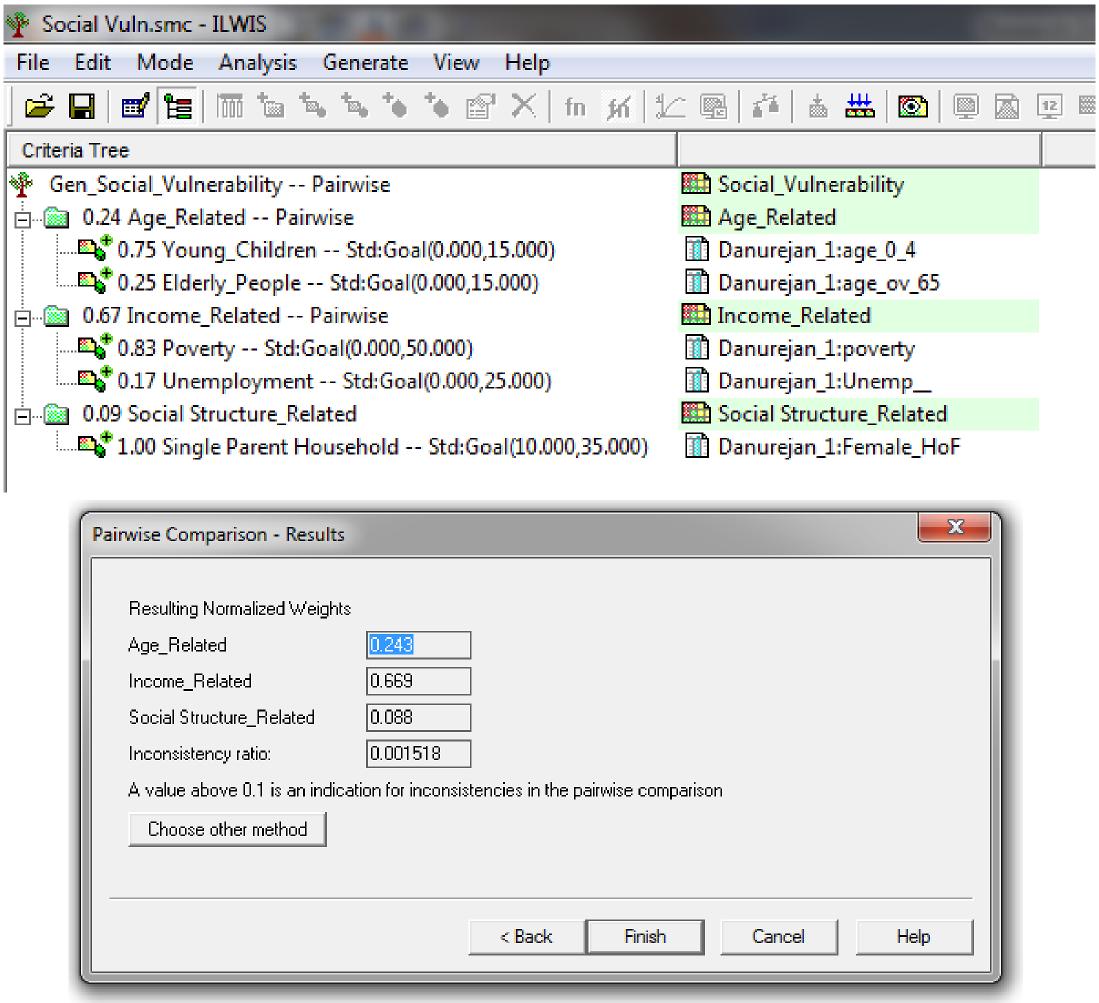

Figure 6.25 Social Vulnerability Criteria Tree and Pairwise Comparison result

Source : Data Analysis

Figure 6.25 above shows the criteria tree of the social vulnerability and pairwise comparison In the criteria tree, it shows some figure that indicate weighting and standardized value. The obtained weight value was comparing three factors i.e Age Related, Income Related and Social Structure Related. In the consideration, Income related was defined as the most important factor compare to other factors. The weight value of those three factors are 0.243, 0.669, and 0.088 respectively. It lead to the inconsistency ratio of 0.001518 which categorized as consistent comparison due to below level of inconsistencies i.e 0.1

The age related was considered percentage of the inhabitants below 4 year (young children) and over 65 year (elderly people). The assumption was that two classifications were chosen due to their less capability of facing the lahar flood. Based on the data from local agency in 2011, it shows the average percentage of young and elderly people in two villages were less than 0.1 or 10 % . In standardized process, goal method was used. The range value of vulnerability between 0 – 15 % which mean if percentage of young and elderly over 15 % the vulnerability equal to 1. Next step was comparing two clasification to get the weight value. The young children was classified into more vulnerable than elderly people due to less experience of lahar flood. Final weight value of young children is 0.75 and 0.25 for elderly people.

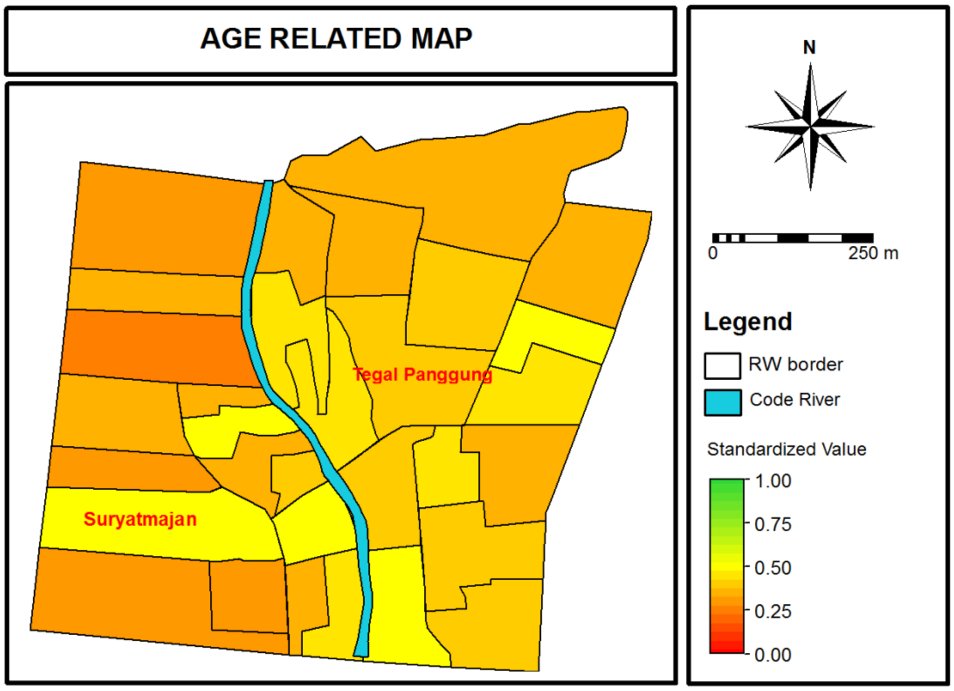

Figure 6.26 Age Related Map

Source : Data Analysis

Figure 6.26 above shows age related map of young children and elderly people in Suryatmajan and Tegalpanggung villages. It can be seen that some of RW near the Code river have lighter color than another RW which mean high population of two classess . To be link with element at risk data base, most sub village (RW) which has lighter colour consist of dense irregular residentials. Meanwhile the darker colour which indicate low value based on figure 6.15 (element at risk map) can be dominated by big building such as government office and commercial building.

For seeking the value of income related, there were two classifications generated i.e. percentage poverty level and unemployment. Those data was obtained from Social and Man Power Agency of Yogyakarta Municipality . It depicted the financial condition of the local community along Code river. Most of them were lived under poverty level. According to the Agency, there were several criteria for defining poverty level such as income, property, health,education, daily meal, clothing and social activity. Those criteria have parameter which given certain weight to obtain the level of poverty. For example , Income criteria has 4 parameter ie. husband or wife is unemploy (weight = 8), monthly average income less than 200.000 IDR (weight = 12), Ownership status building residence not their own (weight = 6), families have no property other than land which is worth more than 1.000.000 IDR (weight = 5). Together with other criteria of poverty , they assessed income factor to generate the poverty level. The result from their calculation was indicated that most of the inhabitants living in poverty (more than 50 %). Meanwhile, the unemployment data was accessed from the demographic data. It was showed that the range of unemployment in those two village started from 9 % to 21 %.

As it showed in figure 6.25, income related has highest value of weight (0.669) . It was defined as the factor which has high vulnerability value. The reason for the assumption was that value of poverty and unemployment picturing less capability to face disaster. In table 6.6 and 6.7, it shows poverty level in both villages over 50% (17 RW). This figures was the basis in defining standardized bound i.e. poverty > 0.5 equal to 1. Different with poverty , unemployment level has lower grade with most of the value below 20 %. In standardizing, 25 % is choosen as upper bound which equal to 1. The comparation of two factors were defined that poverty gave significant contribution than unemployment . The weight values of poverty and unemployment are 0.83 and 0.17 respectively.

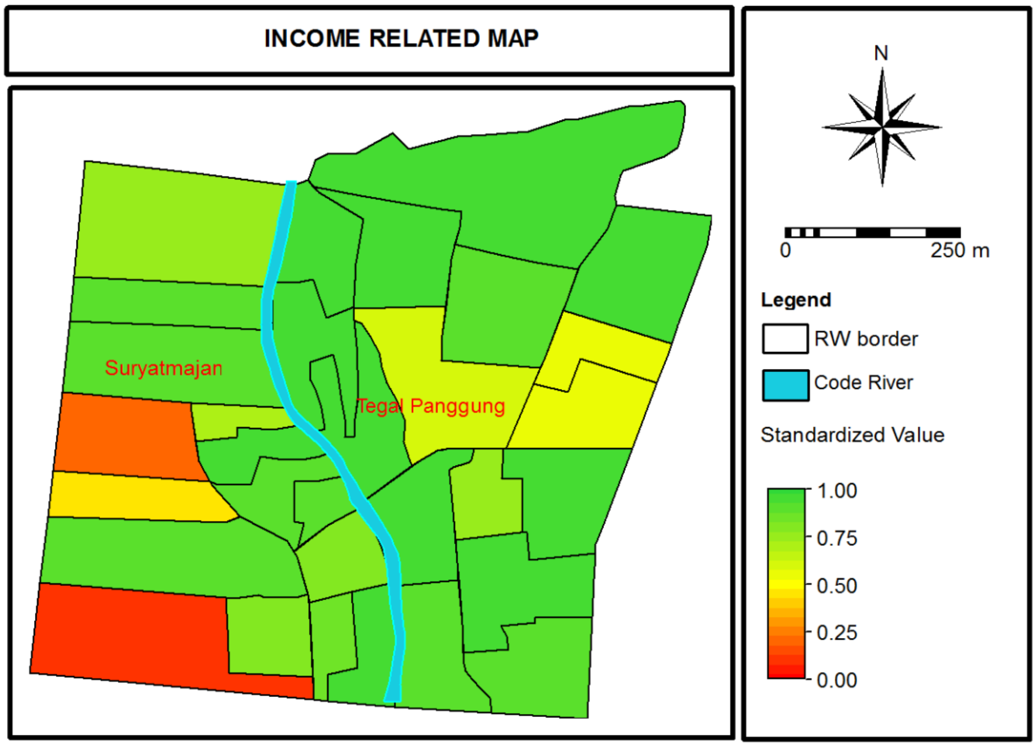

Figure 6.27 Income Related Map

Source : Data Analysis

Figure 6.27 depicts the combination value of poverty and employment. As it explains above, the rate of poverty is high and most of them located in Tegalpanggung village. Most of the building in this village dominated by dense irregular residentials especially area adjacent to Code river. Redish color in Suryatmajan village indicate that the income related value below 0.25 which means those RW less vulnerable. It can be linked with landuse type in this area. Largely, the buildings are commercial or institutional type.

