Developing a Flood Risk Map

A Case study of the city of Pori, Finland

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Summary

Natural hazards are an unavoidable phenomenon. Flood hazards are expected to increase due to climate change. Increasing precipitation will cause floods especially in river catchment areas. Nevertheless, the role of human activity is undeniable. Precise floods risk maps are needed in order to manage flood risk efficiently. Flood risk maps should be sufficient to make good decisions concerning flood protection.
The present thesis reviews five scenarios of flood hazard maps in Pori city and provides a new flood risk map based on flood hazard maps and flood water levels using the ArcGIS software. The situations of buildings at risk are marked in the developed risk map.
The map not only shows the vulnerable buildings, but it may help in making decisions for better flood risk management, flood protection or investment and human wellbeing in the future.

Language: English

Key words: Flood, Flood risk map, Flood hazard, Climate change, Pori, Finland, Human activity, ArcGIS

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List of abbreviations

Geographic Information System	GIS
United Nations Office for Disaster Risk Reduction	UNISDR
Water Framework Directive	WFD
Flood Directive	FD
Area of Interest	AoI
Finnish Environment Institute	SYKE
Geological survey of Finland	GTK
United Nations Framework Convention on Climate Change	UNFCCC
Karlsruher Institut Technology	KIT
Digital Elevation Model	DEM
Risk Analysis	RA
The Environmental Systems Research Institute	ESRI

1. Introduction

Flood hazards have increased in recent years because of different factors, such as climate change, subsidence, fast socio-economic development, population growth and inefficient use of land. Many countries in the world are suffering from the negative impact of climate change. In Europe climate change has several different impacts on river discharge. Floods could become more severe, since the annual precipitation is expected to increase in Finland by 13-26% by the 2080s (Jylhä and Ruosteenoja, 2007) and extreme precipitations are expected to increase (Beniston et al., 2007). In addition, temperature increases of 2-6 ° C by the end of the century are estimated to decrease the snow accumulation by 40-70% (Vehviläinen and Huttunen, 1997; Beldring et al., 2006; Ruosteenoja and jylhä, 2007; Jylhä et al., 2008; Räisänen, 2008). The temperature increase would also decrease snowmelt floods, which are currently the largest floods in most parts of Finland.

Flood risk is a combination of flood hazards and vulnerability. Whereas a flood hazard is a natural phenomenon with certain reoccurrence intervals flood risk is an entirely human concept. The risk is based on both, the hazard and vulnerabilities. By adding vulnerabilities to hazard data it is possible to generate risk maps. Such risk maps have a vital role in the decision making process for decreasing, e.g. flood risks as they can support flood emergency management and land-use planning. Flood risk maps can generate awareness in the population and especially among local people to support land-use planners and investors to decrease the overall flood risk.

This thesis develops a flood risk map in the case study the city of Pori. The proposed map consists of different layers including flood depths (hazard) and buildings (vulnerabilities), of different flooding scenarios. The map displays risk levels of houses in Pori which have been flooded by different water depths during the last 1000 years, modeled by Geographic Information System (GIS) software. The proposed Flood Risk Map comprises five flood recurrences 20, 50, 100, 250 and 1000 years.

2. Background

The United Nations Office for Disaster Risk Reduction (UNISDR, 2016) has reported the year 2015 as the hottest year since the start of temperature recording. The second most important cause for disasters related to natural hazards are floods (the natural hazard causing most disasters is storm). Floods have traditionally affected most people in any given year but were in second place last year when 152 floods affected 27.5 million people and claimed 3,310 lives (UNISDR, 2016). This compares with the ten-year average of 5,938 deaths and 85.1 million people affected. Floods in India last year affected 16.4 million people (UNISDR, 2016).

2.1. Floods in Europe

Floods are projected to increase along with climate change. But more importantly, human activities have increased the impacts of flood events. For instance, population in, often flood prone, coastal areas or river catchments has been growing continuously over the last decades, also in Finland (Schmidt-Thomé & Klein, 2011).

Due to the climate change and increase of the precipitation, river flow increased in northern Europe while it decreased in the south of Europe annually (Kovats et al., 2015). Many European countries are already taking flood protection measures. But concerted and coordinated action at the Community level would bring a considerable added value and improve the overall level of flood protection.

To decrease the flood consequences, EU passed the Flood Directive Framework (FD) in 2007 (DIRECTIVE 2007/60/EC). All of the EU members have had to approach flood risk management in three stages:

1. Preliminary flood risk assessment by 2011,

2. Developing their Flood Hazard and Flood Risk maps by 2013,

3. Flood Risk Management Plan by 2015

In addition, all the above steps should be reviewed every 6 years in a cycle coordinated and synchronized with the Water Framework Directive (WFD) implementation cycle (WFD, 2007)

There is a Flood Directive Scoreboard of the EU members which shows how well the EU members follow the requirements. Based on this Scoreboard, all the EU members were on time in Notification transposition in 2009, competent authorities /Units of management in 2010, Preliminary Flood Risk Assessment 2012, but except Bulgaria and Greece all the European countries have submitted Flood Hazard & Flood Risk Maps in 2014. The next deadline for Flood Risk Management Plans is in 22.3.2016, (Directive 2007/60/EC)).

Figure 1 shows an example of flood damage functions for EU member states. Damage is depending on different functions such as depth of water, type and location of the buildings, flood duration cleaning cost etc. In this case, costs are depending on the condition and location of the buildings and the depth of water.

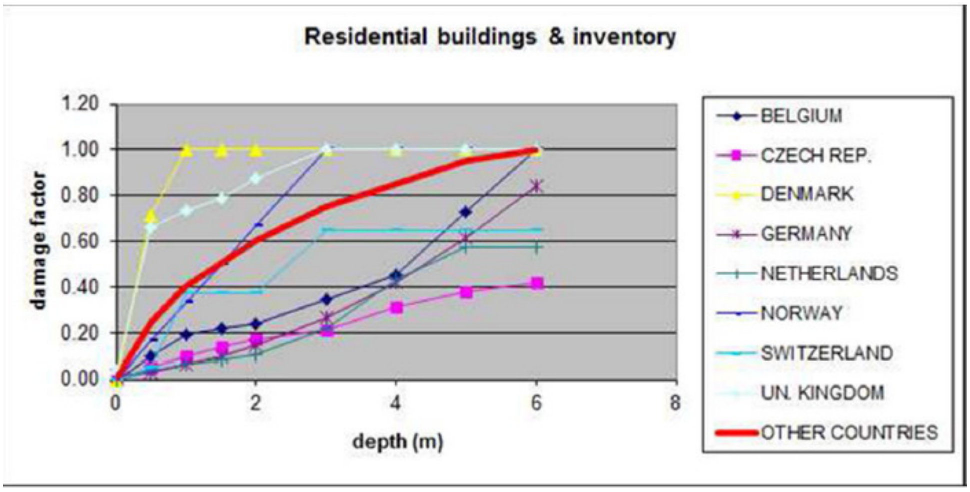

Figure 1: Flood damage functions for EU member states. Technical reports HKV Consultants. Implemented in the framework of the contract #382441 F1SC awarded by the European Commission – Joint Research Center (Huizinga H.J.(2007).

2.2. Floods in Finland

Floods affect different dimensions of the built up environment. Floods may cause damages on human safety and health, public services, properties, economic activities, environment and cultural heritage. All of these damages can be estimated by monetary terms (SYKE, 2011). Some of these damages are irreparable like mortality.

Based on the Finnish Environment Institute (SYKE) report (Pesu et al 201) (table 1), a 250-year flood in Finland would cause a total cost of flood damages of 1285 M€, while 582 M€ has issued for residence buildings. The second place goes to the industrial buildings, with a cost damage of 203 M€.

Table 1: Total cost of damages by a 250-year flood in all flood risk areas in Finland by SYKE (2014)

	M€
Residental buildings	582
Industrial buildings	203
Free-time buildings	117
Commercial buildings	98
Buildings for agriculture, forestry and fisheries	25
Buildings for health care	14
Buildings for education	14
Buildings for traffic	10
Other public buildings	6
Buildings for energy production	6
Other buildings	1
Buildings for emergency services	1
Break in trafic	20
Damages to traffic infrastructures	48
Costs of emergency services	81
Vehicle damages	59
Total	**1285**

2.2.1. Flood Prone Areas

Pori is located at the west coast of Finland with a population of 85,432 (i.e., estimated in early 2015) in an area of 1,704.07 km^2 (Figure 2). Pori is situated on the estuary of the river Kokemäenjoki which is the largest river in Finland. Due to the flat topography, underlying geology and the size of the catchment of Kokemäki River, Pori possesses a high risk of flooding.

Figure 2: City of Pori (Syke, 2009)

As the history of the city shows, Pori has faced several floods during the past 1000 years. Figure 3 shows the Jääräntie Toejoki Street in Pori, which was covered by water in 2007. Based on a Syke report from 2009, about 15,000 people live in the flood prone area in Pori.

Figure 3: Jääräntie Toejoki is covered with water Photo 13.8.2007: Janne Lumme

2.3. Adaptation to climate change

Based on the United Nations Framework Convention on Climate Change (UNFCCC, 2011), the climate change adaptation process includes four main elements: (i) the assessment of climate impacts and vulnerability; (ii) planning for adaptation; (iii) the implementation of adaptation measures; and (iv) the monitoring and evaluation of adaptation actions (UNFCCC, 2011). Figure 4 shows these main elements.

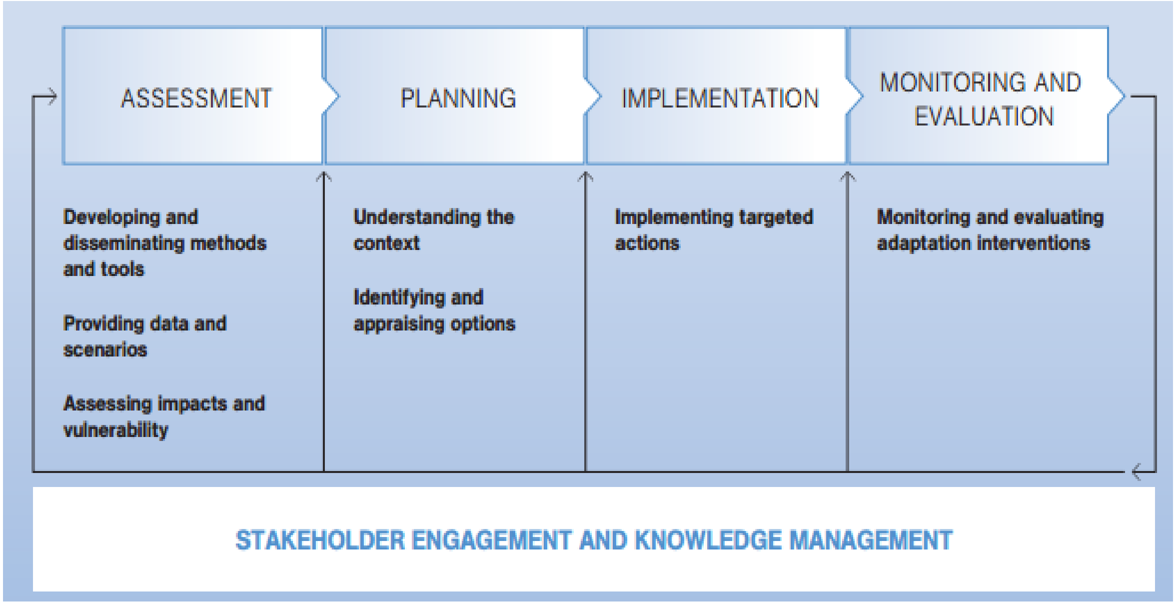

Figure 4: Adaptation process (UNFCCC, 2011)

Climate change has different impacts on environment, nature, human health, industries and other different kinds of impacts. However, these impacts have two sides, they could be unfavorable or beneficial. Finland is one of the first countries to study climate change impacts and to develop a climate change adaptation (Ministry of Agriculture and Forestry 2005).

