Ref. Ares(2025)4439475 - 03/06/2025

D4RUNOFF

Data driven implementation of hybrid nature-based solutions for preventing and managing diffuse pollution from urban water runoff

D5.1 Initial preparatory and testing report in case studies

February 2025

D5.1 Initial preparatory and testing report in case studies	
Work Package	WP5
Deliverable lead	VCS
Author(s)	Laura Roed Bonde (VCS) Contributors: All D4RUNOFF partners
Contact	info@d4runoff.eu
Grant Agreement number	101060638
Start date of the project / Duration	1 September 2022 / 42 months
Type of deliverable (R, DEM, DEC, other)	R
Dissemination level (PU, SEN)	PU
Project website	www.d4runoff.eu

Document history		
Version	**Date**	**Authors (organisation)**
0.1	30.01.2025	Laura Roed Bonde (VCS)
0.2	20.02.2025	Jesús Fernández Águila (ITG), Nicolás Morales (AQU), Begoña Espiña (INL), Anders Risbjerg Johnsen (GEUS), Thomas Karlsson (UCPH), Jorge Rodríguez (UC), Federica Guerrini (MITIGA), Simone Lippi (ACQUE)
0.3	23.02.2025	Laura Roed Bonde (VCS)
1.0	24.02.2025	Anders Risbjerg Johnsen (GEUS),
2.0	30.05.2025	ITG, AQU, INL, UCPH, UC, MITIGA, and VCS have addressed the PO's comments regarding editing and have provided a more detailed description of the next steps and strategy in Section 2. Furthermore, additional information has been included in Section 4 concerning next steps, testing, cooperation, and stakeholder interaction.

R=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other **PU**=Public, **SEN**=Sensitive, limited under the conditions of the GA

D4RUNOFF

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060638.

COPYRIGHT STATEMENT

Executive Summary

This deliverable, D5.1, is produced as the result of the first set of actions implemented within Tasks T5.1 to T5.5. It consolidates the information obtained from preparatory and ongoing testing activities across several key areas: the detection methods developed in WP1, the risk assessment and mapping methodology from WP4, the online sensor system from WP2, the AI-assisted platform also from WP4, and the MCDA framework from WP3. The report details the testing and validation of innovative analytical techniques for characterizing urban runoff pollutants, the refinement of risk assessment models through the integration of new field data, the evaluation of an online monitoring system under real-world conditions, and the deployment of an AI-driven decision support platform. Early findings indicate that the advanced detection methods have significantly improved our understanding of the pollutants present in urban runoff, while initial sensor tests reveal that further refinements in communication and system adjustments are necessary to address the complexities of natural samples. In addition, the risk assessment activities have provided valuable insights for model calibration, and the integration of GIS and real-time data underscores the need for standardized metadata and robust sensor connectivity.

Feedback from the various work packages highlights that while WP1's analytical methods have advanced pollutant characterization, WP2's sensor system requires enhanced communication protocols, WP3's MCDA approach must be adapted to better reflect local cost and operational practices, and WP4's AI-assisted platform would benefit from further data harmonization and stronger cross-WP collaboration.

Looking ahead, the next steps include completing the sampling and analysis, iteratively refining the risk assessment models, finalizing the performance of the online monitoring system, transitioning the AI-assisted platform to full deployment across demo sites, and adapting the NBS library and MCDA methodology to produce feasible Nature Based Solution proposals. In parallel, local working groups will be established at each case study to provide continuous feedback, ensuring that all testing and implementation activities align with practical urban runoff management needs. Overall, this report documents key learnings from the initial testing phase and lays the foundation for further improvements and targeted actions in the subsequent project phases.

Table of Contents

List of Figures

1 INTRODUCTION

1.1 Purpose of the document

This report is a key deliverable from the initial actions implemented within Tasks T5.1 to T5.5 of the D4RUNOFF project. Its aim is to consolidate and present the preliminary findings and data gathered from preparatory and ongoing testing activities, thereby establishing a solid foundation for subsequent development and implementation phases.

1.1.1 Scope of the document

The document covers the initial preparatory and testing activities conducted under Tasks T5.1 through T5.5. It includes the evaluation of advanced detection methods, risk assessment and mapping approaches, online sensor integration, AI-assisted platform operations, and multi-criteria decision analysis. The report is intended to capture both the successes and challenges encountered, along with feedback to refine project methodologies.

Structure of the document

The report is organized into the following sections:

- **Introduction:** Outlines the purpose, scope, and relevance of the report within the context of WP5 and its integration with WP1–WP4.
- **Summary of Data and Testing Activities:** Details the specific testing activities, methodologies, and data collection efforts across the tasks.
- **Feedback to WP1–WP4:** Compiles insights, recommendations, and suggestions for improvement derived from the initial testing phase.
- **Action Plan for Further Testing:** Describes the planned next steps, timeline, and responsibilities for the upcoming testing and validation phases.
- **Conclusion:** Summarizes key findings and outlines implications for future project phases.

Next step of the document

Following this report, the next steps involve refining the testing methodologies based on the feedback collected, enhancing data integration across pilot sites, and progressing with further testing and validation activities. The insights gained will guide the development of improved versions of the project's technical modules and support more targeted actions in the subsequent phases of the D4RUNOFF project.

2 Summary of Data and Testing Activities

The upcoming testing and implementation phase will focus on deploying the developed tools and methodologies across the three pilot sites - Odense, Santander, and Pontedera. A coordinated cooperation strategy has been established to support this effort, ensuring alignment between technical partners and local stakeholders through dedicated workspaces, structured data integration, and feedback loops. This cross-site collaboration will enable site-specific adaptation of the AI-Assisted platform and other components, ensuring that local urban runoff challenges are effectively addressed. The outcomes of this cooperation will be documented in upcoming deliverables D5.3 and D5.4, and further validated through stakeholder engagement activities, including the final D4RUNOFF Open Day in Odense. A more detailed description of the implementation strategy and site-level preparations is provided in Section 2.4.

2.1 Task 5.1: Implementation of Novel Detection Methods

This section details the testing and validation of the innovative detection methods developed in WP1 for characterizing urban runoff pollutants. Task 5.1 focuses on applying advanced analytical techniques — including liquid chromatography-high resolution mass spectrometry (LC-HRMS) for both target and non-target screening, hydrophilic interaction liquid chromatography-HRMS (HILIC-HRMS) for suspect screening of mobile compounds, and digital droplet PCR for quantifying antibiotic resistance markers — to real-world water samples. Composite samples are collected from case study sites in Santander, Odense, and Pontedera during urban runoff events, enabling the project team to evaluate these methods under operational conditions. The resulting data not only provides essential feedback to refine these detection approaches but also lays the groundwork for subsequent tasks (T5.2–T5.6) within the project.

2.1.1 Detection methods

LC-HRMS. A novel LC-HRMS detection method for urban runoff target, suspect, and non-target screening (NTS) was developed and validated in WP1. The method is described in deliverables 1.1, 1.2, and 1.6. It will be implemented in T5.1 for quantification of known chemicals of emerging concern (CECs) as well as identification and quantitative estimation of unknown runoff pollutants.

HILIC-HRMS. In WP1, a HILIC-HRMS method was developed for suspect-screening ofmobile and very mobile compounds, which are otherwise poorly retained in reversed-phase liquid chromatography. As in WP1, the method will cover a large list of suspect compounds, but with special emphasis on the fate of the biocides that were detected in the WP1 inventory samples.

Digital droplet PCR. Digital droplet PCR (ddPCR) will be used to quantify absolute levels of selected antibiotic resistance genes, covering the four classes developed in WP1. In addition, ddPCR will measure the 16S rRNA gene to estimate the total bacterial community and calculate the relative incidence of antibiotic resistance. These analyses will be complemented by traditional plate counts of thermo-tolerant E. coli as a marker for faecal contamination.

Gene	Target
16S rRNA	Ribosomal RNA gene, all bacteria.
tetM	Tetracycline resistance, ribosome protection proteins.
sul1	Sulfonamide resistance.
Bla$_{\text{CTX-M-1 group}}$	Extended spectrum beta-lactam resistance, beta-lactamase.
Bla$_{\text{NDM (variants 1,3,4,5,6,16)}}$	Carbapenem resistance, carbapenemase, broad spectrum beta-lactam resistance, penicillins, cephalosporins and carbapenems.

2.1.2 Sampling

A sampling plan has been developed for collecting stormwater samples in Santander, Odense, and Pontedera. The sampling plan and protocol has been designed based on WP1 findings and information needs identified within the D4Runoff project. Unlike the sampling activities in WP1, this phase emphasizes the collection of both influent and effluent from NBS to enhance the understanding of urban runoff pollutants and their removal in NBS to be used in task 5.2 risk assessment. To this end, samples will be collected at NBS influent and effluent during the same rain events. Furthermore, at least three rain events will be sampled at each NBS to include information about the variation across rain events. The preliminary schedule is shown below and has been coordinated with T5.3 for validation of the sensors. Analysis of microbial indicators and CECs will be done once all samples have been collected.

	Month	29	30	31	32	33	34	35	36	37	38	39	40
		January	February	March	April	May	June	July	August	Septembe	October	November	December
Sampling	**Santander**												
	Odense												
	Pontedera												
Analysis													
			D5.1					D5.3					D5.4

2.1.3 Status

Developments in WP5 are proceeding according to plan.

Initial findings thus far:

- Analytical methods have been developed and successfully implemented for identification and quantification of runoff pollutants in WP1 (results described in D1.3 and D1.4) and will be used to analyse samples in T5.1.
- Sampling experiences from WP1 have successfully been transferred to WP5. This has supported the development of a sampling plan and improved the ability to foresee needs and potential sampling issues, especially related to equipment and time needed for sampling.
- To best improve the knowledge generated in WP1, runoff sampling will be focusing on the inlet and outlet of nature-based solutions to better understand the removal capacities during different conditions.

2.2 Task 5.2: Risk Assessment and Risk Mapping

In T4.4, part of WP4, a risk assessment and risk mapping methodology is developed as part of the Risk Assessment Module within the D4RUNOFF's AI Assisted Platform (see Section 2.4 in this document for further information). This is intended as a tool to assess and locate hotspots of runoff pollution to help identify optimal locations for new Nature Based Solutions. T4.4 delivers in M32 a Version 1.0 of the methodology: in T5.2, this methodology will be implemented, tested, and further calibrated in the Odense Case Study. Importantly, despite the postponement of T4.4 finalization from M30 to M32 (as per Amendment request AMD-101060638-12), no impacts on T5.2 outcomes or delivery dates are expected.

In Task 5.2, the Risk Assessment Module and its internal models will be refined and validated, focusing on the Municipality of Odense, Denmark. This step will involve both the testing and improvement of the risk assessment models in a continuous improvement setup, complementing the historical and climate projection data used during its development in T4.4 with new data from sampling campaigns and from the operation of the novel WP2 sensors.

T5.2 also entails the involvement of local stakeholders and D4RUNOFF partners from the other Case Studies, namely in Pontedera and Santander, culminating in a final workshop, which is expected to take place jointly with the final D4RUNOFF Open Day in Odense (which will be held as part of WP6 activities), intended as final iteration of the continuous improvement loop.

The outcome of T5.2 will be an improved Version 2.0 of the methodology, designed not only to provide improved results, but most importantly to better serve users' needs.

2.2.1 Summary of the Risk Assessment Methodology (WP4)

This section provides a summary of the risk assessment methodology and of its models in a way that supports a clear definition of T5.2's activities: a thorough description is provided in D4.3, due M32.

The Risk Assessment Module within the D4RUNOFF's AI Assisted Platform is based on two internal submodules: the Data Processing Pipeline and the Risk Calculation Agent. While the former is aimed at preprocessing the different types of data used as input (e.g. rainfall data, land cover and land permeability data, digital elevation models), the latter is the core of the Risk Assessment Module.
The Risk Calculation Agent is composed by three main sequential blocks, coded in Python programming language, enabling a step-by-step calculation process: the Runoff block, the Pollution block, and the Risk block (see Figure 2 in D1.5). The risk maps will provide, on a regular georeferenced grid, the probability of exceeding specific pollutant-based risk thresholds (derived for instance from the pollutant's toxicity endpoints).

While the user will be able to access only the final risk maps, the Runoff and Pollution block yield intermediate outputs, like the expected runoff in millimetres and pollutant mass released by urban surfaces for each rainfall event on a regular latitude-longitude grid: these outputs are of interest for testing and validation purposes, as they can be compared with measurements. Quantitative comparisons with measurements will be conducted to: (i) quantify the discrepancy between model outputs and ground truth measurements, and (ii) refine the models through

dedicated techniques, including Machine Learning, within a continuous improvement loop, as mentioned in subsection 2.2.2 below. Furthermore, these intermediate outputs will be shared with D4RUNOFF partners to get further feedback for model improvement.
By implementing this approach, T5.2 will facilitate the evolution of the Risk Assessment Module methodologies from Version 1.0 to Version 2.0, achieving enhanced calibration for Odense and the other Case Study areas.

2.2.2 Implementation of the Risk Assessment Module

The implementation of the Risk Assessment Module – Version 1.0 and its methodology in Task 5.2 will entail two main actions: (i) the validation of the models, leveraging on the new on-site samplings and sensor measurements that will be carried out as part of this task and other WP5 activities, including T5.3 – Implementation of Online Sensors, and (ii) the involvement of stakeholders and entities from the other D4RUNOFF Case Studies in Santander, Spain and Pontedera, Italy. Both actions will contribute to the final Version 2.0 of the methodology.

Model validation will involve only the Runoff and Pollution blocks (see subsection 2.2.1), as the output risk maps are a function of these components. The validation of risk thresholds, which depend upon toxicity endpoints, is out of the scope of D4RUNOFF.

Both actions will be performed as part of feedback loops for continuous improvement, which will be applied on the each of the models of Runoff and Pollution block, with the following general structure:

- **Model improvement**: fine-tuning of the models using new data. This includes model parameter tuning, bias correction approaches, and any other update needed in the pipeline to better describe runoff and pollution dynamics; here we will also take into account feedback from stakeholders and project partners related to quality of the model predictions and their visualisation (Actions i and ii).
- **Model validation:** Validation of the models on the validation dataset, using metrices such as the Root Mean Square Error (RMSE), and storage of the results to track model improvement (Action i)

Action (ii) focuses on the engagement of local stakeholders (Odense case study) and D4RUNOFF partners (other case studies) to improve the output of the Risk Assessment Module to better satisfy the needs of potential users of the platform. These improvements will be incorporated into the module during the execution of T5.2. This will be performed through regular online meetings where T5.2 results and advancements will be presented to stakeholders to gather their feedback and insights. A final in-person joint workshop (date TBD, jointly with the final D4RUNOFF Open Day in Odense will be the last iteration of the continuous improvement loop. During the workshop, the final outputs of the Risk Assessment Module stakeholders and Open Day participants will be presented with to validate if they respond to user needs and enable any required final improvement during the last months of T5.2 and of the D4RUNOFF project, ensuring that the risk assessment methodology evolves into a robust and operationally relevant tool for urban runoff risk management.

2.2.2 Preparatory actions already performed

Several preparatory actions have already been carried out to support the implementation of the risk assessment methodology in T5.2. Historical rainfall data has been gathered from local sensors, provided by VCS, alongside reanalysis data from the ERA5Land reanalysis model (see Deliverable 1.5 for details). A comparative evaluation of total precipitation from ERA5Land against local measurements confirmed its suitability for rainfall-runoff assessments in Odense, as shown for instance in Figure 1 below.

