Team 12: Report Week 2

HYDROEUROPE

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HydroEurope

Case Study : Ouseburn Catchment (United Kingdom)

Team 12 - Report Week 2:
Use of Telemac for Hydraulic Modeling

Team 12
1 March 2024

Summary

1 Introduction

1.1 Study of previous weeks

In our previous hydrological study, we used the SHETRAN software to collect, prepare, and analyze rainfall data to assess water flow in the watershed. This process provided crucial insights into the hydraulic dynamics of the watershed, essential for effective water resource management and informed land use planning.

Our findings indicate that the current climate change quotas adopted by the UK, set at 64%, do not adequately cover the increased river flow caused by median and maximum scenarios. Furthermore, our analysis reveals a higher rate of increase in river flows, leading to more rapid attainment of maximum flow levels in changing climatic conditions. This accelerated increase in river flows presents several risks and challenges, including reduced warning times and increased threats to public safety.

These results underscore the urgency of reassessing and potentially revising existing climate change quotas to better align with observed and projected changes in river flow patterns.

We will now move on to the hydraulic modelling phase, where we will use the generated flow rates and levels to create flood maps for the area.

1.2 TELEMAC 2D: Precise Modelling of Two-Dimensional Water Flows

TELEMAC 2D, a specific module of the TELEMAC system, stands out as a powerful tool for modelling two-dimensional water flows. Developed by the Centre for Studies and Expertise on Risks, Environment, Mobility, and Planning (CEREMA) in France, it represents excellence in the field of hydrodynamic modeling.

Designed to accurately simulate water movements in various environments, TELEMAC 2D utilizes the Navier-Stokes equations to capture the complex behavior of fluids. These equations take into account bed geometry, turbulence effects, and interactions with hydraulic structures, ensuring a realistic representation of hydrodynamic phenomena.

Among its key features, TELEMAC 2D offers the ability to model complex geometries using triangular meshes, allowing for detailed representation of riverine, estuarine, lacustrine, and coastal environments. Additionally, it integrates turbulence models for precise simulations and considers a variety of boundary conditions, such as inflow and outflow conditions.

Widely used in hydraulic engineering and water resources management, TELEMAC 2D finds applications in flood planning, hydraulic infrastructure design, coastal zone protection, and environmental preservation. Its use enables engineers and researchers to obtain reliable and accurate results, essential for informed decision making in various hydrodynamic projects. TELEMAC 2D utilizes the Navier-Stokes equations to capture the complex behavior of fluids.

In summary, TELEMAC 2D represents an invaluable tool for modeling two-dimensional water flows. By combining shallow water equations with advanced numerical methods such as finite element or finite volume methods, it offers exceptional accuracy in a wide range of scenarios, thereby contributing to a better understanding and management of complex hydrodynamic systems.

2 Data and methodology

2.1 Preliminary work on QGIS

Firstly, we retrieved the 2022 DTM (Digital Terrain Model) for the Ouseburn catchment available on the Department and Environment Food and Rural Affairs website. After obtaining a mosaic of data, we selected only the 4 rasters in our study area and merged them. A DTM with a resolution of 2 metres was recovered. In addition, the watercourse is crossed by several bridges, which could potentially pose a problem as the model interprets them as obstacles. That's why we've taken care to create a new DTM to lower the bridges. To do this, we are using the Serval Plugin on QGIS.

The study area was delimited into two distinct parts: the major bed and the minor bed of the Ouseburn rivers. BlueKenue was used to create the mesh in a different way, giving a higher resolution to the minor bed than to the major bed. This is why it was necessary to create these 2 zones in QGIS. This decision stems from the possibility of reducing the resolution as you move further away from the watercourse, thus speeding up the calculations.

We kept the accuracy of the DTM for this part because we wanted to retain as much detail as possible for the simulation.

Once the altimetric data had been extracted from the raster and stored in a text file, we were able to view them on BlueKenue.