A climate change benefit for Finland is the increasing average temperature. By increasing the temperature the gross domestic product (GDP) for natural resources such as agriculture, forestry, recreation business and tourism could be improved by approximately 0.2 per cent (STAT, 2013).

On the other hand, climate change will have more impacts on the water sector. For instance more precipitation in the rainy season may cause infrequent events such as severe floods, which could have direct and indirect impacts. Even in some cases indirect economy cost may cost more in comparison to direct effects (STAT, 2013).

Table 2 shows the economic effects of climate change in different sectors in Finland. The table is from Finland's Sixth National Communication under the United Nations Framework Convention on Climate Change (STAT 2013).

Table 2: Estimation of climate change impacts different sectors in Finland (STAT, 2013)

Sector	Economic impacts	State of research
Tourism	By 2020, EUR 107 million; by 2050, EUR 107 million; by 2080, EUR 107 million (changes in net value added).	International research, with Finland involved from 2006. Research conducted within Finland in 2005.
Insurance	Weather and climate risks increasing, no overall estimates on economic impacts.	No Finnish research.
Agriculture	• By 2020, EUR 60 million; by 2050, • EUR 100 million; by 2080, EUR 120 million (changes in net value added). • About 0.1 per cent of GDP.	Latest study conducted within Finland in 2005. European PESETA project in 2009.
Forestry	By 2020, EUR 75 million; by 2050, EUR 150 million; by 2080, EUR 250 million (changes in net value added).	Latest figures from 2005, estimates also from the recent VACCIA project.
Biodiversity	No economic estimates. An estimate of EUR 10,000 million regarding negative impacts within Europe.	
Health and welfare	No economic estimates.	No overall estimates, research also scarce on a global level.
Built environment	Costs due to rivers flooding: • in Pori, EUR 40–50, or up to EUR 100 million (for flooding events occurring once every 50 years) • 0.2–0.4 per cent of GDP.	TOLERATE, PESETA, and ClimateCost estimated the impacts of river floods; no overall estimates for the built environment.
Transport and communications	Overall estimates based only on current costs. For example, weather-induced traffic accidents: about EUR 230 million; pedestrian slipping injuries: about EUR 2.4 billion.	The EWENT project and the VTT Technical Research Centre of Finland estimated current costs; there are no Finnish estimates on the overall costs induced by climate change.
Energy sector	By 2020, EUR −37 million; by 2050, EUR −73 million; by 2080 EUR −141 million (changes in net value added).	Latest estimates from 2005.

It is expected that, while the temperature increases, the precipitation will increase as well in winter time in contrast to summer time. Other examples of climate change impacts are as follows (STAT, 2013):

- Finland will encounter longer and more frequent heat waves
- Less significant cold seasons
- Higher precipitation in summer time
- Longer precipitation periods
- Shorter snow seasons and less snow melt water, especially in southern Finland
- Cloudier days in winter and consequently lower solar radiation
- Minor increase in wind speeds in autumn and winter time

The above stress factors about the climate change will have impacts on constructions and buildings especially by changes in flood patterns. Changing flood patterns will increase flood hazards in the coastal area, river catchments and lakes and consequently the flood risks if these areas are built up.

According to the Finnish Climate Change Adaptation Strategy (STAT 2014), researchers were trying to find solutions to achieve more benefits from the positive impacts while mitigating negative impacts by adaptation to climate change. Almost, all part of this strategy has been implemented, especially the flood maps for vulnerable areas.

2.4. Impact assessment

Flood impact assessment plays an important role for flood risk management. The European Flood Directive defines flood risk as the combination of the probability of a flood event and of the potential adverse impacts on human health, the environment, cultural heritage and economic activity associated with a flood event (European Commission, 2007). Flood may have both positive and negative environmental effects.

Floods can cause devastating consequences on the living environment. For example, floods can interrupt usual drainage systems in the cities. Or even if the flood is harsh enough, it may cause the destruction of buildings and spill toxic materials such as paints, pesticides, gasoline, etc. into the local environment and contaminate for instance water resources.

On the other hand, like other natural phenomena which have two sides, floods have positive impacts as well. For instance, floods water carries nutrients, which are suitable for agricultural land use, such as cultivating some type of crops. In addition, sediments carried by floods are a kind of a natural flood protection as they maintain the elevation of the land mass above sea level. Also, a flood can bring sediment which has a positive effect to refill valuable topsoil components (Finland’s National Strategy for Adaptation to Climate Change, 2005).

To identify the flood impact a tool such as an Impact Assessment is needed. This assessment could support the mitigation or prevention of the damages. Raising awareness among inhabitants in vulnerable area supports managing emergencies in- time, or avoiding building in flood prone areas (Applying Environmental Assessment for Flood Management, 2007).

By focusing on the buildings and human well-being as the thesis’ main targets, it seems that floods have no positive impacts on the AoI. Land-use planning taking this mapping approach into account can help to reduce risks and impacts on the buildings and people.

3. Previous studies in the Pori case study

In case of the city of Pori, SYKE has provided essential information based on GIS. The system contains flood hazard maps, water level, discharge scenarios and hydrological flood observations. In this case, flood hazard maps are categorized for several different flood recurrence periods including 2, 5, 10, 20, 50, 100, 250 and 1000 years in different scenarios of water levels such as under 0.5 m, 0.5m-1m, 1m-2m, 2m-3m and more than 3m water depth (SYKE, 2014).

A recurrence interval is an estimate of the likelihood of an event, such as an earthquake, flood or a river discharge flow to occur. For instance, the term "100-year flood" is used in an attempt to simplify the definition of a flood that statistically has a 1-percent chance of occurring in any given year. Table 3 shows reoccurrence years and probabilities of occurrence that used in the recent project.

Table 3: Recurrence intervals and probabilities of occurrences

Recurrence interval, in years	Probability of occurrence in any given year	Percent chance of occurrence in any given year
1000	1 in 1000	0.1
250	1 in 250	0.4
100	1 in 100	1
50	1 in 50	2
20	1 in 20	5

Table 4 shows damage costs for damages on buildings, purifying costs and moving costs in the city of Pori based on SYKE researches (SYKE, 2015). It shows monetary damage-estimations for different flood return periods for Pori (based on flood maps, and basic sea level scenarios without ice-jam).

Table 4: Pori flood area, flood protected area included, own research with background data from Syke (2015)

Years		***Damages cost for each sections (M€)***	***Total Cost Buldings Damage(M€)***
20	Building Damages	10.57	15.88
	Purifying	0	
	Movables	5.31	
50	Building Damages	28.82	41.92
	Purifying	0.01	
	Movables	13.09	
100	Building Damages	43.19	64.2
	Purifying	0.01	
	Movables	21	
250	Building Damages	65.1	99.13
	Purifying	0.03	
	Movables	34	
1000	Building Damages	100.35	154.16
	Purifying	0.13	
	Movables	53.68	

Figure 5 illustrates the total cost of building damages in five recurrence periods in Pori city. The amount of the buildings which are impacted by flood was in the highest range in scenario five, 154.16 M€. Therefore Moving costs and Purifying costs have stayed in the highest level in the same scenario as well.

Overall, the total damage costs for a 1000 year probability is in highest level, while the total cost in 20 year probability is in the lowest stage. As a result, as long as the flooded area becomes smaller, consequently the total cost of the damages might be smaller too.

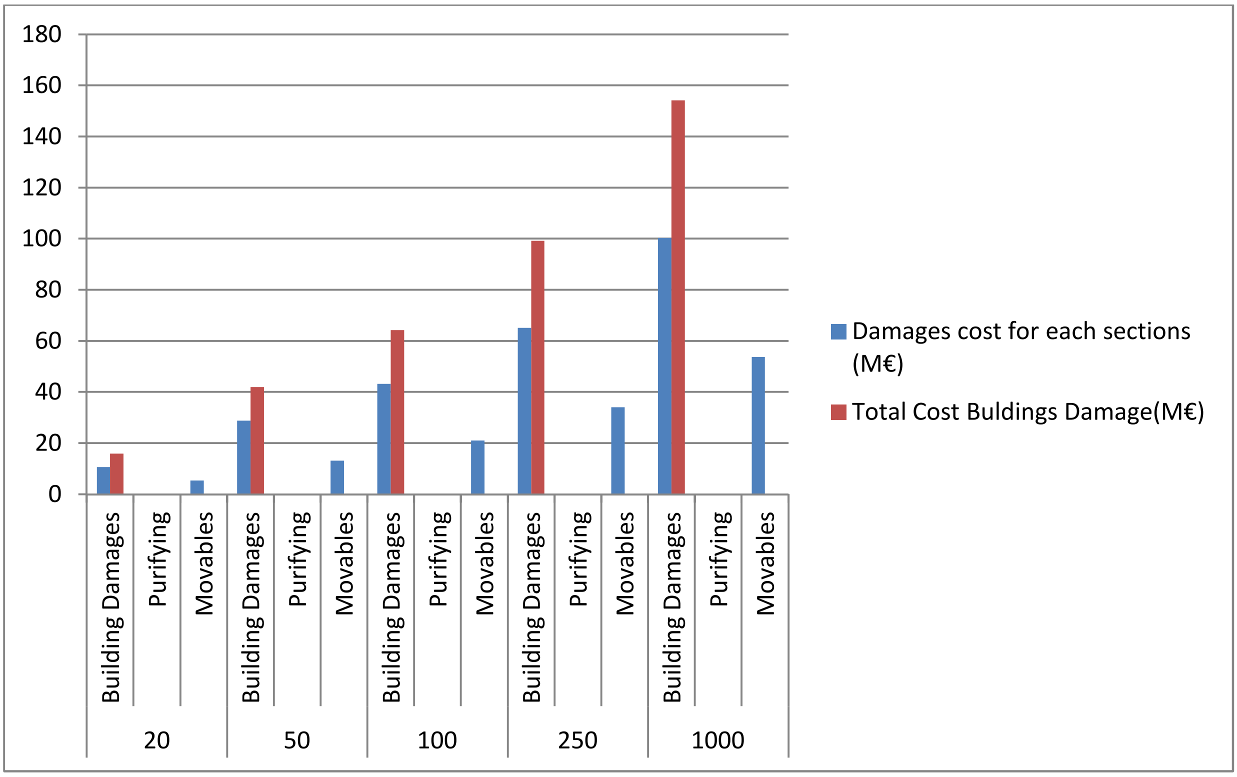

Figure 5: total cost building damages (€), per different scenarios, own research, source: Syke (2015)

Figure 6 shows an example of the SYKE maps in the AoI for flooded areas for recurrence periods of 1000 years in different water depths. It also shows the depth of flooded water and the area which are protected from floods of the respective reoccurrence period. SYKE has provided the same data (Flood hazard data) for several different scenarios.

