United Nations
Educational, Scientific and
Cultural Organization

Institute for
Water Education
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FLOOD RISK MAP

Baxter River

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Assignment: Flood Risk Map

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Please follow separate instruction in the class regarding the specific discharge value that you should be working on. You may be assigned a separate discharge value for which you need to run the HEC-RAS model that you have developed and prepare the risk map for that discharge value. Submit a single pdf report with the following information:

a) Present the map of the following layers with (indicative) 5 sentences on what the layer is about and how it can be useful:

- Flood extent

- Velocity

- Drag force

- Flood danger

- Population

- Vulnerability index (SFVI)

- Vulnerable facilities and hazardous installations

- Economic damage

Present the maps with the basemap at the background.

Answers:

According to the requirement of the assignment, the steady flow conditions for the simulation of flood inundation, using the discharge data at upstream locations corresponding to the 5th flow profile (PF 5), are that the discharge values of the upper reach and lower reach in Baxter River are 5000 and 5650 m3/s respectively, which are much larger than the tributary of Tule Creek with 650 m3/s.

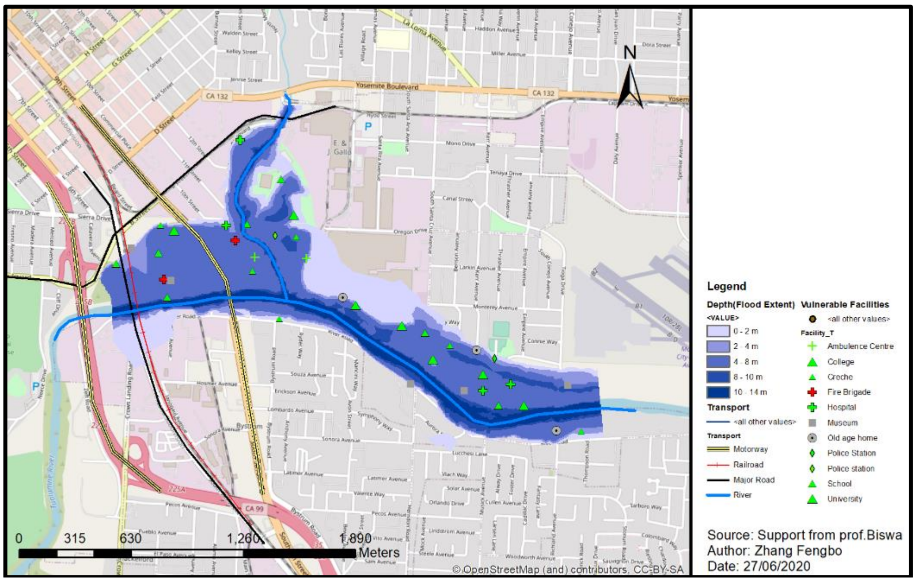

Figure 1 Inundated area together with the water elevation profile (**Flood extent and depth map**)

Figure 1 presents the inundated area together with the water depth profile in Baxter River. This flood extent and depths map provided inundation information about potential flood extent for the flood event of PF5 in the flow profile. Meanwhile, motorways, railways, houses and Baxter River from which the flood originate, are included in this inundation area. This depths map shows that the water depths gradually decrease from the river channel to the outside, except the several areas on the north-east of the river, which go deeper again. And the maximum water depth in this inundation area is 14 meters.