2.2 Mesh generation

First of all, we had to import the point files used to create the outline of the river's major bed and the one delimiting the bed, generated from the shapefile on QGIS. A 25m grid was chosen for the entire catchment area, with a 10m grid for the major bed and a 5m grid for the minor bed, in order to obtain regular contours and avoid mesh discontinuities and therefore inaccuracies in the flow of water around these structures.

Finally, all that remained was to interpolate the bathymetry on the mesh using the point values obtained after processing the DTM 2023 raster in QGIS. Once this mesh had been created, a special file, called slf, had to be created so that Telemac could read the data.

2.3 Defining the boundary conditions of the numerical model

Once the slf file had been created, it was necessary to create a boundary conditions file. Upstream, it was decided to impose the flows from the observed data. The downstream condition was set at a height of 1.66 m. This value was obtained by averaging our observed water levels. The file obtained then contains all the points located at the boundaries of the domain, some of which are marked "upstream" or "downstream". The order in which these appear in the file should be taken into account when creating the flood flow file.

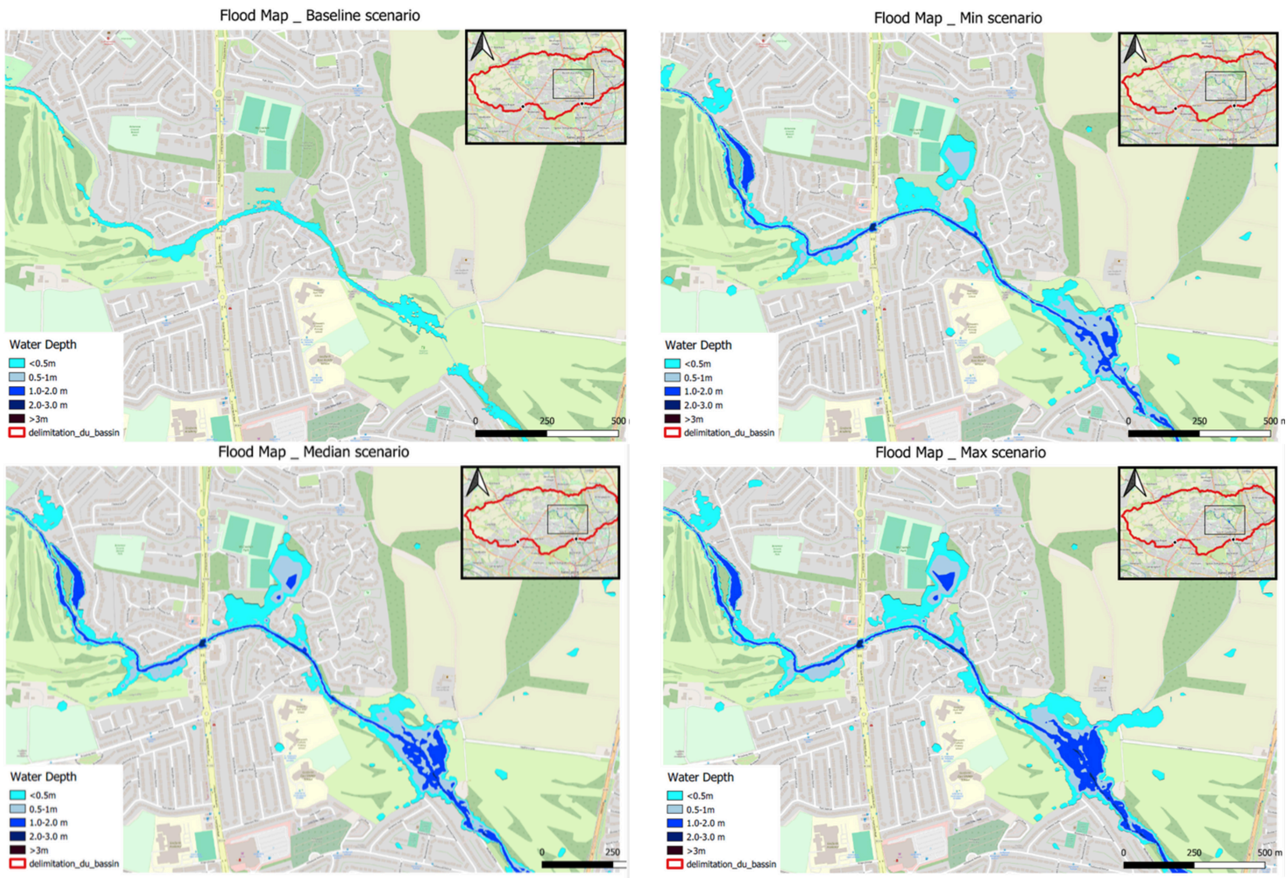
2.4 Input parameters and initial conditions