This thesis focuses on a specific area close to the Kokemäki River in Pori City which had severe flood impacts during the past years. Using five flood recurrence periods including the reoccurrences for 20, 50, 100, 250 and 1000 years in the Area of Interest (AoI). The reason for selecting that area was because of the high amount of buildings affected by floods.

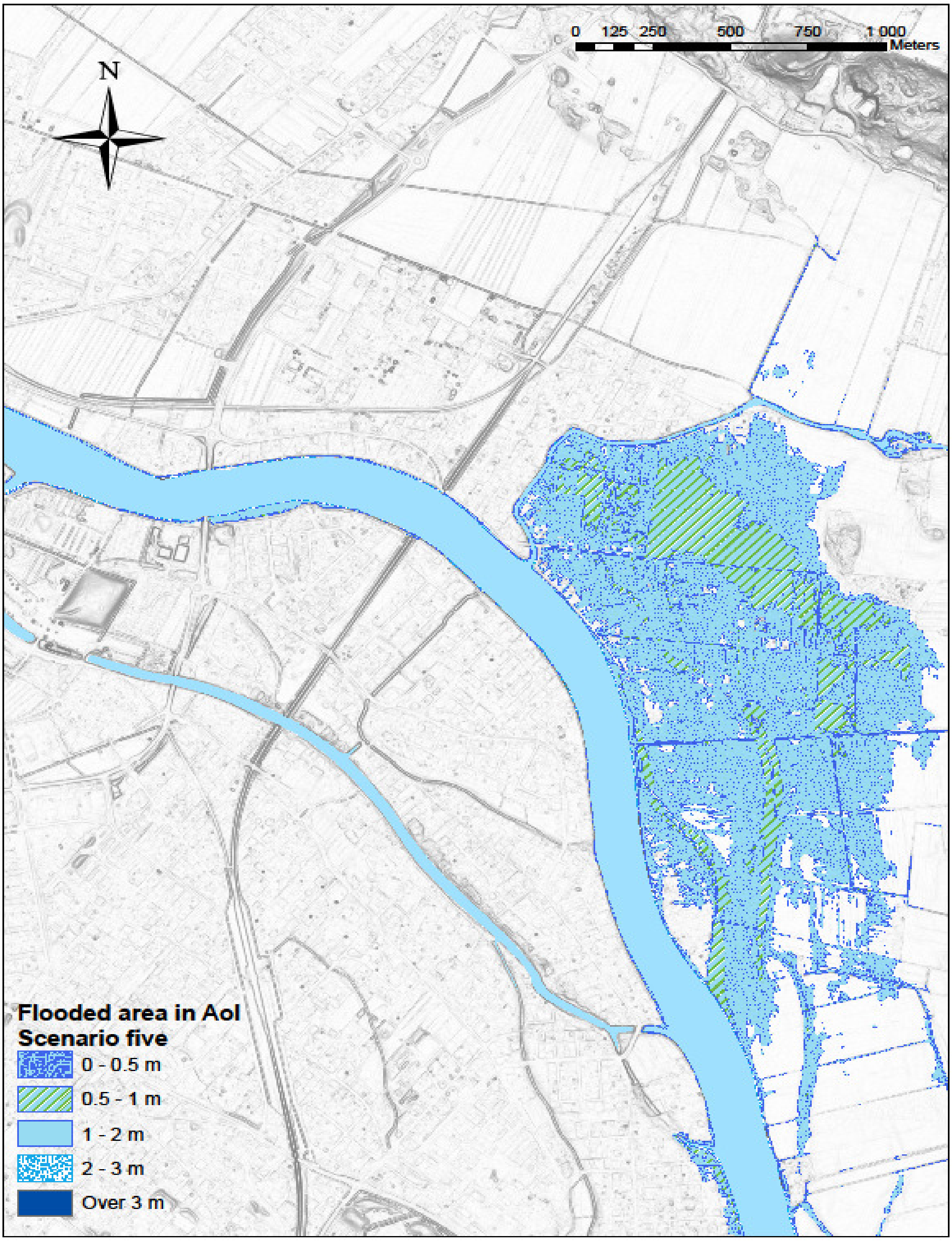

Figure 6: Flooded area in different water depths in scenario five (1000 reoccurrence) (Data source: SYKE, 2014)

SYKE (2014) has also prepared different data such as the type of buildings. Figure 7 shows the different type of buildings located in the area of interest. The thesis focuses on the buildings which are flooded in five chosen recurrence periods.

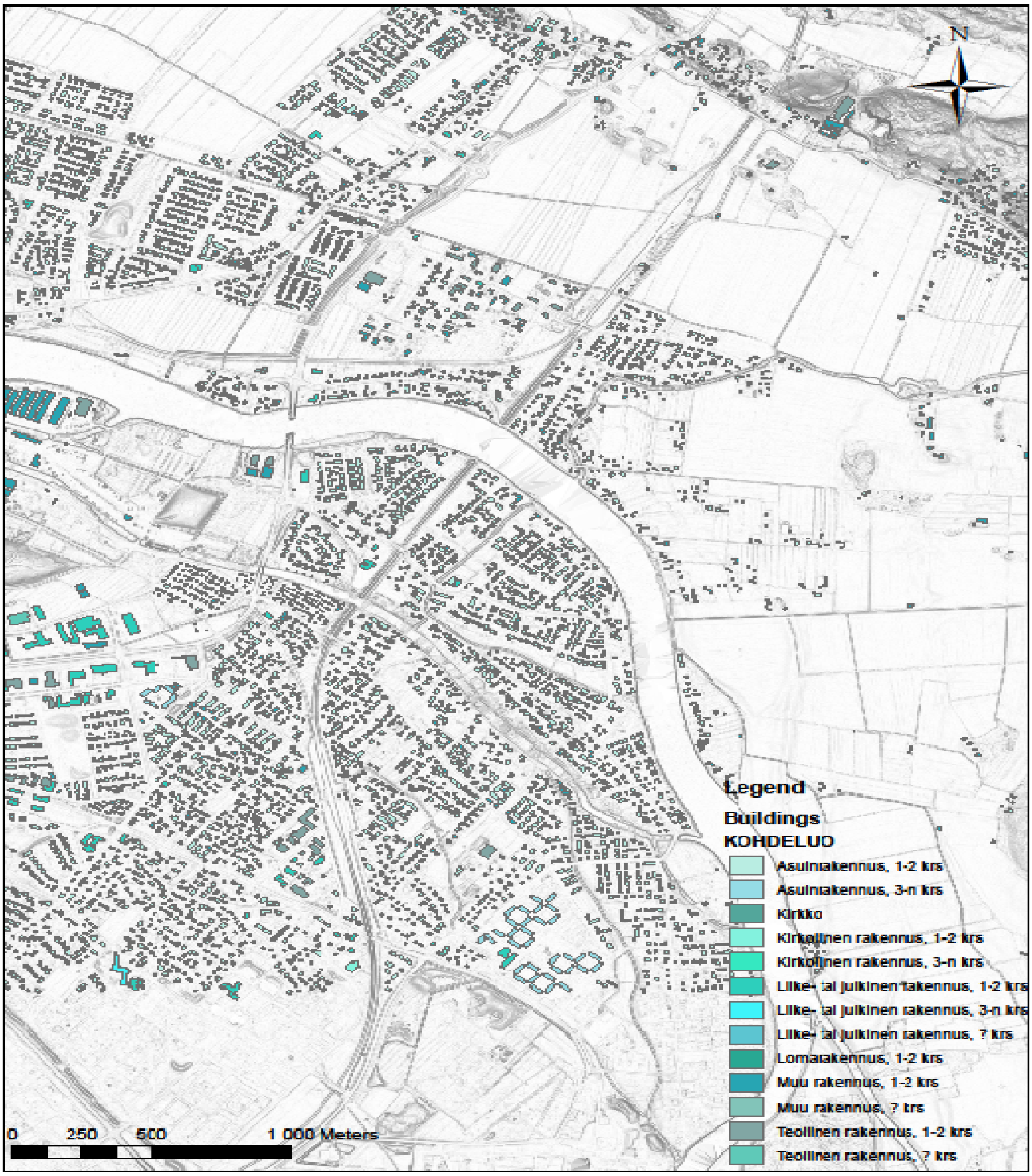

Figure 7: Different kinds of buildings in the Area of Interest (Data source: SYKE, 2014)

4. Purpose of the research

The purpose of the thesis is producing a flood risk map by using the ArcGIS software in the case study of Pori city. The thesis is based on the flood hazard and infrastructure data sets. This method can be used for several dimensions, such as protecting more vulnerable buildings. Consequently, it could be a way to secure economic activities and investment. In addition, the most important outcome is improving flood risk management as result of the production good flood risk maps. These flood risk maps can help to decrease the amount of flood damages.

Damages from floods have increased in recent decades in Europe (Munich Re 2015), due to increasing building activities in flood prone areas and a changing climate. In Finland, the national flood information system has started in 2006 with the essential information on floods based on GIS.

5. Research methodology

There is different kind of methods for creating or developing flood hazards maps. For instance, the EU Flood Directive (2007) demands that all EU Member States carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at flood risk. For such zones the identified areas needed to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU (DIRECTIVE 2007/60/EC). This thesis has created a method for the case study area in Area of Interest (AoI), which can be applied for all over the country with available data sources. This method is combination of several layers in ArcGIS. As risk has a correlation in its probabilities and consequences. This project has researched the impact of flood on the buildings in the AoI as its consequences. Then impacts of several different floods reoccurrence periods on the buildings have been investigated. The thesis reviews five scenarios based on the reoccurrence years, including 1000, 250, 100, 50 and 20. For creating this method, accurate information on flood hazards is crucial.

5.1. GIS Analysis

The main core of thesis has been done by ArcGIS. All data sources have been provided by SYKE (Flood Hazard Areas, Flood Mapped Areas and Infolines, 2015). Almost all the data is in vector format, except the base map which is in raster format. The reason to choose raster for base map was to show clearly the situation and location in the AoI.

Vector and raster are both primary data types used in GIS and both of them have spatial referencing systems. Vector graphics are consisting of vertices and paths using X and Y coordinates to define the locations of points, lines, and areas (polygons). So this thesis has surveyed vector format.

