aqua3S

aqua3S Platform Manual

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ABBREVIATIONS/ACRONYMS

AWS	Amazon Web Services
CCTV	Closed-Circuit TeleVision
CSV	Comma-Separated Values
DEM	Digital Elevation Model
DSS	Decision Support System
DWTP	Drinking Water Treatment Plant
EC	EC European Commission
ELK	Elasticsearch, Logstash, and Kibana
FRMP	Flood Risk Management Plan
GDPR	General Data Protection Regulation
GIS	Geographic Information System
HTML	HyperText Markup Language
HTTPS	Hypertext Transfer Protocol Secure
IMM	Intervention Management Model
IoT	Internet of Things
JSON-LD	JavaScript Object Notation - Linked Data
KMZ	Keyhole Markup Language
NGSI-LD	Next Generation Service Interfaces - Linked Data
OGC	Open Geospatial Consortium
OIDC	OpenID Connect
RBAC	Role-Based Access Control
SCADA	Supervisory Control And Data Acquisition
SFTP	Secure File Transfer Protocol
SME	Small and Medium-sized Enterprises
TLS	Transport Layer Security
UAV	Unmanned Aerial Vehicle
UI	User Interface
VA	Visual Analytics
VV	Vertical Vertical
WMG	Warning Message Generation
WMS	Web Map Server

1. Preface

aqua3S project[1] is the response to the call H2020-SU-SEC-2018-2019-2020[2] Secure societies - Protecting freedom and security of Europe and its citizens. The project started in 2019 and addressed the growing need of utility and water network operators to access real-time data, as well as their need to be able to combine multiple sources for monitoring of water quality and specific parameters. All stakeholders of the consortium, representing various parts of the water sector, as well as experienced technical partners, have combined their needs and efforts to create one solution that would fill in the gaps that end users are currently facing.

aqua3S consortium involves 23 partners (i.e., 4 first responders' organisations, 1 water authority, 5 water utility operator, 1 public security agency, 6 academic and research organisations, 4 technical SMEs, 1 SME focused on dissemination and 1 SME specialized in Ethics and Legal issues) all of which are contributing to the project with their own expertise.

The project is targeted at reducing the risk of exposure of citizens to potential disasters since the drinking water is one of the main sources of risk, when its safety and security is not ensured. aqua3S combines novel technologies in water safety and security, and also supports the standardisation and enhancement of existing sensor technologies by complementing them with state-of-the-art detection mechanisms. On the one hand sensor networks are deployed in water supply networks and sources, supported by complex sensors for enhanced detection; on the other hand, sensor measurements are supported by videos from Unmanned Aerial Vehicles (UAVs), satellite images and social media observations from the citizens, that report low-quality water in their area (e.g., by colourisation), creating also social awareness and an interactive knowledge transfer.

What are aqua3S main achievements?

- To create strategies and methods in order for a water facility to easily integrate solutions regarding water safety;
- To create early warning methods for water authorities;
- To allow easy engagement of different authorities in a water related crisis;
- To create/use methods that estimate the infrastructure resilience level;
- To introduce bottom-up approaches such as citizen mapping initiatives, which can be an effective way to build large exposure databases;
- To model and classify a crisis event.

Finally, the aqua3S platform is the one of the main outcomes of the project. Specifically, aqua3S platform combines the aforementioned novel technologies aiming to assist the water safety and security, Thus, novel sensors are developed and analysis of data from satellites, social media, UAVs, CCTVs is realised. Also, semantic representation and data fusion methods are applied for providing intelligent decision support system (DSS) alerts and generating effective notifications and social interaction, aiming also to engage first responders or agencies. Algorithms for threat detection and localisation as well as 3D representation of early warning systems are optimised and parallelised so as to offer a highly scalable solution to the potential stakeholders.

[1] https://aqua3s.eu/

[2] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-search;callCode=H2020-SU-SEC-2018-2019-2020

It should be noted that the aqua3S platform was validated, tested and demonstrated on several pilots in Trieste, Limassol, Sofia, Thessaloniki, and Brussels.

2. aqua3S System Summary

The current section answers the most common questions regarding the aqua3S platform in view of providing of a summary of the system.

What does the platform do?

aqua3S integrates a series of state-of-art technological achievements from multidisciplinary fields - sensors, Internet of Things (IoT), semantic reasoning, high-level analytics, decision support system (DSS), crisis management and situational awareness focusing on the water sector.

All the above-mentioned features enable easier localisation of pollution, as well as visualisation of the results, providing deeper insight and supporting the decision-making process in response to a water safety or security event. The data obtained from aqua3S sensor networks and from the existing infrastructure of the utility networks is processed by the innovative threat detection algorithms and high-level multimodal fusion techniques. This platform also provides the possibility to monitor data from UAVs and satellite images to detect, assess threats and locate harmful substances, visualize flood map and results from hydraulic models.

Furthermore, social awareness and interactive knowledge transfer are raised and promoted. Semantic representation and data fusion provide intelligent Decision Support alerts and allow message generation to the public through first responders' mediums, enhancing the actual feeling of safety and security.