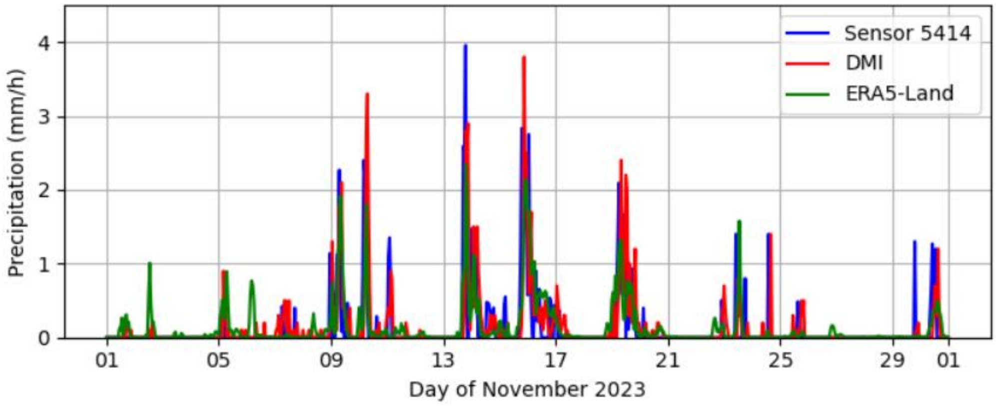


Figure 1 Comparison between hourly rainfall data from one station (Sensor 5414, courtesy of VCS), rainfall data provided by the Danish Meteorological Institute (DMI), and the total precipitation from the reanalysis model ERA5Land for November 2023; a more thoroug

Additionally, land cover data for Odense has been sourced from Basemap04 ([https://envs.au.dk/en/research-areas/society-environment-and-resources/land-use-and-gis/basemap,](https://envs.au.dk/en/research-areas/society-environment-and-resources/land-use-and-gis/basemap) Aarhus University), which serves as a key input for defining pollutant release dynamics based on the actual surface types found in the urban environment Figure 2.

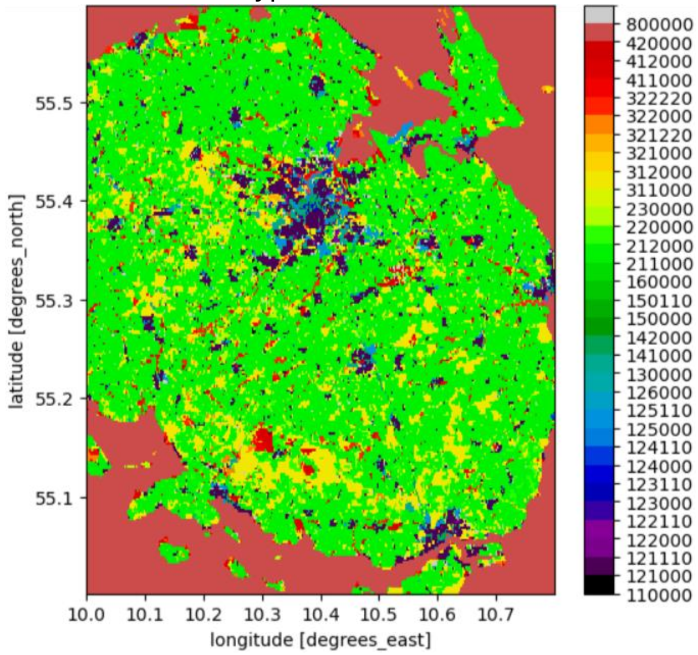


Figure 2 Land cover for the larger Odense area on the island of Funen, Denmark. Each colour corresponds to a different land surface type.

2.2.3 Next steps

The risk assessment and risk mapping methodology will be finalized in its Version 1.0 in M32. In parallel, communication will be established with the Odense Municipality, relevant local stakeholders, and Case Study owners to initiate the Action (ii) feedback loop as soon as the results of the Risk Assessment Module become available. Coordination with WP5 Leader VCS and project partners involved in on-site sampling, such as UCPH, GEUS, and INL, is already underway and will be further strengthened to ensure an efficient and streamlined implementation process.

2.3 Task 5.3: Implementation of Online Sensors

This section outlines the planned testing of the WP2 online monitoring platform. The composition and architecture of the online monitoring system developed in D4RUNOFF has been extensively described in D2.3, D2.4 and D2.5.

Figure 3 Images of the multi-analyte monitoring platform used for metals, microplastics and CECs detection (from deliverable 2.5).

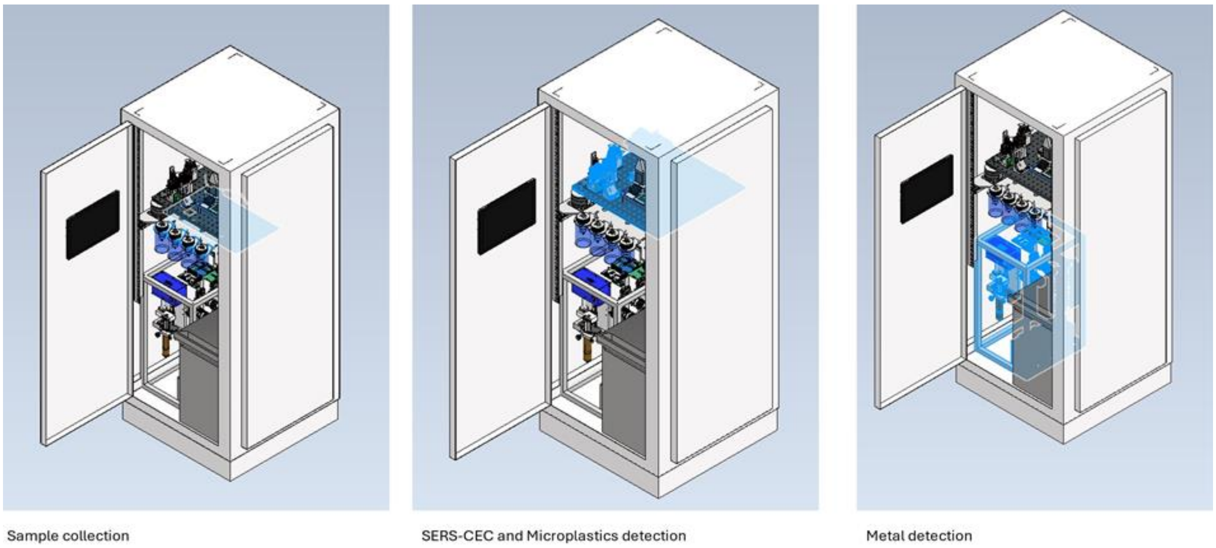


Figure 4 Scheme of the final multi-analyte monitoring platform, including sample collection, metals detection and detection of plastics and CECs.

The small microplastics and heavy metals detection systems are ready. However, the detection system for triazines and 6-ppd-quinone (CECs) is not ready to be implemented in the monitoring platform, at least for the first case study. We will continue working on this once the installation in Santander is finished and the case study is ongoing. The monitoring platform is prepared to implement them when available.
Although we cannot detect and quantify the concentration of these contaminants in real time for now, we are including in-line mini solid-phase extraction (miniSPE) cartridges based on the developed adsorbents (COFs) for triazines and 6-ppd-quinone. This will allow us to trap, pre-concentrate and analyse concentrations back in the laboratory; we will still get information on the concentrations our system should be able to detect in the rain events.

We tested the communication of our monitoring platform with WP4´s AI-Assisted platform. Several problems were identified and corrected. The integration of the entire system has been completed recently.
Today (middle of February 2025), validation of the whole monitoring system is ongoing: Aqualia provided water samples from 2 different locations. We are analysing the samples unspoked and spiked artificially with 2 levels of the target contaminants (triazines, 6-ppd-quinone and small microplastics). The levels are being decided based on the basal concentration in the sample. The counter-analysis is performed by external laboratories contacted by Aqualia while we analyse the samples using INL's monitoring system and in-house analytical methods. Some adaptations of the system (filters, tubing, flows) are being performed based on the complexity of the natural samples received (particularly the ones from Santander, being mostly untreated wastewater, seems to be the most challenging).

Finally, the installation of the monitoring platform in the first case study (Santander) is expected to be completed in the first half of March 2025.

2.4 Task 5.4: AI-Assisted Platform Implementation

The objective of task T5.4 of the D4RUNOFF project is the implementation of the AI-Assisted platform, which is being developed within WP4, at the three demo sites of the project: Odense (Denmark), Santander (Spain), and Pontedera (Italy). This implementation aims to test and validate the functionality and operation of the AI-Assisted platform in real-world environments.

The initial phase of T5.4 has focused on preparatory activities, primarily analysing the available information and data at each pilot site which will later feed the AI-Assisted platform. Additional activities have been developed to verify the connection between sensors and the platform, as well as ensuring the proper storage of data and information generated within D4RUNOFF. Once the development of the AI-Assisted platform is completed within WP4 (expected between M30-M32), task T5.4 will move into a new phase focused on the actual deployment of the platform at the three demo sites.

The following sections of Deliverable D5.1 will describe the preparatory activities carried out so far in task T5.4 for the implementation of the AI-Assisted platform, as well as an overview of preliminary testing and validation activities.

2.4.1 AI-Assisted platform operation

The AI-Assisted Urban Runoff Management platform is being developed within WP4 of the D4RUNOFF project as a web-based GIS tool designed to support urban runoff and stormwater management. The platform will integrate data from online sensors, AI-based models, results from numerical models, external databases, and GIS-based tools, enabling advanced analysis and decision-making processes for different types of users: 1) policymakers, 2) technical operators, 3) the scientific community, and 4) civil society and citizens.

One of the platform's key strengths is its ability to unify and process data from various sources, serving as a digital environment that centralizes information and modelling results generated throughout the project. Specifically, it integrates:

- The characterization of urban runoff pollutants developed within WP1.
- Data collected by novel sensors developed within WP2, including measurements of CECs and other pollutants.
- Tools and methodologies from WP3, such as the NBS Library, preliminary design calculations, and GIS-based MCDA (Multi-Criteria Decision Analysis)
- Information from the three pilot sites, used for testing and validation within WP5.
- Tools for raising citizen awareness about urban runoff issues through Serious Games and increasing their engagement with the project. These tools will be used within WP6 for project dissemination.

Figure 5 presents a diagram summarizing the main components and the planned operation of the AI-Assisted platform in the three demo sites of the D4RUNOFF project. Its operation is based on the information and data available at the pilot sites, which serve as inputs to the platform. The platform can receive real-time data from online sensors or external sources, as well as storing the information in a structured and organized manner for further processing and deployment.

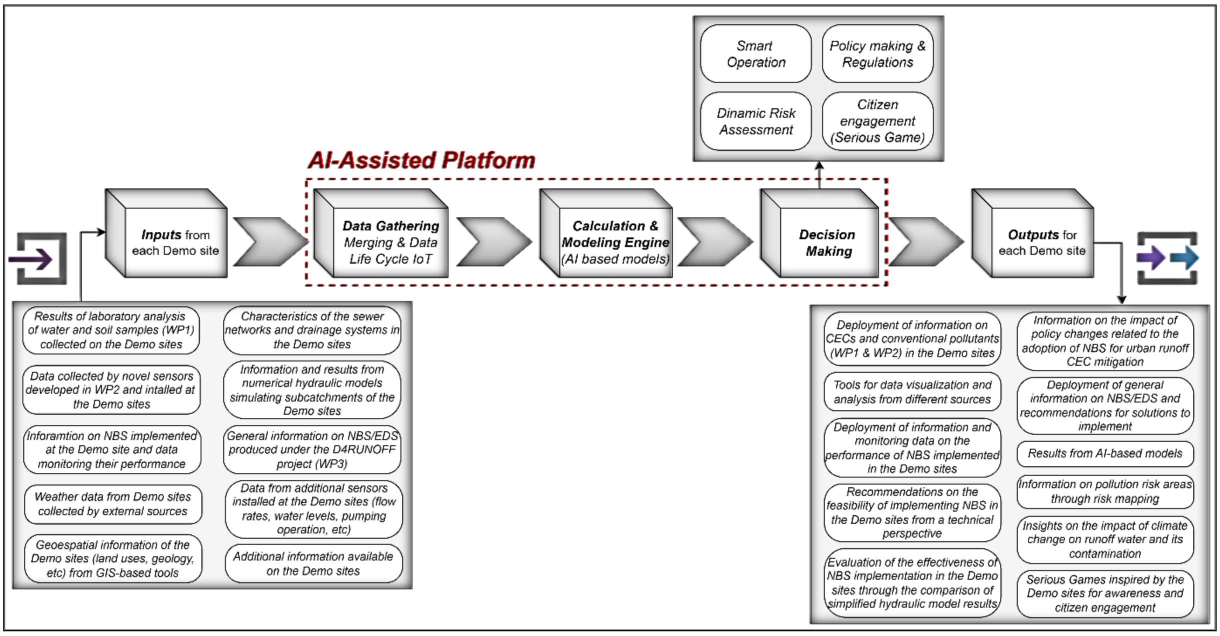


Figure 5 Diagram of the main components integrating the AI-Assisted platform and its operation in the project's demo sites, covering from the input data used to the outputs produced.

The operation of the AI-Assisted platform is based on three core components:

1) Data Gathering, Merging and Data Life Cycle Support. This part of the AI-Assisted platform is responsible for gathering and managing data from IoT and non-IoT sensors, external web services, and other relevant sources. Data processing includes cleaning, merging, and structuring the information to ensure its usability.

2) Calculation and Modelling Engine. This component of the platform supports calculations, analyses, and modelling activities within the project based on the available data and information.

3) Decision Making. This part of the AI-Assisted platform integrates different components/modules to facilitate decision making in developing effective urban runoff and stormwater management plans and implementing NBS. The decision-making block was conceptualized in four dimensions: Smart operation functional module, Dynamic risk mapping functional module, Policy and regulation, and Citizen engagement.

The AI-Assisted platform has been designed to operate through dedicated workspaces, one for each demo site, where information, available data, and generated results will be stored, calculated and displayed. After the collection, storage, and processing of data and information from each pilot site through the Data Gathering and Calculation Engine modules, the platform will produce results to support decision-making from different perspectives. Below is a list of some of the outputs that will be generated and deployed in each of the three demo sites once the AI-Assisted platform is fully implemented:

- Deployment of information on CECs and conventional pollutants (WP1 and WP2) in the demo sites.

- Deployment of general information on Nature Based Solutions (NBS) and Engineering Drainage Systems (EDS) and recommendations for solutions to implement.
- Deployment of information and monitoring data on the performance of NBS implemented in the demo sites.
- Recommendations on the feasibility of implementing NBS in the demo sites from a technical perspective.
- Information on the impact of policy changes related to the adoption of NBS for urban runoff CEC mitigation.
- Evaluation of the effectiveness of NBS implementation in the demo sites through the comparison of simplified hydraulic model results.
- Results from AI-based models.
- Information on pollution risk areas through risk mapping.
- Tools for data visualization and analysis from different sources.
- Serious Games inspired by the demo sites for awareness and citizen engagement.
- Insights on the impact of climate change on runoff water and its contamination.

2.4.2 Preparatory actions for platform implementation in case studies

The implementation of the AI-Assisted platform in the demo sites of the project and its proper functioning depend on the availability of information and data at each site. So far, the work within task T5.4 has focused on preparatory activities, analysing the three demo sites and assessing the available data. The following sections describe the preparatory activities carried out at each demo site.

2.4.2 Odense Case Study (Denmark)

2.4.2.1.1 Spatial domain definition

The operation of the AI-Assisted platform in a specific location requires the initial definition of a spatial domain that encompasses the study area, where the various elements of the case study will be positioned (e.g., NBS and drainage systems, sewer network, wastewater treatment plants (WWTP), sensors, sample locations, etc.). As an initial step toward the future implementation of the AI-Assisted platform at the Danish demo site, a spatial domain has been defined, covering the entire municipality of Odense, with an area of approximately 304 km^2. Figure 6 shows the location of the Danish demo site, highlighting the municipal boundary of Odense, which serves as the defined spatial domain for its implementation in the AI-Assisted platform.
The platform was developed within WP4 to ensure that the spatial domain of study areas can be uploaded via a specific file format (GeoJSON), which includes both geometry and additional information about the site.