Raster data consists of pixels (or cells). The pixel values may indicate elevation above sea level or rainfall, etc. In the raster all of the data has been calculated in grid cells. One of the most important part in using raster is combining different layers with same geodetic height systems. There are different geodetic height systems for Digital Elevation Model (DEM) data, for instance NN has been used during years 1892–1910, N43 and N60 have been more common during the years 1935–1975 and N2000 was produced in the years 1978–2004 (soumen geodeettiset koordinaatistot ja niidenväliset muunnokset, 2009). Now N2000 is more common to use. To calculate Orthometric height system the below formula may be used, Figure 8 shows how Orthometric height can be calculated (soumen geodeettiset koordinaatistot ja niidenväliset muunnokset, 2009).

H=h-N Where: H = Orthometric Height; h = Ellipsoidal Height; N = Geoid Height

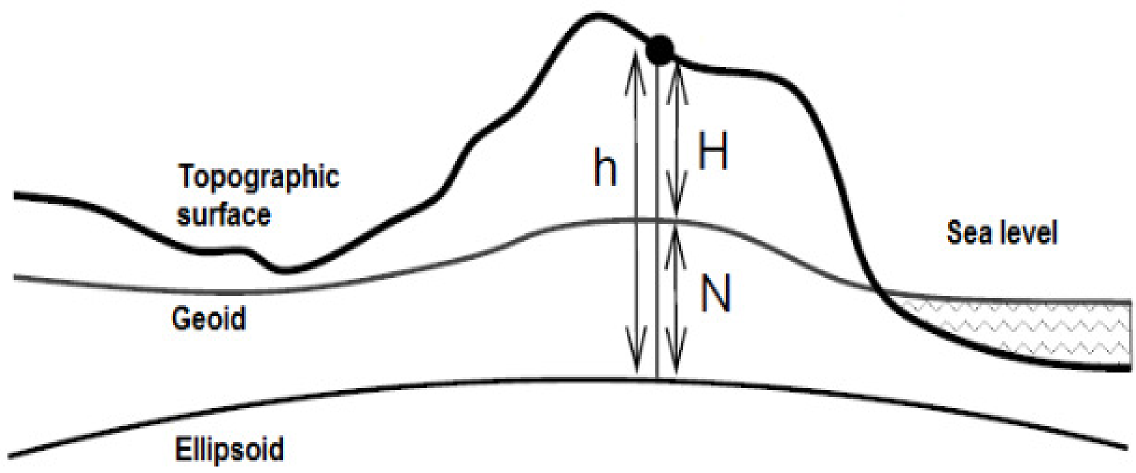

Figure 8: Orthometric height system Pasi Häkli, Jyrki Puupponen, Hannu Koivula, Markku Poutanen, 2009)

Based on ArcGIS, this method has focused on three specific indicators:

First, the focus has been on the flood data layers for five flood reoccurrence periods 20, 50, 100, 250 and 1000 years. So there are five scenarios from one to five for these years, respectively. For all scenarios, flood area and its water depth has been considered.

Secondly, the focus has been on the population at risk in AoI. For instance, figure 9 reveals not only the flood area and its water depth in scenario five, but also the population affected in the AoI. By this method, population at flood risk can be clarified per km^2. It could be more precise if the number of people in each building would be calculated separately.

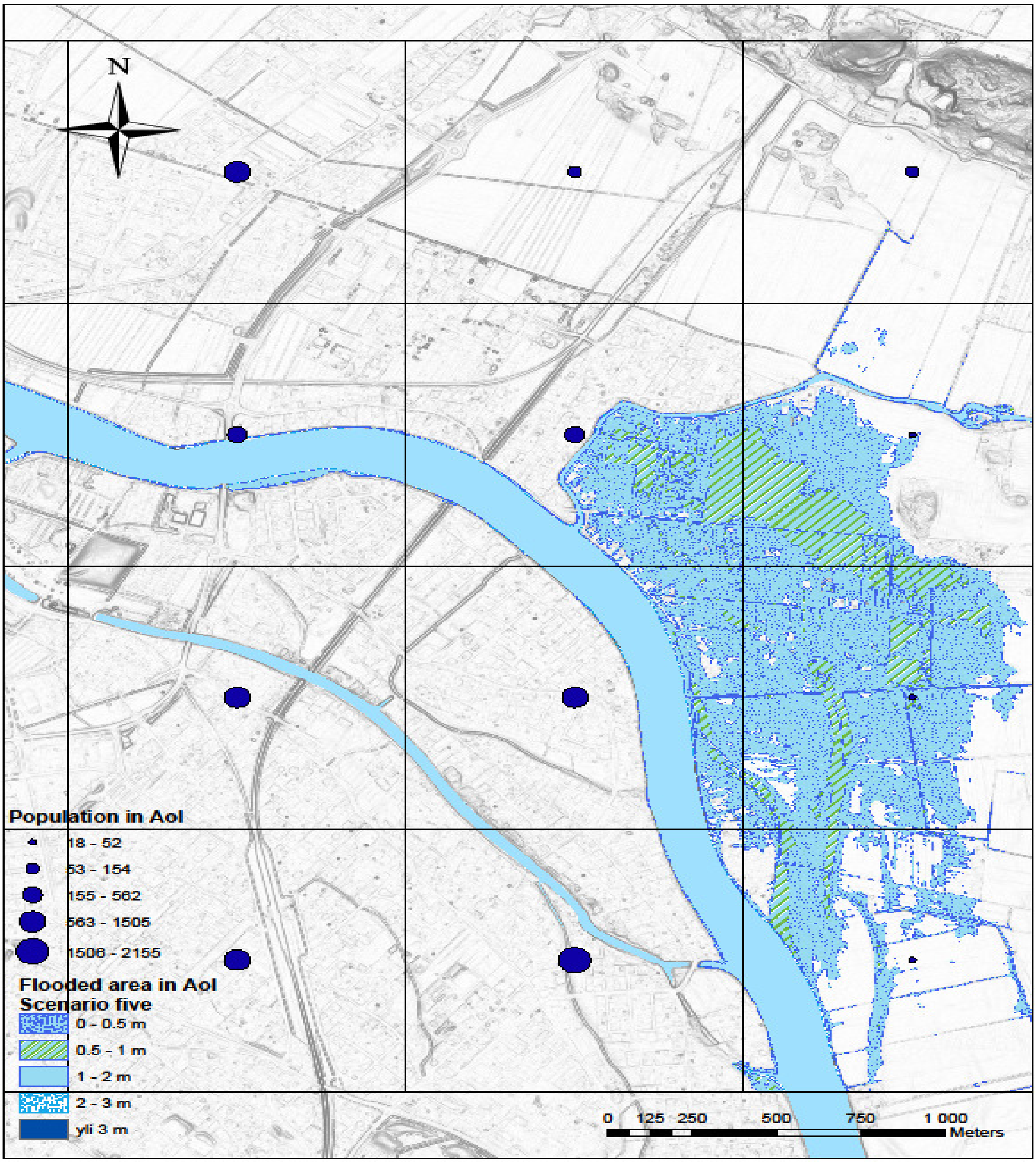

Figure 9: Flooded area in scenario 5, 1000 years and population per km^2. (Data source SYKE, 2014)

Lastly, this approach has considered the majority of different houses situated at risk in the AoI. The vulnerable buildings have been considered as targets. Target buildings are classified in two major classes, 1-2 floor buildings and residential buildings with 1-2 floors. Figure 10 shows two classes of buildings, which are more probable to be impacted by floods in the reoccurrence years in the AoI. Previously, in the figure 6, all types of buildings have been considered.

Figure 10: Two classes of vulnerable buildings (Data source SYKE, 2014)

Since there are many different tools available in GIS, this thesis has found the "Intersect Tool" as a better way with the best result in comparison to the other functions. The main reason for using intersects was the attributes of the result. By using intersect all features which have been used, will be in the output as well. The "Clip Function" has been tried during the process, but in that trend only the input attribute feature has appeared in the output. Whereas the present work needed all the features available for output.

Flood layers as a source layer has been unchanged. Two other layers have been reviewed with the source layer separately. By combination the flood source layer and buildings layer, and using "Intersect Function", the new polygon layer has been created as its output. The new polygon layer shows how many buildings have been impacted by which flood depths during the reoccurrence years. A comparison of the source layer with the population shows how many people are living at the flood risk area in AoI.

After all examination, this thesis has been produced the flood risk map by using two main tools, Clip and Intersect. First, the area of interest has been chosen as a case of study in Pori city. In the next step, by using the Clip function, all the data sources such as flood hazard map for all five scenarios, Buildings and population have been clipped based on the area of interest separately. Then all the buildings which have been flooded have been clarified by using the Intersect function. Finally the results were analyzed by the attribute table.

By using the "select by attributes" function in the Attribute table from ArcGIS, the project has singled out the number of buildings which are potentially flooded by different water depths in all scenarios in the AoI.

5.2. Risk Analyses

Risk Analysis (RA) is one of the vital tools for understanding and identifying the potential the risks in the research area. Indeed, it can help to manage the risks and good decision making how to mitigate the risks. Figure 11 reveals the amount of buildings and inhabitants in the five scenarios in AoI.

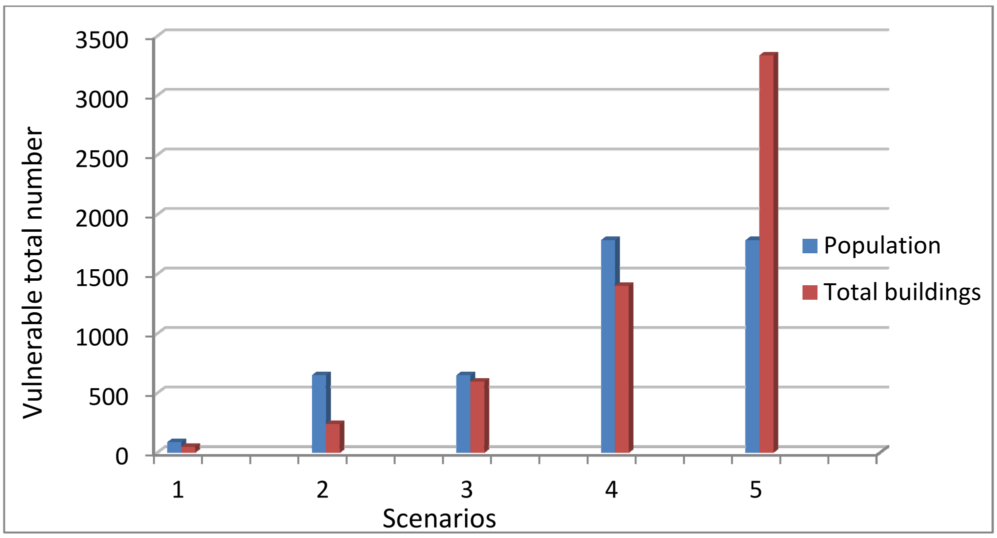

Figure 11: Comparing population and buildings in five scenarios, own research (Data source SYKE, 2014)

As figure 11 shows, in scenario one the smallest amount of buildings and people are impacted. However for the rest scenarios, the total amount of vulnerable persons and buildings become ever larger.