What kind of data can be visualised in the aqua3S platform?

aqua3S platform combines and processes data from the legacy systems of the water operators (e.g., SCADA), newly installed sensors, satellite and drones' observation, CCTV, flood map, results from different hydraulic models and social media in real time. Historic data are also available through graphs depending on the type of data.

Also, aqua3S platform integrates EPANET hydraulic models thus improving usability and visualization. EPANET models can be visualised.

Moreover, alerts are produced from all the above sources and can be found in dedicated tabs of the platform.

What are the main functionalities provided by the platform?

- Online solution – accessible anytime from anywhere, allowing real-time access to data and improving response time, without the need of specialized software or program.
- Visualisation of sensor, satellite, UAV, CCTV, social media data - this module visualises the current and historic data of sensors, UAVs, CCTVs, social media and UAVs
- Warning/Alerts module – this module provides warnings in case of abnormal measurement from the sensors (via mail) related to the overtopping of somepredefined alert thresholds in the measurements by the qualitative and quantitative sensors in the water source, DWTP or supply network.
- Crisis management tool – provides assessment of the organizational preparedness for emergency events and crises. Gives guidance and recommendations based on the level of preparedness.
- Flood map – this module displays detailed vectorial flood risk and hazard maps for the respective regions, layered with the water supply and sewerage network. Helps to understand the vulnerability of the water supply network in case of flood and take preventive measures.
- Results from hydraulic models - display an advanced 3D visualization a map results of the hydraulic model of the rivers, sewerage, groundwater balance and pollutant propagation (i.e., EPANET)
- Intervention Management model - this module identifies optimal responses to possible pipe break events occurring within a water network
- Warning Message Generation module – this module allows the user to promptly generate standardised warning messages which are based on the best practices in terms of the type and format of information included

By whom it can be used?

The product development involved 23 partners (4 first responders' organisations, 1 water authority, 5 water utility operators, 1 public security agency, 6 academic and research organisations, 4 technical SMEs, 1 SME focused on dissemination and 1 SME specialized in Ethics and Legal issues) all of which are contributing to the project with their own expertise. Organizations, combining different background have come together to improve the current methods and create a standardized solution.

All end-user partners have provided requirements for a platform that would better serve their needs, as well as the gaps they are currently facing. The information gathered was used and analysed to define the context of the standardized platform. A contextual product understands the full story around an experience, in order to bring users exactly what they want, with minimal interaction. This means switching the regular approach with a customized design, tailored to the needs of the end users and anticipating their needs, before they occur, ultimately improving the user experience and product delivery.

aqua3S platform is tailored for the needs of Water supply operators, Water authorities; Municipalities; Emergency agencies; First responders; Public security organisations; Decision makers in field of water management. It reflects the need and visions of the public, private, research, citizen and utility sector at international, regional and municipal levels. Practitioners from water, medical sector, first responders and utility providers can be supported by the aqua3S's Early Warning and Decision support system.

For what purpose can it be used?

The platform provides the following possibilities, while allowing for further development and customization.

- Operational monitoring – online monitoring of water quality via sensor status and values. The user can receive notifications for thresholds and limits reached.
- Crisis management - the possibility to have and compare different sources of information, related to a specific event. From client's or end user signal for "bad water quality" in the tap, through sensors in the water network to satellite observation of water source and social media monitoring, the platform can provide valuable informational input to support the decision-making process.
- Emergency situations evaluation – all the stakeholders can evaluate their preparedness via predefined scenarios, according to the best practices in the field of emergency response.
- Emergency communication and awareness - in case of situation with more than one affected organization, the platform allows collaboration of involved stakeholders during the event (emergency responders, water quality operators). There is also an option to generate messages to the Public.

3. Technologies involved and system installation

3.1 Technologies

The platform is deployed and tested in the Linux Ubuntu 20.04 Server. However, all components of the platform are built as Docker containers. Therefore, the platform can be installed on a variety of Linux platforms where Docker Engine is available.

The NGSI-LD protocol and the Smart Data Models are used to ensure semantic interoperability of the platform. In this context, a central place is occupied by the FIWARE[3] Orion Context Broker component that is so-called knowledge hub and provides actual information in JSON-LD format about all entities and their attributes (i.e. sensor measurements, alerts, warnings, etc.).

Cygnus is another FIWARE enabler that is used by the aqua3S platform to provide the historical data service. Internally, Cygnus is based on Apache Flume, an open source technology addressing data collection and persistence.

However, other technology services and standards are used when needed. Therefore, the basic NGSI-LD is complemented with additional tools and protocols:

- To present each individual module an iframe mechanism was implemented in the User Interface (UI). Each different page of the UI application is represented by one or two iframes. An inline frame (iframe) is an HTML element that loads another HTML page within the document. In more detail, each module developed by the partners of aqua3S was integrated into the aqua3S platform via an iframe in order to minimize the risk of dependency failures.
- OGC WMS (Open Geospatial Consortium Web Map Server) technology is used to dynamically request maps from the server, in particular to implement the following services Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS), Web Processing Service (WPS), and Web Map Tile Service (WMTS).
- GeoTiff is used as a domain metadata standard with geo-referencing information. Large images and video from UAV web cameras and satellites are stored in the AWS S3 bucket;
- Mongo DB is a NoSQL document-oriented database that is used by the Social Media Crawler to store the gathered messages from the social network before they have been filtered and published in the Orion. Mongo DB is also used by the Cygnus as a third-party storage to persist the history of context of the Orion CB.
- MySQL is an open-source relational database management system that is used by the Interactive User Interface, Continuity scenarios, Developed Crisis Management Scenarios For Case Studies, and Keyrock application components to store the internal data.

