# IBER-SWMM Module: A New Approach to Model Urban Pluvial Flood in the Sampierdarena district in Genoa (Italy)

## Module IBER-SWMM : une nouvelle approche pour modéliser les inondations pluviales urbaines dans le quartier de Sampierdarena à Gênes (Italie)

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## RÉSUMÉ

Les inondations pluviales urbaines constituent un enjeu majeur, amplifié par l'urbanisation rapide, la dégradation des réseaux d'assainissement et l'intensification des précipitations extrêmes. La fiabilité des modèles dépend fortement des données topographiques, alors que les MNT restent souvent choisis par simple disponibilité plutôt qu'à partir d'une analyse rigoureuse de leurs impacts hydrauliques.

Cette étude examine l'influence de MNT de résolutions et prétraitements variés sur une modélisation 1D–2D du ruissellement de surface et du fonctionnement du réseau pluvial dans le quartier densément construit de Sampierdarena (Gênes, Italie).

Des simulations ont été réalisées avec le modèle IBER, en utilisant une pluie synthétique de 30 minutes générée selon la méthode Chicago Design Storm (CDS). Les résultats montrent que la résolution du MNT modifie sensiblement les hauteurs d'eau, la distribution des écoulements et les étendues inondées, les modèles grossiers atténuant des microformes essentielles et faussant la représentation des aléas.

Pour dépasser les limites d'une approche purement 2D, un couplage 1D–2D IBER–SWMM est développé afin d'intégrer les interactions surface–réseau, incluant surtensions, déversements et points de surcharge. Cette intégration améliore la cohérence hydrodynamique du modèle et fournit un appui opérationnel pour la gestion et la réduction du risque d'inondation pluviale en milieu urbain.

## ABSTRACT

Urban pluvial flooding is an increasingly critical issue for modern cities, driven by rapid urbanisation, ageing drainage systems, and more frequent intense rainfall events. Since model accuracy depends heavily on input data—especially terrain information controlling overland flow—more research is needed to address a key gap in current practice, where DTMs are often chosen for convenience rather than rigorous evaluation.

This study examines how different topographic datasets, varying in resolution and preprocessing, influence the results of a 1D–2D approach for simulating both surface runoff and sewer system dynamics. The analysis focuses on the densely built Sampierdarena district in Genoa (Italy), an area regularly affected by pluvial flooding.

Several simulations were performed with IBER model, maintaining the same synthetic 0.5-hour rainfall, based on the Chicago Design Storm (CDS) method. Results show that terrain resolution strongly influences predicted water depths, flow paths, and inundation extent, with coarser DTMs smoothing out key micro-topographic features, shifting flood outlines and potentially misleading risk evaluations.

To overcome the limitations of purely 2D modelling, the research progresses toward a coupled 1D–2D IBER–SWMM approach. This integrated method improves the representation of surcharge events, overflow points, and surface-drainage interactions. Ultimately, the work supports a more realistic and reliable urban flood modelling and offers practical guidance for improving resilience in flood-prone urban areas.

## KEYWORDS

1D-2D Modelling, IBER-SWMM, Topography, Pluvial Flooding

## 1 INTRODUCTION

Floods remain one of the most severe natural hazards worldwide, as emphasized by the UNDRR[1]. Their frequency and intensity have increased over recent decades due to climate change—driving more extreme rainfall—and rapid urbanisation, which places growing pressure on drainage systems. From 1970 to 2019, water-related hazards constituted 50% of all disasters and 45% of all recorded fatalities. Since 2000, the incidence of documented flood-related disasters has increased by 134% relative to the preceding two decades. In Europe, floods caused roughly 40% of total natural-disaster damages from 1989 to 2008, with recent catastrophic events in 2021 and 2023 highlighting the vulnerability of densely populated regions and critical infrastructure.