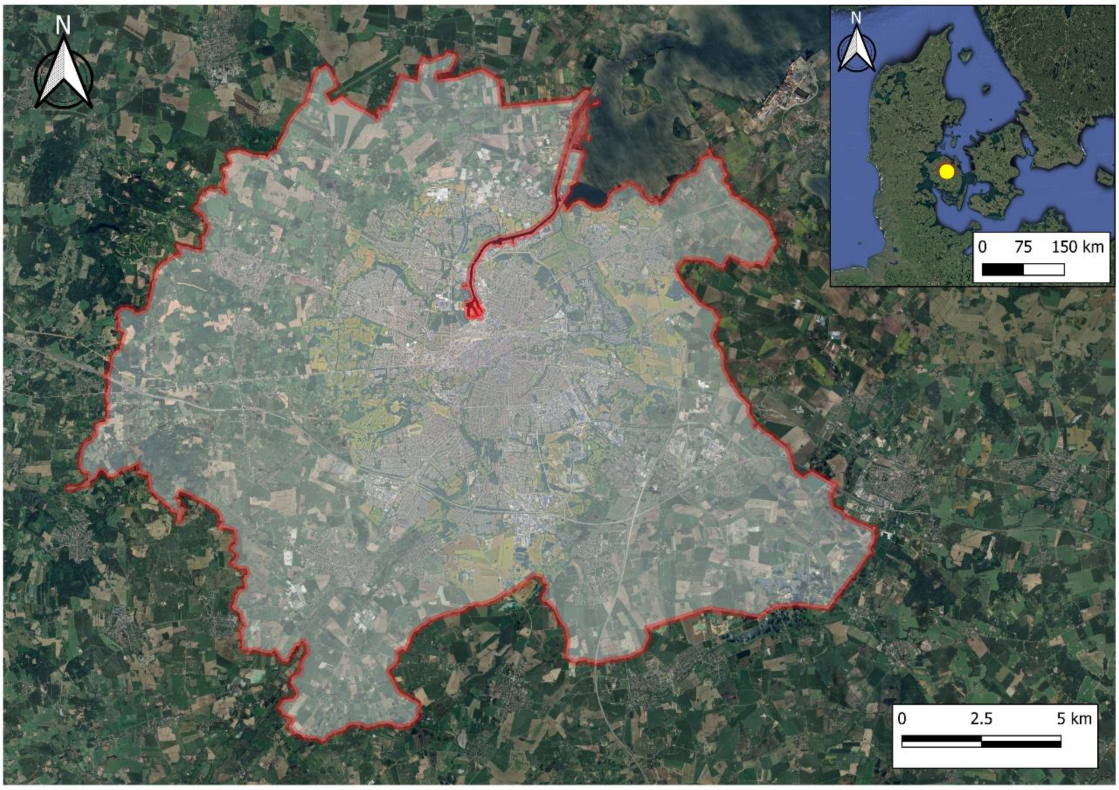


Figure 6 Location of the Danish demo site of the D4RUNOFF project, highlighting the municipal boundary of Odense, which defines the spatial domain in the current phase of the project for its implementation in the AI-Assisted platform.

2.4.2.1.2 Combined sewer network evaluation

In the context of urban runoff pollution and water management, which is the focus of the D4RUNOFF project, sewer networks play a key role. For this reason, the AI-Assisted platform has been designed to store geospatial information and the characteristics of the main elements that make up the sanitation infrastructure in the different case studies. As part of the preparatory tasks for task T5.4, detailed analysis has been conducted on the information provided by the partner responsible for the site (VCS) regarding the sanitation infrastructure of the Danish demo site.

Odense is Denmark's third-largest city, with a sanitation infrastructure capable of transporting and treating wastewater generated by a population of approximately 200,000 inhabitants. The sewer network includes both combined sewer systems and separate sewer systems in different areas of the city. Figure 7 presents a land use map of the municipality of Odense. The water collected by the sanitation infrastructure in the Danish pilot site primarily originates from residential areas and, to a lesser extent, from activities in the tertiary sector.

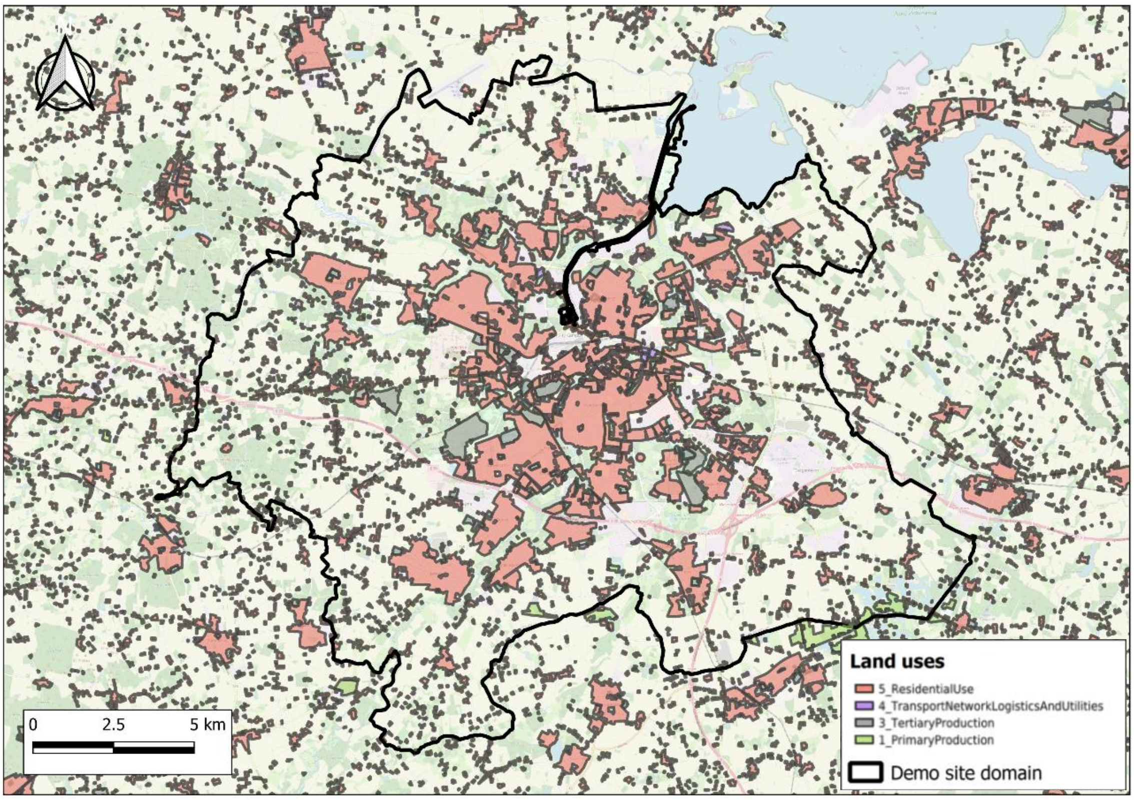


Figure 7 Land use within the spatial domain of the Danish demo site defined in the AI-Assisted platform. The water collected by the sanitation infrastructure in the study area mainly originates from residential areas (red zones) and, to a lesser extent, from activities in the tertiary sector (grey zones).

For the implementation and evaluation of the performance of the sanitation infrastructure within the AI-Assisted platform, five types of elements constitute the main components of the sewer network of Odense: manholes, pipes, pumping stations, spill points, and WWTP. A specific GIS database has been prepared during the preparatory activities of task 5.4 as a starting point for its subsequent upload to the platform. As the sanitary infrastructure of Odense is of considerable size, future phases of task T5.4 will determine whether to upload information for the entire system into the platform or to focus on specific areas where project-specific data is generated within D4RUNOFF, and urban runoff will be evaluated. Figure 8 presents the spatial distribution of the different elements that make up the sewer network in the Danish demo site, as visualized in the prepared GIS database.

The sewer system of Odense has been examined to facilitate its seamless incorporation into the AI-Assisted platform upon completion of its development, as outlined in Section 4.3.3 of Deliverable D4.2 within WP4 of the project. Data on the infrastructure can be integrated into the platform either through individual uploads, element by element, or via bulk imports using standardized GeoJSON files that ensure compatibility with the system. This analysis aims to confirm that the platform's architecture supports the accurate storage and management of the diverse components comprising the sewer network in the Danish demo site.

The available data on the sewer network of Odense includes more than 1,500 km of installed pipelines, with most of the pipes (over 80%) having a circular cross-section. The majority of the pipes have a diameter of less than 1 m, although larger-diameter pipes (>1.2 m) are also present in smaller quantities. The water is transported to three WWTPs for treatment, requiring 158 pumping stations to lift the water and reach its destination. The three main wastewater treatment plants in Odense are Ejby Mølle Renseanlæg, Nordvest Renseanlæg, and Nordøst Renseanlæg. The first of these has a capacity of 385,000 PE and serves as a model of efficiency and sustainability in wastewater treatment, combining technology, optimization, and resource recovery to generate clean energy and reduce its environmental impact.

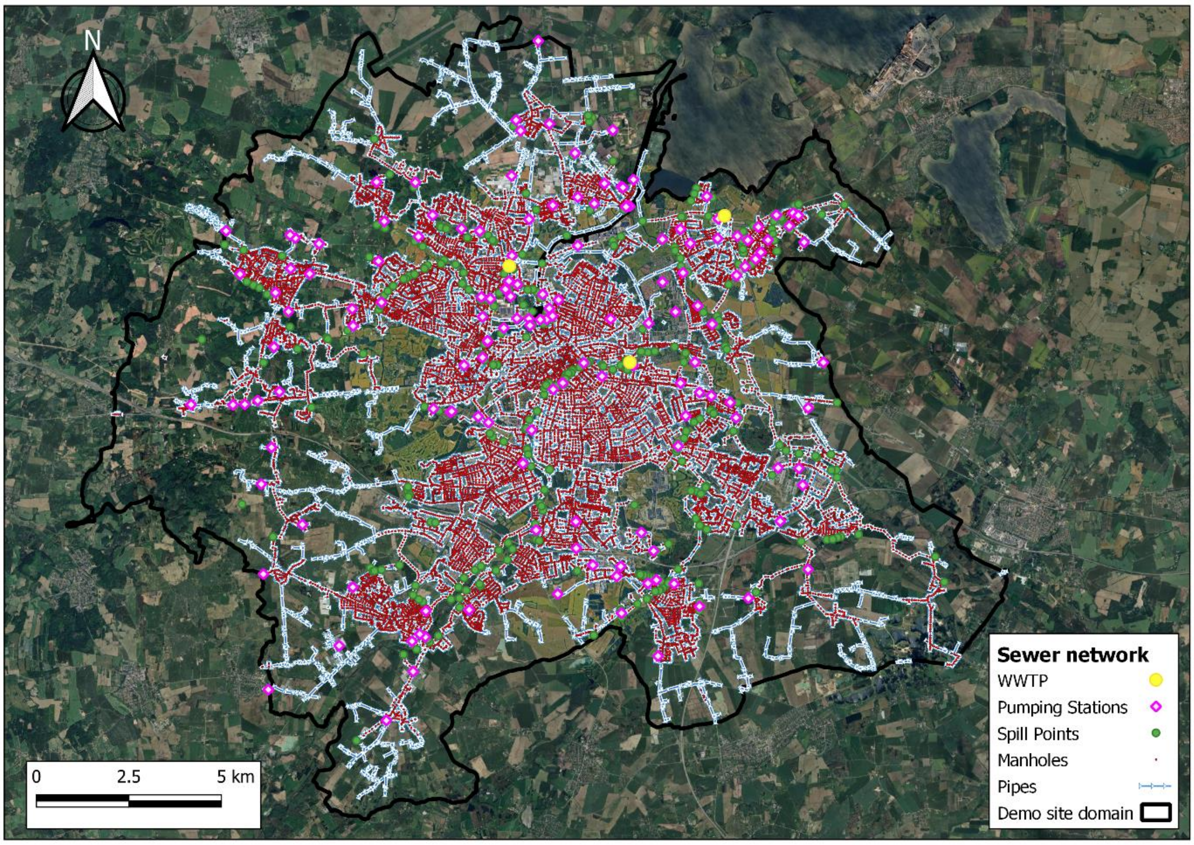


Figure 8 Spatial distribution of the sewer network in the Danish demo site, highlighting the main components that constitute it and will be integrated into the AI-Assisted platform.

2.4.2.1.3 NBS evaluation

The AI-Assisted platform has been designed to store information about NBS implemented at the pilot sites, contributing to urban runoff management alongside conventional infrastructure, and to serve as a monitoring tool for the performance of specific NBS equipped with sensors. Preparatory activities carried out within task T5.4 regarding the installed NBS at the three demo sites indicated that the Danish pilot has the highest number of operational NBS. For example, more than 20 stormwater basins and over 50 rain gardens have been implemented in Odense. However, despite their large number, the vast majority of NBS at the Danish demo site either lack monitoring systems or have only limited sensors for operational control.

Within the D4RUNOFF project and the AI-Assisted platform, implementation and validation efforts will focus on proposed NBS options to be considered for the Danish demo site in Odense: a sustainable drainage system in Helsingborggade and two water basins in

Trykstokken and Risingsvej. Figure 9 shows the locations of the three proposed NBS that will be evaluated within the AI-Assisted platform at the Danish demo site. In future phases of task T5.4, detailed information about the chosen NBS will be integrated into the platform, including their characteristics, operational data, and available measured data for further analysis and evaluation.

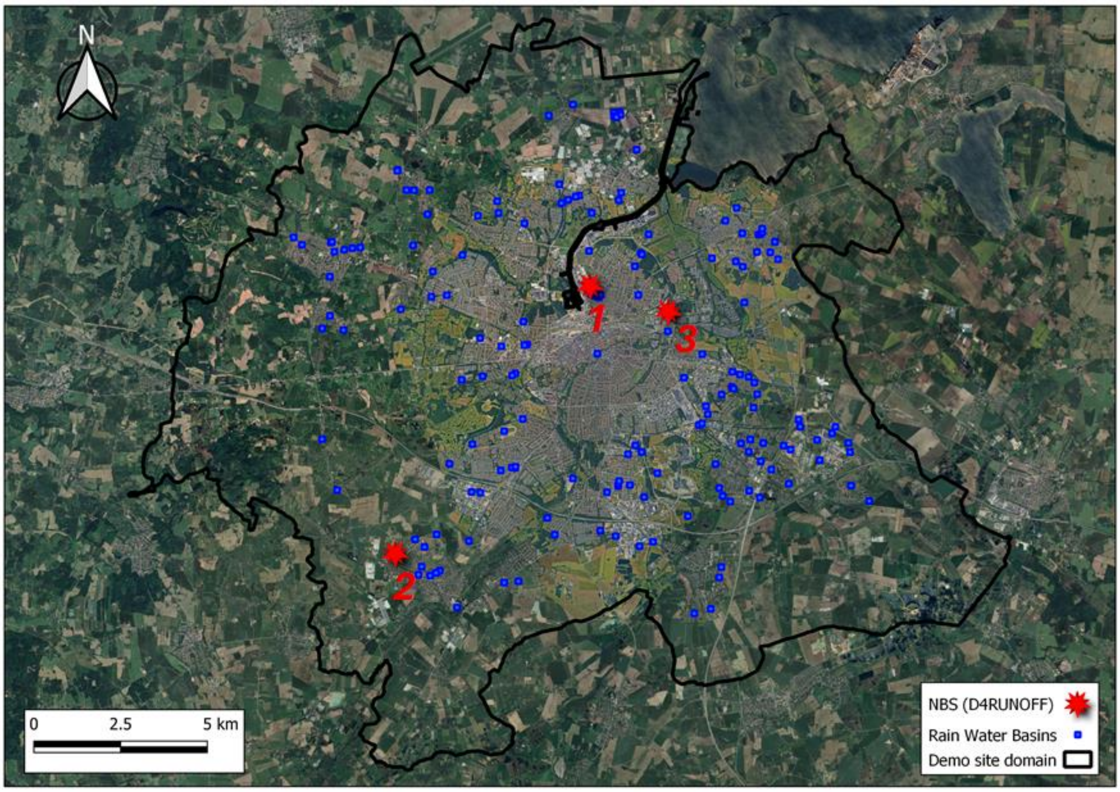


Figure 9 Location of the rainwater basins in the municipality of Odense, along with the proposed locations of the three main NBS selected for implementation and validation within the AI-Assisted platform: (1) a sustainable drainage system in Helsingborggade and two water basins in Trykstokken (2) and Risingsvej (3).

2.4.2.1.4 GIS-based tools identification

The D4RUNOFF platform is being developed as a web-based GIS tool designed to integrate external data sources, enriching the specific project-generated information with broader contextual insights. As part of the preparatory work for task T5.4, multiple data providers relevant to the Danish demo site have been identified, with the potential to be incorporated into the platform through WMS (Web Map Service) or similar integration methods.

These external sources offer valuable datasets, including digital terrain models, geological and hydrogeological information, slope analysis, orthophotos, or hydrographic data. The AI-Assisted platform is built to support a variety of base maps, allowing customization based on user preferences while displaying spatial distributions of key project data. This approach enhances geospatial analysis and overall understanding of the site. Figure 10 presents examples of maps from external sources available for incorporation into the AI-Assisted platform, offering contextual information on terrain elevation, hydrogeology, hydrology, and water hardness levels.