Open standards are also used to secure the platform. The platform security is based on the following open standards and tools:

- TLS/HTTPS is used to protect the confidentiality and integrity of data provided by external systems and to provide the users with secure access to the User Interface. The NGINX plays the reverse proxy role. TSL certificates are installed there in order to provide a secure transportation

[3] FIWARE comprises a suite of software modules supporting the development and dissemination of applications that support the next-generation Internet technologies, https://fiware.org/catalogue/

mechanism via HTTPS protocol for the data exchanged between the platform and external systems as well as to protect the User Interface. Let's Encrypt, which is a nonprofit valid Certificate Authority, provides the TLS certificates for the aqua3S platform.

- SFTP protocol can be also used to transfer data in the form of CSV files if an external system does not support HTTPS. vsftpd, a GPL licensed SFTP server for UNIX systems, is used to implement the SFTP protocol in the aqua3S.
- Keyrock is also FIWARE enabler that is responsible for the user authentication and authorisation in the aqua3S. It provides OAuth2/OIDC based authentication and authorization to secure the aqua3S services and interfaces and to manage the access rights of the user in the platform.
- The Logging and Monitoring is based on the Elasticsearch, Logstash, and Kibana (ELK) stack that is enhanced by the Filebeat and Apache NiFi to collect, transform, and filter logs stored in the log files and through online pipelines, and analyse them in real time. ELK Heartbeat that is part of the Elastic Stack is used to monitor the availability of the platform components and services.

And finally, an AWS Firewall is setup in order to prevent unauthorised access to the aqua3S data and services. That means that we allow only requests from listed IP addresses to the listed ports.

3.2 Prerequisites for system installation

This section describes the actions that are needed to install and configure the infrastructure services that are used by the aqua3S modules. All sizes in the following examples are minimum requirements. It's worth mentioning that no installation is required from the users. The users can access the aqua3S User Interface through a web browser such as Chrome, Microsoft Edge, Opera, etc.

An aqua3S system landscape is structured as follows: one separate Linux server dedicated to the main aqua3 components and the logging and monitoring server. However, one can distribute the different aqua3S components to several servers/hosts (distributed system). To prepare for an aqua3S installation, one should be familiar with the aqua3S platform architecture. The following steps explain how to prepare the installation of aqua3S in the AWS public cloud.

- Set up an Ubuntu 20.04 server (or later) with 32GB RAM and 4 CPUs with a non-root sudo user
  - Login with your AWS account and go to console.
  - Launch Instance on EC2 dashboard.
  - Create security groups to controls the traffic that is allowed to reach and leave the server
  - Login to server and setup and make needed configuration (configure docker, cron, ufw, create new users and user groups, etc.)
- Create an Email service to send emails that is triggered by different events in the platform. Two options are possible:
  1. Create a gmail account/project and enable Google APIs to allow send emails through the REST API.
  2. Set up SES (Simple Email Service)
     - Login with your AWS Account and go to console
     - Get your AWS access keys values to be used in the authentication of the requests

- Verify your domain or email address
- Attach a policy (i.e., ses:SendRawEmail and ses:SendEmail)
- Download an AWS SDK to be used to send email via REST API

- Set up S3 File (object) storage to store large images and video files
  - Login with your AWS Account and go to console.
  - Select the bucket that you want AWS Config to use to deliver configuration items
  - Create Bucket Policy to allows read and write access to objects in an S3 Bucket for the components of the aqua3S platform
- Logging and Monitoring
  - Set up an Ubuntu 22.04 server with 4GB RAM and 2 CPUs set up with a non-root sudo user.
  - Install and configure the Elasticsearch components on the server
  - Install and configure the Kibana Dashboard on the server
  - Install and configure Logstash on the server
  - Install and configure Filebeat to collect data from various sources and transport them to Logstash or Elasticsearch
  - Install and configure Apache NiFi to provide the online API
  - Install and configure Heartbeat monitor the service of the aqua3S platform
- OIDC Identity Provider (Keyrock)
  - Use docker image to install Keyrock
  - Setup environment variables (host,port, https, database, etc.)
  - Add applications, users, groups, roles, organizations, and permissions in the Keyrock
- SFTP server for transferring files through secure file transfer protocols (vsftp)
  - Install and configure vsftp server to support encrypted connections (TLS)
  - Define local folder to store the files
  - Create users and user groups and configure access permissions
- Reverse Proxy (nginx)
  - Install nginx and enable port 443
  - Create Web certificates with a valid Certificate authority, and configure HTTPS

Setting up routing rules for the following aqua3S components: Logging API, User Interface and API, Orion Geoserver, Webdav, Keyrock , Visual Analytics, Historical data service API, 3D Visualization, Warnings, and Alerts when they are deployed

4. System capabilities

This section provides an overview of the aqua3S platform capabilities that were driven by the user requirements.

