Team 11: Report Week 2

Erasmus+ Programme Cooperation Partnerships
2022-1-FR01-KA220-HED-000089658
HydroEurope

WP2: Uncertainty in Advanced Hydrological and Hydraulic Modelling
WP3: Climate Change Impacts on Flash Floods
Case Study Ouseburn Catchment (United Kingdom)

Team 11 - Report Week 2: Flood Hazard Map using TELEMAC-2D for Baseline and Future Climate Change Scenario

Tarannum Tabassum Islam, Ka Kin Tang, Jessica Canchig, Jenna LOTFI, Amélie SIBUET, Tarrin Wilson, Lawrence Whittaker, Ousseynou NDIAYE, Benjamin Leleu, Yi WU, Guillaume VAN MECHELEN, Team 11
Version 1.2 - 08 March 2024

Contents

List of Figures:

List of Tables:

1. Introduction

Analysing Hydrographs and Climate Scenarios

During the 1st week of our project, we focused on creating flow hydrographs to examine different rainfall scenarios of various durations. Specifically, we studied 4-hour and 24-hour durations across three return periods: 30 years, 100 years, and 1000 years, under different climate change scenarios. This task involved using stochastic rainfall data generated through RWGEN during the online phase of HydroEurope 2024.

Flood Inundation Map Development:

In the following week, we shifted our attention to utilising flow data for short-term, intense precipitation events of medium magnitude (4-hour, 100-year return period). We generated flood inundation maps, which depict the depth of flooding within our chosen model domain, considering baseline, minimum future change, and maximum future change scenarios attributed to climate variations. To produce the depths, we utilised TELEMAC-2D hydrodynamic software.

Flood Hazard Map Development:

Using the depth information obtained from flood inundation maps and the velocity field generated by the hydrodynamic software used, we created flood hazard maps following UK guidelines. These maps provide a comprehensive overview of hazard levels within the model domain, identifying areas with varying degrees of risk.

Purpose of this exercise:

Our objective is to assess the flood hazard within our model domain, exploring potential risk escalations due to climate change scenarios affecting river flow dynamics. Through our analyses, we aim to enhance our understanding of the evolving hazard landscape and its possible implications for the communities within the model domain.

2. Methodology

TELEMAC-2D:

TELEMAC-2D is a software designed for simulating two-dimensional free-surface flows, accounting for both depth of water and velocity components at every mesh point. Utilising either finite-element or finite-volume methods, the program solves the Saint-Venant equations on triangular elements of a computational mesh. It enables simulations under both steady and unsteady conditions (Li et al., 2022). In our project, we used steady-state simulation for initialisation of the model, followed by unsteady-state simulation for 2D modelling of the model domain.

Flood Hazard Mapping in UK:

The Environmental Assessment (EA) study outlines that the threshold for a person to lose stability during a flood event is determined by an equation:

$$d*v+0.5=a*hw+b$$

Where:

d: flood depth (m)
v: flood velocity (m/s)

hw: Height times weight of the subject
a and **b**: constants

The Risks to People methodology evaluates flood risks to individuals based on both the physical characteristics of flooding and flood vulnerability. While debris issues are discussed separately, flood hazard is primarily influenced by depth and velocity. Several alternative flood hazard formulas were examined in light of experimental data and within the context of the overall Risks to People Methodology(Environment Agency, 2006b). Table 1 shows the various classes of flood hazards that were created based on the formula. Such categorization could prove beneficial for various applications, including planning safe access and exit routes for new developments, providing emergency planning guidance for individuals at risk and emergency services, and developing household or community flood plans (Environment Agency, 2006a).

Table 1: Hazard to People as a function of depth and velocity

d*(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

For our project, we used the same methodology and flood hazard categories to portray the degree and extent of flood hazard due to different climate change scenarios.

Model Domain

The study area is focused on the Ouseburn Catchment, covering an area of 55 km^2. Figure 1 depicts the catchment with a Digital Terrain Model (DTM), featuring a resolution of 50 cm. Within this, the selected model domain spans 5.8 km^2. Utilising satellite imagery from Google Earth Pro, we georeferenced the imagery to delineate urban areas and vegetation within the model domain. Some of the data obtained from various sources are listed in Table 2.