Initially, we chose to wet the model with a flow of 36 m^3/s and a water height of 1.66 m, which correspond to the average values for the river. This was the only initialization condition chosen. With regard to the boundary conditions, we needed to impose a flow rate for the upstream condition and a head of water H for the downstream condition; these data were obtained during the previous week's simulation, during the hydrological modelling. First, we ran a simulation using the results obtained for the worst-case scenario, then we chose to use data from the average Rhône scenario and, in a third simulation, we imposed the flow rates and water levels corresponding to the average scenario.

3 Telemac simulation

To run the simulation on TELEMAC, we created a case file. This links the mesh, boundary conditions and hydrographs to the modelling software. All the parameters were entered, starting with those for wetting the model and then those for simulating floods. To do this, we started the modelling on an Oracle virtual machine with a coarse mesh model to check that the model was working properly.

3.1 Telemac: Baseline and future scenarios

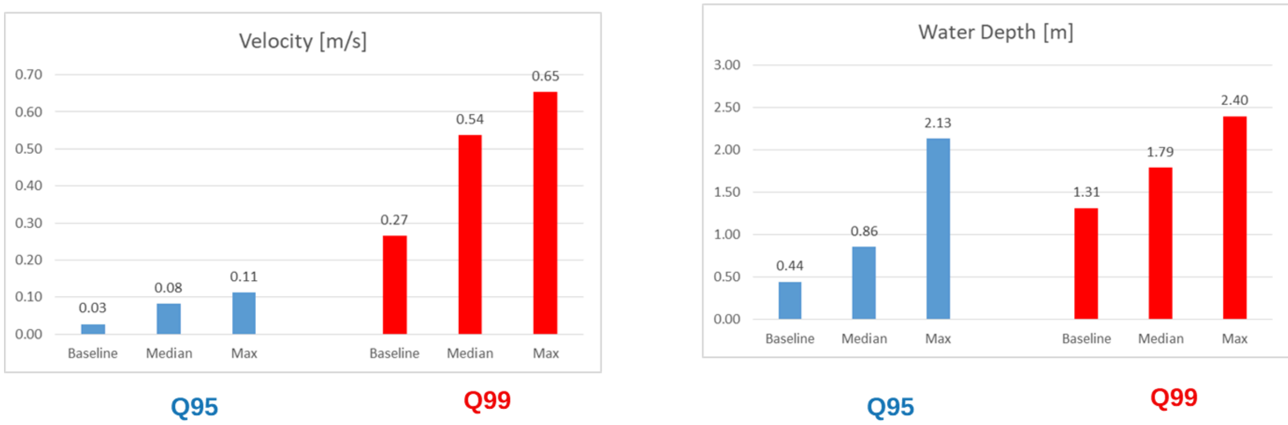


Graph 1 Flood Maps.

The flooding will significantly impact several key areas within the region, including parks, golf clubs, and small houses, where water depth levels hover around 0.5 m for the baseline scenario, 1 m for the minimum scenario, and range from 2 to 2.6 m for the maximum scenario.

Additionally, more zones that were previously unaffected by flooding in the baseline scenario are now inundated in the future scenarios.

