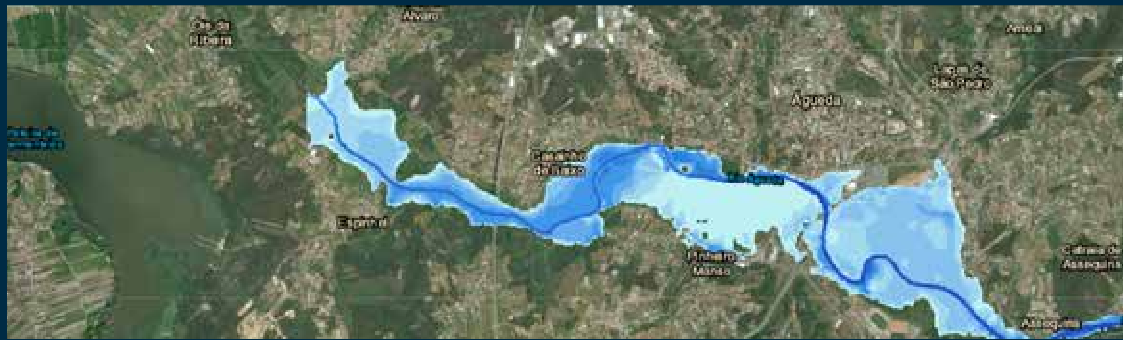
CASE STUDY



OpenFlows™ FLOOD™ Helped Quantify the Most Critical Flood-prone Areas in Portugal

22 Critical Areas Identified, Promoting More Effective Risk Mitigation and Resilience Actions

Project Summary

Organization
Portuguese Environment Agency

Location
Portugal

Project Objectives
- To provide flood inundation and flood risk maps for a Portuguese territory and to properly quantify inundation probabilities and associated risks for the existing and future infrastructures, human health, economic activities, and the environment.
- To support the creation of the Inundation Risk Management Plans, including the definition of the necessary actions to reduce exposure to those flood events.

Products Used
OpenFlows™ FLOOD™

Fast Facts
- Twenty-two critical zones were identified.
- Three different scenarios (20, 100, 1,000 years of return periods) are considered, and using OpenFlows FLOOD integrated flood modeling to generate multiple inundation maps.
- Modeled scenarios were used to obtain flood risk maps split in seven Flood Risk Management Plans covering the Portuguese mainland.
- The completed model allowed us to project customized actions to reduce the risk levels and to increase societal resilience.

ROI
- Model-based decision-making for flood risk management increased effectiveness and reliability.

Flooding and Inundations in Portugal: Past and Present

River flooding affects more people worldwide than any other natural hazard, with an estimated global annual average loss of USD 104 billion.[1] Such damages are expected to increase as a result of continued economic growth and climate change.[2, 3]

Severe rainfall conditions that lead to floods are associated with atmospheric instability which, in mainland Portugal, usually occurs from autumn to spring. However, the climatic change is precipitating the river flooding events in Europe, particularly in western Europe, according to a study published in *Science*.[4] Constant modifications in soil use (including deforestation and the urbanization of flood zones) can also increase the impacts from flooding.

In mainland Portugal, flood events occur in many different zones. Yet, the most significant events occur in the hydrographic basins of large and medium-sized rivers. The Tagus, Douro, and Sado rivers have a long history of floods, frequently reported in the media. Other river basins are regularized through reservoirs with the capacity to laminate or to fit the volumes of the floods that are attenuating the flow.

The hydrological regime of small watercourses in Portugal is usually torrential. During part of the year, the flow is null (or almost null) and years pass by without the beds overflowing. In contrast, in the case of intense precipitation, surface runoff reaches a high velocity, with the specific flow rates of the centenary floods being very high.

The Legal and Institutional Context

In the aftermath of the damaging floods in Central Europe between 1998 and 2004, the European Union initiated a process of studying the phenomenon, as well as developed mitigation and adaptation procedures to reduce Europe's vulnerabilities in the event of floods. By creating these procedures, the European Union sought to reduce harmful consequences. As a result, the European Commission developed a new strategy that led to the publication of a directive (2007/60/EC) on the assessment and management of flood risks. This directive was transposed into national laws, establishing a national framework for the assessment and management of flood risks, with the aim of reducing the harmful consequences associated with this phenomenon for health (including human losses), the environment, cultural heritage, infrastructure, and economic activities.

In Portugal, the Portuguese Environmental Agency (APA), which is the National Authority for Water, is responsible for flood management at a national level, as well as adopting coordination measures in the face of floods. Additionally, the APA applies measures to create alert systems to protect people and assets. The APA is also the main national entity responsible for the effective implementation of the European directive in Portugal. The implementation took place as a result of the elaboration and application of flood risk management plans, which was only possible after the mapping of inundation zones and flood risks. OpenFlows FLOOD was the software used as the integrated modeling capability to estimate the flood characteristics and the associated inundated maps.