As result in scenario one, less people faces flood risks. So, there is less risk of illness, death, injury, or other loss of life. In addition, fewer buildings are impacted by floods in scenario one. By accessing insurance data, it could be possible to estimate the cost of damages by By accessing insurance data, it could be possible to estimate the cost of damages by the below formula:

Risk Value = Probability of Event x Cost of Event

6. Results

As result, figure 12 shows the numbers of buildings that are impacted by different water depths in scenario five in AoI.

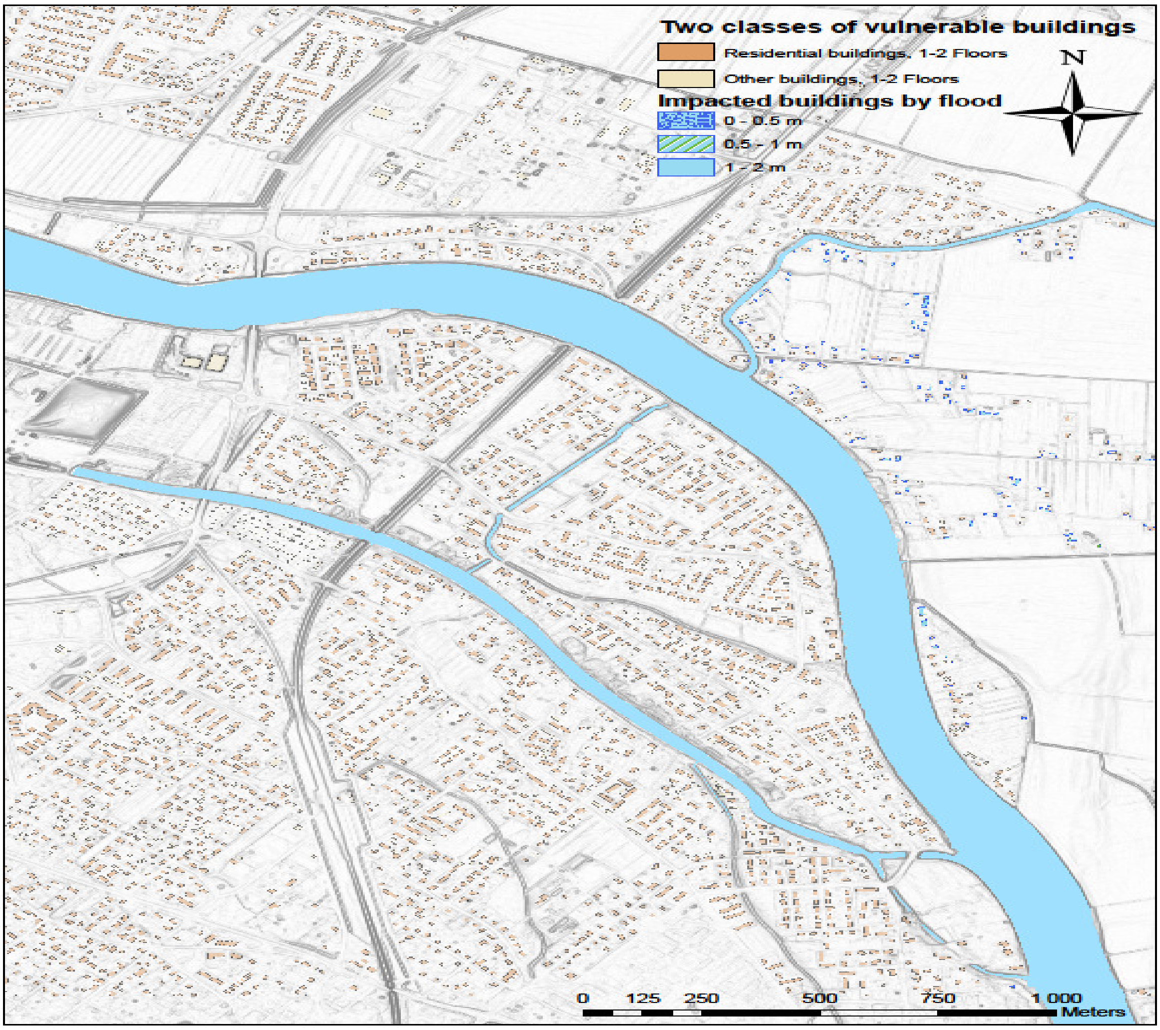

Figure 12: Amount of the impacted buildings by flood in scenario five, own research (Data source SYKE, 2014)

Figure 13 illustrates the amount of the impacted buildings by different water depths, which are the same as in scenario one. Based on the Attribute table in ArcGIS, it reveals that only few vulnerable buildings remain at risk.

Figure 13: Amount of two major types of buildings that impacted by flood in scenario one, own research (Data source SYKE, 2014)

Figure 14 reveals the population at risk per km². However, by reviewing table 4 and figures 15 and 16, the result is more obvious.

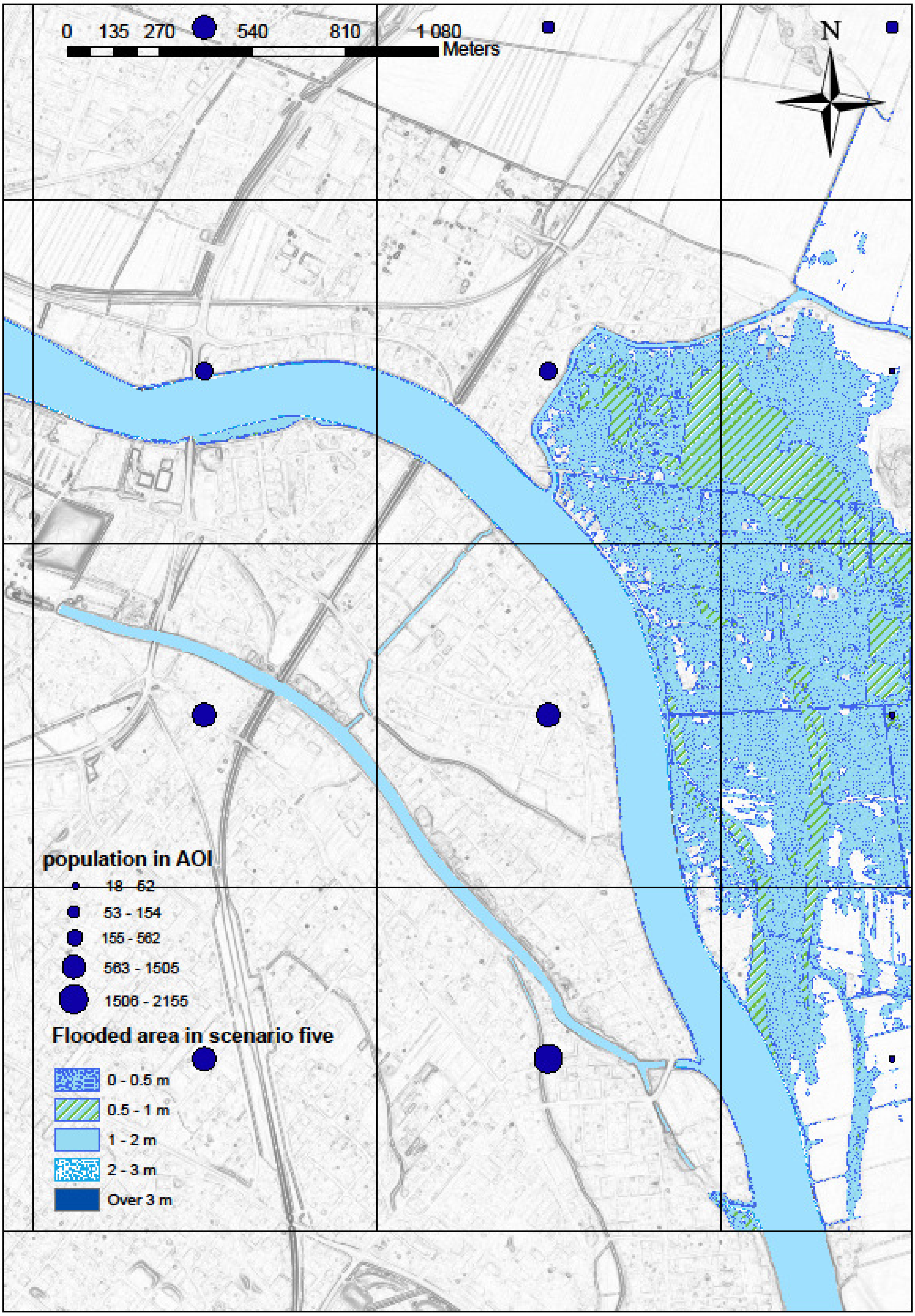

Figure 14: the population at risk perkm² in scenario 5 in AoI, own research (Data source SYKE, 2014)

As table 5 shows the amount of the people who are living at risk area decreases as the reoccurrence years become less. So, vulnerable targets and the flooded areas have a direct correlation. In the scenarios two and three not only the population at risk stayed unchanged, but also the flooded area remains stable. Less people who are living at risk and the smallest area which are flooded per km^2 belong to the scenario one with the smallest reoccurrence years.

The highest amount of buildings may impacted by flood was 3336 in scenario five. In level 0-0.5m, totally 150 buildings are impacted, of which 95 were "Other buildings 1-2 floors" and 55 were "Residential buildings 1-2 floors". In level 0.5-1m, 11 buildings are impacted, of which 10 were "Other buildings 1-2 floors" and only one was "Residential buildings 1-2 floors". Surprisingly, in the level 1-2m, there is not building at risk. In the scenario one, there are no residential buildings affected by floods. However, only one building is impacted by the flood depth 0-0.5m.

Table 5: Result information for AoI, own research (Data source SYKE, 2014)

Scenario	*Reocurence year*	*Population at Risk*	*Area km2*	*Total buildings*	*Water depth*	*Buildings have impacted by flood*	*Type of buildings*
1	20	87	2	48	0-0.5m	1	Other buildings 1-2 floors
					0.5-1m	0	
					1-2m	0	
2	50	649	3	238	0-0.5m	5	Other buildings 1-2 floors
					0.5-1m	0	
					1-2m	0	
3	100	649	3	595	0-0.5m	8	7:Other buildings 1-2 floors 1:Residental building 1-2 floors
					0.5-1m	0	
					1-2m	0	
4	250	1784	6	1400	0-0.5m	41	34:Other buildings 1-2 floors 7:Residental building 1-2 floors
					0.5-1m	1	Other buildings 1-2 floors
					1-2m	1	Other buildings 1-2 floors
5	1000	1784	7	3336	0-0.5m	150	95:Other buildings 1-2 floors 55:Residental building 1-2 floors
					0.5-1m	11	10:Other buildings 1-2 floors 1:Residental building 1-2 floors
					1-2m	0	

Figure 15 reviews the percentage of buildings impacted by floods in three flood water depths and in five scenarios. In figure 15 the graph shows the percentage of buildings impacted by three different water depth floods. In flood reoccurrence 1000 years, high percentage of building has been affected by water depths 0-0.5, in compare to the water depth 1-2m, it has been showed zero. However in flood reoccurrence 20 years, the water depth 0 – 0.5 m, low percentage of buildings are affected by flood.