The expansion of flooded zones emphasizes the need for immediate adaptation measures to bolster community resilience and minimize potential damages.



Graph 2 Velocity and Water depth 95th and 99th percentile.

These graphs provide insights into water depth and velocity at the 95th and 99th percentiles across baseline, median, and maximum scenarios.

In the baseline scenario at the 95th percentile, water depth measures 0.44 m with velocity at 0.03 m/s. Comparatively, in the median scenario, water depth rises to 0.86 m and velocity to 0.08 m/s. However, in the maximum scenario, both metrics increase significantly, with water depth reaching 2.13 m and velocity at 0.11 m/s.

Similarly, at the 99th percentile, the baseline scenario shows water depth at 1.31 m and velocity at 0.27 m/s, while in the median scenario, these rise to 1.79 m and 0.54 m/s, respectively. In the maximum scenario, both metrics increase further, with water depth reaching 2.40 m and velocity at 0.65 m/s.

These statistics highlight the escalating risks associated with higher percentiles across scenarios, aiding in understanding the severity of potential flooding events.

4 Preparing Hazard Maps Utilising TELEMAC Results

To assess the risk increase between baseline and climate change scenarios, risk maps were prepared in QGIS using the calculated flood hazard data derived from Telemac simulation results.

you can generate a flood hazard map. Employing the Environment Agency - UK methodology, the focus lies on assessing flood hazards to people. According to the EA study, the threshold for an individual to lose stability during a flood event is determined by the equation:

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

Where:

- **d**: flood depth (m)
- **v**: flood velocity (m/s)
- **hw**: Heigh times weight of the subject
- **a** and **b**: constants

Table 1: Hazard to People as a Function of Velocity and Depth.

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"*

4.1 Hazard Maps

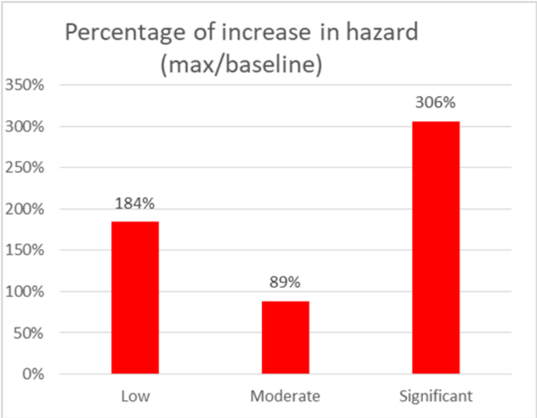
Graph 3 Flood Hazard maps.

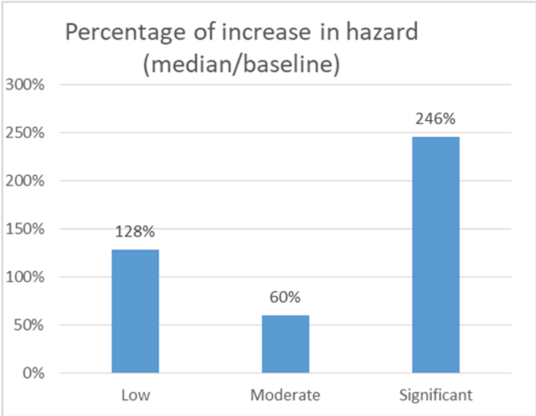
The imminent flooding will significantly affect several pivotal areas across the region, encompassing Gosforth Golf Course, Newcastle Golf Course, and specific sections of housing estates, characterized by a low hazard level.

These locales stand particularly vulnerable to the adverse impacts of flooding, with potential ramifications for infrastructure, property, and community welfare. Acknowledging the susceptibility of these regions to inundation is paramount for deploying efficient flood mitigation strategies and fortifying against potential damages and disturbances.

Conversely, the hazard escalates to a significant to high level along the riverbed, a typical occurrence in such environments.