Flooding is commonly classified into fluvial, coastal, and pluvial categories. While fluvial floods stem from rising river levels and coastal floods from storm surges, this study focuses on pluvial urban flooding caused by intense rainfall that exceeds the capacity of natural or artificial drainage systems. Although often confused with flash floods, pluvial floods differ because they occur mainly as surface runoff accumulation, frequently before water enters any watercourse. They typically affect small urban areas over short time scales, especially where drainage networks are inadequate, blocked, or overwhelmed. When runoff cannot be conveyed effectively through roads, depressions, or stormwater inlets, water ponds in low-lying zones, and system surcharges or failures may occur.

Those events are studied and simulated in different ways, in particular through the use of commercial 1D–2D modelling platforms such as InfoWorks ICM[2], MIKE FLOOD[3], and TUFLOW[4] or the open software IBER-SWMM[5]. This software are widely used for simulating urban pluvial flooding by coupling detailed 1D sewer hydraulics with 2D surface flow dynamics. In this way, they integrate rainfall–runoff processes, surcharge behaviour, and surface inundation to provide high-resolution flood mapping in complex urban environments. Their ability to capture fine-scale interactions between streets, drainage inlets, and overland flow pathways is what distinguishes them from simplified 0D–1D rainfall–runoff approaches such as SWMM, making them the standard for urban flood risk assessment. This allows them to capture local ponding, flow exchanges between streets and sewers, and small-scale topographic effects that 0D–1D models inherently miss.

Given these dynamics, accurately modelling pluvial floods requires capturing fine-scale rainfall-runoff processes and detailed terrain characteristics. Yet model outputs remain highly dependent on the quality of topographic data, which is often selected based on availability rather than systematic evaluation. This research therefore investigates how terrain data characteristics influence pluvial flood simulation outcomes, aiming to establish a more rigorous, evidence-based framework for selecting topographic inputs in hydrodynamic modelling.

## 2 CASE STUDY

To evaluate more effectively the influence of input-data weighting within the hydraulic models, the case study shown in Fig. 1 (left) was selected. The chosen site is a densely urbanised sector of the Metropolitan Area of Genoa, Italy, which is frequently affected by pluvial flooding triggered by rainfall events with relatively low return periods (T between 1.5 and 3 years).

The study area lies in the western part of the city, within the Sampierdarena district, and initially covered approximately 1 km². The domain was later expanded to roughly 1.5 km² to ensure proper inclusion of the stormwater drainage network. This district forms a compact urban cluster positioned between the commercial port and the left bank of the Polcevera River.  It also contains three minor watercourses—Fosso Bartolomeo, Fosso Promontorio, and Fosso Belvedere—each of which is partially channelled along its urban stretch, playing a relevant role in local drainage dynamics.

[1] United Nations Office for Disaster Risk Reduction https://www.undrr.org/gar/gar2025/hazard-exploration/floods

[2] InfoWorks Integrated Catchment Modeling https://damassets.autodesk.net/content/dam/autodesk/www/pdfs/meet-the-new-infoworks-icm.pdf

[3] Mike FLOOD +2D https://www.dhigroup.com/technologies/mikepoweredbydhi/mikeplus-2d-overland

[4] TUFLOW, BMT 2018 https://downloads.tuflow.com/_archive/TUFLOW/Releases/2018-03/TUFLOW%20Manual.2018-03.pdf

[5] IBER-SWMM https://www.iberaula.es/1070/iber-model/about-the-model

[6] SWMM, EPA https://www.epa.gov/water-research/storm-water-management-model-swmm

A synthetic Chicago hyetograph (Fig. 1, middle), generated with a duration of 1 hour, with a time-to-peak ratio of 0.5 and return periods of T = 10 years. The rainfall intensities were derived from the regional Depth-Duration-Frequency (DDF) curves developed for Liguria (Gnecco et al, 2023), as reported in the study of extreme precipitation by ARPAL (DG ARPAL 77/2019).