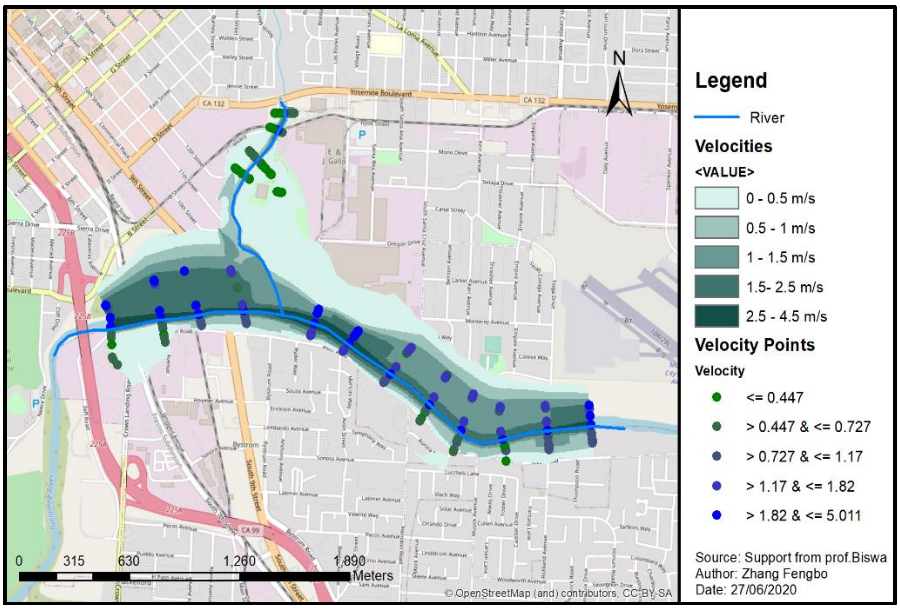

Figure 2 Inundated area with the flow velocity profile and velocity points (**Flow velocity map**)

Figure 2 presents the flow velocity profile and velocity points in the inundation area. The flow velocities reduce from the river to outside. Moreover, the flow velocities in the main channel are generally higher than that in the tributary, and the flow velocities of flood on the south of the Baxter River are lower than that on the north area. It is useful that the flow velocity map is added to provide the additional information to the risk map, such as determining the structural damage caused by the flow velocity(*Kreibich et al.*, 2009).

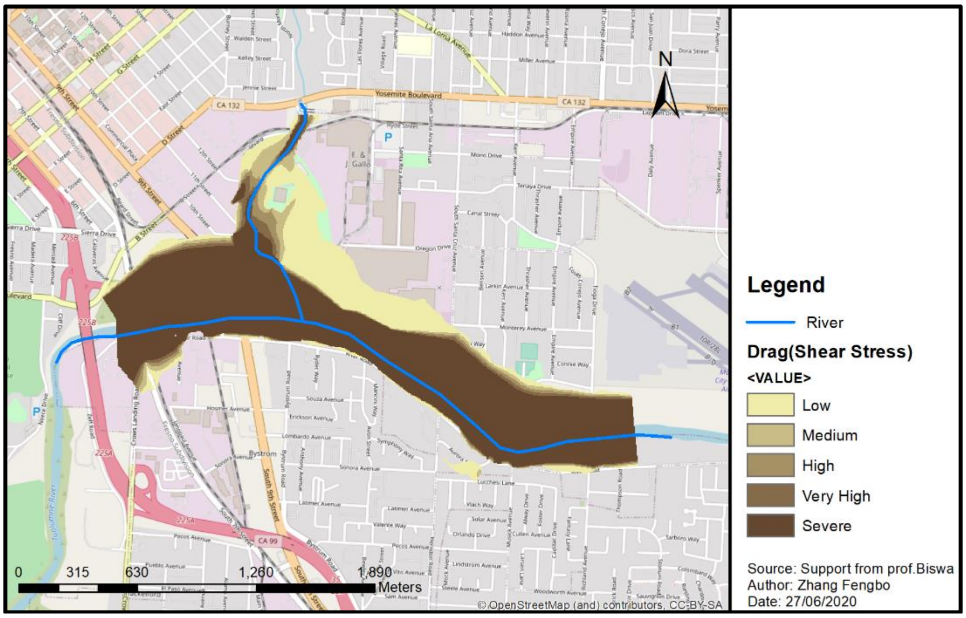

Figure 3 Inundated area with the shear stress profile (**Drag Force map**)

The shear stress profile in the inundation area is shown in Figure 3. It is severe in the almost whole area, expect the small south area along the Baxter River and the north part in the inundation area, where the drag forces are low. This information helps in identifying critical locations of flood defence structures and evacuation. The classification of the drag force follows the table below:

	Drag force from N/m2	Drag force to N/m2	Drag class
1	0	1	Low
2	1.01	2.5	Medium
3	1.51	4	High
4	4.01	5.5	Very high
5	5.51	7	Severe