The third factor was family structure. Percentage of the female as the head of the family was the main subject to consider. The asumption for this consideration was if female as the head of family, they will have some burden that they can not handle compare to male in term of physical capability to cope with lahar flood. The percentage was calculated based on number of the family in two villages. 13 % was the lowest value in RW 1 (Suryatmajan) and the highest value in RW 11 (Suryatmajan) ie. 39.39 %. The average value of this factor is 25.56 %. Based on those value, lower and upper bound of goal standardize value are 10% and 35 % (see figure 6.25).

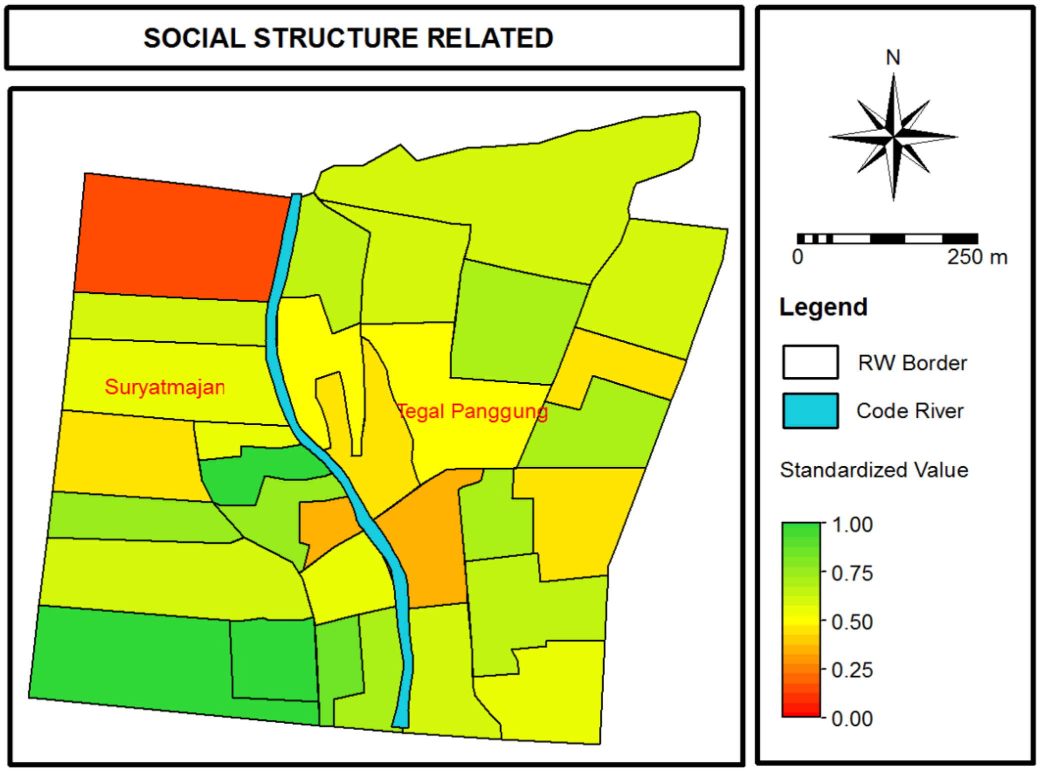

Figure 6.28 Social Structure Related Map

Source : Data Analysis

Different pattern with previous category, figure 6.28 shows highest value of standardized family structure belong to Suryatmajan village. Meanwhile, Tegalpanggung has relatively the same value.

The final result of social vulnerability is combining all factors mentioned above in the SMCE calculation (see figure 6.25) . Social vulnerability map will be presented in qualitative and quantitatif map. To categorize in qualitative classification, the final value of social vulnerability was separate into four class ie.

No Vulnerability	*Vulnerability Value = 0*
Low Vulnerability	*Vulnerability Value ≤ 0.25*
Moderate Vulnerability	*Vulnerability Value 0.25-0.50*
High Vulnerability	*Vulnerability Value < 0.50*

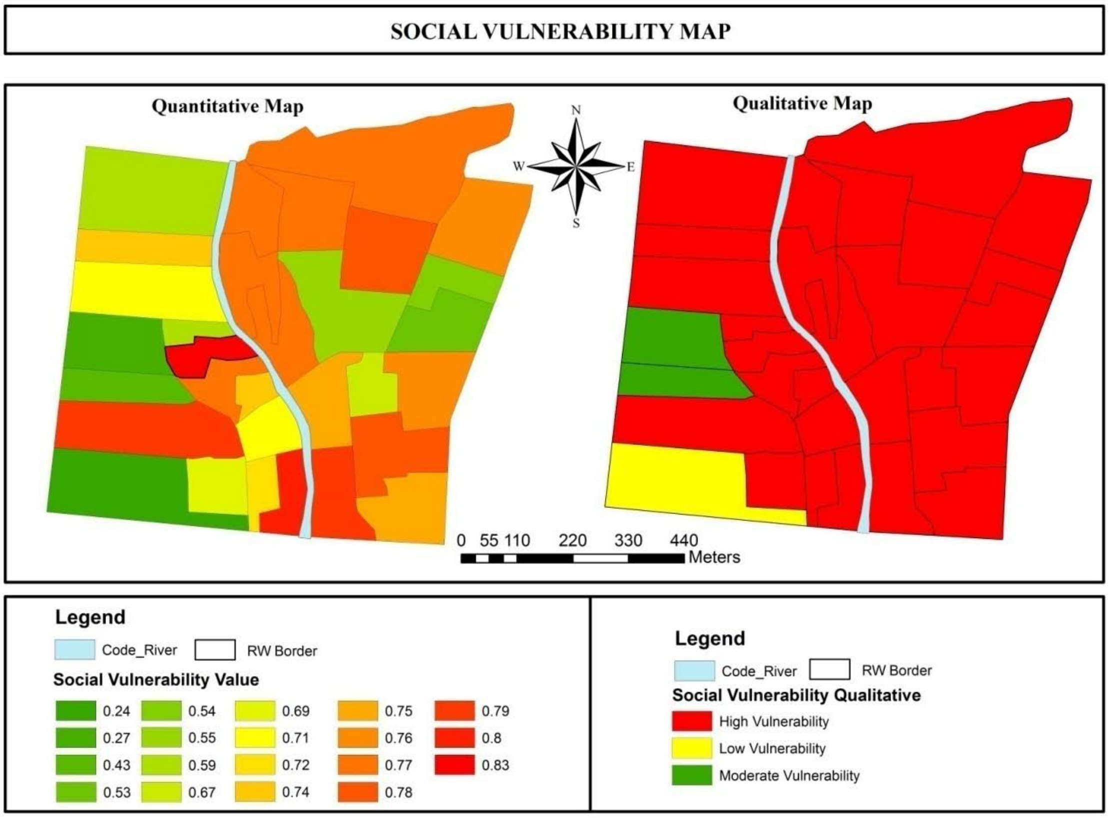

Figure 6.29 Social Vulnerability Map
Source : Data Analysis

Figure 6.29 is the calculation result of social vulnerability. The right side is the slicing result based on four classification above.

6.3.5 Capacity

To calculate the capacity, only one factor was included to generate the awareness level ie. literacy rate. It was generated from the education data. This data contained the education level data which stated that there are two classifications of education, namely, no / not attending school and have not yet finished elementary school. The percentage of literaracy rate presented in table 6.5 and 6.6 in previous chapter. Figure 6.30 below shows the criteria three for capacity.

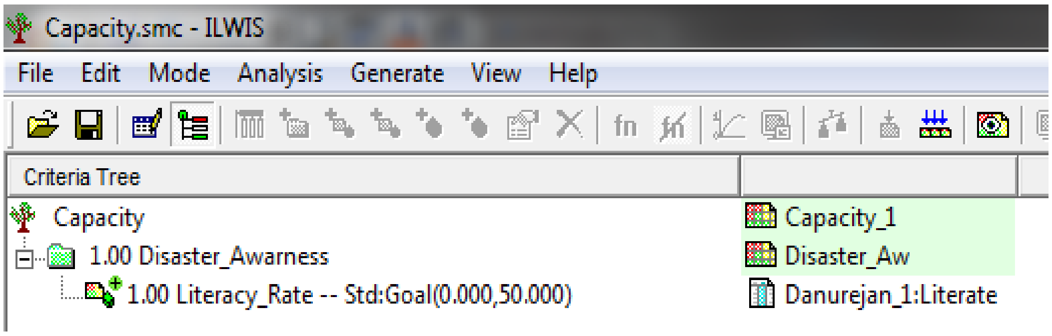

Figure 6.30 Capacity Criteria Tree

Source : SMCE process

Most of the in habitants in those two village can read and well educated. It was showed by the percentage in table 6.5 and 6.6. Precentage of the literacy was more than 70 %. This figure became the basis to define the standardized that over 50 % the value is equal to 1 (see figure 6.30). It means that Code River's inhabitant had high capability to face lahar flood. Following map (figure 6.31) is the result of capacity calculation.