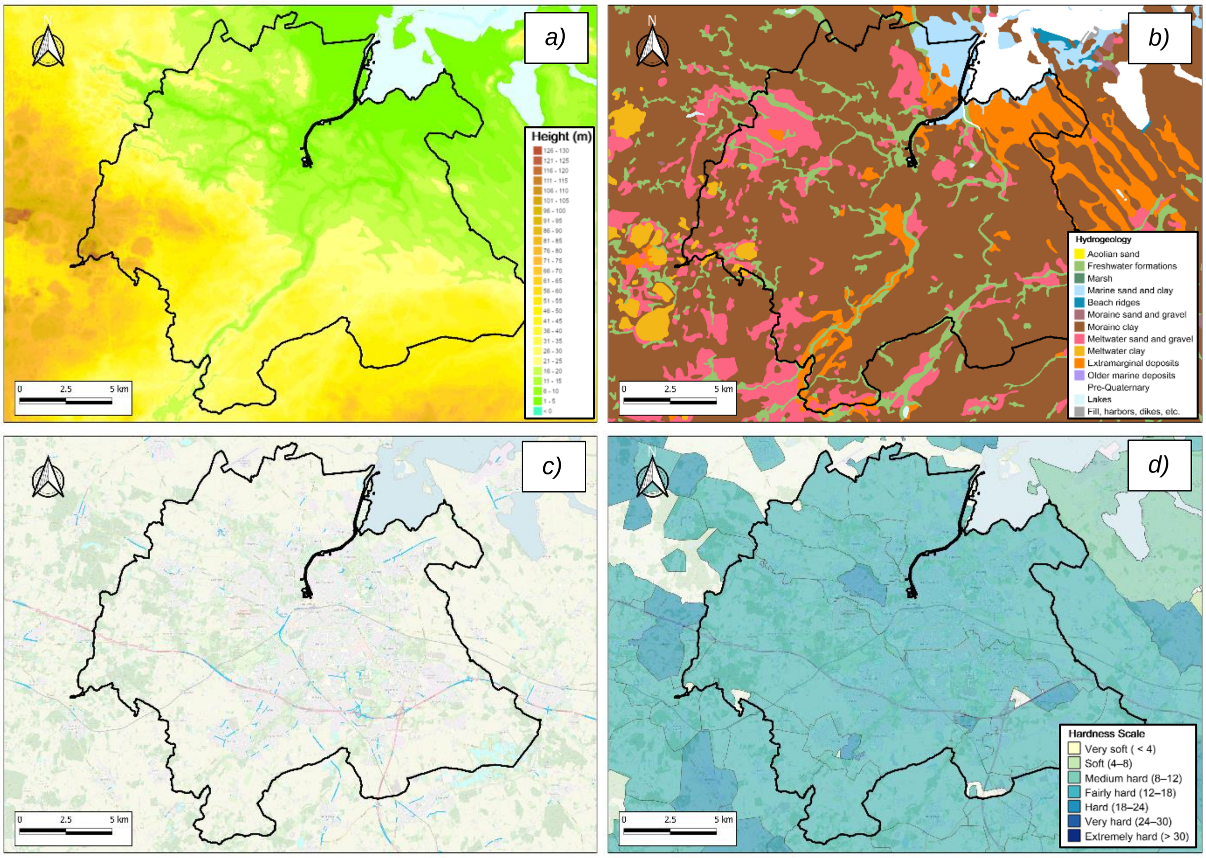


Figure 10 Example of external GIS data sources available for integration into the AI-Assisted platform, providing contextual information for the Danish demo site: (a) Terrain elevation (Digital Elevation Model), (b) Hydrogeology, (c) Hydrology, and (d) Water hardness levels.

2.4.2.1.5 Preliminary analysis of available data

The operation of the AI-Assisted platform being developed within the D4RUNOFF project relies on data collected from sensors installed at the pilot sites or obtained from external sources. These data play a crucial role in its function as a Decision Support System (DSS) being designed to receive and process data in real-time from both sensors and external providers.

As part of the preparatory activities for task T5.4, external monitoring sensors operating at the Danish demo site have been identified as potential data sources for integration into the AI-Assisted platform. One of the key external data providers is the Danish Meteorological Institute (DMI), which supplies weather forecasts, climate monitoring, and meteorological, oceanographic, and atmospheric studies.

For the Odense area, the DMI provides both historical meteorological data and forecast models relevant to the D4RUNOFF project, including precipitation, temperature, humidity, and other parameters. A particularly critical component for the project and the efficient operation of the AI-Assisted platform is the availability of high-frequency precipitation data, as these measurements are essential for assessing runoff generation caused by rainfall events of varying intensities and their correlation with key pollution indicators. High-quality, high-frequency precipitation data are already available in Odense through the partner responsible for the Danish pilot site. However, additional precipitation and meteorological data can be integrated into the platform via the services provided by the DMI.

In this context, the DMI offers precipitation data recorded at different time intervals in Odense. Figure 11 presents an example of precipitation data measured every hour between January 2024 and February 2025, which can be incorporated into the platform and utilized for developing numerical and AI-based models for the Danish demo site.

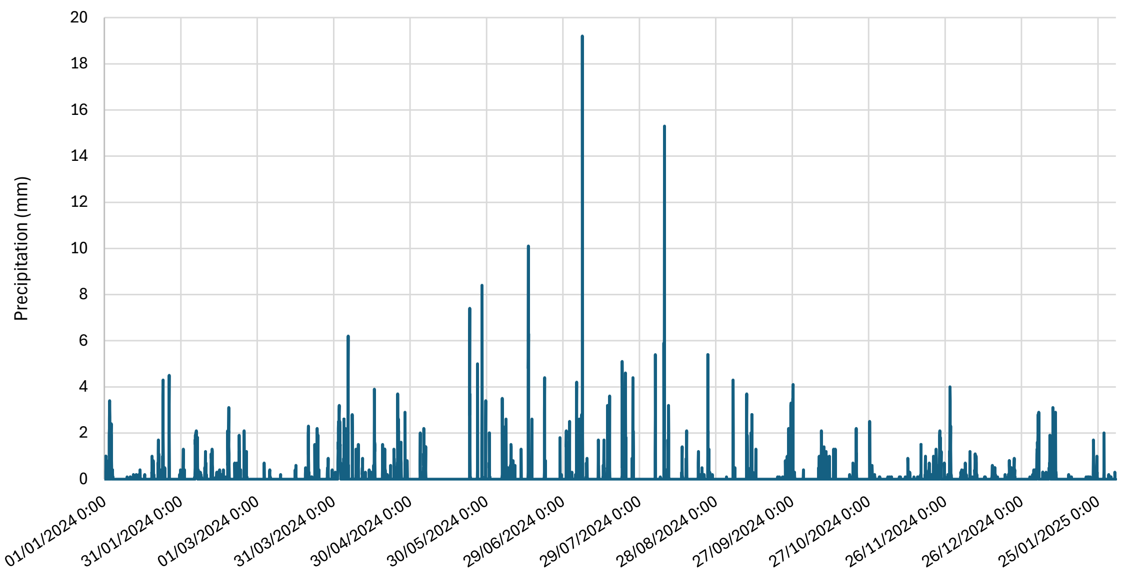


Figure 11 Example of 1-hour interval precipitation data recorded in the vicinity of Odense between January 2024 and February 2025. Rainfall datasets will be integrated into the AI-Assisted platform and used for numerical and AI-based model development within the Danish demo site.

2.4.2 Santander Case Study (Spain)

2.4.2.2.1 Spatial domain definition

Defining the spatial domain constituted the first activity within the preparatory activities to kick off the Santander case study, as it establishes the area of interest for the rest of activities to be performed in the platform such as data storage, analysis and result generation.
In the case of Santander, the whole municipality, which covers 36 km² is considered. To use these boundaries in the platform, GeoJSON files were elaborated and uploading to the platform incorporating other relevant data such as the population in this area.

Figure 12 depicts the location of the Spanish demo site, being highlighted in red the municipal boundary of Santander and its location in the north of the Iberian Peninsula.

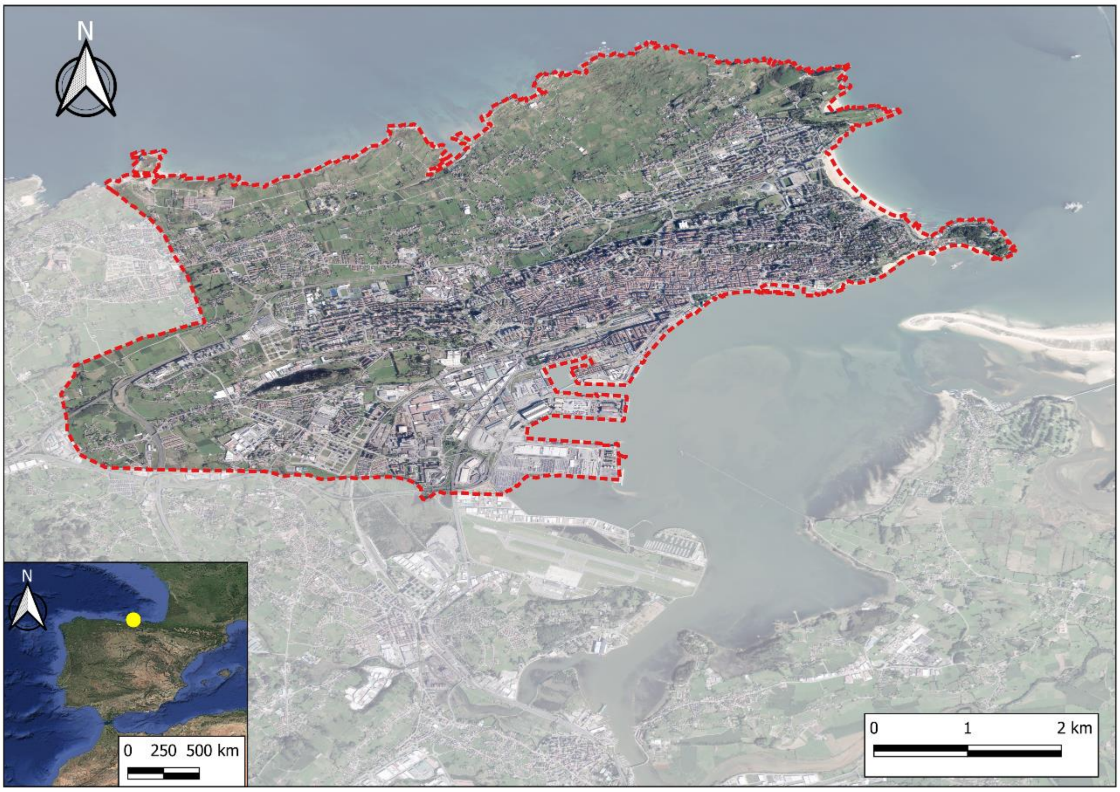


Figure 12 Location of the Spanish demo site of the D4RUNOFF project, highlighting the municipal boundary of Cantabria (red dashed line) along with the spatial domain defined in the current phase of the project for its implementation in the AI-Assisted platform.

2.4.2.2.2 Combined sewer network evaluation

To implementing the AI-Assisted platform at the Spanish demo site, the information on the sewer system within the Santander area is of paramount relevance to better understand the current infrastructure which is being used to manage urban runoff.
The information on which the subsequent analysis of the wastewater and drainage infrastructure of Santander is based has been supplied by the lead partner for the case study (AQUALIA). The initial understanding of this information has been the main target for the work undertaken during the initial phase of T5.4.

As detailed below, Santander global water cycle counts with a hybrid system which comprises two types of NBS, a wetland in “Las Llamas” and a permeable pavement parking lot close to it. Additionally, a traditional system consisting of several pumping stations that convey water towards the wastewater treatment plant, which discharges the treated effluent into the Cantabrian Sea is also present. As depicted by Figure 13 , the collected water comes mainly from urban areas and commercial and industrial units. The current challenges faced by the system are mainly connected with the risk of its collapse due to water runoff and stormwater overflows incidents when combined sewer overflows may occur.

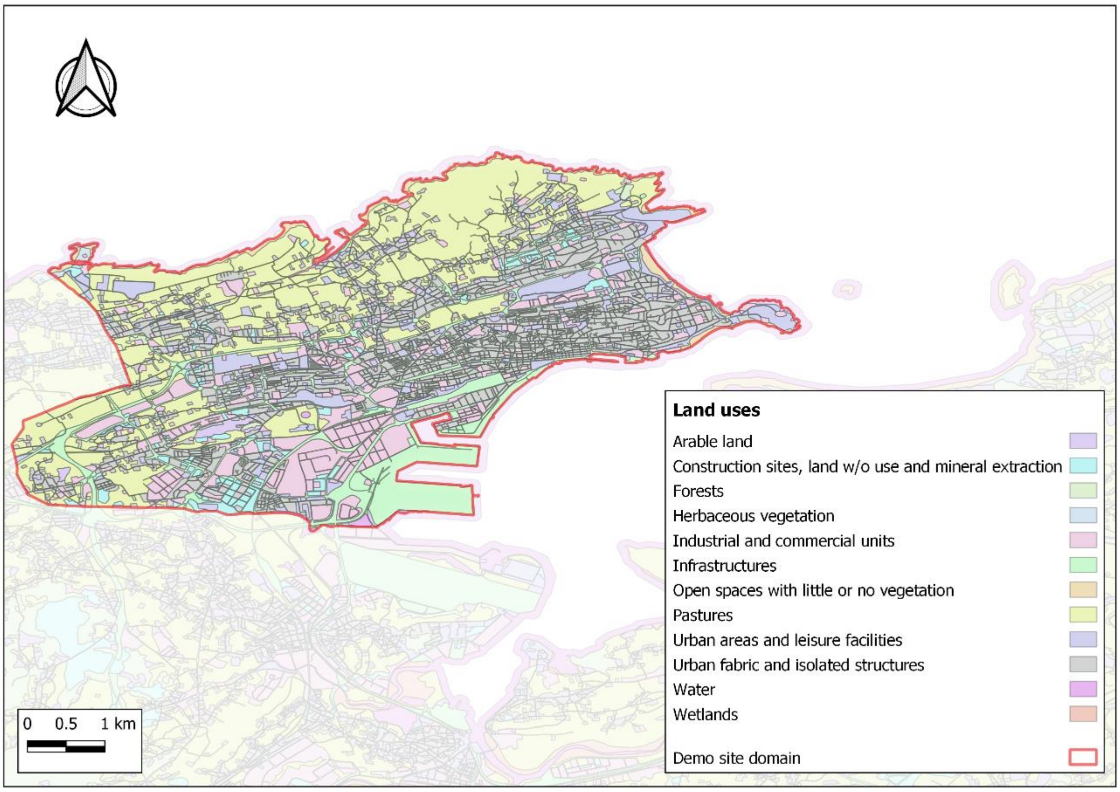


Figure 13 Land use within the spatial domain of the Spanish demo site defined in the AI-Assisted platform. The water collected by the sanitation infrastructure in the study area comes mainly from urban areas (gray zones).

For the setup and assessment of the sanitation infrastructure within the AI-Assisted platform, six types of elements constitute the main components of the Combined Sewer Network (CSN) of Santander: manholes, pipes, pumping stations, spill points, storm tanks and the WWTP. A database has been prepared during the activities of task 5.4 to be developed during the subsequent stages in which it will be uploaded to the platform. It is noteworthy that the current information does not cover all the study area. Thus, the figures included in this preliminary analysis may differ to the ones that are finally implemented.

The part of the network studied comprises more than 100 km of pipelines assuming a part of the overall sanitation of the city. In their majority, they convey combined wastewater. Over 90% of these conducts have a circular cross-section, around 3% have an ovoid profile, and the remaining percentage is not reported. The main material for pipes is concrete, followed by plastic materials (PVC)... Most of the network consists of medium-sized diameters (200–800 mm), with large-diameter pipelines (>1000 mm) being relatively scarce, although general collectors have larger diameters: the recently built "Saneamiento de la Bahía de Santander" interceptor collector in the southern basin has a variable diameter between 800 and 2000 mm. The Saneamiento de la Vagoada de las Llamas includes a pumping station from which the water is pumped to a general collector with a diameter of 1200 mm that reaches the San Román WWTP, The Cueto - Monte main collector in the North basin has a diameter of 600 mm, and finally the General Collector Barrio de San Martín - 1st of May - Ría de Raos has two 1,200 mm pipes.

Figure 14 presents the spatial distribution of the different elements that make up the CSN in the Spanish demo site, as visualized in the prepared GIS database.