4.1 System requirements

The aqua3S platform was developed following the requirements set by a large and heterogeneous group of experts, including people working in water authorities, water utilities, public security agencies, and emergency responder authorities.

The system requirements that were gathered can be seen in Table 1, and they are organised into the following categories, i.e., user management, Level 1 data, visualization, Level 2 data visualization, Alerts and warnings, and finally Standalone functionalities. Regarding the characterisation of data as Level 1 or Level 2, it should be noted that the higher the level the more the data are processed. Thus, Level 1 data result from the processing of raw data, while Level 2 data result from the further processing of Level 1 data.

ID	System requirements – Description
SR1	User Management
SR1.1	The users should be able to log in using their credentials.
SR1.2	The users should be able to see different information according to their permissions.
SR2	Level 1 data visualisation
SR2.1	The system should be able to visualise data from sensors, their status and show the different parameters on a GIS interface.
SR2.2	The system should be able to receive satellite data and visualize the outcome of the analysis for several types of pollution events and phenomena on a GIS interface.
SR2.3	The system should be able to retrieve and visualize social media posts related to flood events and water quality issues on a GIS interface.
SR2.4	The system should be able to retrieve and visualize data from water operators' Call Complaints centers on a GIS interface.
SR2.5	The system should be able to receive and visualize data from drones (UAVs) on a GIS interface and identify specific type of objects in the retrieved images.
SR2.6	The system should be able to receive and visualize data from CCTVs on a GIS interface and identify specific type of objects in the retrieved images.
SR2.7	The system should be able to visualise GIS layers provided by its users.
SR2.8	The system should be able to retrieve and visualise historic data either on a GIS map or on a graph depending on the type of data.
SR3	Level 2 data visualisation
SR3.1	The system should be able to display the results of the hydraulic model of the rivers, drainage network, ground-water balance and pollutant propagation.
SR3.2	The system should be able to identify and provide a set of solutions in case of a pipe repair and pipe break mitigation (requires the existence of hydraulic model).
SR3.3	The system should be able to produce and visualise flood risk and hazard maps on a GIS interface.
SR4	Alerts and warnings
SR4.1	The system should be able to allow the user to adjust the sensor thresholds.
SR4.2	The system should be able to provide alerts in case of abnormal values/ events from the Level 1 data.
SR4.3	The system should be able to provide warning notifications in case of abnormal values/ events in a clear way that can be seen from the user from any tab.

SR4.4	The system should be able to automatically send a mail to a pre-defined mailing list of operators.
SR4.5	The system should be able to support the creation of historic reports containing the alert events.
SR5	Standalone functionalities
SR5.1	The system should be able to visualize and monitor continuity scenarios that involve the triggering of specific unavailability scenarios by different events.
SR5.2	The system should let the users to upload and share documents related to internal procedures among different users.
SR5.3	The system should be able to allow the user to draft standardized set of warning messages.
SR5.4	The system should be able to provide a high-level vulnerability and preparedness assessment for different cases of crisis.

Table 1. System requirements.

Given, the aforementioned system requirements, several modules have been developed and integrated into the aqua3S platform to address them.

4.2 System capabilities

In this section, a brief overview of the system capabilities/ modules is provided, while providing a link to the system requirements (Table 1).

Level 1 data visualisation

As the far as the "Level 1 data visualisation" is concerned, it can be separated further by considering whether the data are provided real-time, near real-time or on demand.

As far the real-time monitoring of water quality is concerned, the following modules have been developed:

- Sensors, which are used for real time monitoring of the levels of several parameters. The location of the sensors is visualized on a GIS/map interface and the measurements taken from the available (existing and newly installed) sensors in the water source, drinking water treatment plant (DWTP) supply network are displayed. For more information, please check Section 6.1.1. This module responds to the system requirement SR2.1.
- Social media, which are used for real time capture of single tweets and eventually tweets from monitoring keywords identified as related to water quality or floods. Moreover, the module localizes potential pollution around the water source through social media and pins the social media posts on a GIS map. For more information, please check Section 6.2.1.1. This module responds to the system requirement SR2.3.
- Call complaints, which captures citizens' complaints and sends them to the official call complaints centres of water operators. The call complaints are localised and visualised on a GIS map. For more information, please check Section 6.2.1.2. This module responds to the system requirement SR2.4.
- CCTV data, which involves the real time retrieval and visualisation of image frames retrieved by the cameras, and the identification of specific objects in them including people, boats and vehicles. For more information, please check Section 6.2.2.2. This module responds to the system requirement SR2.6.

As far the near real-time monitoring of water quality is concerned, the following modules have been developed:

- Satellite data, which are used for identifying and localising pollutants such as oil spills, algae blooms. Also, water floods and fluctuation in level of water bodies can be observed via satellite images. For more information, please check Section 6.2.3. This module responds to the system requirement SR2.2.