4.2 Percentage increases in flood hazard





Graph 4 Percentage increases in flood hazard levels.

The analysis shows significant percentage increases in flood hazard levels between the maximum and baseline scenarios across different risk categories. Low-risk areas experience a surge of 184%, while moderate-risk zones see an 89% increase. However, the most striking escalation occurs in significant-risk areas, with a surge of 306%.

Similarly, comparing flood hazard levels between the median and baseline scenarios reveals notable increases. Low-risk areas witness a 128% uptick, while moderate-risk zones experience a 60% increase. Significant-risk areas show the most significant escalation, with a surge of 246%.

Conclusion

In conclusion, the majority of the flooded areas predominantly encompass parks and golf clubs, with minimal impact on residential zones.

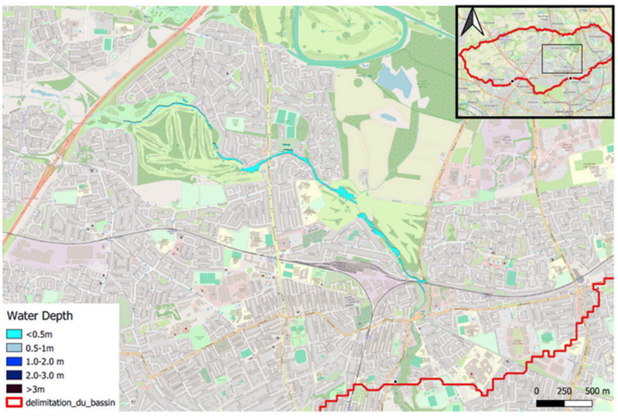
However, implementing flood barriers within these areas will significantly enhance the protection of the population. It's imperative to acknowledge the uncertainties inherent in the input data, particularly concerning resolution and future scenario projections.

Therefore, employing hydrodynamic modeling, specifically focusing on pluvial flooding, is recommended. This approach will allow for a comprehensive assessment of all watersheds, ensuring a robust understanding of flood dynamics and facilitating more informed decision-making regarding flood mitigation strategies.