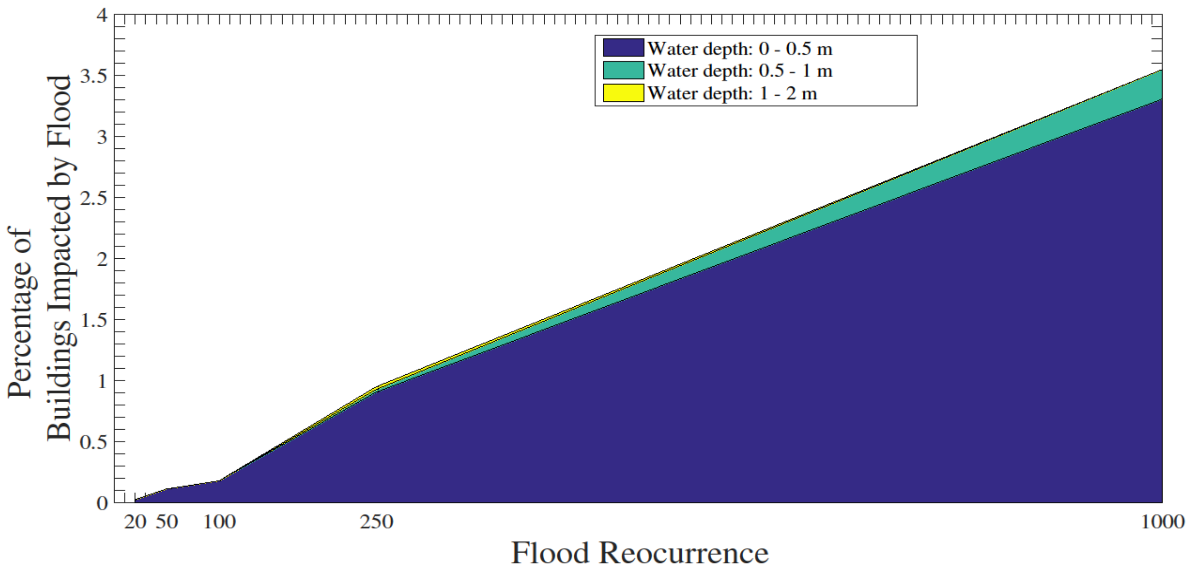

Figure 15: Percentage of buildings impacted by flood in three flood water depth in five scenarios in AoI, own research (Data source SYKE, 2014)

In overall, by analyzing the graph, two general results are obvious. Longer period for reoccurrence years will cause more floods probability. And how much the water depth has been raised, inversely the amount of buildings which are impacted by flood have been decreased.

Figure 16 illustrates the percentage of buildings impacted by three different water depths in a chart bar for more clarification.

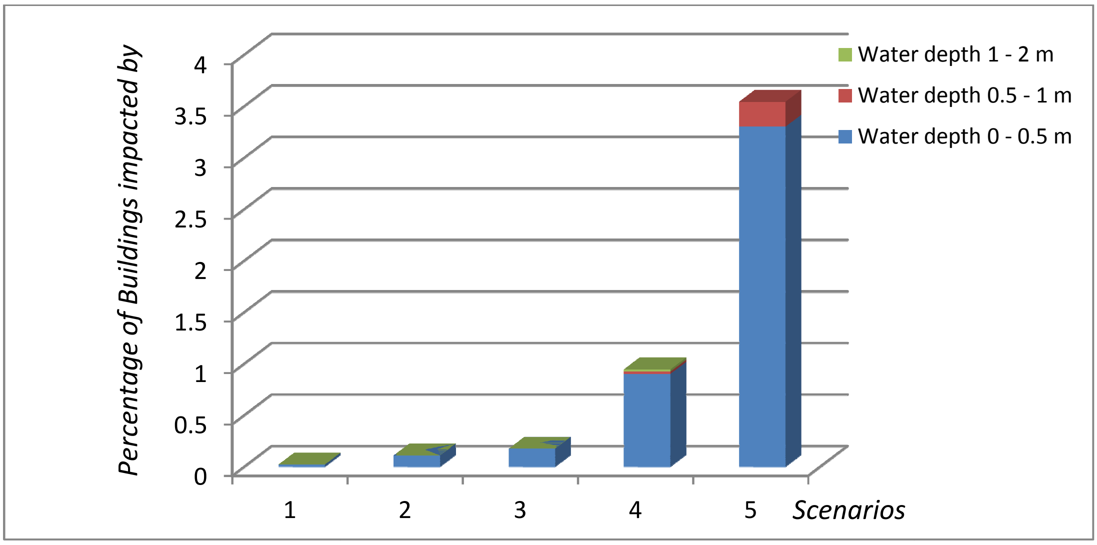

Figure 16: Percentage of buildings impacted by flood in three flood water depth in five scenarios in AoI, own research (Data source SYKE, 2014)

During the statistical analysis, the research encountered "Outlier ". This outlier has indicated bad data for the statistics process. The building determined as an outlier is situated just close to the river. Figure 17 shows the location of this outlier. An outlying point is in fact erroneous, so the outlying values should be deleted from the analysis. As a result, the building which is defined as outlier has been removed from the statistical analysis.

Figure 17: The outlier location, own research from Google map

7. Critical analysis

The thesis encounters obstacles. These problems are classified in two parts. The first step was during the data collection and the second one happened during producing the map by Arc GIS. Below more description can be found.

7.1. Data collection

The thesis tries to develop a risk map independent of the land use and using insurance data and damages caused by increased flood risk and flood depth. The thesis has used many different websites such as SYKE and GTK for collecting data. Most of the data were useful.

One of the major problems during data collection was to collect data frominsurance companies. Almost all Finnish insurance companies have been contacted, Finish and Swedish consultant companies, a German insurance company and a German consultant company. Some of the answers were negative; they did not like to share data because of confidentiality issues, while others did not reply at all. It is also possible that they do not use any specific formula or rules for flood damages. It seems that insurance policies have not covered damages caused by floods in Finland (STAT, 2011).

Insurance companies business is very likely to be impacted by climate change in the future. Therefore, insurance companies could adopt their policies to climate change. Like many other sectors, climate change may have positive effects for insurance companies as well (Munich Re 2015).. For instance, they can offer their customer new products and innovation services and products, such as new flood insurance and risk management products and etc.
Interviews with insurance companies in the Nordic countries regarding their climate change adaptation actions revealed that in Finland, environmental issues and climate change had not yet been faced to the same degree as in other Nordic countries (STAT, 2011).

As a result of the lack of information from insurance companies, this thesis emphasizes on the level of the water depth corresponding to the buildings in the flood prone area independent of potential damage data.

7.2. Map production with ArcGIS

The Environmental Systems Research Institute´s (ESRI) GIS software (ArcGIS) is one of the most powerful mapping software in the world (B.Booth, A.Mitchell, 2001). The software applications support planning and decision making in all sectors (agricultural, industrial, service), both for public and private users that require geo spatial data. ArcGIS can also be used to find a suitable way to mitigate damages or catastrophes caused by natural hazards. This thesis used ArcGIS to create a flood risk map.

The thesis encounters several problems during using ArcGIS. However they finally solved, but it waste a lot of time. Almost the problems were common for the software, so the solution can be found in the Esri Webpage.

8. Discussion

8.1. Pros and Cons of the thesis

However, this method is simple, but it is an efficient method to use. Only access to the floods hazard map and buildings data is needed. The result from the thesis could be great. For instance, by identifying the type of buildings which are most at risk can help to decrease flood impacts.

The other positive point from the thesis is that, it could be easy to apply for the countries with flood hazard datasets. In addition, the best ways to structure land-use, e.g. for residential, agriculture and industry etc can be clarified by this methodology. Consequently, investing becomes safer. This method also reveals that which area need more protection.

But in this method, only the range of the water depth has been considered. A precise depth of water was not taken into account. With better digital elevation data (e.g. laser scanning) more precise results would be possible in the future. Plus, damage records and damage functions taking flood depths into account would lead to more detailed risk maps.

8.2. Recommendation

For developing this method, providing a specific formula to calculate damages of floods by insurance companies for further studies could be beneficial. And it could be an advantage to produce a risk map independent to the land use by using insurance damage data to create artificial vulnerability maps.

9. Conclusions

Natural hazards are unavoidable phenomena. Flood as a natural hazard will increasing due to climate change. Human activities also have increased impacts of flood events, creating risks by building in flood prone areas. Risk is a product of hazard and vulnerability. Where the vulnerability is less or zero, as result there are less risk or no risk. To mitigate damages or catastrophes borne by natural hazards, appropriate land-use can minimize the creation of risks and a good risk management plan can save lives in risky areas.

To manage flood risk, it is essential to have a flood risk map. To produce a good flood risk map, a precise flood hazard map is needed. ArcGIS data sets ease to the production of flood risk maps. As a consequence of this thesis, it seems that Finland is doing well to protect vulnerable buildings and human health.