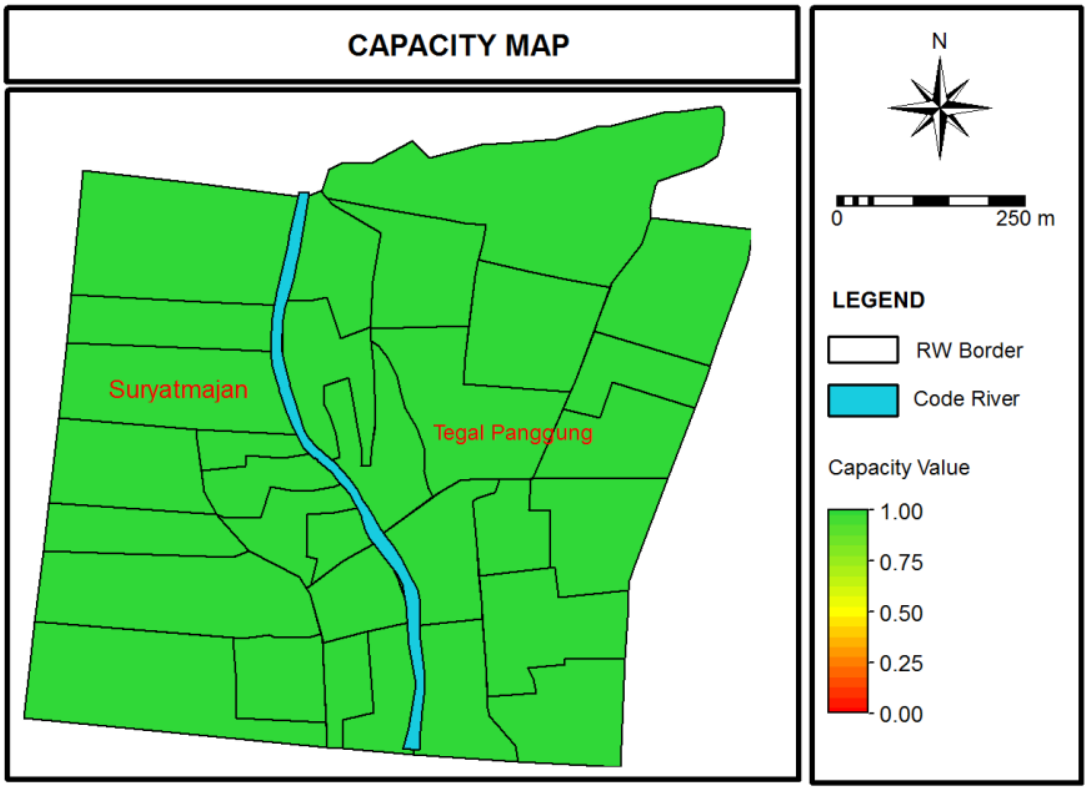

Figure 6.31 Capacity Map

Source : Data Analysis

6.3.6 Overal Vulnerability

V factor in risk formula is overal vulnerability from calculation of physical vulnerability, social vulnerability and capacity which has been done in previous chapter . This step was used the same method as social vulnerability i.e. Spatial Multi Criteria Evaluation (SMCE). The social vulnerability and capacity were the factor remained the same. Meanwhile, physical vulnerability used two situations i.e. lahar flood event 2011 and predicted lahar flood event.

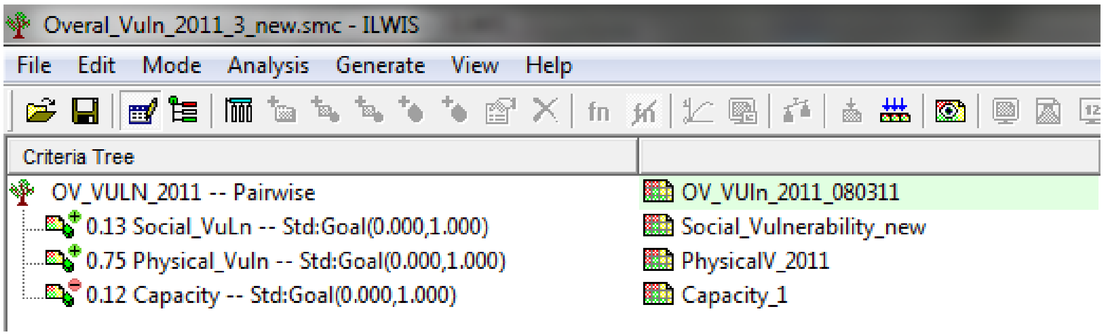

Figure 6.32 Overal Vulnerability Criteria Tree based on 2011event

Source : Data Analysis

As it was done in social vulnerability, the three factors weighted using pairwise comparison (see figure 6.32). The 2011 event was the first calculation, resulting weigh of 0.13, 0.75 and 0.12 for social vulnerability, physical vulnerability, and capacity respectively. The value of consistency was 0.002406 (see figure 6.33) . It was categorized as consistency comparison due the value far below maximum consistency level i.e. 0.1.

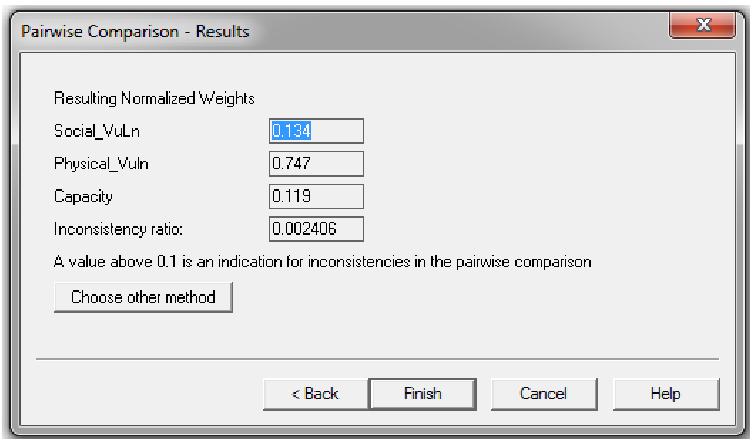

Figure 6.33 Overal Vulnerability Pairwise Comparison result

Source : Data Analysis

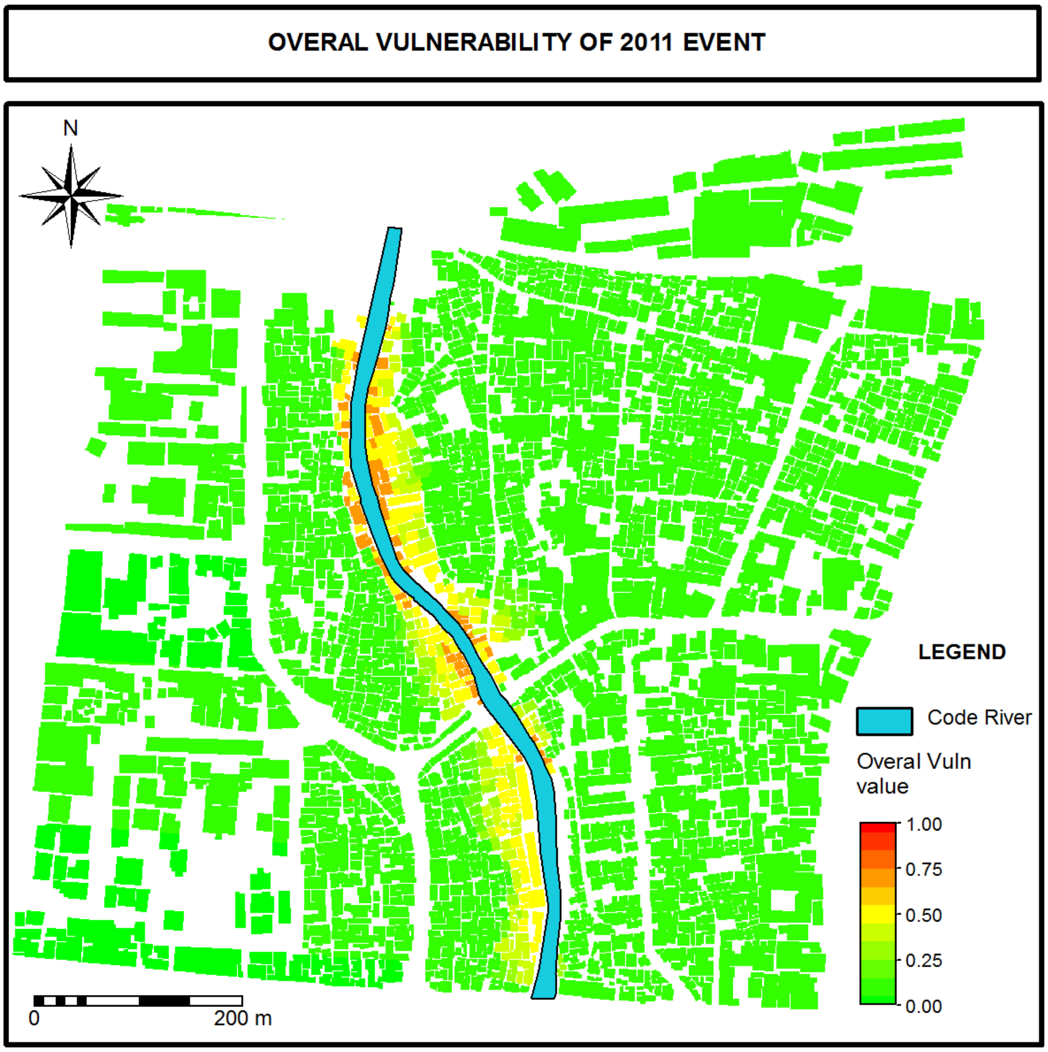

Figure 6.34 2011 Event Overal Vulnerability Map

Source : Data Analysis

The result of overal vulnerability in 2011 lahar flood event shows in figure 6.34. As it indicated on the factors that constructed the result, most of the building with value more than 0.5 located close to Code river. Those buildings had direct impact from the 2011 lahar flood event. In table 6.5, building especially residential which inundated 50 - 100 cm has a value of 0.5 physical vulnerability and 0.8 for over 100 cm water depth. Some of those buildings have second floor. It can be lowered the value of physical vulnerability as well as in overal vulnerability. In figure 6.34, distance to the river edge was not the factor that give contribution to the vulnerability value.

Second calculation was deal with predicted physical vulnerability after structural effort from local community and government to heighten the protection wall. Similar to previous calculation , the three factors were involved in this stage. Pairwise comparison was the method to generate weigh value. The value result of weighting process was 0.119, 0.747 , 0.134 for social vulnerability, predicted physical vulnerability (see figure 6.35).

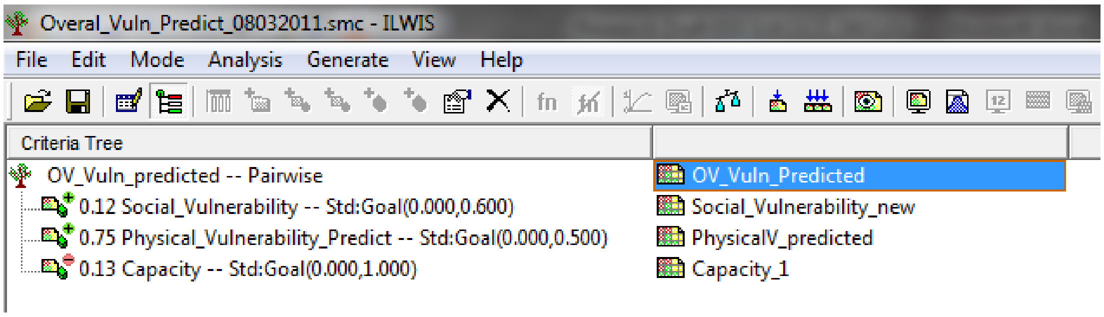

Figure 6.35 Predicted Overal Vulnerability Criteria Tree

Source : Data Analysis

The value of consistency (see figure 6.36) was below the minimum requirement (below 0.1) i.e. 0.002406. It means that the pairwise comparison between the three factors was consistence.