Finally, as far the on demand monitoring of water quality is concerned, the following modules have been developed:

- UAV data, which involves the visualisation of the on demand flights realised by end users along with several metadata from the flight. Moreover, an analysis of key image frames of the video was realised, and specific objects were identified including people, boats and vehicles. For more information, please check Section Error! Reference source not found.. This module responds to the system requirement SR2.5.
- GIS layer, which involves the visualisation of user GIS layers on the GIS map. For more information, please check Section 6.1.3 and Section 6.2.5. This module responds to the system requirement SR2.7.

Depending on the type of the source, specific visualization capabilities are offered by the system, i.e., via map or graphs (see Table *2*). Graphs capturing the sensor values in time, per parameter (please check Section 7). It should be noted that historic data are also available either via the graphs (in case of sensors) or via map (in case of satellite, social media, CCTV, UAV, and call complaint data). This feature covers the system requirement SR2.8.

Sources	Map	Graphs	Images/videos
Sensors	✓	✓	
Social Media	✓	✓	
Call complaints	✓	✓	
Satellite data	✓		✓
UAVs	✓		✓
CCTVs	✓		✓

Table 2. How data can be visualized.

Level 2 data visualisation

As the far as the "Level 2 data visualisation" is concerned, the following modules have been developed.

- EPANET module, which display in advanced 3D visualization a map results of the hydraulic model of the rivers, sewerage, groundwater balance and pollutant propagation (i.e., EPANET). For more information, please check Section 6.1.2. This module responds to the system requirement SR3.1.
- Intervention Management Model module, which identifies and and provide a set of optimal solutions in case of a pipe repair and pipe break (requires the existence of hydraulic model) through a GUI. For more information, please check Section 12. This module responds to the system requirement SR3.2.
- Crisis maps, which display detailed vectorial flood risk and hazard maps for the respective regions, layered with the water supply and sewerage network. The aim is to help to understand the vulnerability of the water supply network in case of flood and take preventive measures. For more information, please check Section 6.2.4. This module responds to the system requirement SR3.3.

Alerts and warnings

As the far as the "Alerts and warnings" is concerned, the following modules have been developed.

- Alerts module, which provides the user the ability to adapt the thresholds of the devices. Moreover, it produces alerts in case of abnormal measurement from the aforementioned sources. The alerts can be related to the overtopping of some predefined alert thresholds in the measurements by the qualitative and quantitative sensors in the water source, DWTP or supply network or the overtopping of predefined values for satellite related analysis, or the identification of specific types of objects in images taken by UAVs/ CCTVs. For more information, please check Sections 8.2.2, 8.2.3, 8.2.4, 8.3, 8.4, 8.5, and 8.6. This module responds to the system requirements SR4.1 and SR4.2.
- Warnings module, which provide warning notifications to inform the users regarding the new or updated alerts that are made available via alert sources (i.e., Devices, CCTVs, UAVs, Social Media and Satellites). The difference between warnings and alerts is that the information provided is rather concise and that it is available to the users constantly regardless of the tab there are browsing. For more information, please check Section 8.7. This module responds to the system requirement SR4.3.
- Email Generation module, which allows the users to receive emails in case that an alert triggered by any of the aforementioned Level 1 sources. For more information, please check Section 8.8. This module responds to the system requirement SR4.4.
- Historic Reports, which is responsible for identifying and keeping track of the historical alerts that comply with the criteria defined in the platform. The reports can be converted to PDF files and downloaded by the user. For more information, please check Section 14. This module responds to the system requirement SR4.5.

Standalone functionalities

As the far as the "Alerts and warnings" is concerned, the following modules have been developed.

- Continuity scenarios module, which involves specific unavailability scenarios, triggered from different events related to a water infrastructure. The module aims at serving as a reference procedure during the planned crisis drills of a water infrastructure and also acts as a guide when an event occurs. For more information, please check Section 11. This module responds to the system requirement SR5.1.
- Files module, which provides the users to access, upload and share documents related to internal procedures among different users. For more information, please check Section 9. This module responds to the system requirements SR5.2.
- Warning Message Generation module, which allows the users to promptly generate standardised warning messages. The main purpose of the tool is to support various departments to quickly generate and share pre-approved messages in-line with the best practices. For more information, please check Section 13. This module responds to the system requirement SR5.3.
- Preparedness assessment module, which provides assessment of the organizational preparedness for emergency events and crises. It also provides guidance and recommendations based on the level of preparedness. For more information, please check Section 10. This module responds to the system requirement SR5.4.

5. Overview of platform

This section provides a short overview of the platform including the login page and examples of different tabs.

Thus, users can access the platform through the Login page. The user should have a username and password. Each user is assigned a specific role that affects the type of information, they are able to visualize.

Figure 1.Log in page.