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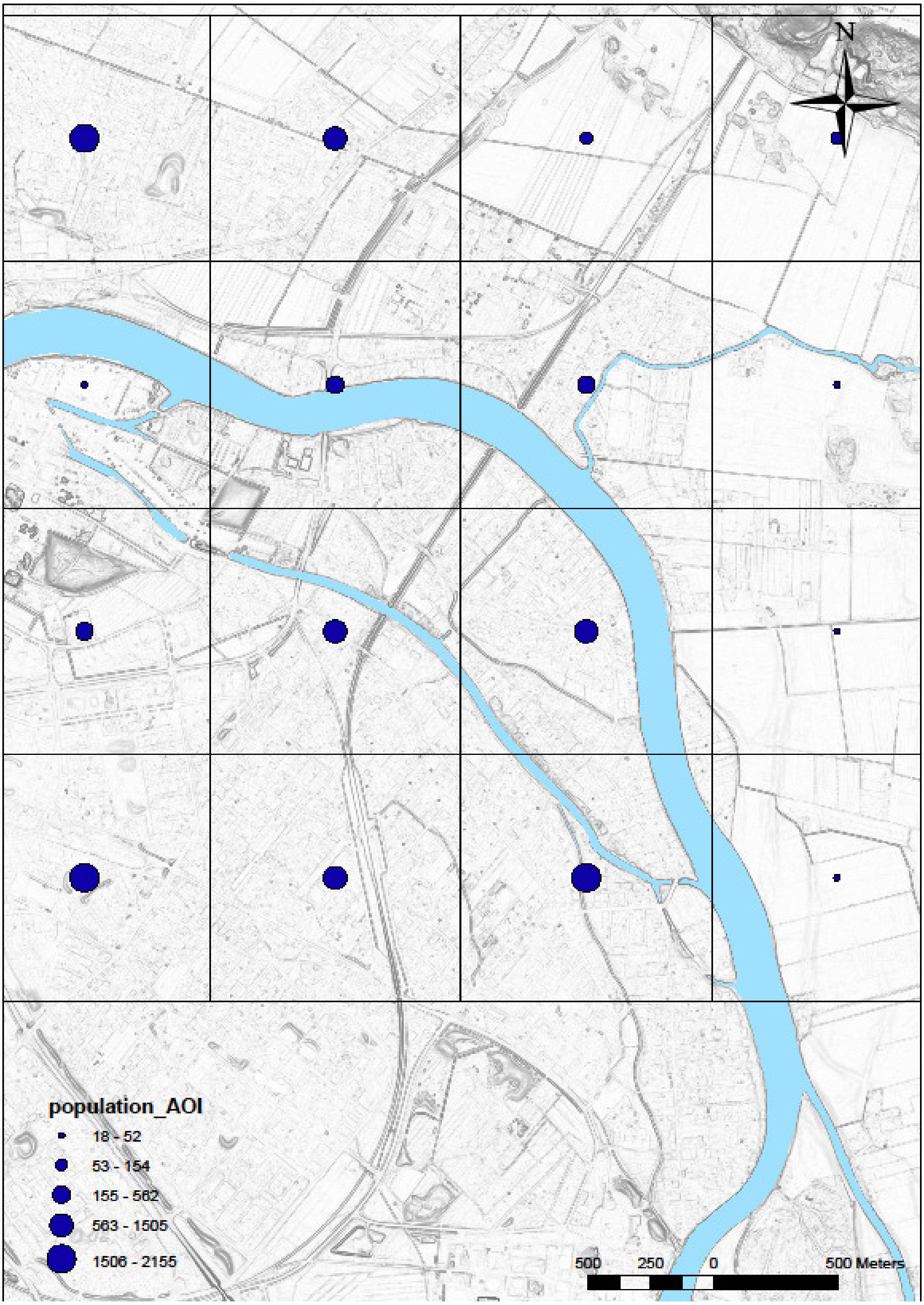
Appendices

Appendices I

Buildings in Area of Interest

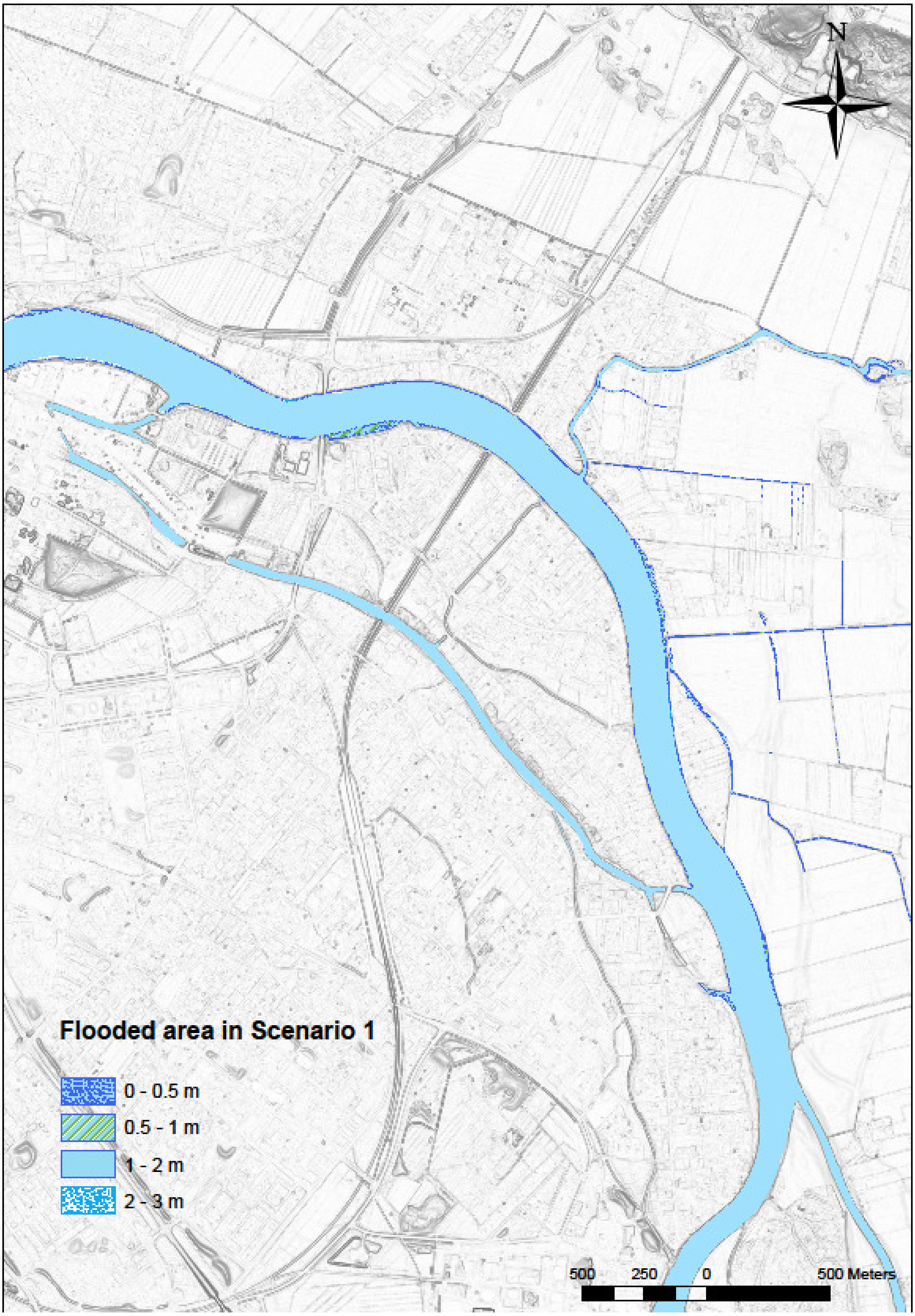
Appendices II

Population in Area of Interest



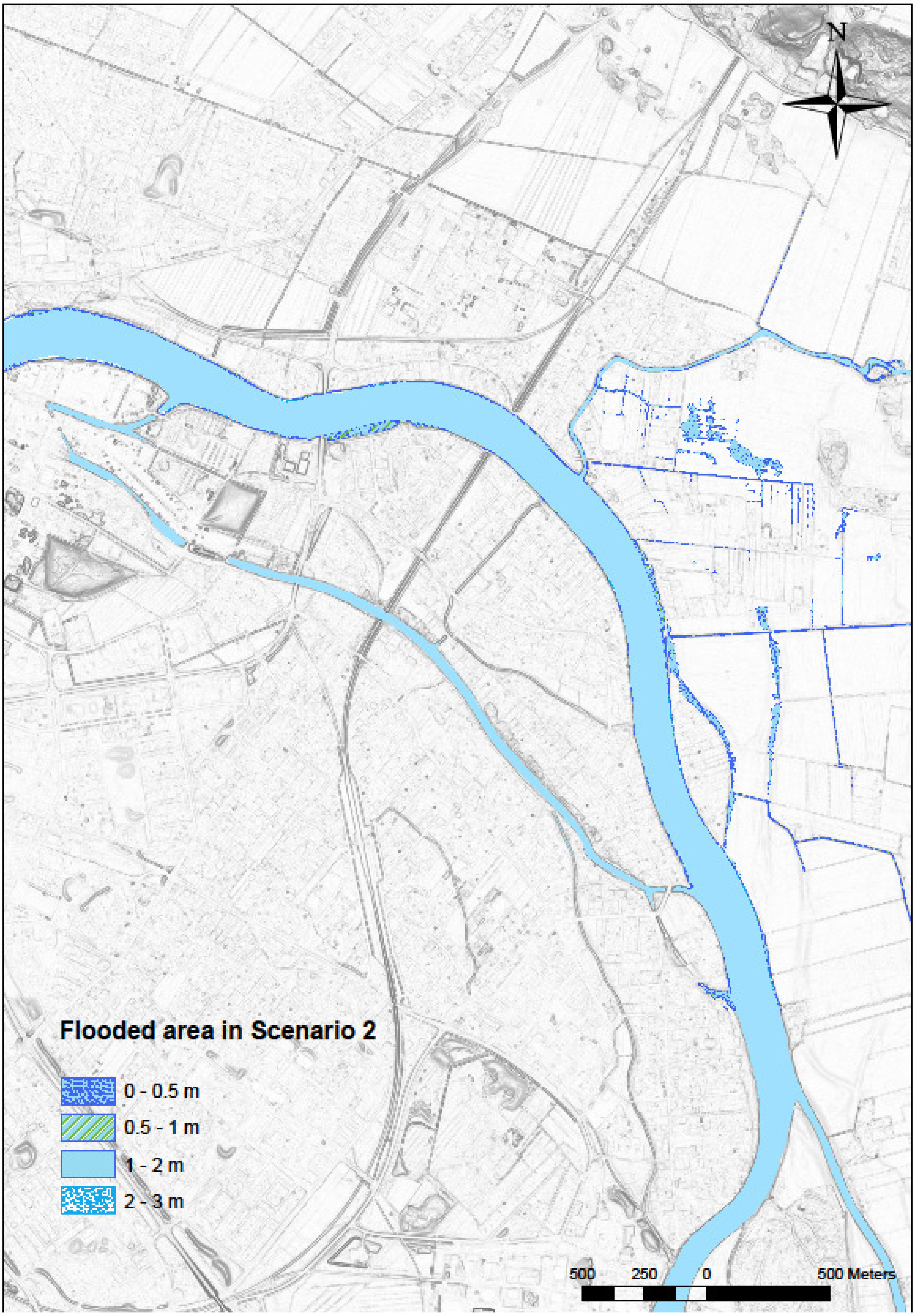
Appendices III

Flooded area in scenario 1 (20 years reoccurrence)