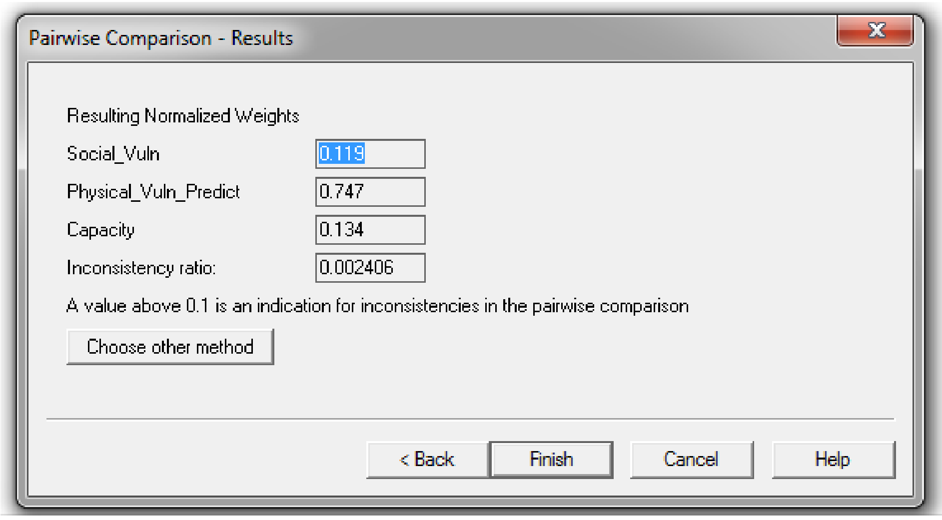

Figure 6.36 Predicted Overal Vulnerability Pairwise Comparison result

Source : Data Analysis

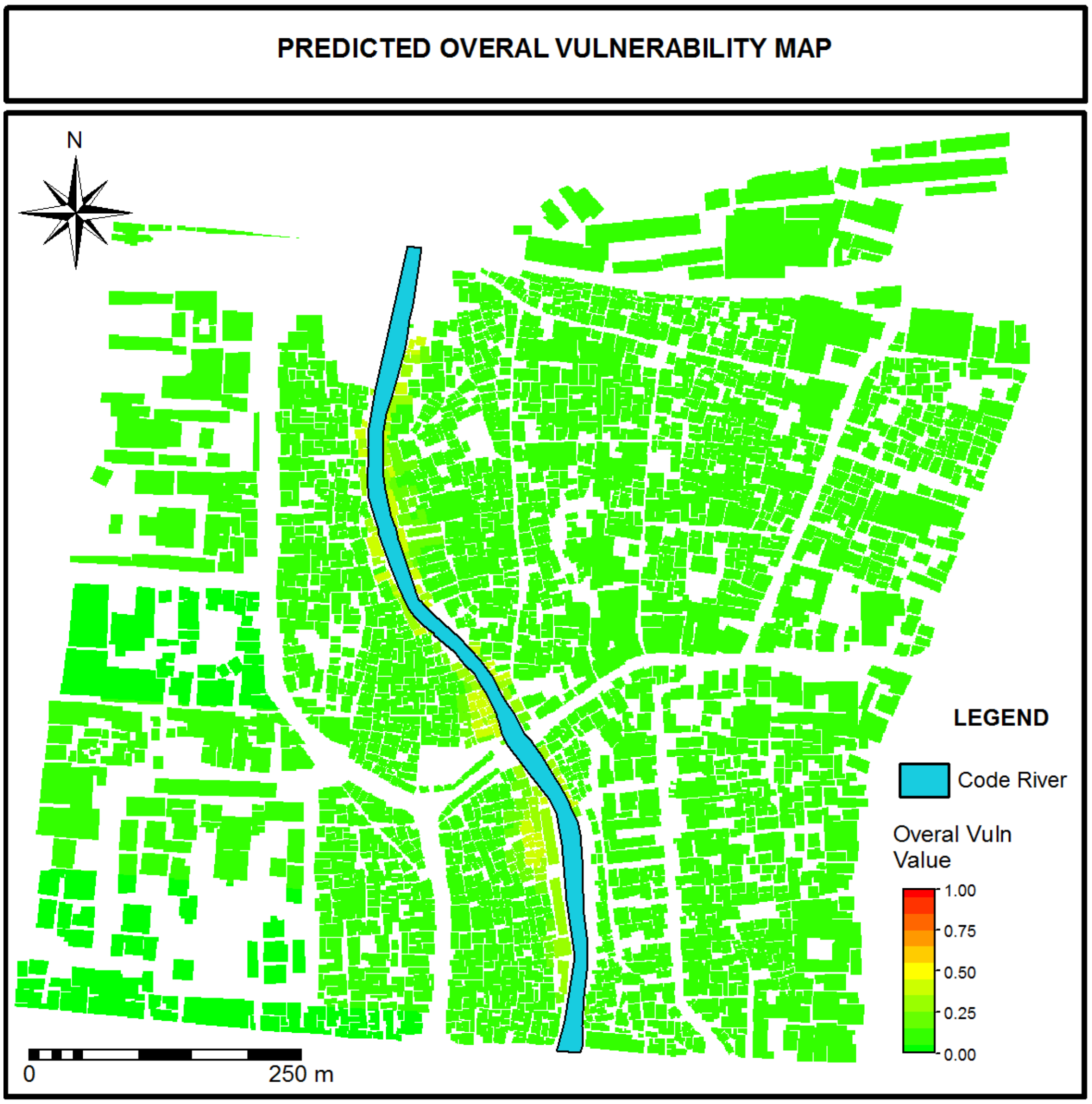

Figure 6.37 Predicted Overal Vulnerability Map

Source : Data Analysis

The second calculation of vulnerability, it gave result that the value of vulnerability mostly below 0.5. Figure 6.37 depict green color dominated the building color indicating low value of vulnerability. As it described in vulnerability, figure 6.37 was result of vulnerability based on 2011 event. In the near future, if the area struck by lahar flood ,it would have those vulnerability value.

6.4 Method for Lahar Flood Risk Analysis

As defined in the chapter 2, " Risk is product of hazard and vulnerability (R = H * V)," (Kohler, et.al. 2004). According to van Westen (2009), the formula is multiply with amount (A) factor to quantify the element at risk in currency (R = H * V * A). For further calculation , used currency was Indonesian Rupiah (IDR).

Due to the limited data base of lahar flood hazard map which presented in one-dimensional flood modelling, only 20 year return period was used in lahar risk calculation. This limitation led to the condition that risk curve can not be constructed because of the minimmum return period of lahar flood is 3 return periods. Spatial Planning zoning can not be done only on basis of the 20 year flood period. Further studies should be done to construct the 50 and 100 year flood extent and depth. This can be done by 2 D modelling using the precise Digital Elevation Model (DEM) data and element at risk database provided in this research.

6.4.1 Damage Calculation

In this research, the damage calculation was based on the land value per square meter. The value was generated from Land Value Zone Map which owned by National Land Agency of Yogyakarta Province. According to National Land Agency , this map was generated by mapping the actual land price from the land valuation survey in 2011.

Firstly, they defined the zone based on the proximity to the main road and then made the buffer zone . In each zone, some samples of land building transaction were acquired and calculated to seek the land price average. As their main objective to obtain the land value, some of the transaction could be including building above it. Considering that most of the area of Yogyakarta municipality was builtup area, the calculation was also including on building valuation. Final land value value, as they reported, was value of the transaction minus building valuation. If the calculation showed high root mean square value,it means that one or more sample were not in the same zone. This result would caused generate new land price zone according to adjacent land value. The map of Land value zone shows on figure 6.38 below.

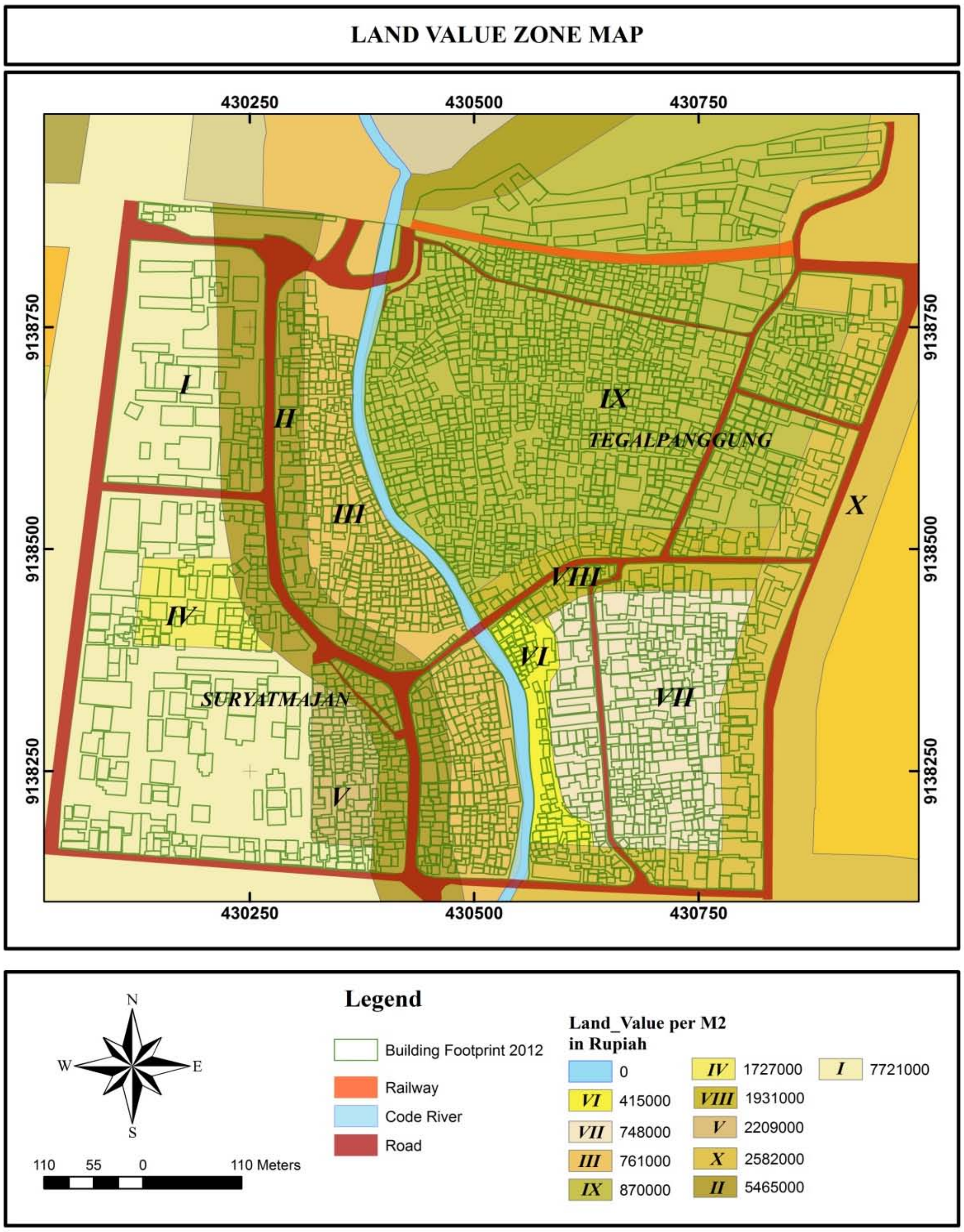

Figure 6.38 Land Value Zone Map

Source : National Land Agency of Yogyakarta Province

Based on figure above, Danurejan district was included in 10 zone of Land Value Zone Map range from 415,000 IDR/M2 to 7,721,000 IDR/M2. Meanwhile, there are 5 zone in the range of lahar flood extent i.e. zone III, VI, VIII, IX and X respectively. In the damage calculation, it involved 5 zone only.