Table 2: Sources of various data used in the model:

Data	Source
50 cm LIDAR DTM	DEFRA UK
8K UHD SATELLITE IMAGERY	Google Earth Pro (retrieval date: 27/02/2024)
BUILDINGS	Ordnance Survey UK
ROADS	Ordnance Survey UK

Data	Source
OUSEBURN RIVER	Ordnance Survey UK
OUSEBURN CATCHMENT	National River Flow Archive

The model domain was chosen due to its lower elevation according to the DTM data. We reasoned that areas with lower elevation might be more susceptible to flooding, given their basin-like characteristics, as opposed to hilly terrain. While our model does not incorporate rainfall-runoff dynamics, we anticipate that water from surrounding higher elevations could potentially runoff into these lower areas. Also, since this area is highly urbanised, we think there might be more vulnerable infrastructures and communities compared to other parts of the catchment.

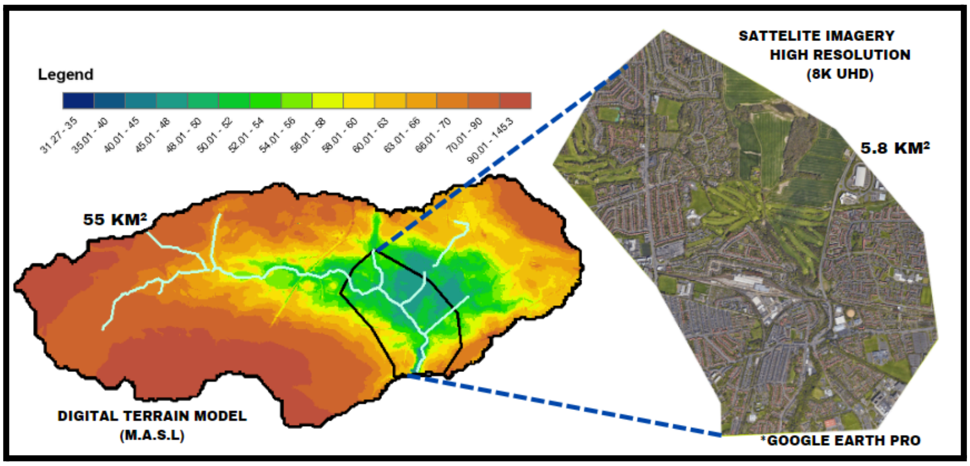

Figure 1: DTM, Study Area, and Chosen Model Domain

We visualised the land use and key buildings in our study area to identify potential vulnerable areas within our model domain. In Figure 2, it can be observed that the land use distribution within the model domain, while in Figure 3, the extent of urban areas covering the domain can be seen. Notably, approximately 70% of the model domain comprises urbanised areas.

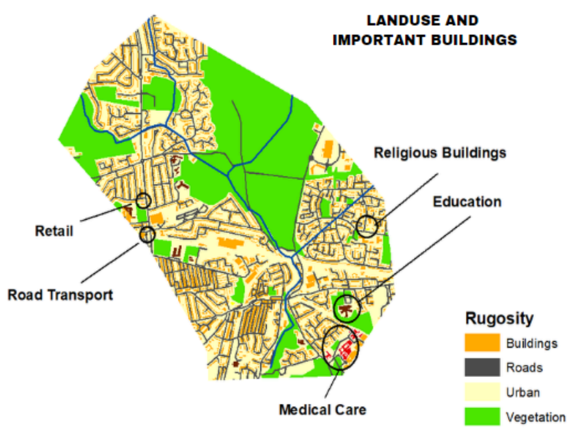

Figure 2: Landuse and Importance Buildings with Different Rugosity

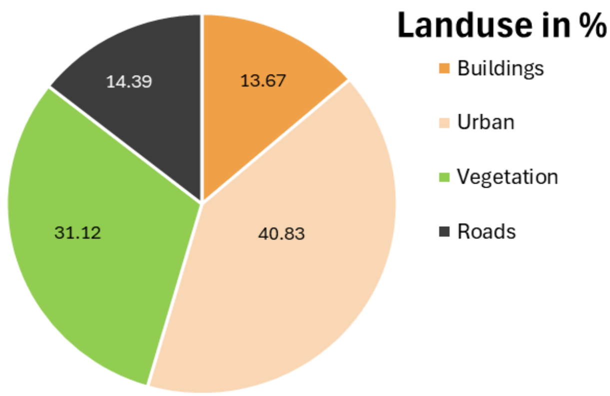

Figure 3: Pie Chart showing % of landuse in Model Domain

Given that we are conducting a 2D model, it is essential to consider overland flows. Therefore, we needed to establish a roughness parameter. This parameter was determined based on the land use characteristics of the model domain. Subsequently, we assumed and applied a suitable Strickler's number in our model for further analysis. The values used for roughness for different landuse in TELEMAC-2D are tabulated in Table 3.