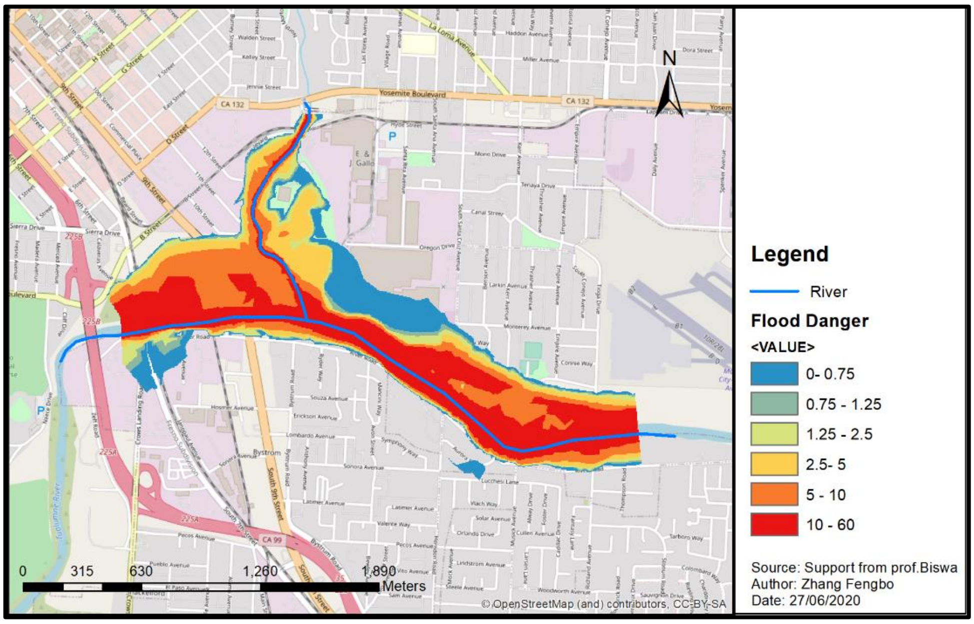

Figure 4 Flood hazard in the inundated area (Flood Danger map)

Figure 4 shows the flood danger in the inundated area, which have high hazard (extreme) along the Baxter River, especial in the north of the river. The danger levels of the area on the east of tributary are low or moderate. The values of the flood danger are given by the formula, $HR = h * (v + 0.5)$, Where *HR* is hazard rating (an arbitrary rating of the hazard); h is the flood depth in m and v is the flood velocity in m/s. The map is used for emergency flood management and awareness-raising purposes, interpreted based on the following table from the Environmental Agency:

d x (v + 0.5)	Degree of Flood Hazard	Description
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 – 1.25	Moderate	Dangerous for some (i.e. children) "Danger: Flood zone with deep or fast flowing water"
1.25 – 2.5	Significant	Dangerous for most people "Danger: flood zone with deep fast flowing water"
>2.5	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"

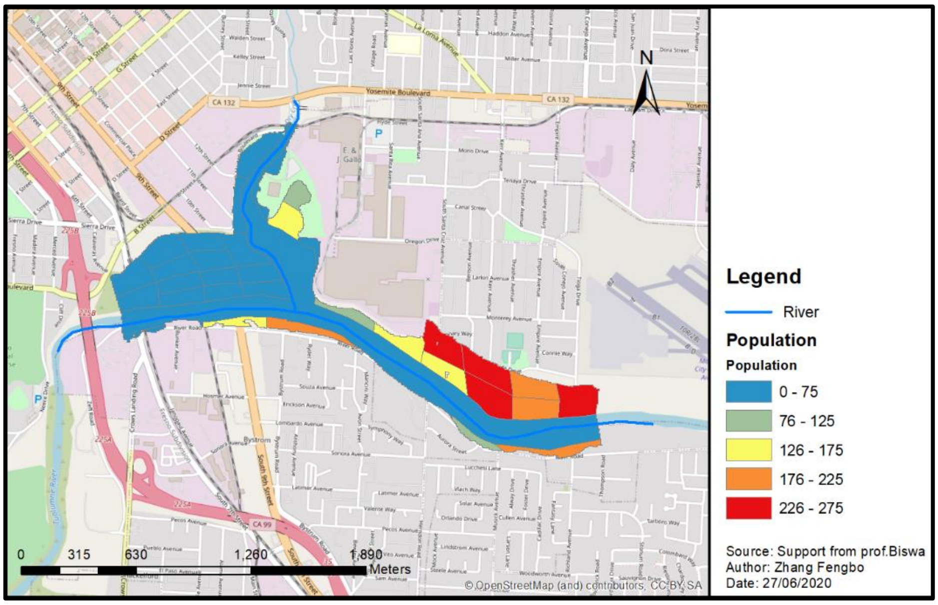

Figure 5 Population profile in the inundated area (Distribution of Population map)

The distribution of the population in the inundated area is represented in figure 5. Figure 5 shows that most of the people live along the Baxter River, especial in the north of the upstream of the river. Moreover, people about approximate two hundred distribute on the east of Tule Creek. This information helps in identifying critical locations for evacuation and pre-preparing for the flood risk map.