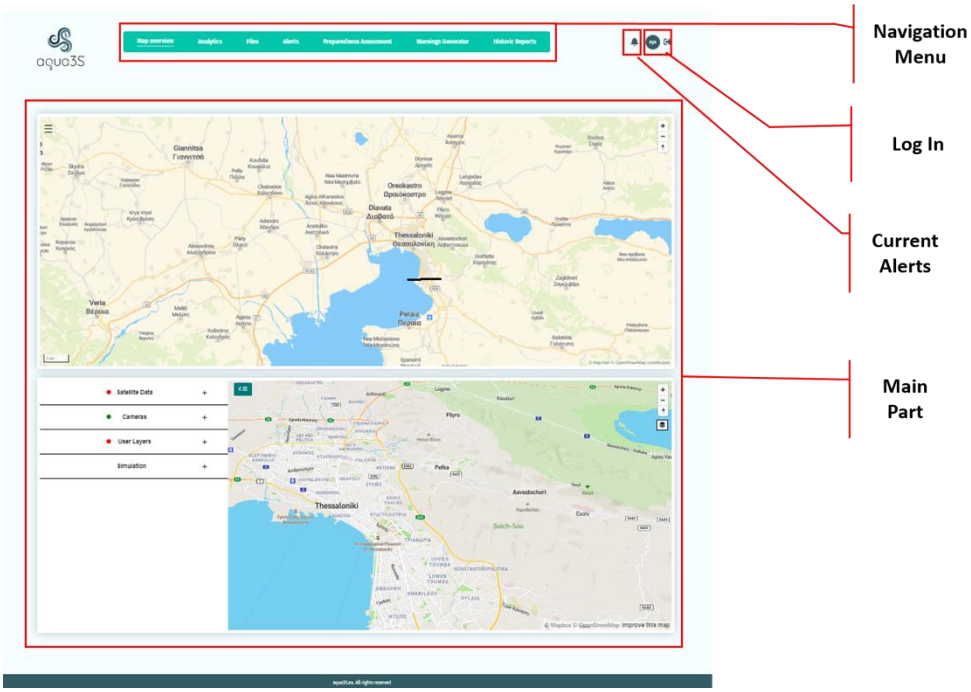


Figure 2. Home Page.

To log in, the user should navigate to https://platform.aqua3s.eu/login, as shown above and enter his/her credentials (thus addressing the system requirement **SR1.1**).

Once logged in, the user will see the home page (Figure *2*). Depending on the user role, the available functionalities (as seen in the 'Navigation Menu') are customizable (thus addressing the system

requirement **SR1.2**). Figure *2* serves as an example of all available modules and the available functionalities for the specific user are: Map overview, Analytics, Files, Alerts, Preparedness Assessment, Warning Generator and Historic Report.

Below, few examples of the different tabs of the aqua3S platform are provided.

Specifically, Figure *3* depicts **sensor data** and provides information on the exact location of the device itself. In order to visualize the **satellite and UAV** images, as well as the citizen data, please scroll down the page, as shown in Figure *4*. The **Analytics** tab (Figure *5*) visualizes historical data from the different sensors in a graph format. The **Alerts** tab (Figure *6*) visualizes the thresholds for the different parameters monitored and enables the user to activate notifications and setup the min/max values. The "**Preparedness against hazardous events**" (Figure *7*) tool is a crisis management tool that aims to support stakeholders that are responsible for the water infrastructure, in assessing their preparedness level against a series of hazardous events and helps them improve their level of preparedness by providing downloadable high-level recommendations.

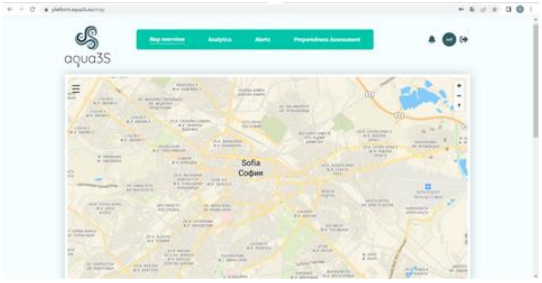


Figure 3. Sensor map.

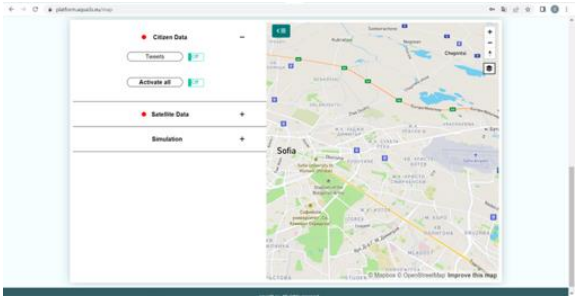


Figure 4. Satellite/ UAV/ social media/ CCTV map.

Figure 5. Analytics tab.

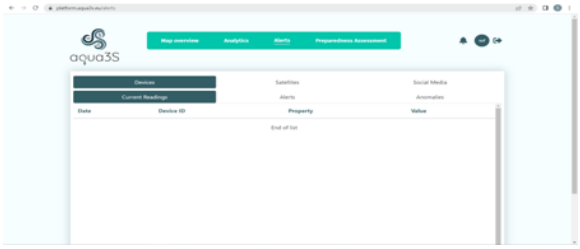


Figure 6. Alerts tab.