Table 3: Landuse and Corresponding Strickler's Number for Model

Landuse	Rugosity (Strickler's)
Buildings	5
Urban	62.5
Vegetation	25
Roads	70
River	25

The following figures (Figure 4, Figure 5) show the application of the DTM and Rugosity in the TELEMAC-2D software:

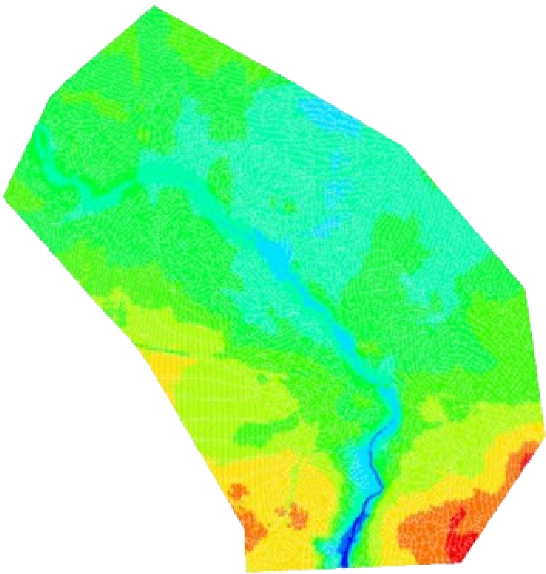

Figure 4: DTM in TELEMAC-2D

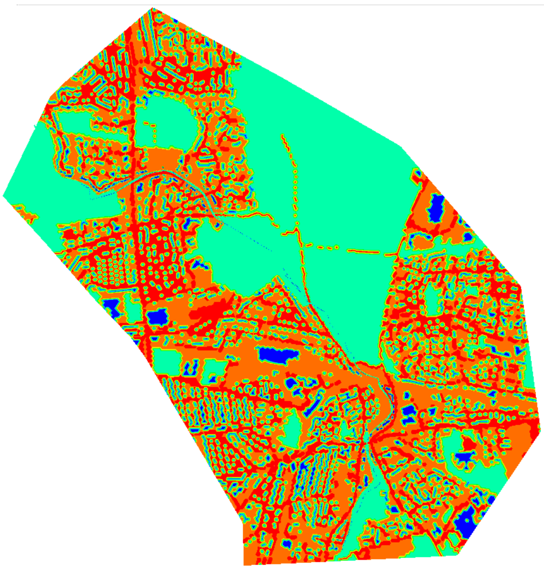

Figure 5: Rugosity in TELEMAC-2D

Numerical Parameters and Model Inputs

The numerical parameter inputs are shown in Table 4. At the upstream end (Figure 6), the river discharge was set as an open boundary condition, allowing water to flow freely into the model domain. Conversely, at the downstream end (Figure 7), we established a rating curve using Python. This curve serves as a closed boundary condition, regulating the outflow from the river to adhere strictly to the values specified by the rating curve, ensuring that the outflow does not exceed its limits.

Table 4: Numerical Inputs for Model

Parameter	Value
Mesh (River)	2m
Mesh (Landuse)	15m
Model Domain	5.8 km^2
Upstream Boundary Condition	River Flow (m^3/s)
Downstream Boundary Condition	Rating Curve
Timestep	4 seconds
Duration	691200 seconds