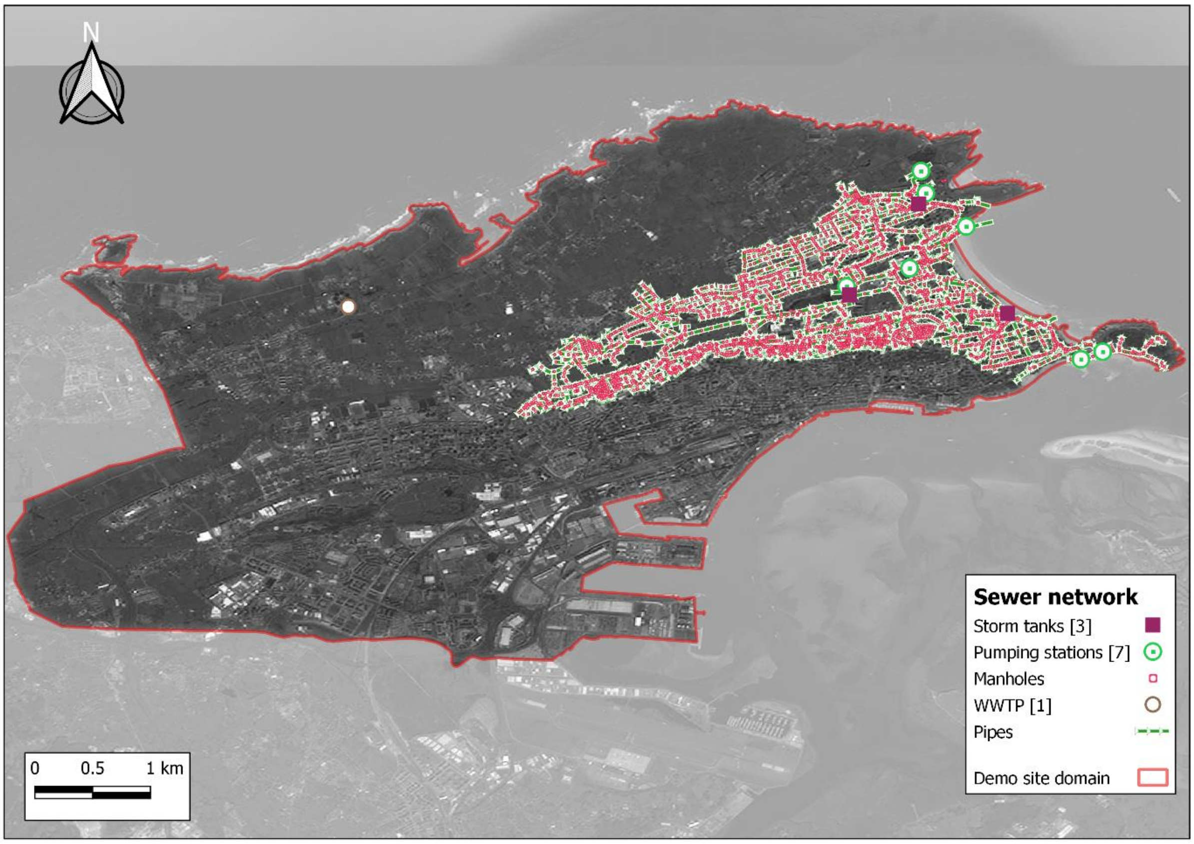


Figure 14 Spatial distribution of the combined sewer network in the Spanish demo site, highlighting the main components that constitute it and will be integrated into the AI-Assisted platform.

2.4.2.2.3 NBS evaluation

With the aim of contributing to urban runoff management together with the traditional systems, the AI-Assisted platform includes also in its design the ability to store information regarding the NBS implemented at demo sites.

Thus, it intends to serve as a tool to monitor the performance of specific NBS equipped with sensors. In the frame of the activities undergone within T5.4, the two systems located in Santander, a wetland and a permeable pavement car park, have been identified. Integrating new IoT sensors to gather critical data on specific CECs is the primary challenge, as it will improve monitoring, modelling, and decision-making processes.

Figure 15 illustrates, a monitoring point has been initially identified in the wetland, while 4 locations near the implemented NBS and collecting specific streams from other areas in the city are as well indicated.

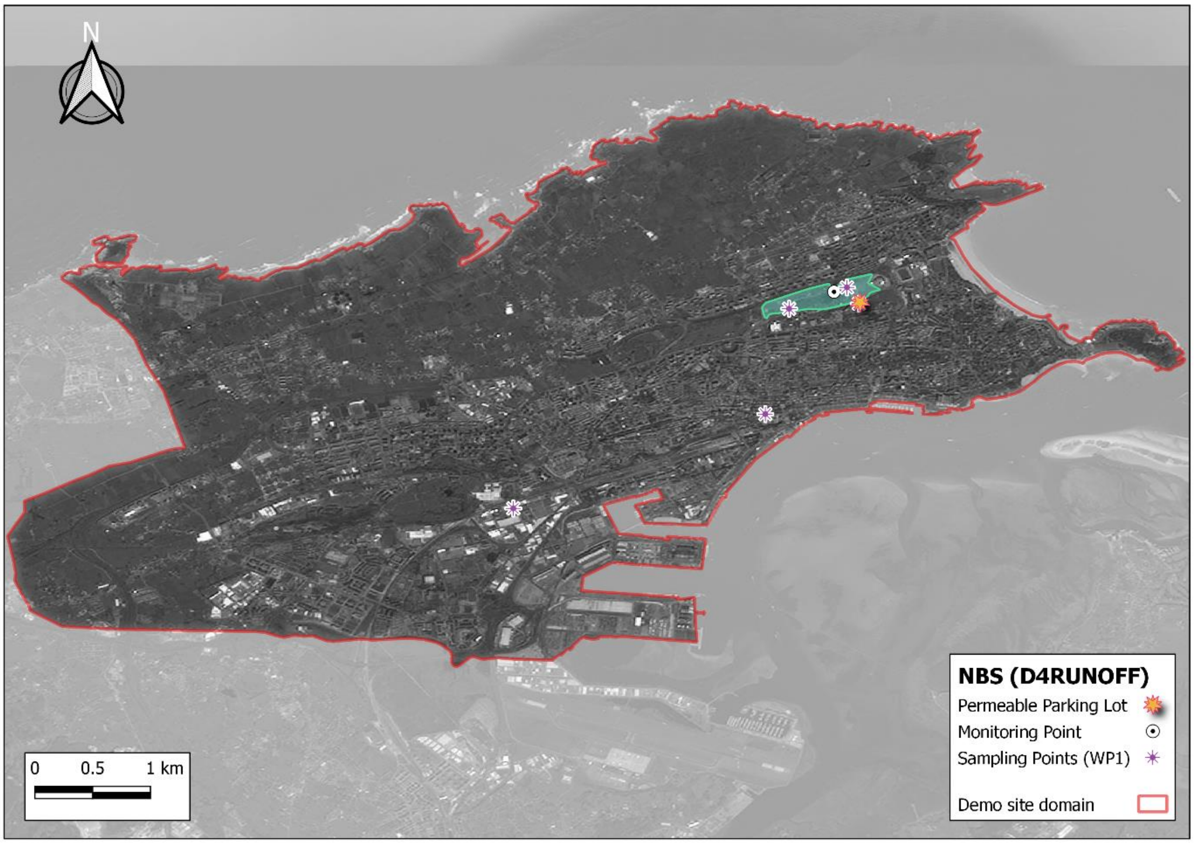


Figure 15 NBS considered in the spatial domain of the Spanish demo site to be defined in the AI-Assisted platform together with the sampling points and location for monitoring CECs. Due to the different scales, the permeable parking lot is represented by a point

2.4.2.2.4 GIS-based tools identification

The AI-Assisted platform is a web-based GIS tool capable of connecting relevant information used to contextualize data and results derived from project actions. For this reason, some external sources have been identified during T5.4 as potential data providers for the Spanish demo site. They are provided as OGC (Open Geospatial Consortium) compliant services, mainly through WMS (Web Map Service), which allows smooth integration within the system.

More specifically, the identified sources offer information on hydrography, edaphology, permeability and terrain, among others, besides the basic contextual base layers such as orthophotos and street maps.

Figure 16 includes some examples of these external sources available to be incorporated into the AI-assisted platform.

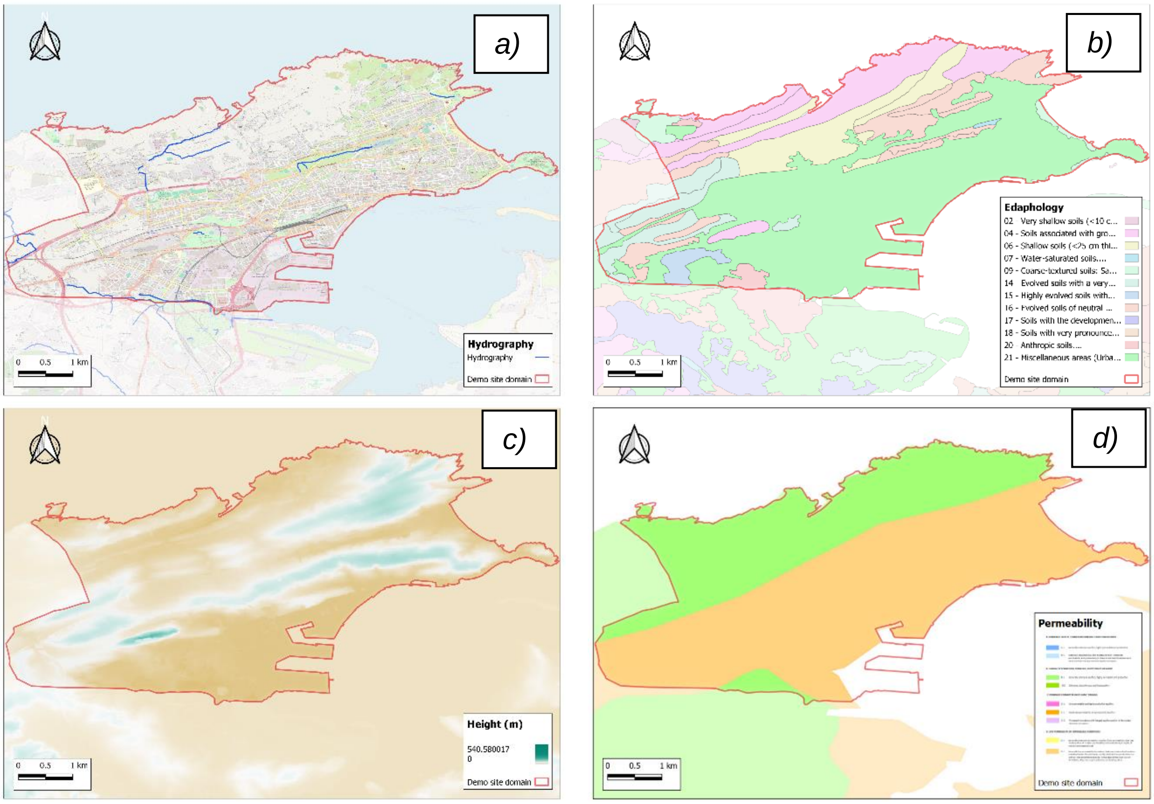


Figure 16 Example of external GIS data sources available for integration into the AI-Assisted platform, providing contextual information for the Spanish demo site: (a) Hydrography, (b) Edaphology, (c) Terrain elevation (Digital Elevation Model), and (d) Soil permeability types.

2.4.2.2.5 Preliminary analysis of available data

For the AI-Assisted platform being a Decision Support System (DSS), the integration of data from different sources (both project-related sensors and external providers) plays a key role in having up-to-date measurements that furnish a snapshot of the current situation or even forecast, for example, in the case of weather information.

As part of the preparation described in this document and framed in task T5.4, the main external data provider identified is the State Meteorological Agency of Spain (AEMET) which provides amongst its services observed and predicted data for topics such as weather forecasting, climate monitoring, supporting studies for water balances or meteorological drought.

In the Santander municipality, AEMET offers information for the purposes of D4RUNOFF project, both in terms of predicted data, at municipality level, and observed data. Two automatic weather stations are located near the area, as shown in Figure 17.

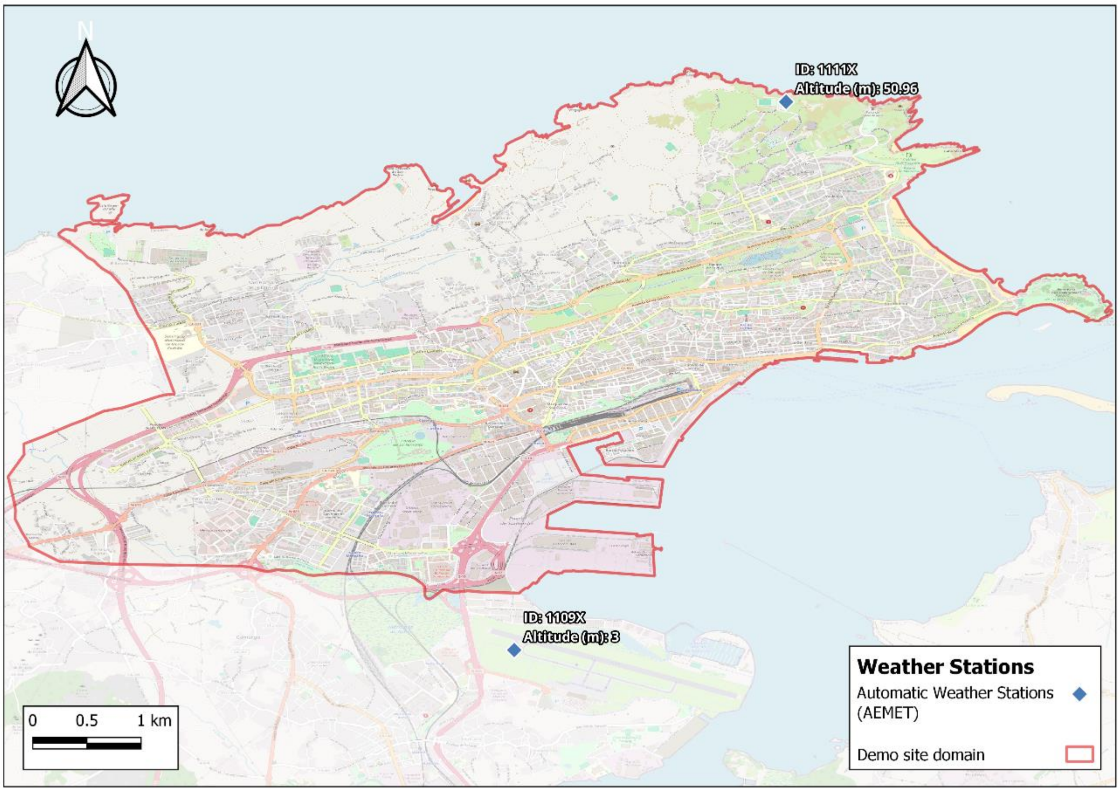
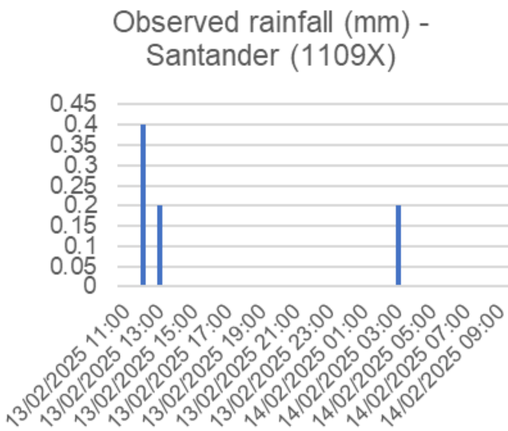


Figure 17 Location of the Automatic Weather Stations in the domain of Santander. Main parameters observed: temperature, wind velocity, rainfall or humidity.

Rainfall data constitutes one of the parameters of superior interest for the purposes of the project. In this preliminary analysis, the available data for it has been assessed, both to determine the granularity of data, which is 1-hour sampling-frequency based and the observed differences between both locations regarding the observed values, as depicted in Figure 18. This data can be integrated into the platform and utilized for developing numerical and AI-based models for the Spanish demo site.



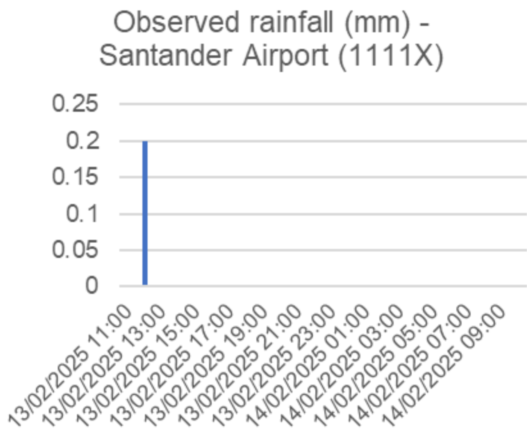


Figure 18 Example of 1-hour interval precipitation data recorded at Santander weather stations.