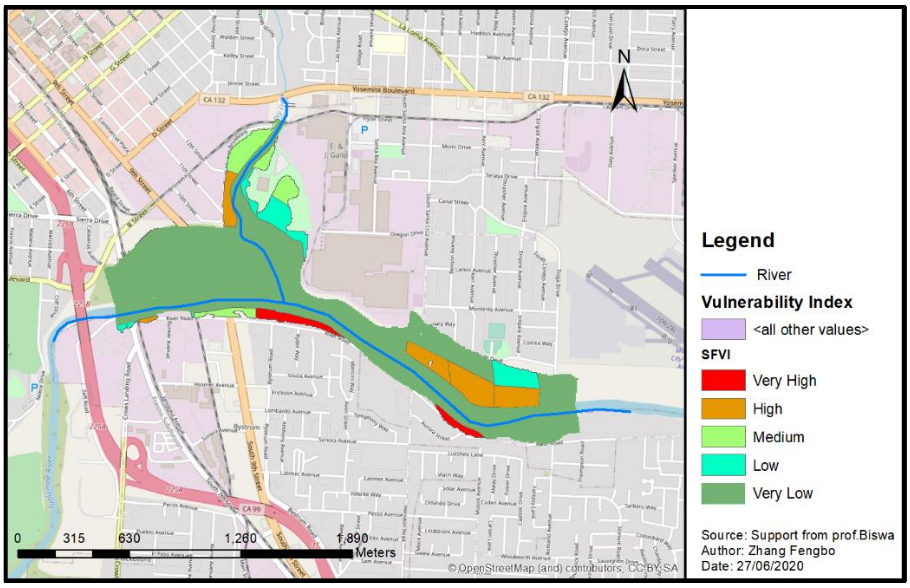

Figure 6 Inundated area together with Social Flood Vulnerability Index (SFVI)

A flood vulnerability index is presented in a risk map so that the identification of vulnerable groups and their evacuation becomes easily. In this case, the methods for estimating SFVI values are used from the Environmental Agency for England and Wales. The identification of the SFVI values is based on three social groups and four indicators for economic conditions: Aged 75 years or older, Single parents, Long term sick, Unemployed, Live in overcrowded houses, Do not own a car and Do not own their home. Figure 6 presents the distribution of the SFVI values in the inundated area. The very high values appeared along the south of the Baxter River and fortunately are not in very big areas. Moreover, the area on the north of the upstream of Baxter River and the west of the tributary has high flood vulnerability, while there is a low or very low vulnerability in other areas.