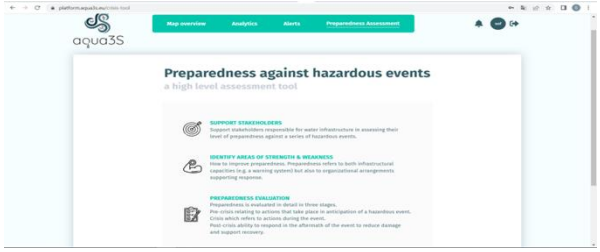


Figure 7. Preparedness assessment tool.

6. Map overview

aqua3S platform includes two maps on the “Map Overview” tab. The first one visualizes sensor - related data including data from EPANET and it is called “Sensor – related map” (for brevity map1), while the second visualizes all the other data coming from satellites, social media platforms, call complaint centres, UAVs and CCTVs and it is called “Multi – source map” (map2).

It should be noted that both maps give the ability to users to visualise GIS layers.

6.1 Sensor - related map

This section describes the functionalities of the “Sensor – related map” including the ability to visualise sensor data, sensor status, and hydraulically related data.

6.1.1 Sensor data

The primary view of this map is the pilot’s sensors (Figure *8*). This data is collected from the FIWARE context broker and presented as a set of markers or pins on a geographic ‘slippy map’[4], like Google Maps. This map is using MapLibre which is an open source slippy map. For visualisation, sensors are grouped by the FIWARE ‘name’ field in the device smart model, such that all sensors that share a common name are placed at the same location. This is done in part as the slippy map framework will only display the most recent marker if markers are placed at the same, or very similar locations.

[4] Slippy maps is in general, a term referring to modern web maps, which let you, zoom and pan around (the map slips around when you drag the mouse).

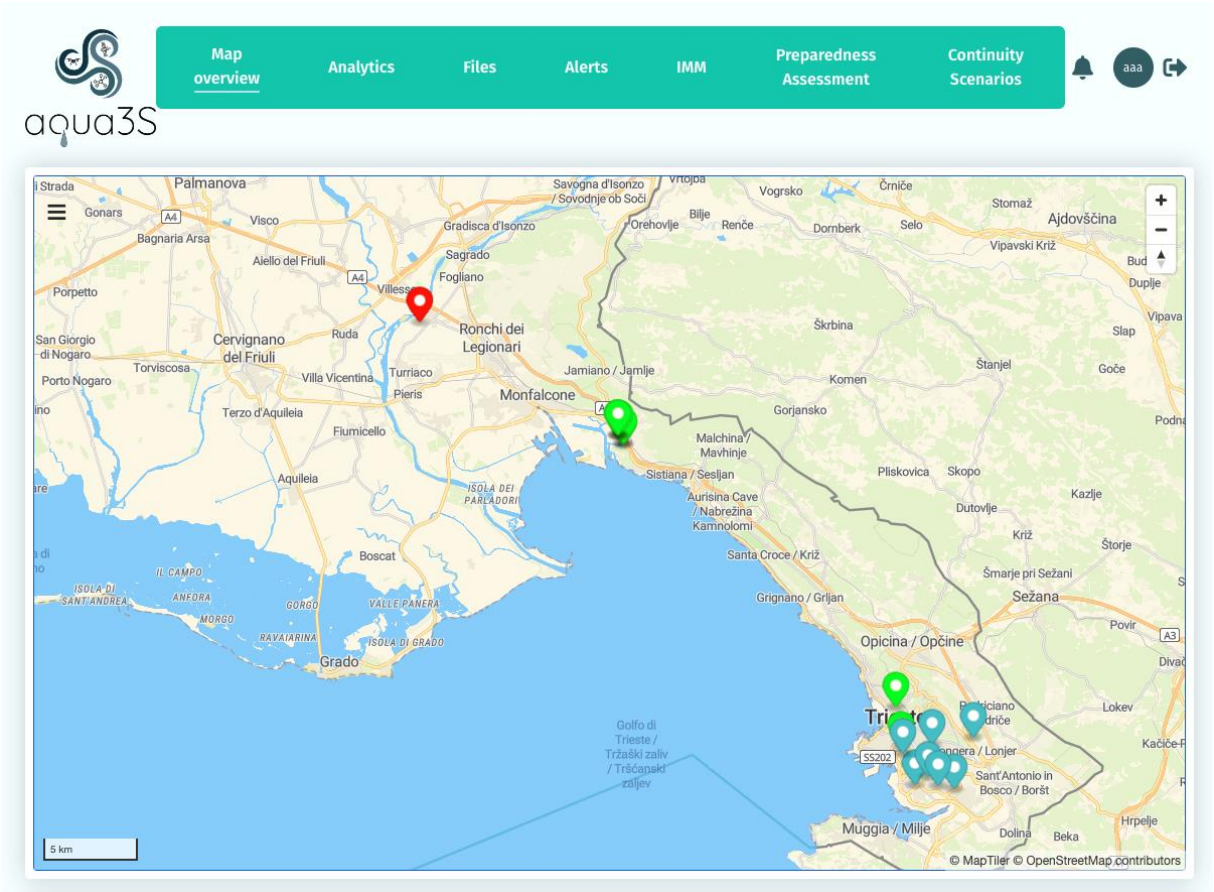


Figure 8. Map view showing sensor data.