2.4.2 Pontedera Case Study (Spain)

2.4.2.3.1 Spatial domain definition

The preparatory activities of task T5.4 for the Pontedera case study in Italy began with defining the spatial domain that will serve as the focus for data storage, analysis, and result generation within the AI-Assisted platform.

While the municipality of Pontedera covers approximately 46 km^2, the case study is concentrated in its most urbanized area. For this reason, the domain of the Italian demo site was defined as a smaller area, focusing on the urban zone where urban runoff and pollution are being assessed within D4RUNOFF project. GeoJSON files were prepared in a predefined format for uploading to the AI-Assisted platform, including not only geometry but also relevant information about the study area, such as the associated population.

Figure 19 shows the location of the Italian demo site, highlighting the municipal boundary of Pontedera and the preliminary spatial domain defined for its implementation in the platform.

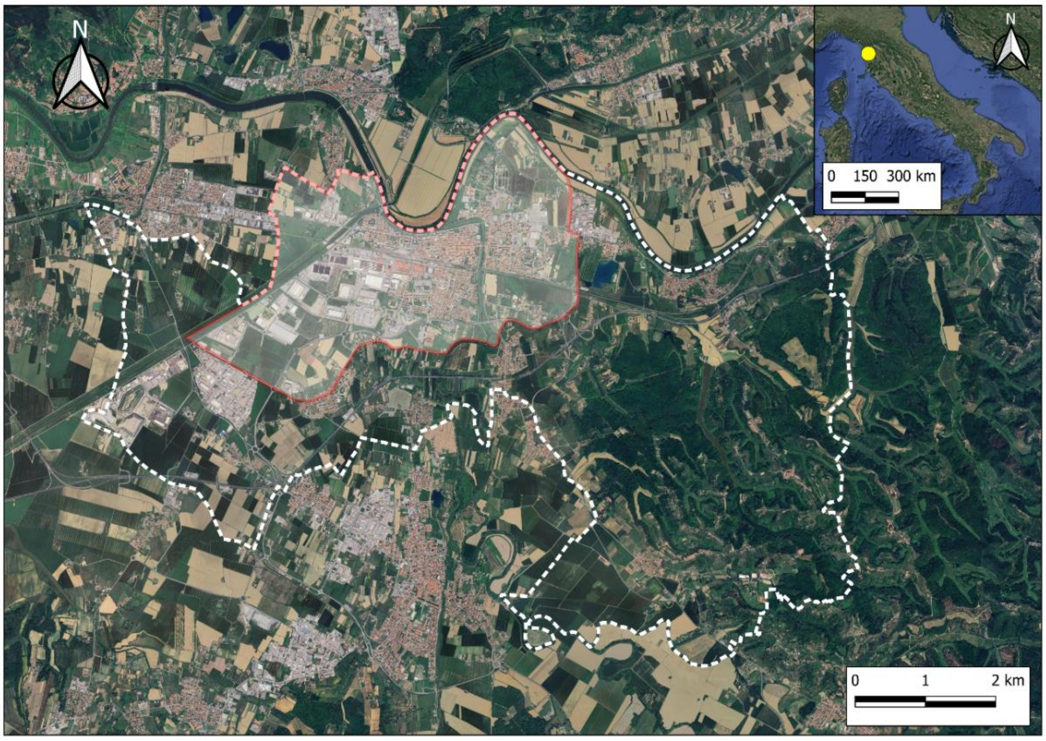


Figure 19 Location of the Italian demo site of the D4RUNOFF project, highlighting the municipal boundary of Pontedera (white dashed line) along with the spatial domain defined in the current phase of the project for its implementation in the AI-Assisted platform.

2.4.2.3.2 Combined sewer network evaluation

One of the key aspects of implementing the AI-Assisted platform at the Italian demo site is having access to information on the drainage systems and sewer networks within the urban area of Pontedera, as these are critical infrastructures for managing urban runoff. The detailed analysis of the drainage and wastewater infrastructure in Pontedera, provided by the project's lead partner for the case study (ACQUE SPA), has been the focus of the preparatory activities carried out in the initial phase of task T5.4.

Pontedera relies predominantly on a CSN that conveys both stormwater and WWTP located to the east of the city, which discharges the treated water into the aquatic environment near the Arno River. As shown in Figure 20, which illustrates land use in the Italian demo site, the water collected by the drainage and sanitation infrastructure mainly comes from urban and industrial areas. However, during periods of intense rainfall, there is potential for discharges of polluted water into the aquatic environment due to the insufficient capacity of the CSN to collect stormwater and wastewater.

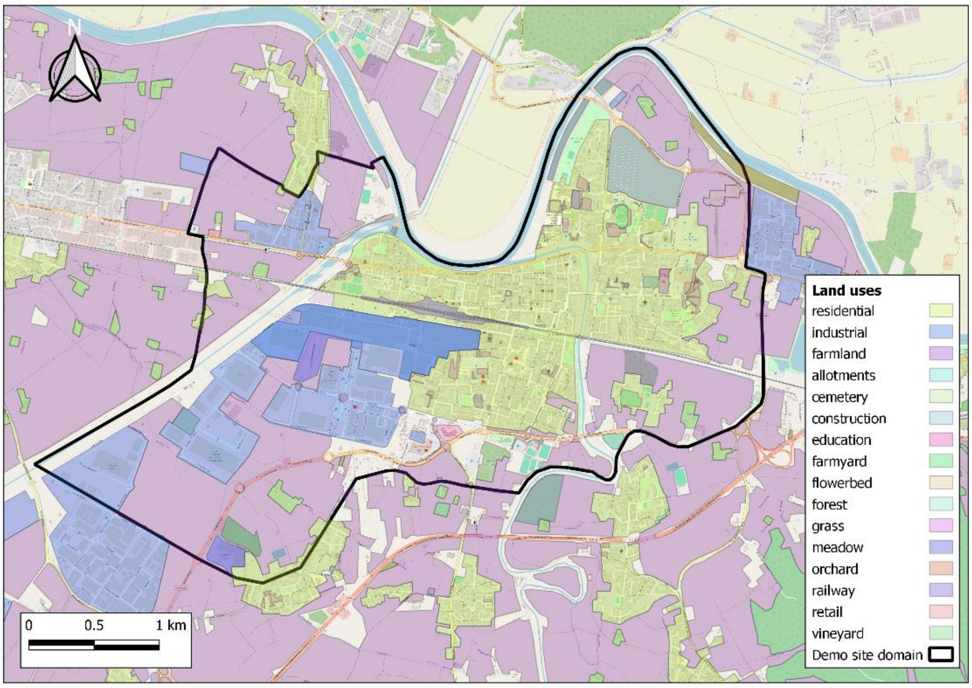


Figure 20 Land use within the spatial domain of the Italian demo site defined in the AI-Assisted platform. The water collected by the sanitation infrastructure in the study area comes mainly from urban areas (yellow zones) and industrial areas (blue zones).

For the implementation and evaluation of the performance of the sanitation infrastructure within the AI-Assisted platform, six types of elements constitute the main components of the CSN of Pontedera: manholes, pipes, pumping stations, discharge points or outlets, overflows or spill points, and the WWTP. In addition, 1086 subcatchments are identified in the urban area contributing runoff water to specific manholes within the urban area of Pontedera. A specific GIS database has been prepared during the preparatory activities of task 5.4 as a starting point for its subsequent upload to the platform. Figure 21 presents the spatial distribution of the different elements that make up the CSN in the Italian demo site, as visualized in the prepared GIS database.

The sewerage infrastructure of Pontedera has been analysed to ensure its successful integration into the AI-Assisted platform once its development is complete, as described in Section 4.3.3 of deliverable D4.2 within WP4 of the project. Infrastructure data can be uploaded to the platform either individually, element by element, or in bulk using preformatted GeoJSON files that the platform can interpret and manage efficiently. The primary goal of this data analysis is to guarantee that the platform's design and development allow for the correct storage and management of the various types of elements present in the CSN of the Italian demo site.

The available data on sewer network pf Pontedera includes more than 60 km of installed pipelines. Over 60% of these have a circular cross-section, while more than 20% have a rectangular profile, and the remaining ones are irregularly shaped. Concrete and masonry account for 87% of the pipeline materials, while plastic materials (PVC) represent only 7%. These material distributions reflect the network's age: most pipelines (59%) were installed around 1970, although significant renovations and new installations took place between 2016 and 2018, accounting for 32.5% of the total network. Most of the network consists of medium-sized diameters (200–800 mm), with large-diameter pipelines (>1 m) being relatively scarce. The pipelines transport both wastewater and stormwater to the WWTP, where the main spillways are also located.

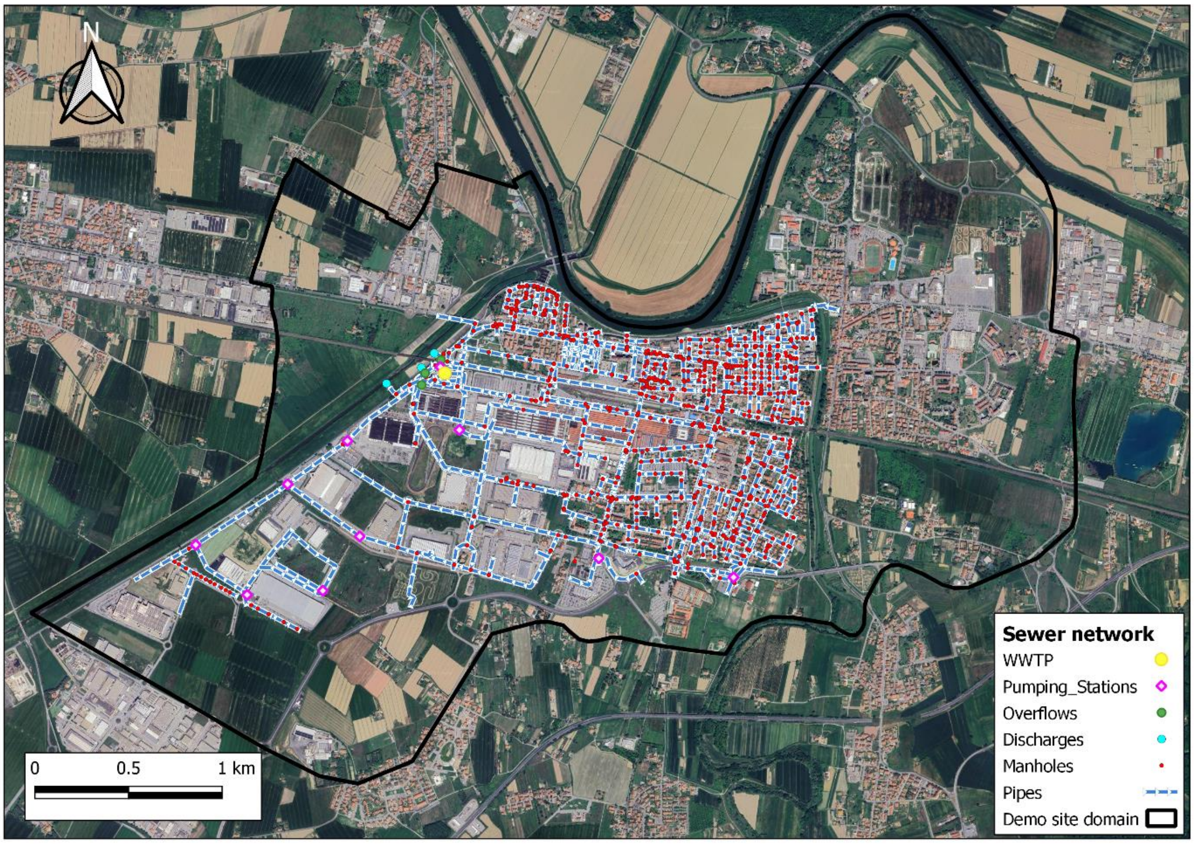


Figure 21 Spatial distribution of the combined sewer network in the Italian demo site, highlighting the main components that constitute it and will be integrated into the AI-Assisted platform.

2.4.2.3.3 NBS evaluation

For the Italian demo site, the specific NBS to be implemented in the AI-Assisted Platform for assessing their impact on urban runoff management will be determined in the upcoming phases of the D4RUNOFF project.

2.4.2.3.4 GIS-based tools identification

The platform being developed within D4RUNOFF is a web-based GIS tool capable of connecting to external sources to incorporate relevant information that contextualizes and enhances the specific data and results generated within the project. During the preparatory activities for task T5.4, various external sources have been identified as potential data providers for the Italian demo site, which could be integrated into the platform via WMS (Web Map Service) or similar services.
Specifically, several external sources have been identified for potential integration with the platform, providing contextual information on terrain elevation (digital terrain models), geology, slopes, orthophotos, hydrography, impermeability levels, and more. The AI-Assisted platform has been designed to support various base maps (customizable according to user preferences) from external sources, alongside the spatial distribution of project-specific data and results. This integration enhances the comprehension and geospatial analysis of the information.
Figure 22 presents examples of maps from external sources available for incorporation into the AI-Assisted platform, offering contextual information on terrain elevation, geology, hydrology, and soil impermeability levels.

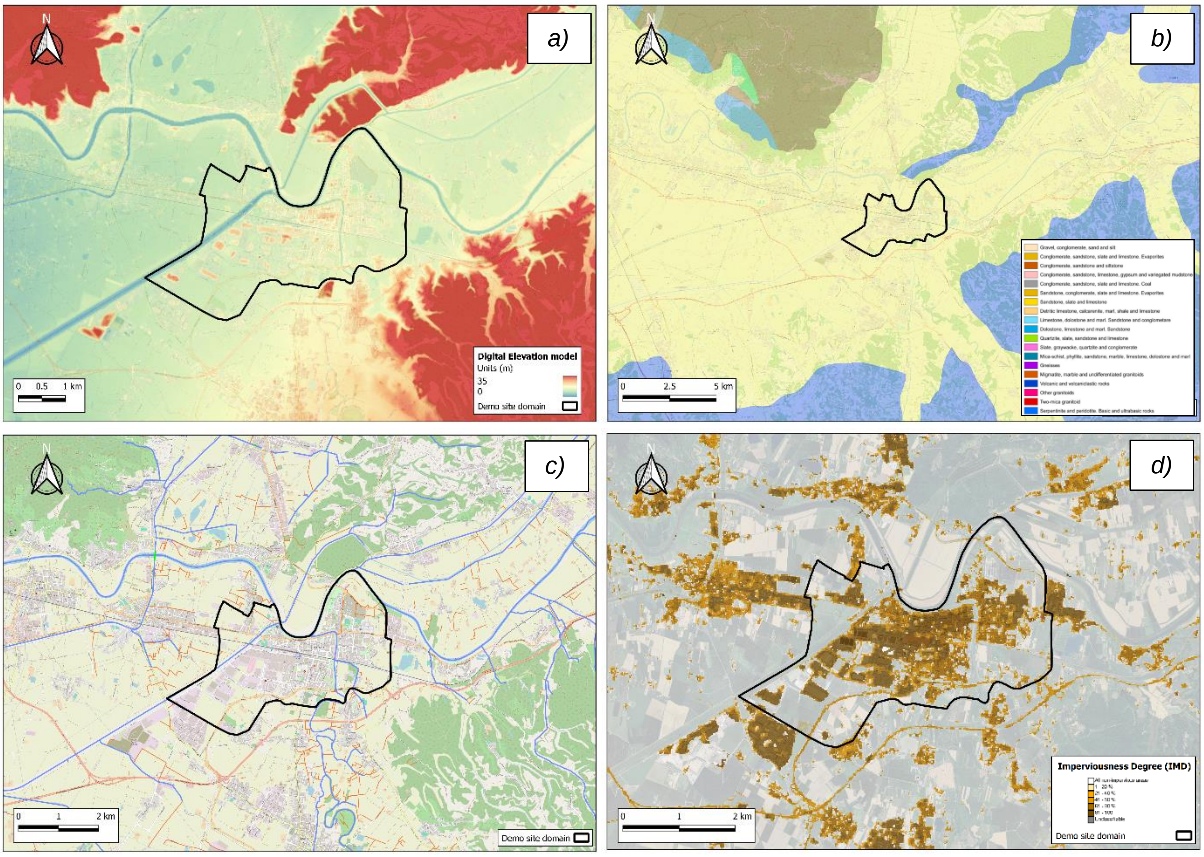


Figure 22 Example of external GIS data sources available for integration into the AI-Assisted platform, providing contextual information for the Italian demo site: (a) Terrain elevation (Digital Elevation Model), (b) Geology, (c) Hydrology, and (d) Soil impermeability levels.