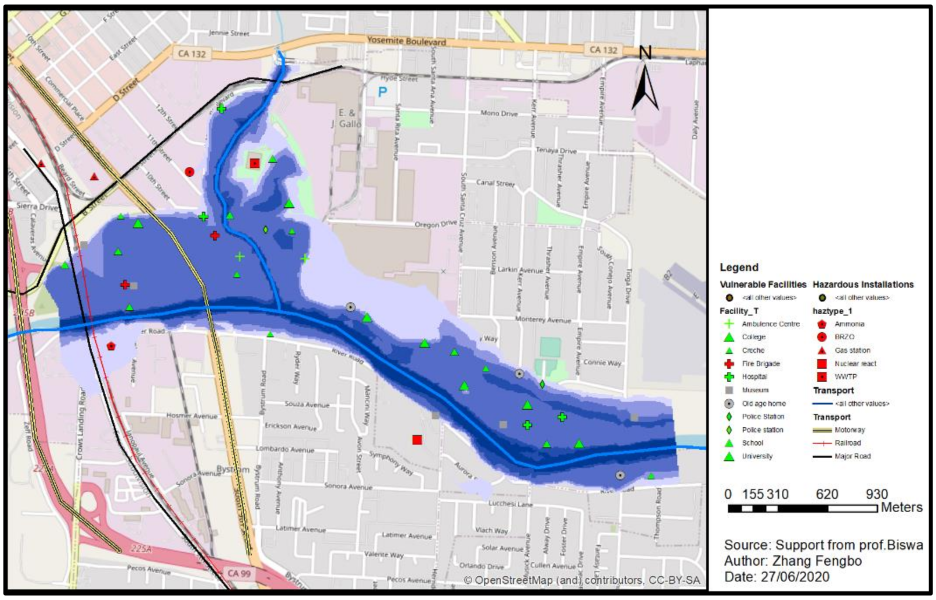

Figure 7 Vulnerable facilities and hazardous installations in or out of the inundated area

The locations of the vulnerable facilities and hazardous installations as well as transports are indicated in Figure 7. The green and grey symbols indicate vulnerable facilities. But the fire brigade is presented by a red cross in the figure. The red symbols of hazardous installations indicate that those areas are dangerous and may cause indirectly damage in a flood event. This map, combining with depth map, is useful for identifying critical locations of flood defence structures, such as compartmentalisation of areas.

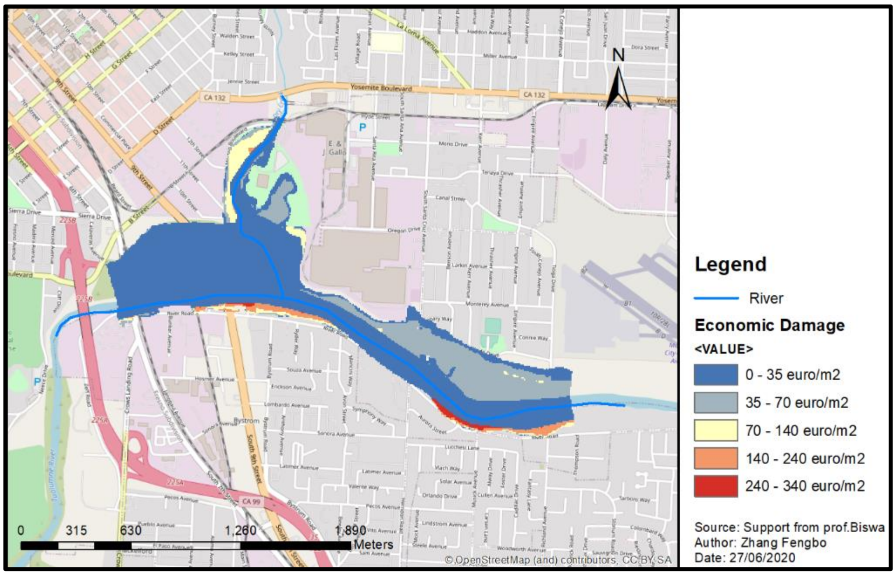

Figure 8 Inundation area together with the economic damage profile (Flood Damage map)

The flood damage map represents the potential damage caused by this flood event (PF 5), as shown in figure 8. The potential values of the damage are classified by land use, and an equation is used for determining the actual damage values in this case, given as $D_j = h_j * DMax_i / h_{max}$, where $DMaxi$ is the potential damage value, according to land use; h_{max} is the maximum water depth in the inundated area, and h_j is the water depth at location j. Figure 8 present that there are serious economic damages after the flood event along the south of the Baxter river with above 240 euro/m2 loss. Moreover, the areas along the tributary have moderate economic damage around 35-140 euro/m2 loss. And the economic damages in the north of the upstream of Baxter River, after the occurrence of the flood, are relatively low around 35-70 euro/m2 loss.

b) Search literature and present a more realistic depth-damage curve. Create a new data layer with the damage computed with your proposed damage function. **Present the damage map and point out with a brief explanation your arguments in favour of this damage map over the one computed with the linear damage function.** In order to save time you may just use one depth-damage curve for all land use types.