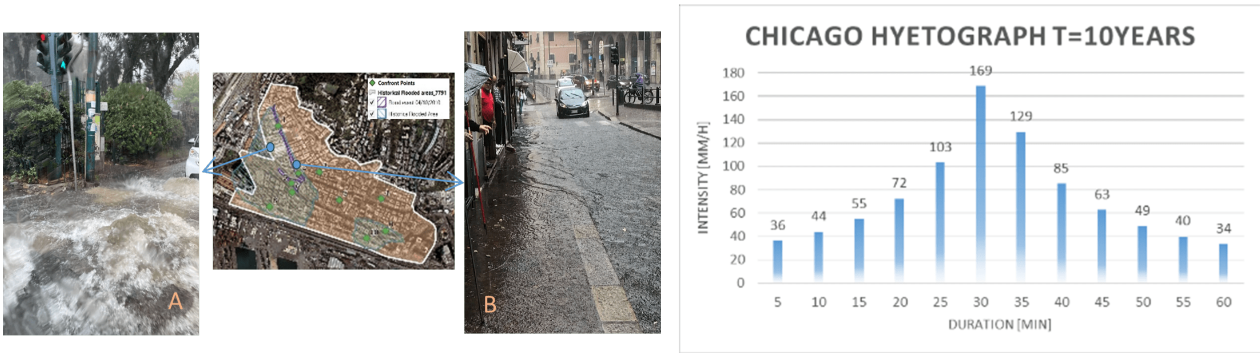


Fig.1: Schematic map of the study area with points used for sensitivity analysis. Photo A and B: real event of 24/09/2022 (Primocanale). In the middle the hyetograph used for the analysis methodology

A review of existing literature reveals a persistent gap: although many studies acknowledge that terrain data significantly affects model behaviour, DTMs and DSMs are often selected based solely on availability or convenience, rather than through a structured evaluation of their sensitivity (Acquilino et al, 2025). The accuracy of digital terrain models, their preprocessing, and their spatial resolution directly influence the representation of micro-topographic features such as streets, depressions, curbs, and underground inlets—elements that are crucial to the real behaviour of overland flow during intense rainfall events (García-Alén, 2022). Yet, studies frequently overlook these aspects by relying on datasets that may be coarse, inconsistently processed, or mismatched with the spatial scales governing urban hydrology. Against this backdrop, the present research seeks to quantify the hydrodynamic consequences of terrain input choices and to develop guidelines supporting modellers and practitioners in the appropriate selection and preparation of topographic datasets.

The methodological framework builds upon freely distributed hydrodynamic tools, with IBER serving as the primary platform for two-dimensional (2D) rainfall-runoff flow simulations. A series of controlled numerical experiments were designed to evaluate how different topographic datasets—varying in resolution, origin, and preprocessing level—affect flood simulation outputs. High-resolution LiDAR-derived DTMs were compared to coarser photogrammetric products and derivative datasets commonly used in engineering practice. Each dataset was used to simulate pluvial flood under the same extreme rainfall scenarios, ensuring that all variations in results stemmed exclusively from terrain input differences. Model outputs, including water depth, flow velocity, inundation extent, and spatial distribution of overland flow pathways, were analysed both qualitatively and quantitatively. Special attention was given to identifying distortions in flow accumulation, artificial barriers induced by interpolation methods, and the displacement or elimination of minimum-elevation points that typically control water storage areas or preferential flow routes.

## 3 RESULTS

Preliminary findings indicate substantial variability in simulation outcomes linked directly to the terrain dataset employed. Coarser DTMs often smooth out critical micro-topographic details, resulting in misrepresentation of flow concentration zones and significant deviations in predicted water depths. Even moderate differences in grid resolution—such as moving from a 5 m to less than 1m cell size (see Fig.2)—can shift the simulated flood outlines, alter peak inundation depths, and misguide vulnerability assessments for critical infrastructure. In urban environments, where depressions, curbs, and small drainage pathways govern runoff behaviour, these discrepancies can lead to divergent risk classifications and potentially flawed decision-making. The study's systematic comparison confirms that terrain resolution and processing quality are not merely technical input choices but central determinants of model realism and predictive reliability.