Used Data and Considered Scenarios and Model Engine

The modeling approach used to delineate the inundated areas depends on the baseline information and on the specificities of each region. The estimation of flood inundated zones is contingent upon the selection of the flood peak flows for the different return periods being studied. In the eight areas with default flows provided by the APA, the flood peak flows provided were considered directly.

In the 10 areas where the watershed does not show significant regularization and/or does not have hydrometric records near the flood zone, hydrological modeling has been developed to estimate flood peak flows. For this, the MOHID Land model, provided by OpenFlows FLOOD, was used. In the four remaining zones, the peak flows were obtained by analyzing the existing hydrometric records.

The determination of the inundated zones was obtained through the hydraulic modeling of the superficial runoff.

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This determination enables the flood flow characteristics to be estimated. Hazard mapping was also obtained, integrating maximum depth and associated velocity.

For all the zones to be modeled, two-dimensional models were implemented, using MOHID Land (for the inland waters) and MOHID Water (applied to estuarine zones). These 2D models are based on the equation of conservation of mass and conservation of momentum in two horizontal directions. With these models, the bed is discretized with high-resolution finite element meshes, determining the components of the flow velocity in the horizontal plane and considering the respective average value according to the vertical.

At each study site, the various available topographic data sources were collected and integrated (including 0.5-meter resolution from LIDAR in some areas). Also, interpolation methods were used to describe the flood plains with the greatest detail possible. Based on the topographic data available and the needs for each specific zone, the computational meshes adopted varied between 2 meters and 40 meters, with the most frequent resolution being 10x10 meters. The number of computational points for the different grid meshes varied between 101,500 and 1,402,800. All the data processing was done inside OpenFlows FLOOD.

Regarding the boundary conditions, a schematic variable hydrograph was imposed in the river side to represent the flood rise as a function of different flows and velocities. In the critical areas under the tidal influence, the imposed sea level considered was the average height from two consecutive spring tides; and in the estuarine zones, an overelevation (representing the storm surge from the atmospheric pressure, wind, and waves) was also considered.

A set of 22 flood risk critical zones were assessed under three different return periods (20, 100, and 1,000 years). Multiple inundation maps were generated.

Models have also been run for calibration and validation for historic events.

Using Flood Marks from Previous Incidents

The existing marks in infrastructure that were recorded from previous flood events have been compared with the simulated scenarios. Although some of these marks did not specifically refer to the instant, or the associated flow, this qualitative analysis allowed the team to make a positive comparison between the modeled and measured water heights, enabling them to validate the models.

The Bottom Line: Quantified Risks Promote Suitable Actions and Prioritization

The generated inundation maps allowed for the development of a realistic risk assessment for the areas of study, resulting in the same number of flood risk maps. The flood risk quantification integrated the hazard mapping, which was modeled from inundation maps and the exposure obtained from the consequence mapping.

The quantified risk maps for all those critical areas provided valuable instruments to project suitable actions capable of preventing, protecting, and mitigating the potential effects derived from future flood events in the next 20 years. All these actions were later included in the different Inundation Risk Management Plans developed by the APA as an important management instrument. The identification of the most critical areas and infrastructures allowed them to efficiently prioritize the implementation of specific actions, which is particularly relevant when resources are scarce.

Inundation maps and flood risk maps have been produced for all these places and are now public on the environmental agencies website: https://sniamb.apambiente.pt/content/inundações-diretiva-200760ce-portugal-continental.

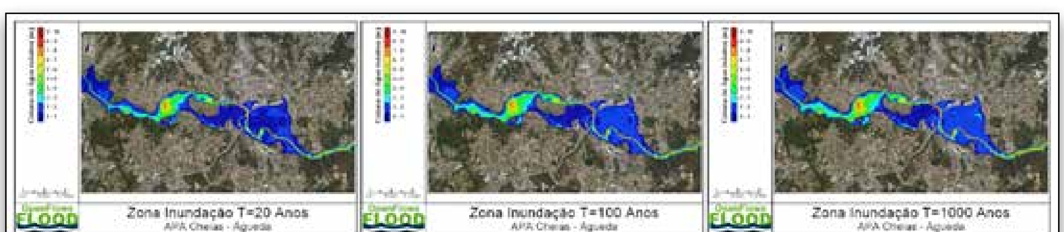
References

1. https://www.unisdr.org/we/inform/publications/42809

2. Winsemius H C et al 2016 Global drivers of future river flood risk Nat. Clim. Change 6 381–5

3. IPCC, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (Cambridge Univ. Press, 2012).

4. http://science.sciencemag.org/content/357/6351/588 (DOI: 10.1126/science.aan2506)



The image shows the maximum water depth for three different return periods.

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