The first calculation was multiply area of each building to land value in each zone. Some of the buildings could be located in two zone. The predominant area was choosen to define the land value zone. Figure 6.39 below shows some of the building which included at two zones.

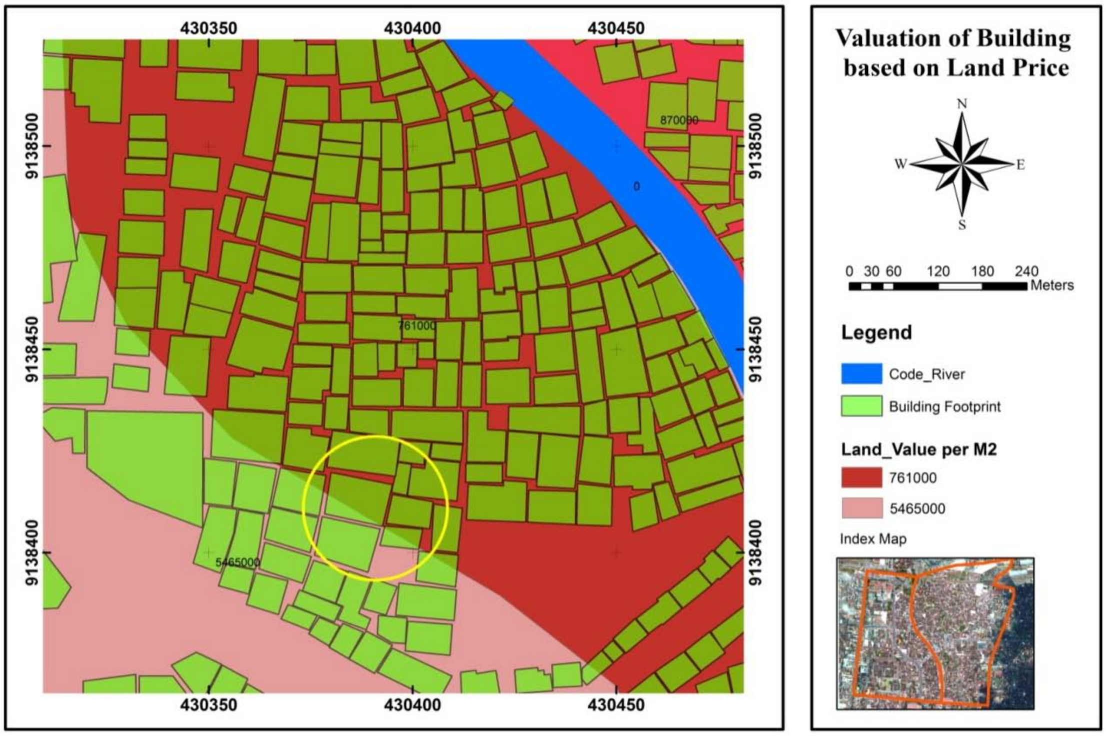

Figure 6.39 Process on building valuation

Source : National Land Agency of Yogyakarta Province

Yellow circle on figure above denotes that some of the buildings located on zone 761.000 IDR /m^2 and zone 5.465.000 IDR/m^2. Predominan evaluation was needed to define which zone is appropriate for the building. To know the cost of land, each building area was multiply with land value per square meter. In the last step, damage calculation was the result of multiply cost of land and overal vulnerability (see table 6.8).

Table 6.8 Damage Calculation Result

Source : Data Analysis

No.	Event	Total (in Indonesian Rupiah)
1.	2011 Lahar Flood	85.5 billion
2.	Predicted Lahar Flood with similar magnitude of 2011 Lahar Flood event	68.3 billion

6.4.2 Lahar Flood Risk Calculation

Following the result of overal vulnerability, the risk in Code river was determined on two conditions i.e., after and before lahar flood proofing activity. The probability of 20 year return period is 1/20 = 0.05. This value was multiplied with each vulnerability value both 2011 event and predicted value.

The qualitative classification of 20 year return period risk zone map was classified based on multiply value of occurence probability and overal vulnerability. The result of calculation was reclassified as below :

	Probability of Occurence x Overal Vulnerability
No Risk	*Value = 0*
Low Risk	*Value ≤ 0.02*
Moderate Risk	*Value 0.02 - 0.03*
High Risk	*Value ≤ 0.03*

To know the quantitative risk in Indonesian currency, the result in damage claculation in sub chapter 6.41 was multiplied by probability of occurence 20 year return period. All the value of the calculation were added up to obtain the total risk value (see table 6.9).

Table 6.9 Risk Calculation Result in Currency

Source : Data Analysis

No.	Event	Total (in Indonesian Rupiah)
1.	2011 Lahar Flood	4.2 billion
2.	Predicted Lahar Flood with similar magnitude of 2011 Lahar Flood event	3.4 billion

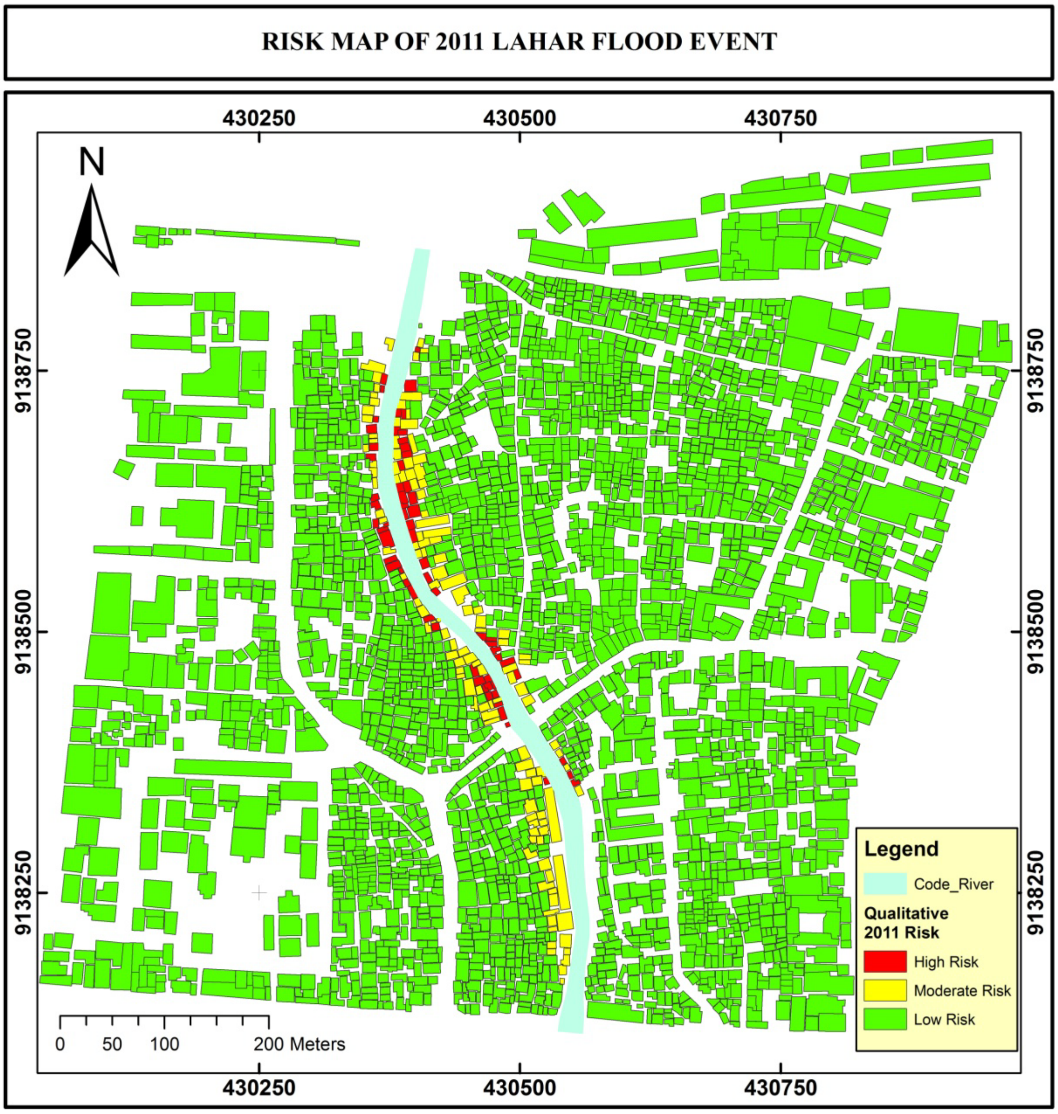

Figure 6.40 Risk Map of 2011 Lahar Flood Event

Source : Data Analysis

Result of the risk 2011 computation which involved occurence probability and overal vulnerability shows on figure 6.40. It depicts that left side of the Code river (Suryatmajan Village) has higher risk compare to Tegalpanggung village. Overal, northern part of the study area both right and left side have similar risk value. Meanwhile, the most of the buliding categorized low risk on green color.