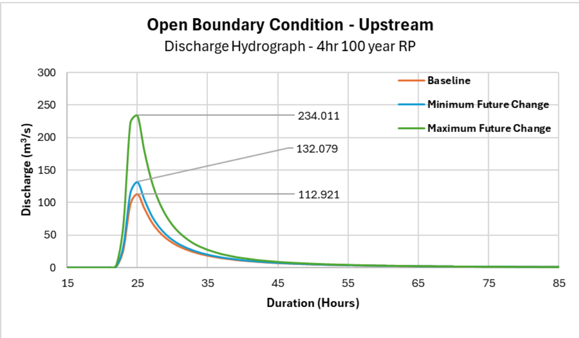

Figure 6: U/S Boundary Condition

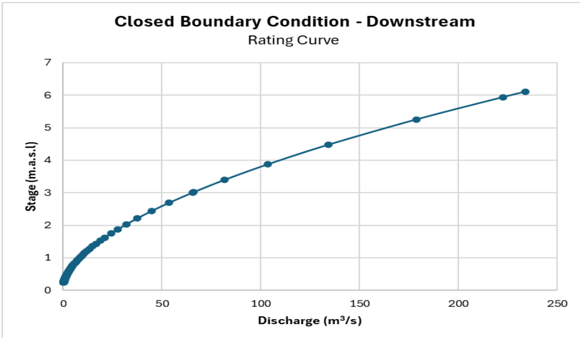

Figure 7: D/S Boundary Condition

3. Results

Flood inundation Maps

Using TELEMAC-2D, we created flood inundation maps through unsteady-state simulations. These maps show water depth (m) and velocity (m/s) for three scenarios: baseline (Figure 8), future minimum change (Figure 9), and future maximum change (Figure 10). The maps indicate that under the maximum climate change scenario, water depths can exceed 4m, posing significant hazards when coupled with high velocities.

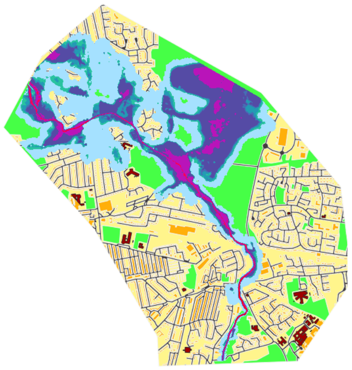

Figure 8: Baseline Scenario

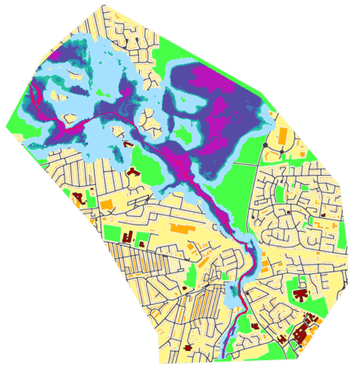

Figure 9: Minimum Change Scenario

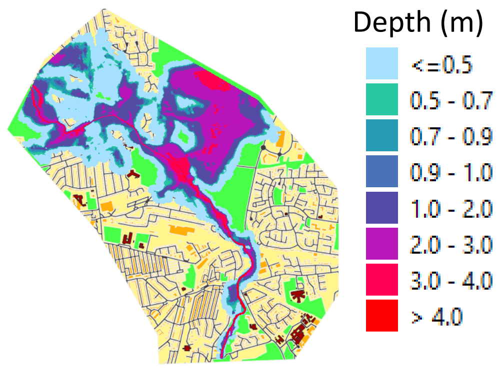

Figure 10: Maximum Change Scenario

Comparing the maps to the Digital Terrain Model (DTM), we observed that some vulnerable buildings are situated in low-lying areas. For instance, water depths around some primary schools reach approximately 0.5 m. However, most important buildings appear to be safe. It is worth mentioning that deeper inundations are mostly found in vegetated areas, such as golf courses and national park reserves within our model domain. Additionally, certain urban settlements are more prone to flooding due to lower elevations in the model domain.

Depth difference with Baseline Scenario

The following figure illustrates the variation in water depth between the baseline scenario and the minimum and maximum scenarios, respectively. In Figure 11, it appears that under the minimum climate change scenario, water depth may increase by up to 0.5 m compared to the baseline scenario. However, a significant portion of the inundated areas shows a depth increase of only 0.1 m, while a greater depth is seen primarily in the downstream reach of the river.

Figure 12 displays the depth difference for the maximum climate change scenario. Here, a substantial portion of the inundation indicates a depth increase of 0.9 m, with additional areas susceptible to potential flooding.