Answers:

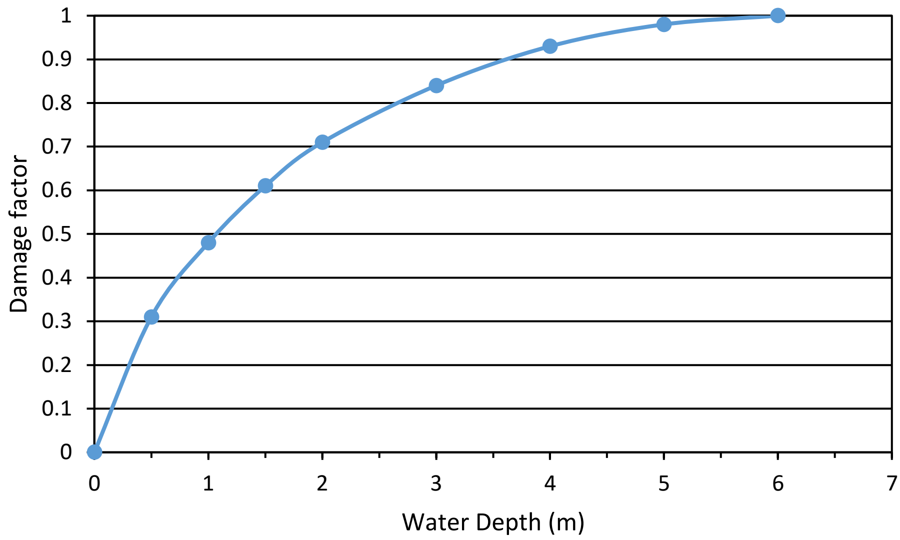

Figure 9 A normalisation depth-damage curve for North America – Industry

Table 3 Average continental damage function for North America – industry

Water Depth (m)	Damage factor
0	0
0.5	0.31
1	0.48
1.5	0.61
2	0.71
3	0.84
4	0.93
5	0.98
6	1

The depth-damage curve was used from a technical report by the Joint research centre(JRC), the European Commission's science and knowledge service, as shown in figure 9(*Huizinga et al.*, 2017). And Damage function was adopted, used to the industrial area in North America in that report, as shown in table 3. The reasons why choose this damage function are that the study area is in the USA, and most of the land is used for industrial purposes.

Compared with the linear depth-damage curve, this curve is more realistic. Because the buildings have limit height and it is impossible that the damage rises linearly with the increase of the water depth to the maximum depth. Thus, there should have a threshold of water depth. If the actual water depth is higher than the threshold, the buildings should be full inundated, and damage factor is one. Moreover, the early stage of the flood event caused huge economic damage, which tended to be gentle as the water depth rose. Therefore, the upward curve is better than the straight line.

Figure 10 presents the economic damage computed by this depth-damage curve in the inundated area. Furthermore, the damage grows dramatically, except the small areas along the river, which are the open space, compared with the economic damage in figure 8. The open space does not have any buildings or other things.

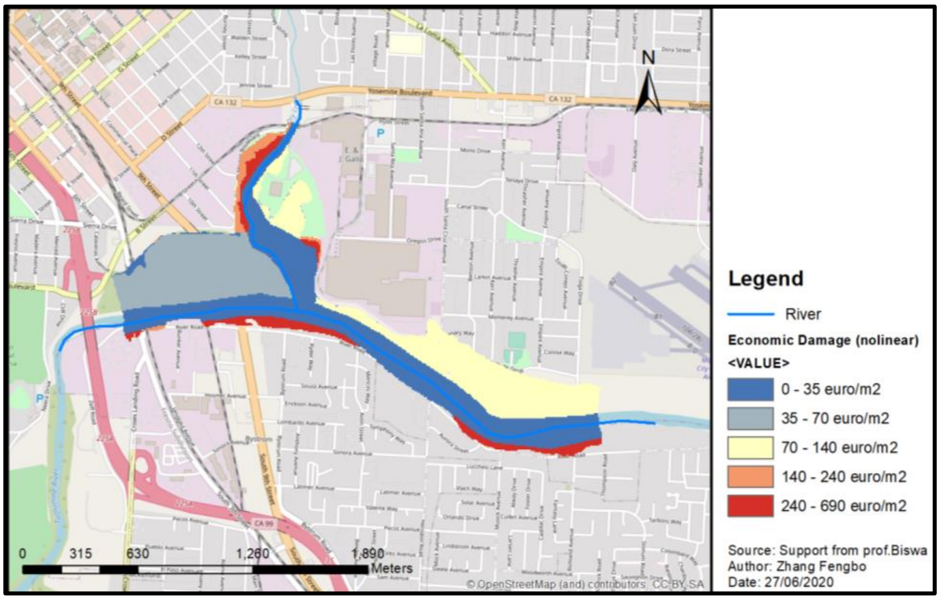

Figure 10 Economic damage profile calculated by a nonlinear depth-damage curve (Flood Damage map)