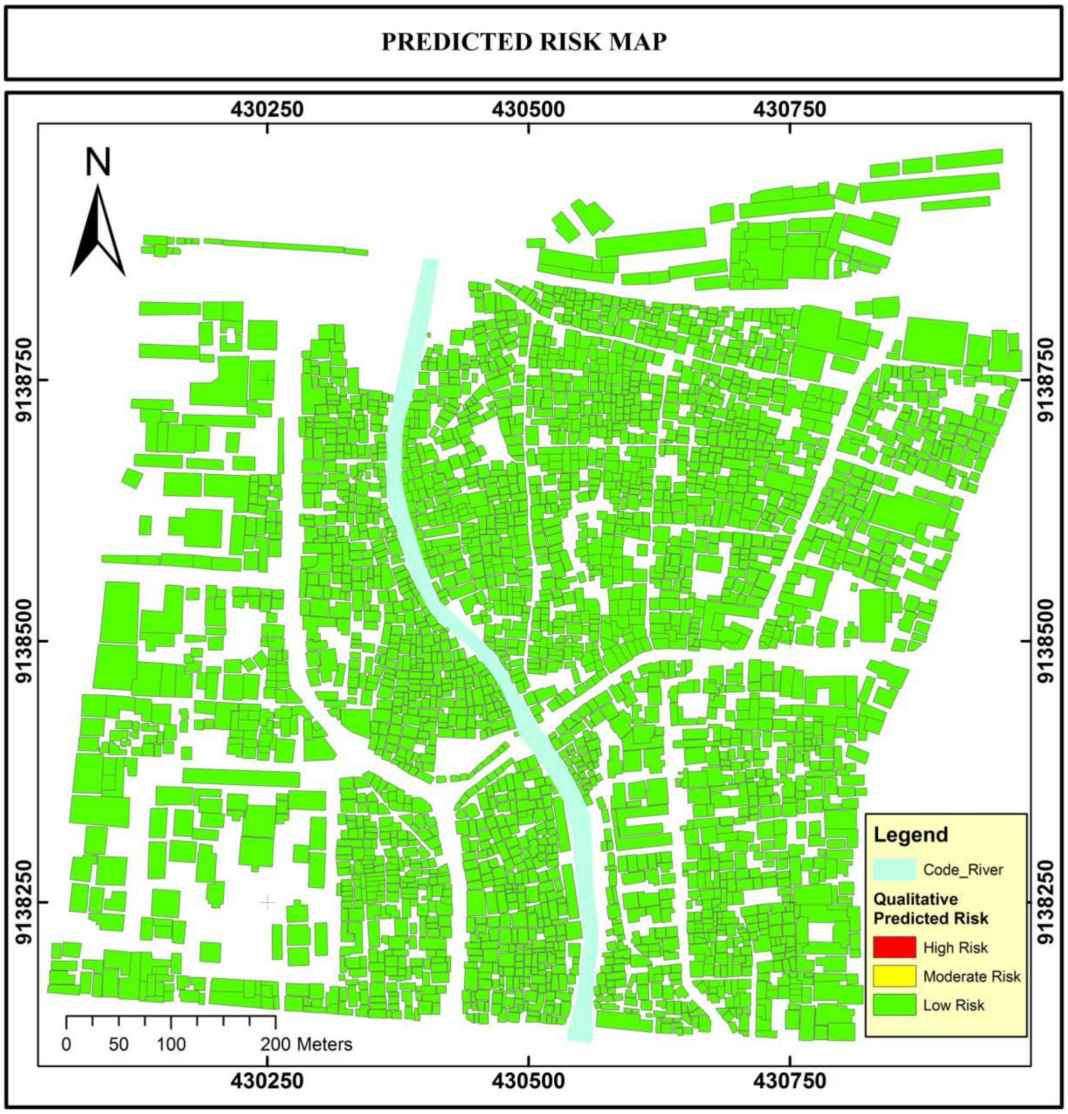

Figure 6.41 Predicted Risk Map

Source : Data Analysis

The result of predicted risk map in figure 6.41 was based on lahar flood 2011 and structural proofing activity by heigthening protection wall along Code river. All of the area were classified as low risk as long as in the near future the protection wall does not break and no lahar flood event larger than 2011 event which will overtop the wall.

7. ZONING IMPROVEMENT FOR DETAIL SPATIAL PLANNING

The final objective in this research was to improve the existing zoning system in the present spatial planning of Yogyakarta municipality year 2010 – 2029 number 2 year 2010 for supporting higher scale of detailed spatial planning. In chapter 5, detail spatial planning was clearly explained in Government Regulation Number 15 year 2010 about Implementation of Spatial Planning in chapter 61 (article 1 and 2). Some of the data which is needed to construct detail spatial planning were accomodate in this research by applying method in collecting data and data analysis especially on lahar flood risk analysis.

7.1 Data Extraction on Spatial Planning

As it explained in earlier chapter, the spatial planning map of Yogyakarta Municipality was only available in raster version. The GIS tools was used to generated the existing zone on this regulation. Figure 7.1 below shows clip map of present spatial planning (see figure 1.1) especially on Danurejan subdistrict.

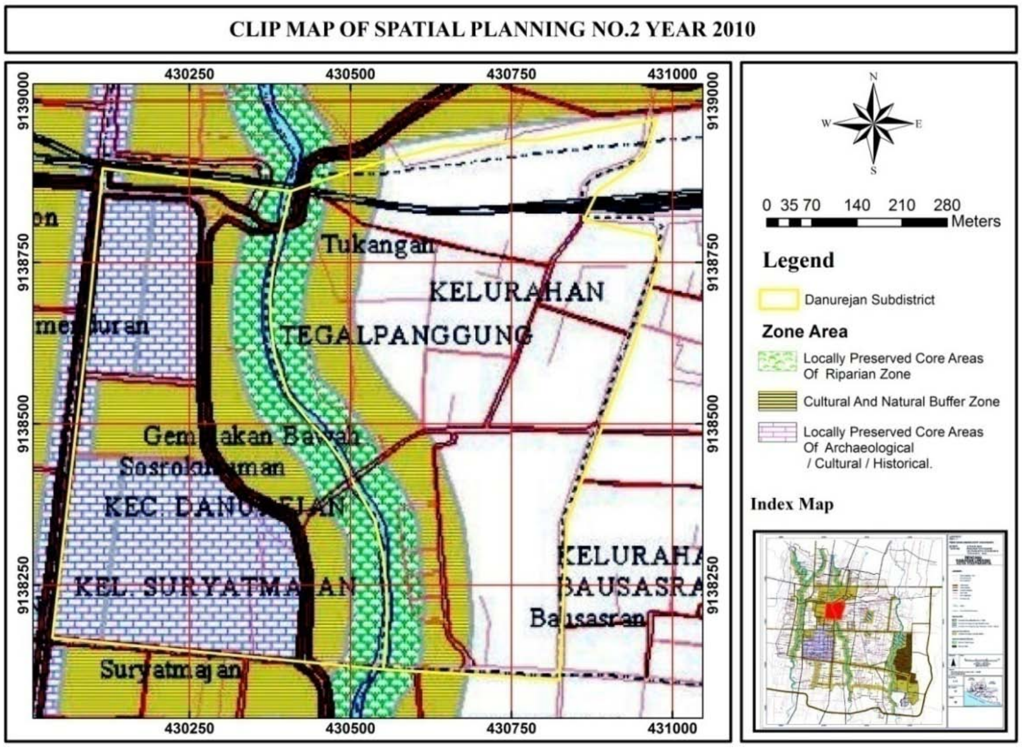

Figure 7.1 Zone Map in Spatial Planning No. 2 year 2010

Source : Spatial Planning No. 2 year 2010 and Data Analysis

Table. 7.1 Zone Area on Present Spatial Planning in Danurejan Subdistrict

Source : Data analysis

No.	Subdistrict	Village	Zonning	Area_Ha
1.	Danurejan	Suryatmajan	Locally Preserved Core Areas Of Archaeological / Cultural /Historical	16,2149
2.	Danurejan	Suryatmajan	Locally Preserved Core Areas Of Riparian Zone	3,9114
3.	Danurejan	Suryatmajan	Cultural And Natural Buffer Zone	5,4202
4.	Danurejan	Suryatmajan	Cultural And Natural Buffer Zone	2,0730
5.	Danurejan	Tegal Panggung	Non Preserve Area	24,7070
6.	Danurejan	Tegal Panggung	Locally Preserved Core Areas Of Riparian Zone	3,9893
7.	Danurejan	Tegal Panggung	Cultural And Natural Buffer Zone	6,5553
8.	Danurejan		River	1,2609

To summarize, table 7.1 above shows the area of each zoning in Danurejan Subdistrict. According to table above, the whole area of Suryatmajan village was plotted to become preserve area. Mean while, Tegal Panggung village was defined 10,54 Ha in total for Locally Preserved Core Areas Of Riparian Zone and Cultural And Natural Buffer Zone. There was 24,707 Ha for Non Preserve Area in this village.

Table 7.2 below gives a number of element at risk (building type) in each zone. There were 26 building types which generated from the Small Format Aerial Photogrametry (SFAP) and validated with in fieldwork stage. In coulumn squatter , there were two value in Cultural And Natural Buffer Zone and Locally Preserved Core Areas Of Riparian Zone i.e. 270/261 and 322/311. The first value 270 and 322 were number of buildings in 2010. Meanwhile, 261 and 311 were validated building number in 2012.

The result of GIS data extration from the regulation was overlaid with element at risk data based on chapter 6.2.

Table. 7.2 Overlay result Zone Area on Present Spatial Planning
with element at risk data base in Danurejan Subdistrict
Source : Data analysis

		Elemen At Risk																									
Subdistrict/ Village	**Preserve Area Zonning**	A	B	Bu	ES	GO	GP	H	HR	K	M	Ma	MH	MC	Mo	O	P	PO	PSc	PR	PS	RC	SH	SQ	SBH	TC	W
Danurejan/ Suryatmajan	Locally Preserved Core Areas Of Archaeological/ Cultural / Historical	-	4	22	-	44	-	23	5	1				1	2								79	220	1	2	
	Cultural And Natural Buffer Zone	-	1	30		1	-	-	-	-	2	-	1	-	1	-	-	-	-	-	-	-	84	270/ 261	-	-	-
	Locally Preserved Core Areas Of Riparian Zone	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	1	-	6	322/ 311	-	-	-
Danurejan/ Tegal Panggung	Locally Preserved Core Areas Of Riparian Zone	1	1	-	-	-	-	-	-	-	-	-	-	-	4	1	-	-	-	-	-	-	7	242			
	Cultural And Natural Buffer Zone	-	-	3	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	35	386	1	-	2
	Non Preserve Area	-	-	7	13	12	6	5	-	-	-	9	-	-	3	-	1	2	5	1	-	26	93	976	-	-	27
		3	6	62	15	57	6	28	5	2	2	9	1	1	11	2	1	2	5	2	1	27	304	2416 /2396	2	2	29

Legend

A	Apartment	HR	House Of Representative	O	Outpost	SH	Shop
B	Bank	K	Kindergarten	P	Pharmacy	SQ	Squatter
Bu	Business	M	Mall	PO	Post Office	SBH	Student Boarding House
ES	Elementary School	Ma	Market	PSc	Private School	TC	Tourist Center
GO	Government Office	MH	Maternity Hospital	PR	Public Religius	W	Warehouse
GP	Government Pawnshop	MC	Money Changer	PS	Public Service		
H	Hotel	Mo	Mosque	RC	Railway Company		

Table. 7.3 Total Element at Risk of each Zone Area
on Present Spatial Planning in Danurejan Subdistrict
Source : Data analysis

No.	Subdistrict/ Village	Zone	Element at Risk	
			2010	2012
1.	Danurejan /Suryatmajan	Locally Preserved Core Areas Of Archaeological / Cultural /Historical	404	404
		Locally Preserved Core Areas Of Riparian Zone	334	323
		Cultural And Natural Buffer Zone	390	381
2.	Danurejan/ Tegal Panggung	Non Preserve Area	1617	1617
		Locally Preserved Core Areas Of Riparian Zone	256	256
		Cultural And Natural Buffer Zone	431	431
			3001	2981

According to table 7.3, total element at risk in Locally Preserved Core Areas Of Archaeological / Cultural /Historical zone of Suryatmajan is 404 in both year . The second zone for Suryatmajan village is 334 buildings in 2010 and 323 in 2012. On the right side of Code river , Tegal Panggung village in 2010 and 2012 has 256 buildings. The last zone i.e. Cultural And Natural Buffer Zone, as in second zone, Suryatmajan village has 390 buildings in 2010 and 381 buildings in 2012. Meanwhile, the other village has the same number of 431 buildings in two years. Non preserve area only plotted in Tegal Panggung village which covering 1617 buildings. To sum up , total buildings in 2010 and 2012 were 3001, 2981 repectively

In chapter 5, the latest Government Regulation No. 38 year 2011 about River article 8 and 11, the preserve area minimum distance of the river in urban area with protection wall is 3 meters from the wall. This regulation should be taken into account in constructing detail spatial planning which will start in this year. If this regulation applied along Code river, it may reduce the distance of Locally Preserved Core Areas Of Riparian Zone from 50 meters to 3 meter. It will have significant changes of building number in this zone.