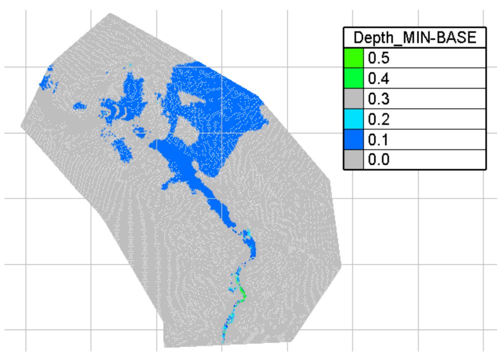

Figure 11: Minimum Change - Baseline Scenario

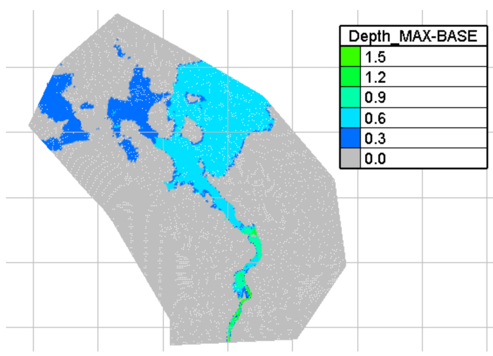

Figure 12: Maximum Change - Baseline Scenario

Flood Hazard maps

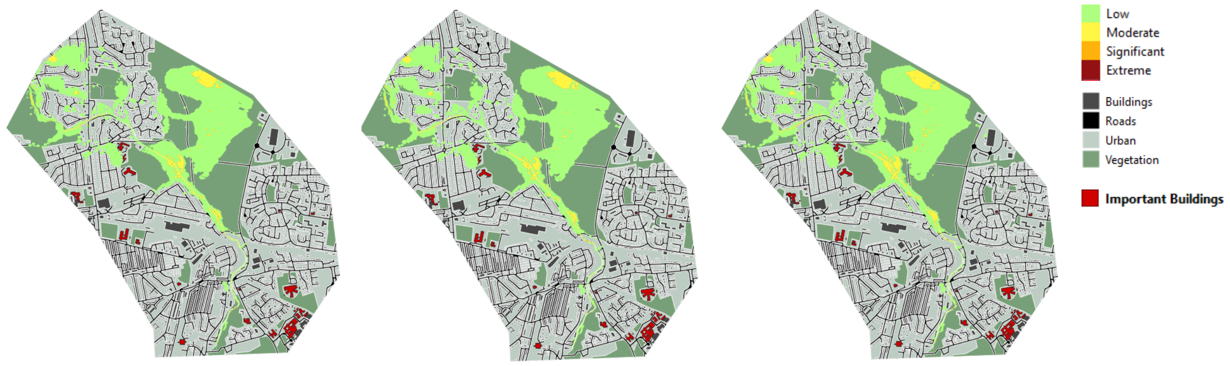

Figure 13: Flood Hazard Maps - Baseline (Left), Minimum (middle), Maximum (Right)

The generated maps , following the flood hazard methodology for people, are shown in Figure 13. These maps illustrate different flood hazard classes on the map for various scenarios: baseline, minimum change, and maximum change. While the maps themselves do not display significant changes, the analysis of flood hazard extent will be detailed in the subsequent section of the report.

4. Discussion

Inundation Depths Comparison

For the baseline, minimum, and maximum climate change scenarios, we compared the depths of inundation and categorised them into ranges to better visualise the impact of climate change. In Figure 14, it is noted that due to various climate change perturbations, areas experiencing inundation depths exceeding 1 m may potentially increase. This increase is based on the depth and its effect on the extent of inundation. Our analysis reveals that for our model, areas with inundation depths of 1 m can increase by almost 0.05 km^2.