c) Consider the uncertainty in the inundation mapping. You do not have to follow an uncertainty assessment, for example, using Monte Carlo simulation. Imagine that this uncertainty assessment has been carried out before. From the ensemble of simulated inundation maps (in total *N* number) the mean (μ) and standard deviation (σ) of flood depth has been computed at every location of the floodplain (for your profile). Assume that the flood depth at any location – corresponding to the profile you have been assigned to – is the mean flood depth (μ) for that location and the σ at that location is 20% of the flood depth at that location. Present the flood inundation map for μ +2xσ and μ – 2xσ. **Compare these two maps with the flood inundation map you have presented in (a) and provide your understanding of the uncertainty present in the inundation mapping.** Assume that the flood extent remains the same in all of the *N* simulations (note that it is unrealistic assumption). Please note that the procedure is very approximate and it is not suggested that you should carry out uncertainty in inundation mapping by following this approach. The main limitation is in assuming the values of μ and σ and the flood extent (same for all *N* simulations). However, this exercise will introduce you to the uncertainty present in inundation mapping and the procedures to carry out an uncertainty assessment.

Answers:

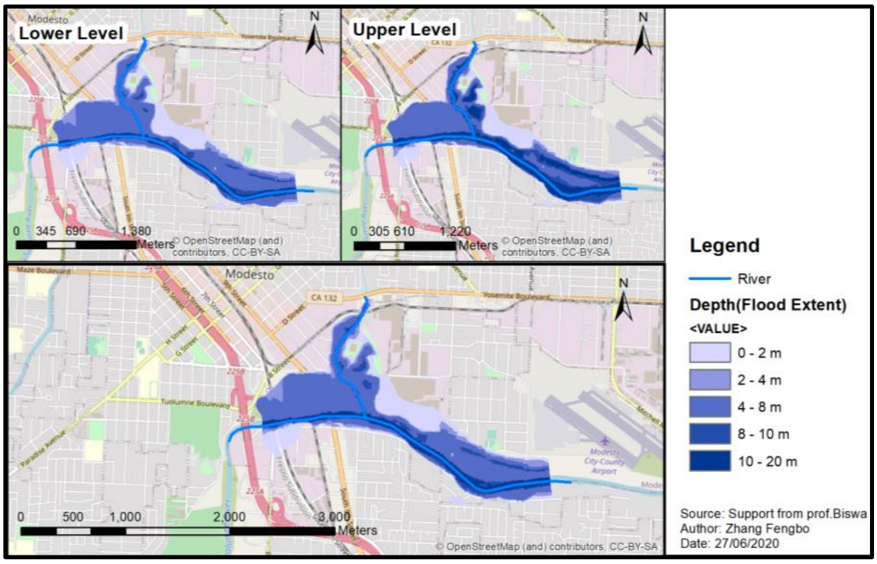

Figure 11 Uncertainty assessment of the water depth in the inundated area

The lower level and upper level of the water depth profile in the inundated area represent the potential uncertainty errors, compared with the water depth profile simulated by HEC-RAS model, as shown in figure 11. The upper level map shows that the area with high water depth on the north of river generally increase, while that area decreases in lower level map. Thus, the uncertainty errors primary influence on the inundated area on the north of the river. Uncertainty analysis is an indispensable part of model prediction because the actual study area is non-idealised environmental(*Teng et al.*, 2017). Therefore, the actual water depth in the inundated area may not be the same as the values simulated in the model, and the uncertainty assessment is necessary.

Reference

Huizinga, J., et al. (2017), Global flood depth-damage functions: Methodology and the database with guidelines, Joint Research Centre (Seville site).

Kreibich, H., et al. (2009), Is flow velocity a significant parameter in flood damage modelling?, *Natural Hazards and Earth System Sciences (NHESS)*, *9*(5), 1679-1692.

Teng, J., et al. (2017), Flood inundation modelling: A review of methods, recent advances and uncertainty analysis, *Environmental Modelling & Software*, *90*, 201-216.