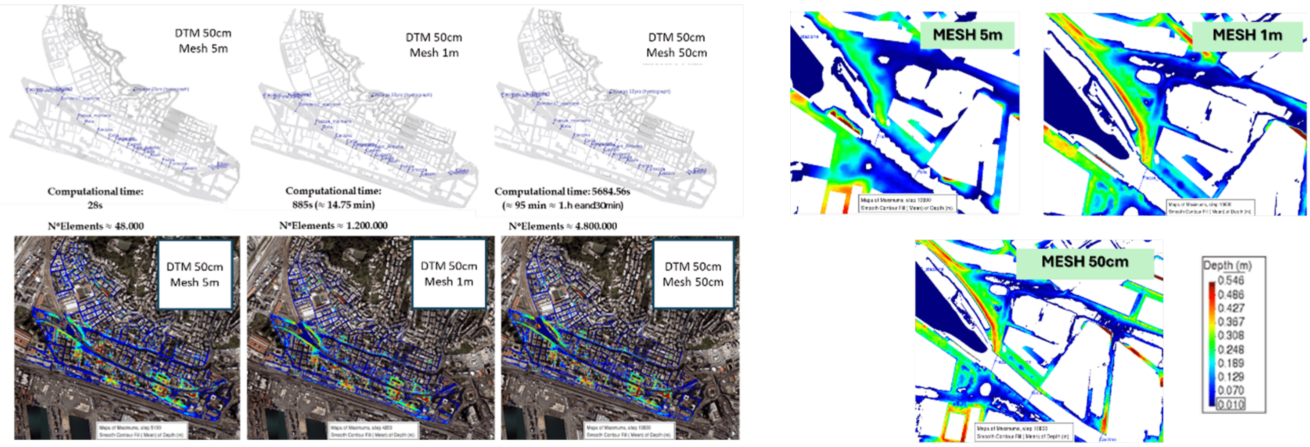


Fig.2: on the left the maps of 2Dsimulation (same DTM, varying mesh); on the right focus on Piazza Montano to better visualize the differences

Building on these insights, the research expands in a subsequent phase by integrating the 2D IBER model with the 1D SWMM (Storm Water Management Model) through a coupled 1D–2D hydrodynamic framework. This integration aims to overcome inherent limitations associated with purely 2D pluvial flood simulations, which traditionally represent the drainage system only indirectly or not at all. A coupled approach allows simultaneous modelling of surface flows and subsurface drainage processes, including surcharge behaviour, inlet capture efficiency, and internal network bottlenecks. The outcomes of this forthcoming phase include a more accurate representation of the interactions between runoff and sewer systems, improved identification of flow exchanges between streets and drainage conduits, and a better understanding of the conditions leading to drainage system failure. Moreover, incorporating dynamic sewer behaviour is anticipated to refine predictions of flood peak timing, identify localised overflow points, and enhance the ability to model cascading hydraulic failures during extreme rainfall events.

Those results from the IBER–SWMM coupling can be particularly relevant for municipalities and designers seeking integrated flood-risk management tools. By capturing both overland flow propagation and stormwater network dynamics, the coupled model will support more realistic simulations of flood evolution and provide a basis for evaluating adaptation strategies such as green infrastructure, retention systems, or drainage network upgrades. Additionally, this integrated approach will open the door to future data assimilation studies, where real-time rainfall and sensor data may be incorporated to refine model predictions during live flood events.

## 4 CONCLUSION

In summary, this research contributes to advancing the state of the art in urban flood modelling by systematically investigating the impact of topographic input data—an aspect that has often been underestimated or treated empirically in previous studies. By demonstrating the significant influence of terrain data characteristics on hydrodynamic predictions and by outlining a path toward more comprehensive 1D-2D modelling through the integration of IBER and SWMM, this work lays the foundation for improved accuracy, transparency, and reliability in the simulation of pluvial flood events. Ultimately, the project aims to support both scientific understanding and practical decision-making in urban flood risk management, promoting more resilient and better-informed planning for cities facing increasing hydrological challenges.

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