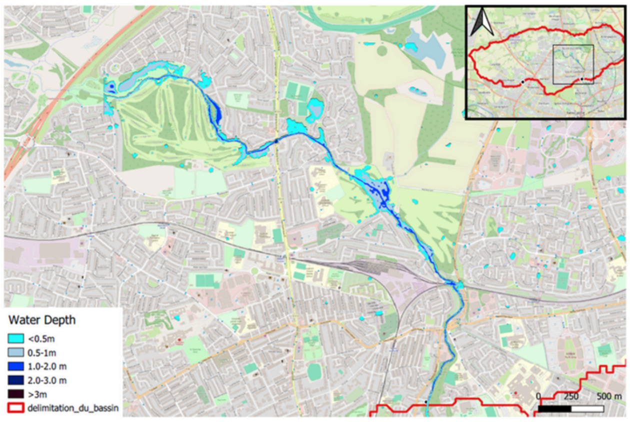
Appendix

Flood Maps

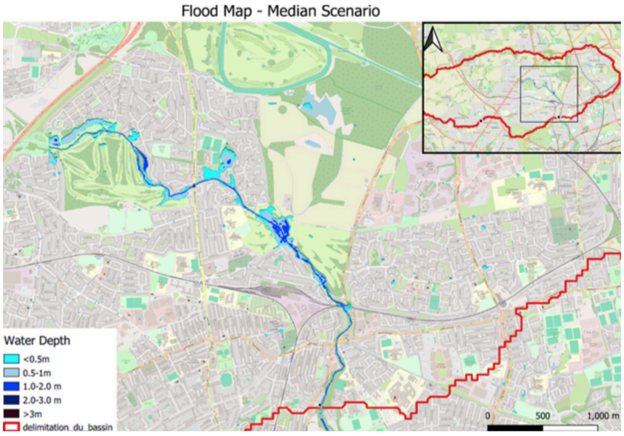
Flood Map _ Baseline scenario



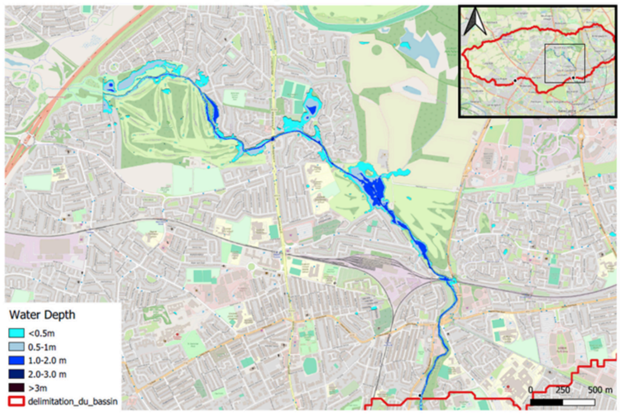
Flood Map _ Min scenario



Flood Map - Median Scenario

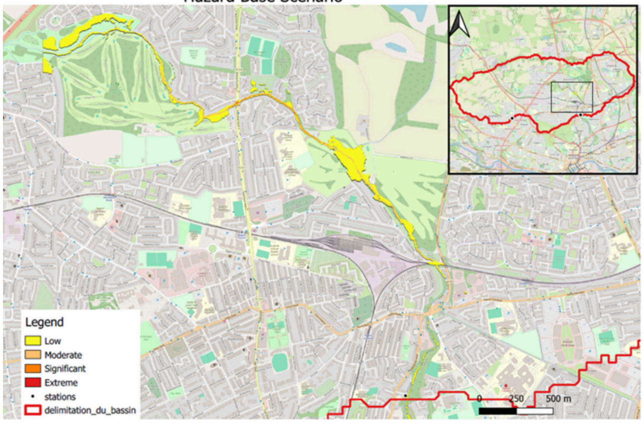


Flood Map _ Max scenario

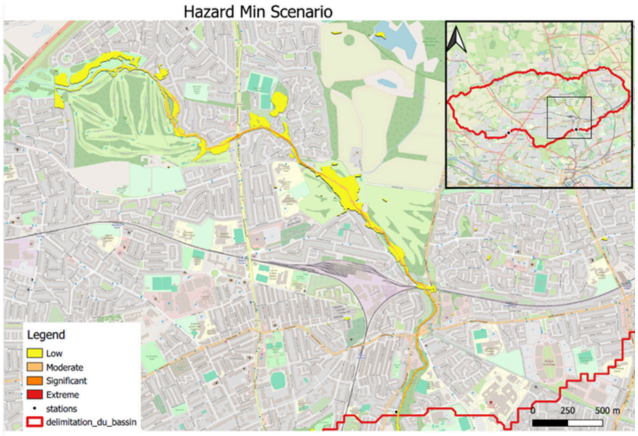


Hazard Maps

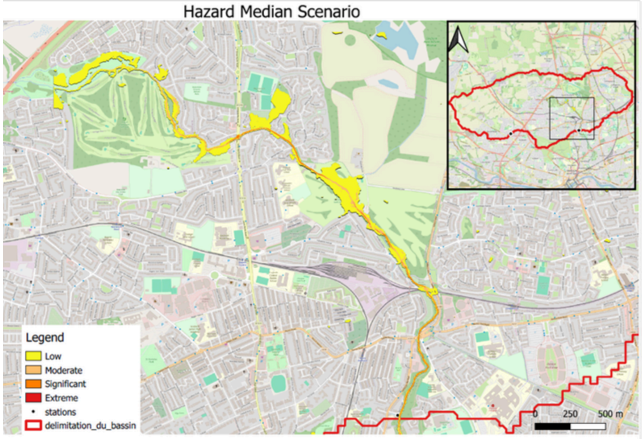
Hazard Base Scenario



Hazard Min Scenario



Hazard Median Scenario



Hazard Max Scenario