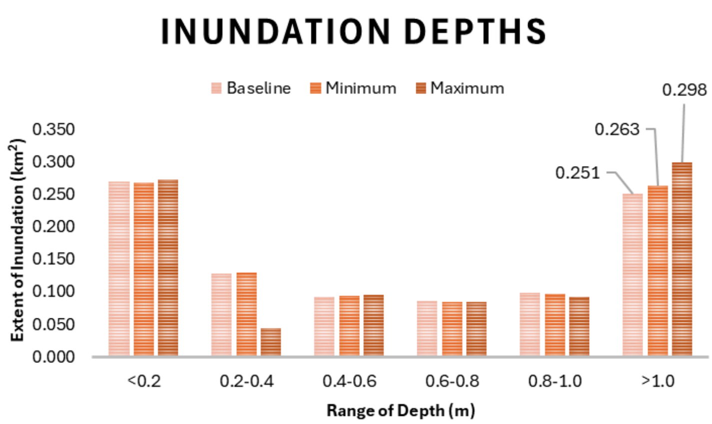

Figure 14: Flood Inundation Depth Comparison

Flood Hazard Area Comparison

Conversely, the flood hazard mapping indicates that within the model domain, areas experiencing low-hazard inundation may increase due to climate change scenarios. Approximately 13% of the model domain is vulnerable to low-hazard flooding in baseline scenario simulation, while certain areas may face moderate-hazard flooding (Figure 15). However, the occurrence of higher-end hazards appears to be negligible within our model domain even for higher-end climate change scenarios, which is an encouraging outcome.

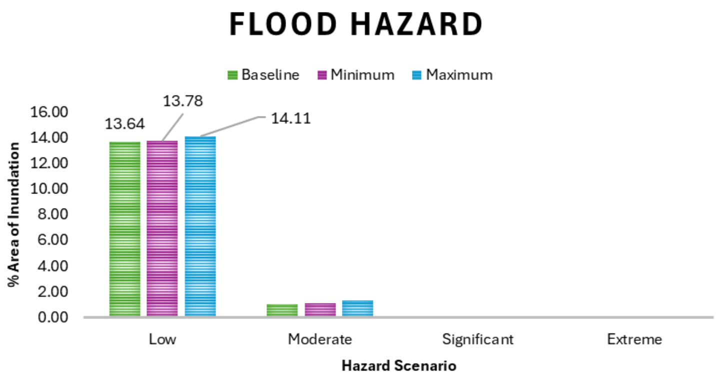

Figure 15: Flood Hazard Area Comparison

From the maps in Figure 8, Figure 9, Figure 10 and Figure 13, it seems that even though inundation may increase significantly over time, the hazard levels do not vary much from the baseline scenario. This observation could suggest potential areas overlooked in the model. Additionally, it may indicate the necessity of considering additional boundary conditions and parameters for more precise modelling. These considerations could encompass factors such as saturated soil leading to groundwater flooding, limited drainage capacity through networks, or runoff from outside the model domain influencing flash flooding risks.

5. Conclusion

In our modelling and analysis of a section of the Ouseburn catchment, we noticed slight variations in hazard levels. Despite a small rise in the proportion of low-hazard areas, it's still worthwhile to address.

We conducted an unsteady-state simulation using discharge as the boundary condition upstream and a rating curve downstream. Different upstream boundary conditions might have yielded different outcomes. We acknowledged that urban areas are vulnerable to floods, particularly from pluvial and fluvial sources. Pluvial floods, stemming from overwhelmed drainage systems during heavy rainfall, can cause substantial damage over time. Unfortunately, we did not account for this in our model (Martínez-Gomariz et al., 2021). Urbanisation amplifies runoff volume, worsening flood impacts, and climate change is anticipated to exacerbate sewer surcharging, posing further challenges to urban resilience—a potential concern for the Ouseburn catchment.

Furthermore, our model did not account for potential surface runoff from elevated areas, nor did it consider the interaction with saturated soil that could lead to groundwater flooding—a significant concern in urban flash flooding scenarios. The Ouseburn is a small fluvial sub catchment that empties into the River Tyne at the Ouseburn Barrage. It reacts swiftly to precipitation and is primarily influenced by fluvial flows. Additionally, according to reference reports, about a quarter of historical flooding incidents resulted from prolonged rainfall (Environment Agency, 2012). Overall, there is a lot of room for improvement in this model, but it certainly depicts the increase of flash flooding due to climate change in future scenarios in the catchment.

6. References

Environment Agency (2006a) *Flood Risks to People Guidance Document*.

Environment Agency (2012) *Tyne Catchment Flood Management Plan*.

Li, G., Liu, J. & Shao, W. (2022) 'Flood Risk Assessment Using TELEMAC-2D Models Integrated with Multi-Index Analysis in Shenzhen River Basin, China', Water, 14(16), p. 2513.

Martínez-Gomariz, E., Forero-Ortiz, E., Russo, B., Locatelli, L., Guerrero-Hidalga, M., Yubero, D. & Castan, S. (2021) 'A novel expert opinion-based approach to compute estimations of flood damage to property in dense urban environments. Barcelona case study', *Journal of Hydrology*, 598p. 126244.