7.2 Delineating Actual Riparian Zone

In chapter 5, it disscussed about present spatial planning and its relation with higher level of regulation. The preserve area along the river was clearly stated in Government Regulation Nr. 38 Year 2011 about River. In present Spatial Planning of Yogyakarta Municipality Nr. 2 year 2010, the second zone is Cultural And Natural Buffer Zone . The fuction of this zone is intended to support the role of preserve core areas in maintain river conservation. Important finding in assesing various regulation on spatial planning zoning system was there is no chapter that regulate on how far the buffer zone and how delineate the zone. In this research, it tried to propose the method in defining buffer zone by delineating actual riparian zone of Code river based definition in sub chapter 2.5.

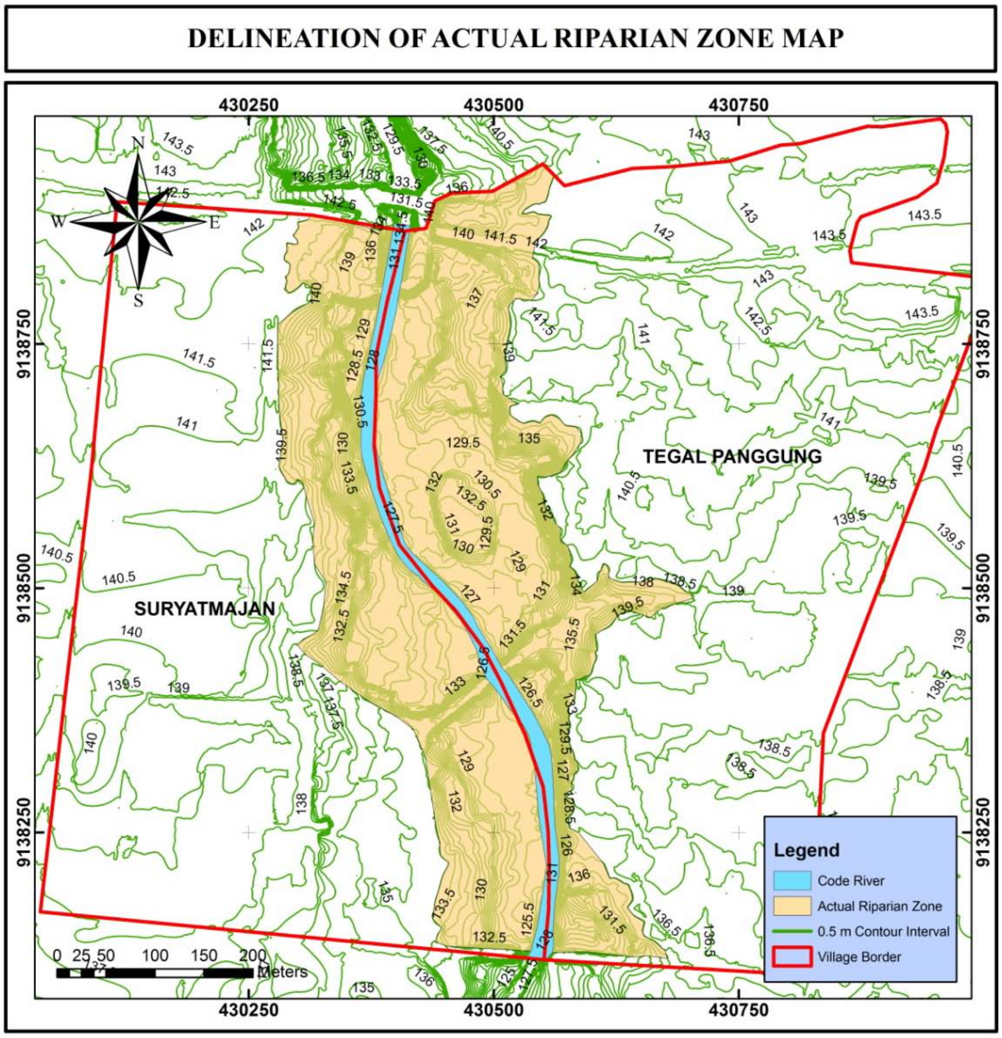

Figure 7.2 Generating Actual Riparian Zone

Source : 3D analysis

This zone above (figure 7.2) was defined on digital terrain model from LiDAR and GPS RTK data. In 3D analysis, DTM raster data was generated into 0.5 m contour line interval . There were two information that can be generated from proximity between the contour lines. First, if the distance between adjacent contour lines too close, it can be concluded that the area has steep slope. On the other hand, if the gap between contour line getting larger , the area will be the more flat.

Brown color in figure 7.2 shows the result of actual riparian zone at Code river.It was defined in accordance with figure 2.2 in chapter 2. Following the terrain shape along the river , some part of area has close distance to the river edge. Southern part in Tegalpanggung village, it has the shortest distance compared to the other side and steepest slope. The actual riparian zone in Danurejan subdistrict has an area of 17.634 hectare.

7.3 Lahar Flood Risk Data Information

As the objectives of the research, it will give overview on lahar flood analysis to support process in constructing detail spatial planning. The result of risk zone map based on 2011 lahar flood event and predicted risk map after flood proofing activity were presented in figure 6.40 and 6.41. In this chapter will give information on element at risk data which included in those map and their level of risk.

Table. 7.4. Element at Risk on 2011 Risk Map
and Predicted Risk in Danurejan Subdistrict
Source : Data analysis

	2011 Risk Map			Predicted Risk
Element at Risk Data	**High Risk**	**Moderate Risk**	**Low Risk**	**Low Risk**
Apartment		2	1	3
Bank			5	5
Business			63	63
Elementary School			15	15
Government Office			57	57
Government Pawnshop			6	6
Hotel			28	28
House Of Representative			5	5
Kindergarten			2	2
Mall			2	2
Market			9	9
Maternity Hospital			1	1
Money Changer			1	1
Mosque		3	8	11
Outpost	1		1	2
Pharmacy			1	1
Post Office			2	2
Private School			5	5
Public Religius			2	2
Public Service		1		1
Railway Company			27	27
Shop			304	304
Squatter	62	120	2234	2396
Student Boarding House			2	2
Tourist Center			2	2
Warehouse			29	29
Grand Total	63	126	2812	2981

According to table 7.4 above, most of the element at rsik which have high risk and moderate risk in 2011 event were squatter/ residential class. Total building in those category is 182 buildings. Relating to the number of floor, those building categorized in one floor building and their position close to the river edge. Based on the social vulnerability assessment, social economic condition in down part of Danurejan subdistrict categorized as middle to lower society which lots of inhabitants living under poverty. Similar to table 7.4, further research should make table in another minimum of 2 different return periods(50, 100 year retrurn periods)

In the predicted risk coulumn, result shows all of the element at risk in Danurejan Subdistrict classified as low risk. This prediction only applied with the condition similar to lahar flood event in 2011 and the protection wall strong enough to cope with extreme event of 20 year return period.

The result above were overlay with zoning area in present spatial planning to know the position of building in certain level of risk both in 2011 event and predicted risk. Figure 7.3 below show the overlay between preserve area zone , 2011 event and latest regulation in Government Regulation No. 38 year 2011 about River which regulated preserve area minimum distance of 3 meters.

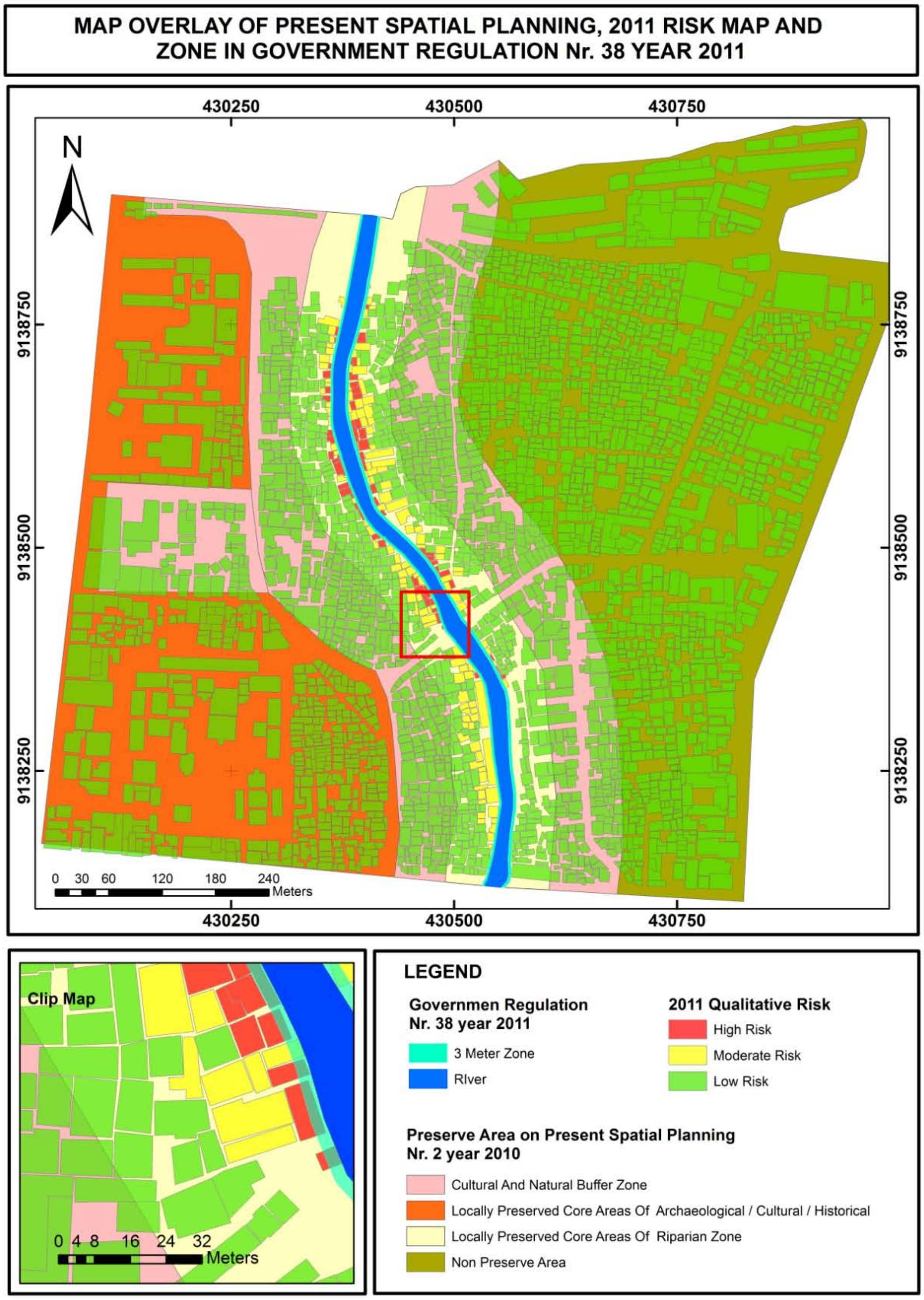

Figure 7.3 Map Overlay of Three Zone Map

Source : Data Analysis

The main map is on scale of 1 :5.000 and the clip map on the left bottom is 1 : 1.000. Similar with map overlay above, predicted risk when overlay with two other zones will give overview on condition of Low Risk along Code River. It can be generated overlay result into table that shows element at risk with each categorization in both risk map.