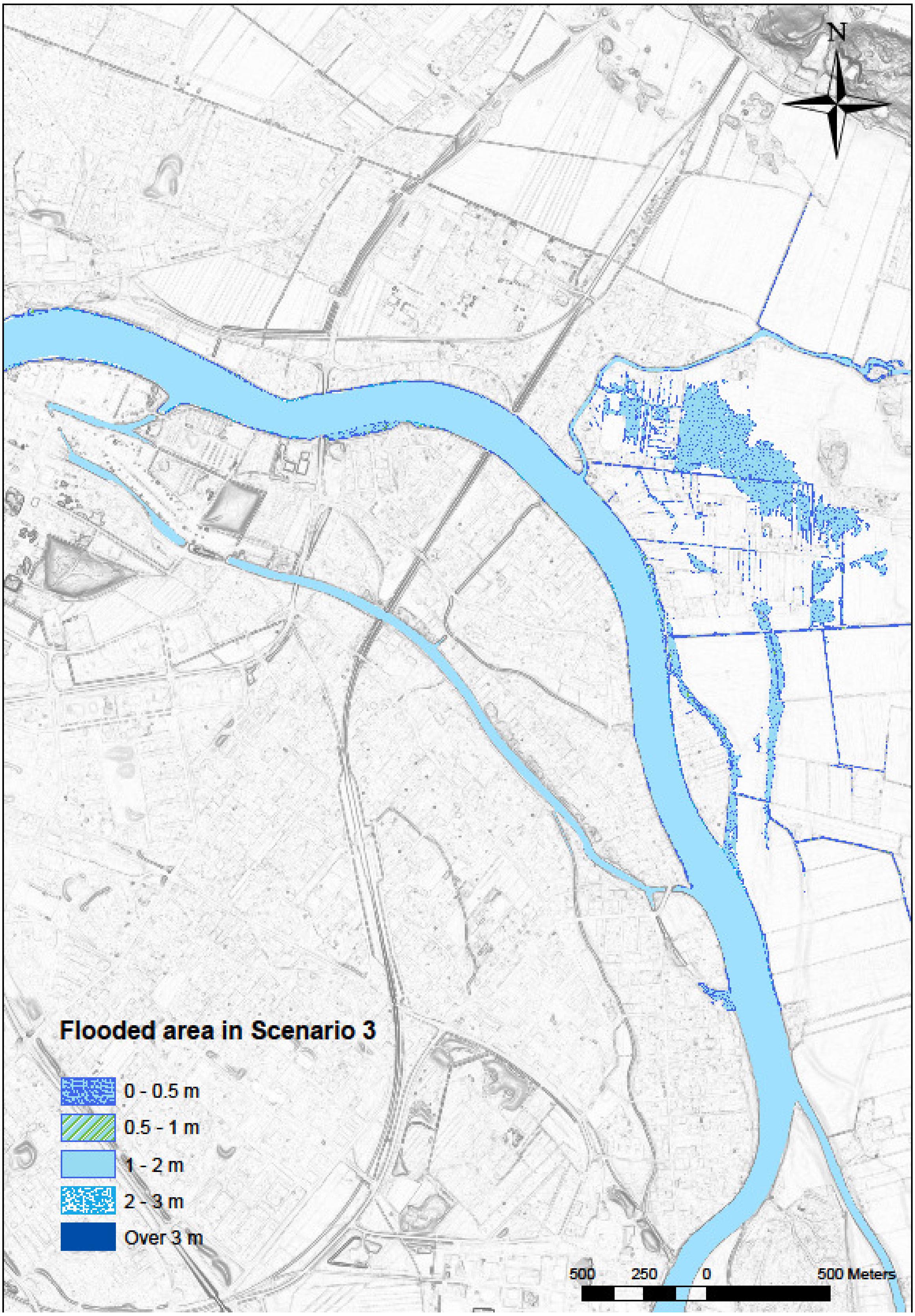
Appendices IV

Flooded area in scenario 2 (50 years reoccurrence)



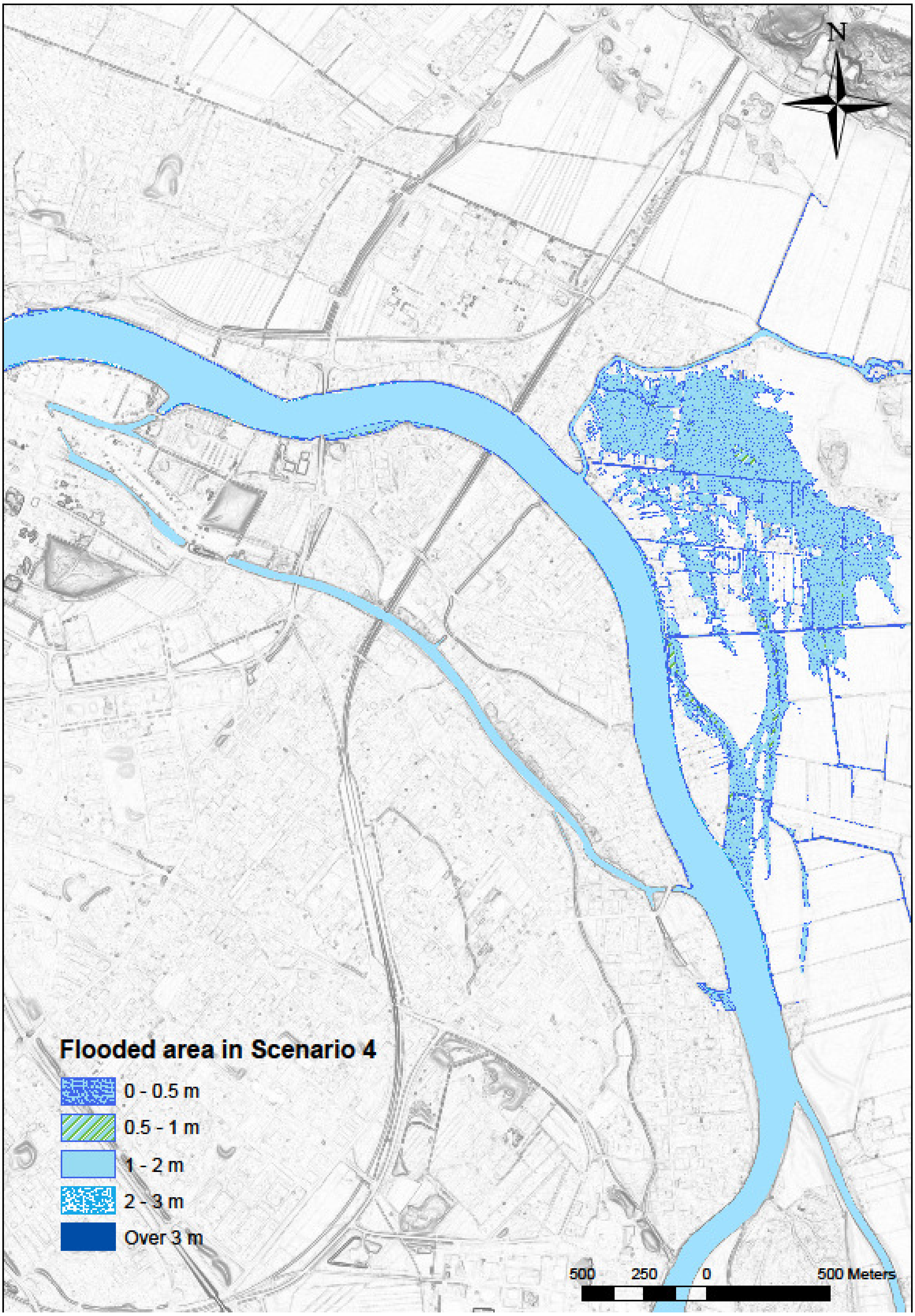
Appendices V

Flooded area in scenario 3 (100 years reoccurrence)



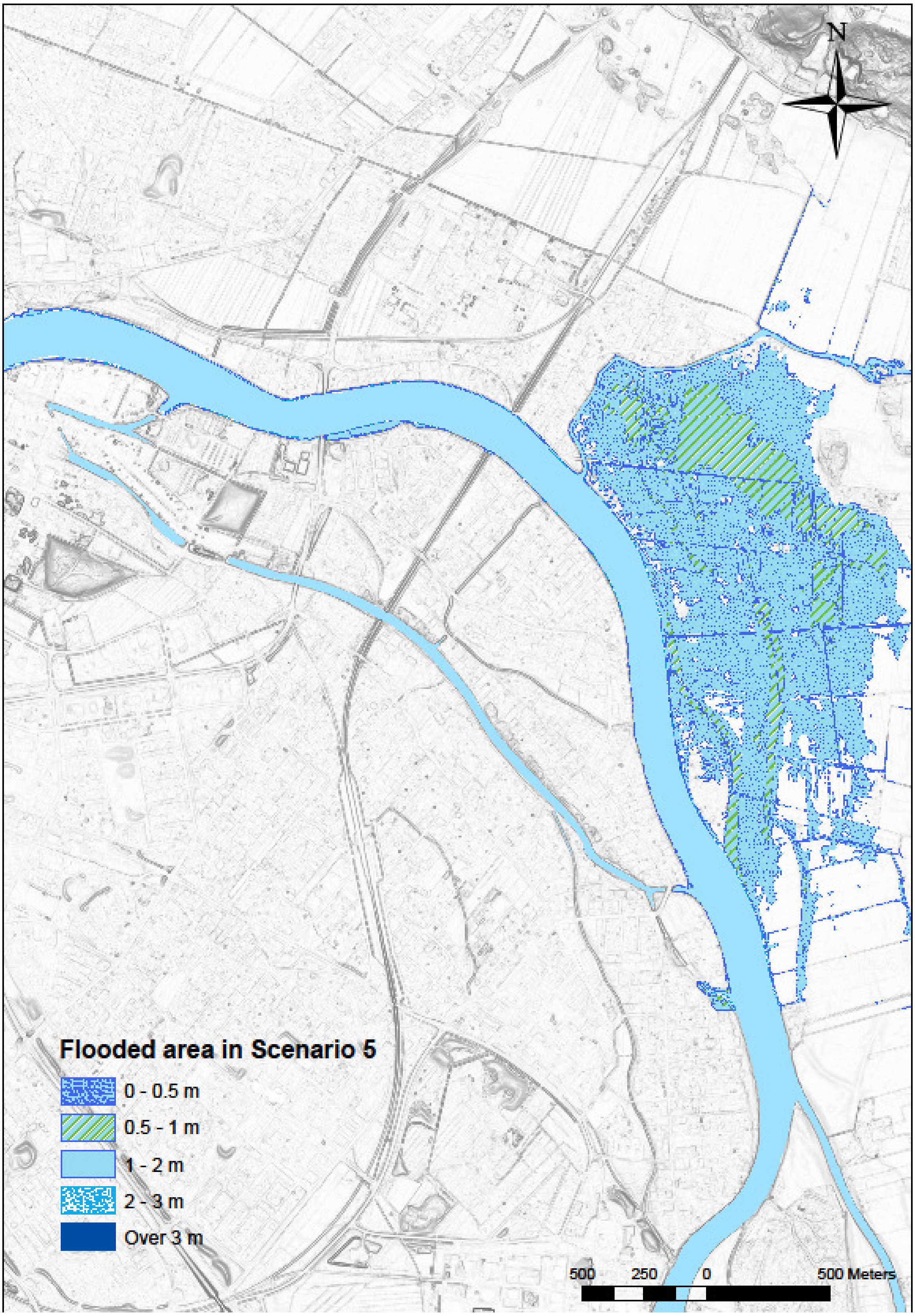
Appendices VI

Flooded area in scenario 4 (250 years reoccurrence)



Appendices VII

Flooded area in scenario 5 (1000 years reoccurrence)



Appendices VIII

Impacted buildings by flood in scenario 1 (20 years reoccurrence)

Appendices IX

Impacted buildings by flood in scenario 2 (50 years reoccurrence)

Appendices X

Impacted buildings by flood in scenario 3 (100 years reoccurrence)

Appendices XI

Impacted buildings by flood in scenario 4 (250 years reoccurrence)

Appendices XII

Impacted buildings by flood in scenario 5 (1000 years reoccurrence)