2.4.2.3.5 Preliminary analysis of available data

External monitoring sensors operating at the Italian demo site have been identified as potential data sources for integration into the AI-Assisted platform within the D4RUNOFF project. One of the key external data providers is the Regional Hydrological Service (SIR) of the Tuscany Region, which manages a network of monitoring stations collecting real-time hydrological and meteorological data.
For the Pontedera area, the SIR provides hydrometeorological data from its monitoring stations, including precipitation levels, river water levels, temperatures, and other relevant parameters. Particularly crucial for the D4RUNOFF project and the effective operation of the AI-Assisted platform is the availability of high-frequency precipitation data, as these measurements enable the assessment of runoff generation caused by rainfall events of varying intensities and their correlation with key pollution indicators.
In this context, the SIR provides precipitation data recorded at 15-minute intervals in Pontedera. Figure 6 presents an example of precipitation data measured every 15 minutes between 2020 and 2024, which will be incorporated into the platform and utilized in the development of numerical and AI-based models for the Italian demo site.

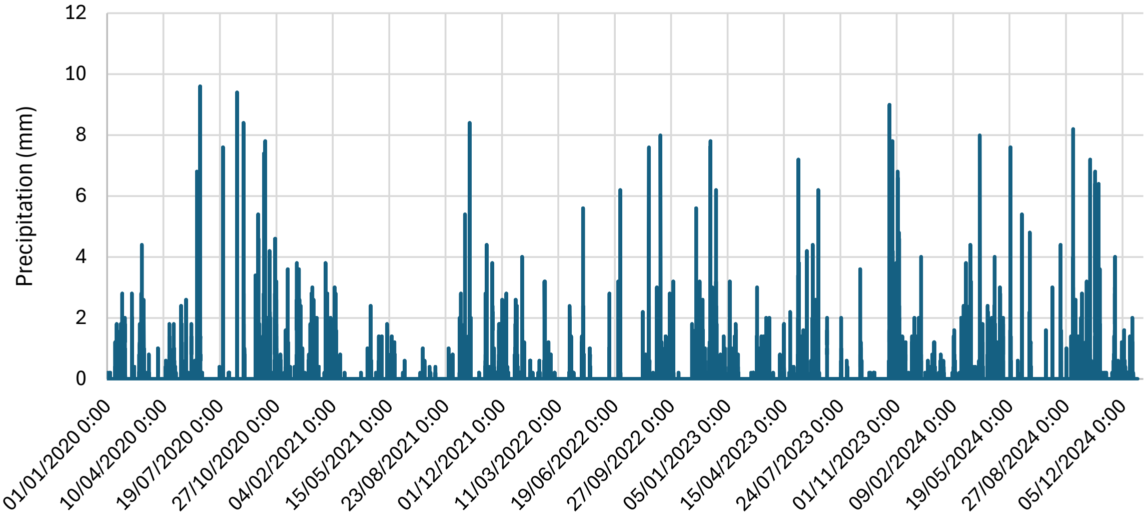


Figure 23 Example of 15-minute interval precipitation data recorded in Pontedera between 2020 and 2024. This dataset will be integrated into the AI-Assisted platform and used for numerical and AI-based model development within the Italian demo site.

2.4.3 Testing activities

The core of the testing activities for the AI-Assisted platform at the three demo sites will take place starting from month 30 of the project (M30). During this phase, information and data about each site will be integrated into the platform as a foundation for model generation and the production of results that will support platform users in making informed decisions regarding urban runoff. However, during the initial phase of task T5.4, in addition to the previously mentioned preparatory actions, some preliminary activities related to the validation of data upload and reception on the AI-Assisted platform have also been carried out.

The platform will operate using results and data generated within different work packages of the D4RUNOFF project. On one hand, it will utilize results from laboratory analyses of runoff water samples taken at the pilot sites using innovative contaminant characterization methods developed within WP1. On the other hand, it will incorporate data collected by the novel sensors developed within the framework of WP2 for the identification and monitoring of CECs and new pollutants. The initial testing activities have focused on validating the proper storage of results from WP1 and data from WP2, as well as improving the platform to enable real-time communication with the novel sensors being developed within the project.

First, actions have been taken to validate the proper storage of the results generated within WP1 of the project in the AI-Assisted platform, using the data model designed for this purpose within WP4 (see Deliverable D4.2, Section 4). This model aims to ensure the unambiguous storage, organization, and structuring of the information from the collected samples at the pilot sites by identifying their location based on interrelated elements. The testing activities carried out during the initial phase of task T5.4 focused on verifying the proper storage of preliminary information and results from WP1 on the platform. These activities have helped refine and improve the storage system for these results through a data model structured into the following elements, from the top level to the bottom:

1) Site. Defines the general location where samples are collected. The sites correspond to the three pilot locations of the project, along with external collaboration sites.

2) Station. Specific sampling location within a site, covering different scales: 1-2 large-scale/composite sources and 3-5 small-scale/local sources. Local stations (e.g., rain beds, storm drain runoff) must have a sufficiently large catchment area to ensure representative sampling.

3) Sampling Point. The exact location within a station where a sample is collected. Samples can be taken from different elements of the NBS or sewer network (e.g., inlet, outlet, bypass pipes). They are categorized as "lab" (samples analyzed in a laboratory) or "device" (samples collected by sensors for in situ analysis).

4) Sample. A portion of a substance (water or soil) collected at a sampling point. A sample is mainly identified by its sampling point, collection date, and additional parameters.

5) Analysis. The process of determining the measured result of a parameter within a sample. Each analysis is mainly defined by the sample (sampling point + date), the analysed compound/parameter, the measurement result, and its units.

Second, a set of preliminary tasks has been also undertaken during this phase to initiate the validation of the data communication with sensors developed in WP2 for the identification of new pollutants and CECs. To streamline the acquisition to the AI-Assisted platform from these devices, a significant enhancement has been made thanks to the implementation of MQTT protocol that allows to interact with the sensors for some of the following purposes:

1) Data acquisition. Automatic data acquisition form observed parameters measured by the abovementioned sensors have been tested as shown in Figure 24.

2) Actions. Several examples of MQTT actions were examined during this initial stage to validate that the platform can interact with the devices. For instance, one action could

be used to initiate a sampling process (Figure 25). Moreover, over this period, the possibility of triggering these actions based on other observed parameters (e.g. rainfall or precipitation probability) or a defined schedule has begun to be considered. In the coming months, additional tests are expected to be conducted to fine-tune these sensors operation scenarios

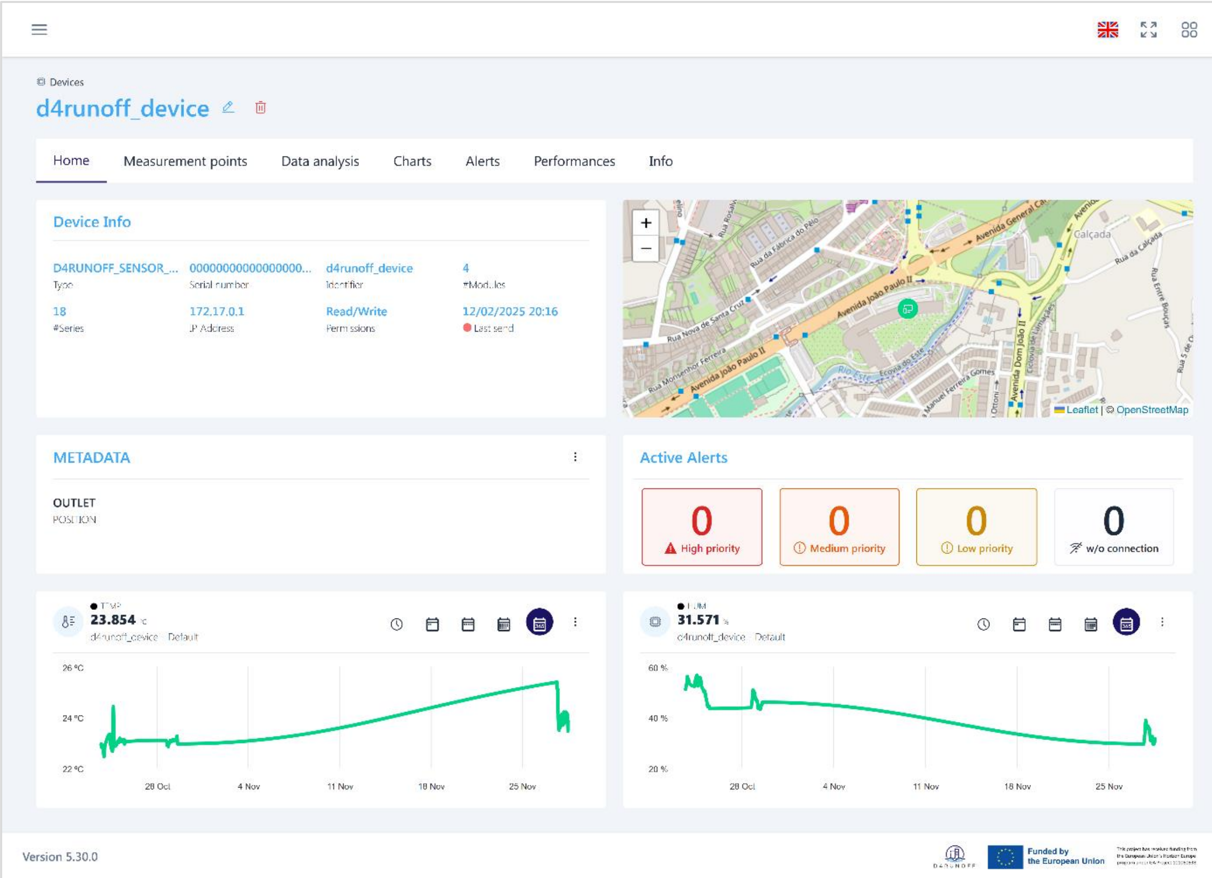


Figure 24 Screenshot of the tested connection between devices in WP2 and AI-Assisted Platform to acquire observed data

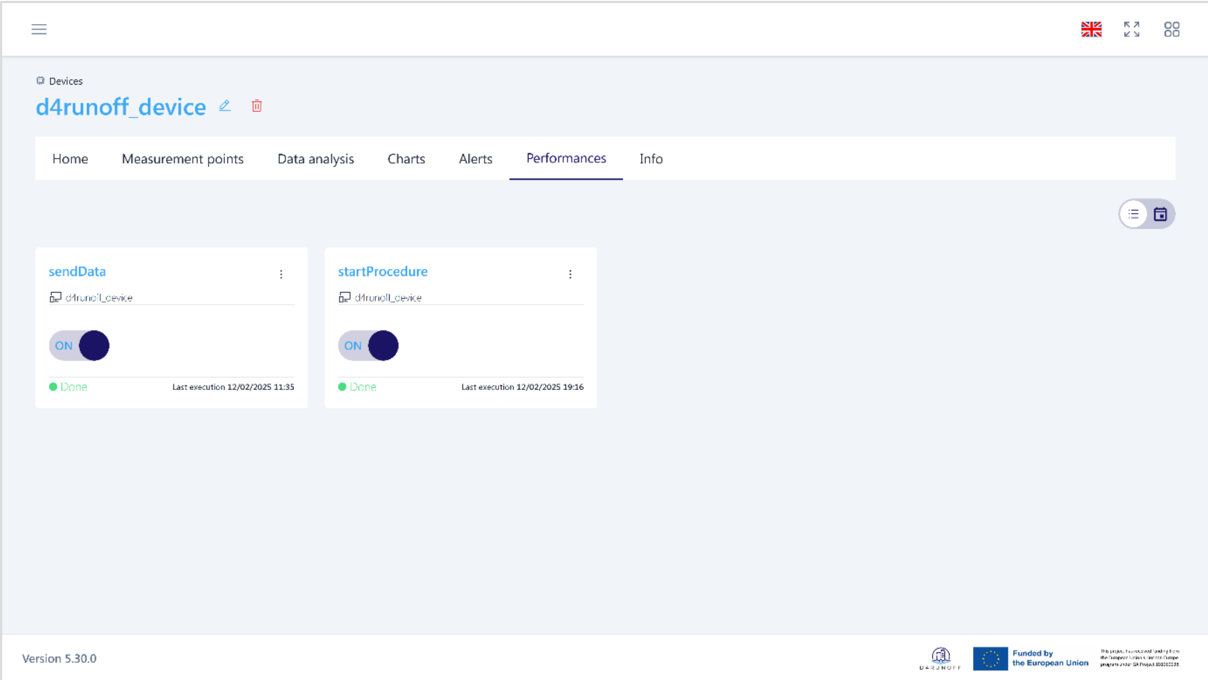


Figure 25 Screenshot of some MQTT actions tested during the initial activities to validate the communication between the AI-Assisted Platform and the WP2 sensors

2.4.4 Conclusions and next steps

During the initial phase of task T5.4 for the implementation of the AI-assisted platform at the demo sites, efforts have focused on preparatory activities, analysing the characteristics and specific features of the three pilot sites and evaluating the available information and data at each location. Additionally, the availability of external information sources, including GIS tools and real-time data sources, has been identified as potential integration pathways for the platform.

Preliminary testing activities were also carried out during the first months of task T5.4. These tests verified, on one hand, the proper storage of project-generated data and results in the AI-assisted platform and, on the other hand, the communication between the platform and the novel sensors being developed in D4RUNOFF. Particularly significant were the improvements made to the platform for using the MQTT protocol to interact with the sensors, as well as the tests conducted to validate platform-sensor communication.

In the next phases, testing and validation of the AI-assisted platform at each demo site will be further developed, integrating the available information and data from each location. These data sources will serve as the foundation for the development and execution of AI-based models within the platform at the three pilot sites, as well as for generating numerical results to assess the effectiveness of NBS implementation. The progress and achievements of the AI-assisted platform implementation in future phases of task T5.4 will be detailed in Deliverables D5.3 (intermediate testing) and D5.4 (final testing and conclusions).

2.5 Task 5.5: Multi-Criteria Decision Analysis (MCDA)

Case study leaders (VCS, ACQUE and AQUALIA) participated directly during the development of the MCDA methodology in the WP3. Thanks to this, it was possible to identify some potential limitations for its application from the beginning, as for example the scarce power of decision of the utilities now or the lack of consideration of some new environmental criteria. Now, in the WP5, the limitations are addressed with three main objectives:

- Perform the application of the WP3 results to the case studies, in coordination with the WP4 and the T5.4, using the related functionalities of the D4RUNOFF platform.
- Put into value the construction of NBS in the different locations and learn from it to update the parametric design library and the ranking obtained from the MCDA.
- Propose the construction of new NBS soon using the MCDA and the GIS analysis of the selected areas in each city.

The preliminary actions developed during these last months with the support of the case study leaders (VCS, ACQUE and AQUALIA) have been:

1. Review the deliverables D3.1, D3.2 (both public and available in https://d4runoff.eu/results/), D3.3 (sensible and available only for the partner organizations) and D3.4 (public summary).
2. Look for NBS under construction now and soon (e.g., the SSF wetland in Pontedera) to compare the designs with the ones that can be obtained from the parametric library.
3. Share the available information about the cost of construction and maintenance of urban drainage techniques in each country (i.e. national database of prices, including not only pipes but also NBS) to particularize some figures used in the MCDA.
4. Validate the ranking of NBS obtained from the MCDA and evaluate if it needs to be adapted to each specific location to generate a particular ranking.
5. Confirm the selection of the specific study area in each city (e.g., Las Llamas valley in Santander) to focus there the analysis of the potential NBSs to execute in the future solving existing problems related with urban drainage (this means update the results of the D3.3 if needed).

From the results of the WP3 and the responses of the case study leaders, the effectiveness of the real application of the MCDA has been discussed during the preliminary actions of this task 5.5.

VCS states that most of the NBS techniques considered in the ranking performed with the MCDA methodology are not commonly used in Denmark for rainwater management. The most used ones are the rain beds (bioretention areas) with a variable cost that goes from 16.000 to 31.500 €for around 20 square meters, which means 2 to 3 times the average cost considered in WP3. Consequently, the NBS ranking from the MCDA needs an important adaptation to the local practice in Denmark to ensure a proper application. Mainly particularizing the list of techniques and the vocabulary use together with the real costs of construction.