Table. 7.5 Element at Risk on 2011 Risk Map and Predicted Risk overlay with Present Spatial Planning and Govt. Regulation Nr. 38 Year 2011

Source : Data analysis

	Element at risk in 2011 Risk Map			**Element at risk in Predicted Risk Map**		
Zonning in Present Spatial Planning Nr.2 Year 2010	**High Risk**	**Moderate Risk**	**Low Risk**	**High Risk**	**Moderate Risk**	**Low Risk**
Locally Preserved Core Areas Of Archaeological / Cultural /Historical	0	0	404	0	0	404
Locally Preserved Core Areas Of Riparian Zone	63	126	401	0	0	579
Cultural And Natural Buffer Zone	0	0	821	0	0	812
Non Preserve Area	0	0	1186	0	0	1186
Total	63	126	2812	0	0	2981
Total Element At Risk			3001			2981
Zonning in Government Regulation Nr. 38 Year 2011						
Preserve Area of 3 meters	45	52	10	0	0	105
				0	0	
Total Element At Risk			107			105

The data in table 7.5 above illustrates element at risk in both regulation zoning system. Those data can one of the input for stake holder in defining new zone of preserve area with consideration of existing element at risk along Code River.

8. CONCLUSION AND RECOMMENDATION

8.1 Conclusion

General objectives of this research are analyzing the present spatial planning on its zoning system and relating to lahar flood risk analysis at riparian zone of Code river. In this chapter, it will discuss on brief explanation of the sub research objectives and research questions on the first chapter.

Assessing the present spatial planning related to zoning system

The result on literature study and indepth interview with several local agencies indicate that Local Regulation No. 2 year 2010 on Spatial Planning of Yogyakarta Municipality year 2010 – 2029 not yet including lahar flood analysis in the zonation process of preserve area along the river which passing through the Yogyakarta municipality. Furthermore, the existing of the preserve area zonation along the river did not precisely following higher regulation (national level) on zonation at riparian zone and some zones did not have clear regulation or research reference.

Calculating lahar flood risk in riparian zone of Code river

Three factors of risk were assessed in this research i.e. physical vulnerability, social vulnerability and Capacity. One-dimensional lahar flood map of 20 year return period from previous reserach was updated on its extent and depth using Participatory Geographic Information System and 3D analysis.
In vulnerability calculation , the assessed element at risk was building footprint especially on its landuse type and number of floor. Conducted analysis were on two conditions i.e. based on lahar flood event 2011 and after community built structural lahar flood proofing in their settlement area. Due to the study area of the research in village level, the changes of city inhabitant (demographic data) in several years was ignored. The factors in social vulnerability assessment were age related, income related and social structure related . Spatial multi criteria method (SMCE) was choosen method in mapping vulnerability. In this calculation the capacity factor was also included which contained literacy level of city inhabitant. Used method to give weigh on each factor was pairwise comparison.

Obtained value level on lahar flood risk analysis were devided into two conditions as it in vulnerability assessment. The first condition, it categorized in three level i.e. high risk, moderate risk and low risk. The second condition, it was only classified as low risk level.

Improving on present spatial planning zonation to support appropriate zoning system in detailed spatial planning which including lahar flood risk analysis

The improvement on zoning system of Spatial Planning Regulation Nr. 2 year 2010 was on the mapping method. It was done by adding information on element at risk data in each existing zone,proposing method in defining buffer zone by deliniating actual riparian zone of Code river and new information of risk level each element which overlay with new zone regulation according to the latest Government regulation number 38 year 2011 about River . This regulation defined minimum distance of the preserve area along the river in urban area was 3 meters.

8.2. Recommendation

Risk analysis should be applied in the process of constructing zoning system at riparian zone. This method can give detailed information related to lahar flood which periodically threaten the city inhabitant following eruption event of Merapi Volcano. Some of limitation in lahar flood risk calculation should be adressed to obtain precise calculation.

In vulnerability assessment, the physical vulnerability can be added building assessment based on physical properties i.e. building construction, building material, building safety equipment etc. Moreover, building valuation citeria can use the criteria from the Indonesian Finance Ministry. This criteria were adjusted to the real condition of building value in Indonesia.

The 20 year return period of lahar flood can not become the only basis in zoning system for spatial planning. Further studies should be done to construct the 50 and 100 year flood extent and depth. This can be done by 2 D modelling using the precise Digital Elevation Model (DEM) data and element at risk database provided in this research.

REFERENCES

Anonymous, 1990, Presidential Decree No. 32 Year 1990 on the Management of Protected Areas Retrieved February 1, 2013 from : http://www.jkpp.org/downloads/Keppres_32_1990.pdf

Anonymous, 1991, Government Regulation No. 35 year 1991 about River. Retrieved 1 February 2013 from : ww.carsis.ubb.ac.id/files/PP_NO_35_TH_1991_SUNGAI.pdf

Anonymous, 1992, Act No. 4 year 1992 about Housing and Settlement. Retrieved January 22, 2013 from : http://ciptakarya.pu.go.id/pbl/pustaka/BG/UU/UU%20NO_4_1992_TTG%20PERUMAHAN%20&%20PERMUKIMAN.PDF

Anonymous, 2000, Government Regulation of Republic Indonesia No. 10 year 2000 about Map Accuracy Level for Regional Spatial Planning Retrieved January 22, 2013 from : www.bakosurtanal.go.id/perpres/artikel/PP10-2000.pdf

Anonymous, 2007, Act No. 26 Year 2007 on Spatial Planning. Retrieved January 13, 2012 from : http://prokum.esdm.go.id/uu/2007/uu-26-2007.pdf

Anonymous, 2008, Government Regulation Number 26 Year 2008 on National Spatial Plan. . Retrieved February 1, 2013 from : http://www.penataanruang.net/taru/nspm/BatangTubuh_PP26-2008.pdf

Anonymous, 2010, Government Regulation No. 15 year 2010 about Implementation of Spatial Planning. Retrieved February 1, 2012 from : http://www.dephut.go.id/files/PP15_10.pdf

Anonymous, 2010, Local Regulation No. 2 year 2010 on Spatial Planning of Yogyakarta Municipality year 2010 – 2029. Retrieved July 24, 2012 from : http://bapeda.jogjaprov.go.id/

Anonymous, 2011, Government Regulation No. 38 year 2011 about River. Retrieved July 25, 2012 from : http://portal.mahkamahkonstitusi.go.id/eLaw/mg58ufsc89hrsg/14d4b8d26824136cc408654c449483a6617e25938.pdf

AI. (2012), What is LiDAR? Retrieved December 27th, 2012 from : Airbone Informatics http://lidar.co.id/service.html

BNBP. (2010). Data dan Informasi Bencana Indonesia. Retrieved June 15th, 2012 from BNPB : http://www.bnbp.go.id

BPS. (2009). *Yogyakarta City in Figures, 2009.* Yogyakarta: BPS-Statistics of Yogyakarta City.

Conyers, D., & Hill, P. (1984). The Planning process *An Introduction To Development Planning In The Third World*. Chichester: John Wiley & Sons.

Coto, E. B. (2002). *Flood Hazard, Vulnerability, and Risk Assessment in the city of Turrialba, Costa Rica.* Master of Science, International Institute For Geo-Information Science and Earth Observation, Enschede, The Netherlands.

Ehow. (2012) How to Calculate Bankfull Discharge, Retrieved January 1st, 2013 from Ehow : http://www.ehow.com/how_8617141_calculate-bankfull-discharge.html

FEMA. (1997). *Multi Hazard Identification and Risk Assessment*. United States of America.

Green, C. H., & Haney, R. (2000). *Riparian Zones.* Temple, Texas: USDA-ARS.

Grasso, M. (2010). Adaptation to Climate Change, *Justice in Funding Adaptation under the International Climate Change Regime* (pp. 11-28). Netherlands: Springer Netherlands.

Heryanti, D. N. (2012). *Community Based Approach To Assess Flood Risk Perception And Coping Mechanism Along Code River,Yogyakarta Municipality*. Master of Science, Graduate School Gadjah Mada University Faculty Of Geo-Information And Earth Observation University Of Twente.

Kelly, P. M., & Adger, W. N. (2000). Theory And Practice In Assessing Vulnerability To Climate Change And Facilitating Adaptation. *Climatic Change, 47*, 325-352.

Kohler, A., Jülich, S., & Bloemertz, L. (2004). *Risk Analysis – a Basis for Disaster Risk Management*. Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

Kompas,(2011 May 1st), *Lahar Dingin Merapi Menerjang Lagi*. Retrieved October 2012 from Kompas.com : http://megapolitan.kompas.com/read/2011/05/01/21212699/Lahar.Dingin.Merapi.Menerjang.Lagi

Lavigne, F. (1999). Lahar hazard micro-zonation and risk assessment in Yogyakarta city, Indonesia. *GeoJournal, 49*(2), 173-183. doi: 10.1023/a:1007035612681

NRCAN. (2010), How to do a GPS survey to centimetre accuracy Retrieved December 27th, 2012 from Natural Resouces Canada : http://www.geod.nrcan.gc.ca/edu/rtk_e.php

SE. (2012), High Resolution Satellite Imagery and Remote Sensing Retrieved December 27th, 2012 from Spatial Energy : http://www.spatialenergy.com/products_imagery.html

Smith G.A., and Fritz W.J. (1989). Penrose Conference report: Volcanic influences on terrestrial sedimentation. *Geology* **17**: 376.

PU. (2009). Balai Besar Wilayah Sungai Serayu-Opak. Retrieved May 10th,2012 from PU : http://www.pu.go.id/.

Rossi, G., Harmoncioglu, N., & Yevjevich, V. (1994). Coping With Floods. *257*. Dordrecht: Kluwer Academic

UNECE. (2008). Spatial Planning Key Instrument for Development and Effective Governance with Special Reference to Countries in Transition. Geneva: United Nations.

USGS. (2012). Flood Definitions. Retrieved May 8th, 2012 from USGS : http://ks.water.usgs.gov/waterwatch/flood/definition.html

van Westen.et al. (2009). Introduction of Risk Assessment Guide Book. International Institute for Geoinformation Science and Earth Observation Enschede, The Netherlands.

Yasin, A. (2012). *Determining The Impact of Volcanic Eruption on The Discharge Using Hydrological Model Case in Code Watershed, Yogyakarta Special Province, Indonesia.* Master of Science, Graduate School Gadjah Mada University Faculty Of Geo-Information And Earth Observation University Of Twente.

Zhang, C., Tang, H., Xia, J., Hu, L., & Pu, Q. (2009). Edge-Effect of Ecological Riparian Zone Advances in Water Resources and Hydraulic Engineering (pp. 465-471): Springer Berlin Heidelberg.