ACQUE is now working in constructing a SSF wetland in Pontedera, taking advantage of this to check the preliminary results obtained from the parametric library developed in the WP3. The comparison shows that the library is useful for the initial design of different alternatives but not yet for real projects where all the details must be described. Moreover, as in Denmark, in Italy is also needed a selection of alternatives and a vocabulary adaptation to apply the NBS ranking obtained from the MCDA performed in the WP3.

Finally, AQUALIA highlights the importance of one of the initially identified limitations: utilities do not decide what NBS must be applied where. Consequently, even though the company in charge of the water management agrees with the NBS ranking coming from the MCDA, it is the corresponding water authority the one deciding, depending on the feasible solutions available in the market in that specific moment. With all, in Santander, the importance of the wetland constructed in Las Llamas Park in growing thanks to the D4RUNOFF project, and similar NBS are being considered in the plans development of the city.

In the three case studies, the selected study areas have been confirmed.

In the next months of the WP5, the MCDA methodology will be adapted to each location, collecting the recommendations from the three case studies and implementing the improvements needed for the tailored application in each of the selected areas in Odense, Pontedera and Santander.

The consideration of local updated costs in each location (Santander, Odense and Pontedera) could affect the approach for the selection of NBS, modifying the initial proposed ranking and consequently the potential locations. The local authorities will have to decide if the initial weighting is suitable or they prefer to change it. As reference, with the objective weighting methodology used, the Entropy Weight Method (EWM), the construction costs have a weight of 13,44% and the maintenance costs a 15,75%, being the two more important indicators to consider.

3 Feedback to WP1-WP4

Although WP1–WP4 activities is almost completed by M30, feedback remains crucial as WP5 is currently testing and applying the developed methods and technologies in practice. In this deliverable, the feedback is presented not as a basis for adjusting WP1–WP4, but as a reflection on the achieved results and an evaluation of their implementation. This documentation of key learnings ensures that we capture important insights and identify any future needs for adjustments in the application of these methods. Moreover, the feedback serves to address questions regarding our approach and helps improve guidelines for similar projects in the future.

WP1 – Contaminant Characterization and Analytical Methods

- In WP1, it became clear that thorough planning of the sampling process is essential. In particular, several sampling locations (especially in Odense) had to be changed or even cancelled because the limitations of the Nature Based Solutions were not fully understood beforehand.
- Additionally, the safe transportation of sampling equipment must be ensured to prevent damage during transit.
- Moreover, a high degree of coordination is required to ensure that physical sampling is effectively synchronized with sensor data collection, considering both weather conditions and the practical challenges of collecting samples concurrently with sensor operations.

WP2 – Online Monitoring System

- Initial tests with the online monitoring system are scheduled to start in month 31.
- Close collaboration is essential to resolve technical issues and ensure smooth integration of the sensors with the AI-assisted platform.

WP3 – Multi-Criteria Decision Analysis (MCDA) and NBS Evaluation

- The academic approach initially adopted for the MCDA has highlighted discrepancies when compared to professional practice, particularly regarding cost considerations and terminology.
- It is recommended that WP3 leverage the outcomes of tasks T5.5 and T5.6 to adapt the MCDA methodology to the local contexts of Denmark, Italy, and Spain.
- These adaptations are crucial for producing a more realistic ranking of proposed NBS options for urban water management.
- Adapt the MCDA methodology to better reflect local conditions by updating cost data and aligning vocabulary, ensuring the decision framework is practical for professional water management applications.

WP4 – AI-Assisted Platform and Data Integration

- The primary focus during this phase has been the evaluation of available data at each pilot site, including two main groups:
  - **GIS Data Sources:** Assessment of metadata from sewer networks, NBS identification layers, and base maps (e.g., aerial images, land use).
  - **Real-Time Data:** Verification of data connections from internal sensors and external providers (e.g., weather forecast services).

- Key insights include the need to homogenize metadata for seamless integration into the AI-assisted platform and to ensure reliable real-time data transmission.
- Maintain strong collaboration with partners responsible for the demo sites in WP5 to secure data integration into the AI-assisted platform.
- Work closely with WP1 to ensure proper storage, display, and utilization of laboratory results from runoff water samples.
- Collaborate with WP2 to guarantee that the innovative sensors for monitoring CECs and new pollutants are effectively connected, and their data is seamlessly processed.
- Coordinate with WP3 to integrate methodologies for sustainable urban drainage solutions (including the D4RUNOFF Library, NBS parametric design spreadsheets, and the MCDA within GIS).
- Engage with WP6 to raise awareness about urban runoff and pollution issues through the social module of the AI-assisted platform, including the use of Serious Games.

4 Action Plan for Further Testing

Task T5.1 – Sampling and Analysis
Sampling in Pontedera, Santander, and Odense has been planned to commence in Santander between February and May (M30–M33). Sampling will be done by case-study responsible, and samples shipped to Copenhagen for laboratory analysis using methods developed in WP1 (detailed protocols in D1.2, D1.3, and D1.6). There will be close collaboration between case-study responsible (AQUALIA, ACQUE, and VCS) and analytical laboratories (GEUS and UCPH) during selection of sampling stations and sample collection, to ensure that the collected samples fulfil the data needs of the project and that sampling is efficiently coordinated. This is particularly important due to the dependency on rain events for runoff sampling, which makes close communication essential for adapting to actual weather conditions. All runoff samples will be collected by October (M38), with subsequent analysis carried out by GEUS and UCPH. The samples will serve to test and validate the methods developed in WP1 by providing additional data to evaluate the detection of pollutants using the developed workflows.

Task T5.2 – Risk Assessment Module Refinement and Validation
In T5.2, MTG leads the technical development while VCS provides expertise and coordinates a citizen science sampling campaign supported by UCPH and the Municipality of Odense; other D4RUNOFF partners are involved in update/review meetings offering additional input and insights. Further testing and improvement of the Risk Assessment module will be carried out using new data from T5.1, T5.3, and from the citizen science sampling initiative. New model outputs will be discussed with local stakeholders to evaluate relevance and usability. With the conclusion of T4.4 in M32, this task will refine and validate the Risk Assessment Module in Odense.

From M32 to M39, T5.2 will focus on data integration, model refinements, and stakeholder feedback. Cooperation with the Municipality of Odense and VCS involves a series of technical meetings, covering the status of the methodology, presentation of interim results, and collection of feedback, including on data formats and applicability for local decision-making. This feedback is then considered to perform further model modifications, which are then discussed again with stakeholders, in a continuous improvement loop. Partners in Pontedera and Santander (ACQUE spa and AQUALIA) also contribute, ensuring the methodology is robust across different contexts. A validation workshop in M39, held alongside the D4RUNOFF Open Day in Odense, will mark the final iteration of this process. Final updates to address deviations and optimize model performance will take place between M40 and M42, resulting in the release of Version 2.0 of the Risk Assessment Module.

The continuous improvement and feedback loop with site-specific stakeholders, through technical meetings, review of interim results, and adaptation to local planning workflows, is designed to identify additional practical barriers beyond those already highlighted, such as mismatched data formats or uneven monitoring coverage, which are currently addressed through dedicated data pipelines. Capturing these issues will inform both the remaining project months and future replication efforts, providing tested cooperation guidelines for application in other urban contexts.

Task T5.3 – Implementation of Online Monitoring System
At the end of the RP2, the automated monitoring platform (details in deliverable 2.5) was validated in the laboratory with real water samples, and it is ready to be implemented in the

first case study site: Parque de las Llamas, Santander, Spain. During this RP2, efforts were made between INL and ITG to implement the sensor communication and integration with the AI-assisted platform, ensuring robust data acquisition during real-world rain events.

Deployment Planning and Coordination. During the reporting period, many bilateral meetings INL-Aqualia were carried out to coordinate the deployment and implementation of the monitoring system in the first case study. After careful consideration and discussion, the prototype will be installed in the pumping station managed by Aqualia in Santander; this decision was made considering the relevance of the water sample, but also the protection of the system in the first case study in a closed, secure location, minimizing the risks of vandalism. Three sampling campaigns are expected to be carried out during heavy rain periods fulfilling the minimum requirements established in WP1. In short, once the compliant rain event is detected by the case study's managers (Aqualia), the automated monitoring system will be activated and a manual sampling campaign is carried out in parallel at the same time to obtain water samples from the same event to be analysed CECs and metals by U. Copenhagen in Task 5.1 and microplastic by an external lab (AIMPLAS), serving as a comparison method. The external service for microplastics is required by case study's managers (i.e., Aqualia). Up to three measurements will be performed out of rain events to record the contaminants' background levels. The data obtained on the contaminant's levels will be automatically sent to the ITG AI/assisted platform. The information obtained will be reported in the D5.2, D5.3, and compared with the laboratory analysis performed in task 5.1 (e.g., CECs and metals). For microplastics, the data will be compared with the results generated by the external laboratory. Results will contribute to a deep analysis of all collected data in the context of the events, location, and NBS performance. Moreover, it will be jointly reported in the deliverables (deliverables 5.3 and 5.4), as well as a joint publication with the participation of all partners involved.

System Installation and Operation. The monitoring system will be transported to the pumping station in Parque de Las Llamas, Santander, and INL technical personnel will oversee the reception and carry out the installation with support from Aqualia. After completing the check-ups, and operational tests, INL will provide an in-situ training session to Aqualia and UC on the regular maintenance procedures based on Standard Operating Procedures (SOPs) previously prepared by INL.

A fluent direct communication should be established between Aqualia, UC, ITG, UPCH and INL technical staff to be able to troubleshoot any unexpected problems with hardware, firmware or data communication. If severe errors occur requiring specialized technical intervention (not being possible to solve by Aqualia and UC staff), INL team will travel to Santander to solve the problem. A comprehensive matrix will be developed to document the technical, organizational, and contextual barriers encountered during the installation of the prototype in the first case study, along with the corresponding mitigation measures. This tool is designed to serve as a practical reference for future prototypes implementations.

Contingency Planning for next Case Studies. There is a risk that there are not enough heavy rain events during the 3-month period of the case study in Santander. If after the first 2 months, we cannot carry out at least 2 measurements, we will consider a short delay in the implementation of the monitoring platform in the second case study (Odense, Denmark), which is expected to have minimal risks in these regards. This decision should be taken in coordination with the rest of the partners, particularly VCS, in charge of this case study, but also the rest of the consortium as all the activities will be impacted. The monthly steering committee serve as a general information platform, but ad hoc multi-partner meetings will be organised in a dynamic manner to enable fast decision-making.

During the implementation period, a meeting between INL and VCS for the second case study planning was carried out, defining the most probable dates for installation and operation of the monitoring system, location specifications and constrains, as well as discussion of the required adaptations (possible change of pumping system and length of the water collection tubing, adaptation of side walk to host the prototype tubing, adaptation of the NBS to accumulate inflow water for effective sample collection, etc). The target number of heavy rain events with measurements will be the same as for the rest of the case studies, at least 3. The same protocol will be also followed for the last case study in Pontedera.

Task T5.4 – AI-Assisted Platform Deployment

Task T5.4, aimed at implementing the AI-Assisted Platform at the three demo sites (Odense, Santander, and Pontedera), began in September 2024 (M25) with preparatory activities. These initial efforts involved analyzing available data at each site and conducting preliminary tests to verify the connection between sensors and the platform, ensuring proper data storage and accessibility.

Once the platform's development within WP4 is finalized (expected between M30 and M32), T5.4 will transition into full deployment at the demo sites. In this phase, further testing and validation will be carried out through the progressive integration of site-specific data, supporting AI-based model development and the generation of numerical outputs to assess the effectiveness of proposed NBS solutions. Close collaboration will be established between the AI-Assisted Platform developers and the Pilot site partners (AQUALIA, ACQUE, and VCS) to facilitate data integration and connectivity. In parallel, the following implementation tasks will be carried out as part of the platform deployment:

- Completion of the storage of laboratory analysis results generated under WP1.
- Connection of novel sensors developed within WP2, as they are installed at the demo sites, to enable real-time data collection.
- Integration of external services and relevant data sources available at each pilot site to enhance the analysis capabilities of the platform.

Specific activities will also support the implementation of the Policy-Making Module (PoMM) of the AI-Assisted Platform, starting with the Italian demo site and then extending to the Spanish and Danish sites. Updated versions of the risk maps for each pilot site—generated in Task T5.2—will also be integrated into the platform.

A clear cooperation strategy across the three pilots is in place and will be continuously reinforced through joint technical sessions and feedback loops between platform developers and pilot partners. The outcomes of this collaboration will be reflected in upcoming deliverables (D5.3 and D5.4), serving as the foundation for testing and validating the platform's modules and functionalities. In addition, identifying existing barriers and documenting how they are addressed will help support the future replication of project results.

Task T5.5 – Adaptation of the NBS Library, MCDA, and GIS Location Tool

From March 2025 (M31) to September 2025 (M37), the University of Cantabria will work in parallel with the three case study leaders to refine the NBS library (identifying the local NBS to consider), adapt the MCDA methodology (tailoring the weighting where needed), and optimize the GIS location tool (considering local restrictions and new layers with additional information to consider). Cooperation from local working groups is fundamental for a fluent communication, organising workshops and videoconference meetings when needed. Feedback regarding the initial methodology, proposed improvements, existing barriers, and final conclusions will be discussed from August 2025 (M36) until the project's conclusion in February 2026 (M42), leading to feasible NBS proposals for each location as the main output. This process will be documented in Deliverables D5.3 and D5.4.

4.1 Local working groups

To ensure that the project outcomes are well adapted to the local context and benefit from relevant knowledge, "WP5 local working groups" will be established in each of the three case studies (Odense, Pontedera, and Santander). These groups are intended to serve as platforms for real co-creation, where stakeholders are not only consulted, but actively contribute to shaping the development, adaptation, and evaluation of the implemented solutions.

Each local working group will include representatives from the local utility company (e.g., VCS in Odense), municipal decision-makers, local citizen groups, and, where relevant, civil society actors such as environmental NGOs or academic institutions. These groups will meet regularly to discuss the implementation of WP5 tasks in their respective cities, including the deployment of the AI-assisted platform (T5.4), the application of analytical methods (T5.1), risk assessment (T5.2), sensor integration (T5.3), and the MCDA-based decision framework (T5.5).

Importantly, interaction with the working groups is structured as a feedback loop: stakeholders are introduced to the project tools and methodologies, but equally encouraged to provide critical input on usability, local constraints, and preferences. This feedback is then used by technical partners to refine models, tools, and decision-support features—ensuring that the outputs are not only scientifically robust but also locally relevant and practical. The same co-creation methodology will be applied consistently in Pontedera and Santander.

5 Conclusion

The testing activities in D5.1 have produced specific, measurable results. For instance, the WP1 methods (LC-HRMS, HILIC-HRMS, and ddPCR) have been successfully used to detect and quantify target and suspect pollutants in urban runoff, with actual concentration values now available for further comparison. In WP4, the risk assessment module has been recalibrated using new sampling data from Odense and sensor readings, resulting in adjusted model parameters that more closely match measured runoff events. The WP2 online monitoring system's initial tests have identified and resolved issues with sensor communication—improvements that are now reflected in stable data transmission during controlled tests. Moreover, the AI-assisted platform has been integrated with both laboratory data and sensor inputs, generating preliminary risk maps and decision support outputs that highlight areas for further refinement. Finally, the MCDA framework from WP3 has been reviewed against local cost data and operational practices, leading to concrete recommendations for adapting the methodology to suit regional differences in Denmark, Italy, and Spain.

These results will directly inform the next project phases. The quantitative data from pollutant analyses and risk mapping will be used to adjust model thresholds and parameters. Further testing will validate sensor performance under varying field conditions, ensuring that the online monitoring system maintains reliable operation during real-world events. In addition, the ongoing adaptation of the MCDA framework will be guided by specific cost and performance data from each case study, enabling a more accurate ranking of Nature Based Solutions. Overall, the findings provide a solid basis for improving each technical module, and the planned actions are designed to address the precise issues identified during this phase.

6 Acronyms

AM - Analytical Module

CECs – Contaminants of emerging concern

COF – Covalent organic frameworks

6PPD-Q – 6PPD-quinone

WWTP - Wastewater treatment plant

CSN - Combined Sewer Network

AEMET - Automatic Weather Stations