The map visualisation uses several device smart model attributes to colour-code the sensor markers. Figure *8* shows a typical geographic sensor view, with sensors bundled together into groups and represented by colour-coded markers. For a group of sensors that are operating 'normally', the marker is coded green, as shown by the markers in the middle of the map. For a group of sensors where at least one sensor's smart model 'deviceState' is set to 'Red', the marker will be red, as per the marker to the left of the map. The 'deviceState' property is part of the IoT processing component of aqua3S and is typically used to denote a sensor as not working or offline.

Figure *9* details sensors that are over-topping or under-bottoming. aqua3S has three mechanisms to track sensor values (alerts, anomalies and EPANET anomalies). The olive green marker in the top left of the map is indicating that at least one of the sensors in that group is triggering an alert (where a sensor has gone out of an operator defined range limit), whilst the purple marker in the bottom right of the map is indicating that a sensor has triggered an anomaly (where a sensor has gone outside of historical limits). Finally, the blue markers in the bottom right-hand side of Figure *8* are indicating that sensors have gone outside of EPANET anomaly limits (based on EMWA data).

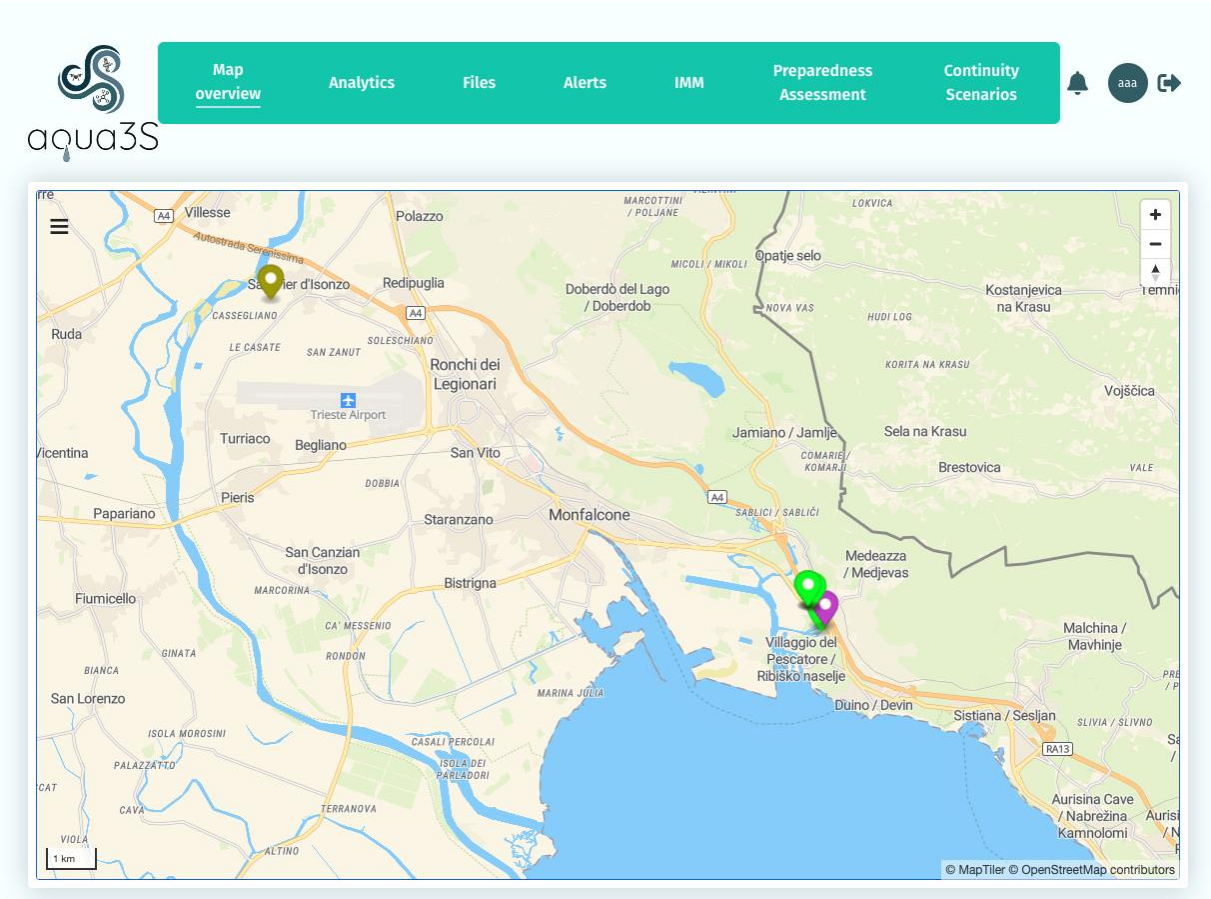


Figure 9. Map view showing markers with alert and anomaly status.

In addition to the visual / colour representations of sensors, clicking on marker will bring up textual data concerning the sensors that are represented by the marker (see Figure *10*). The pop-up box reveals information containing the date and time at which the sensor was read, along with its name, property, and current value. For sensors that are triggering alerts, anomalies or EPANET anomalies, this text is colour-coded to match the condition and text is included to state the nature of the triggering condition.

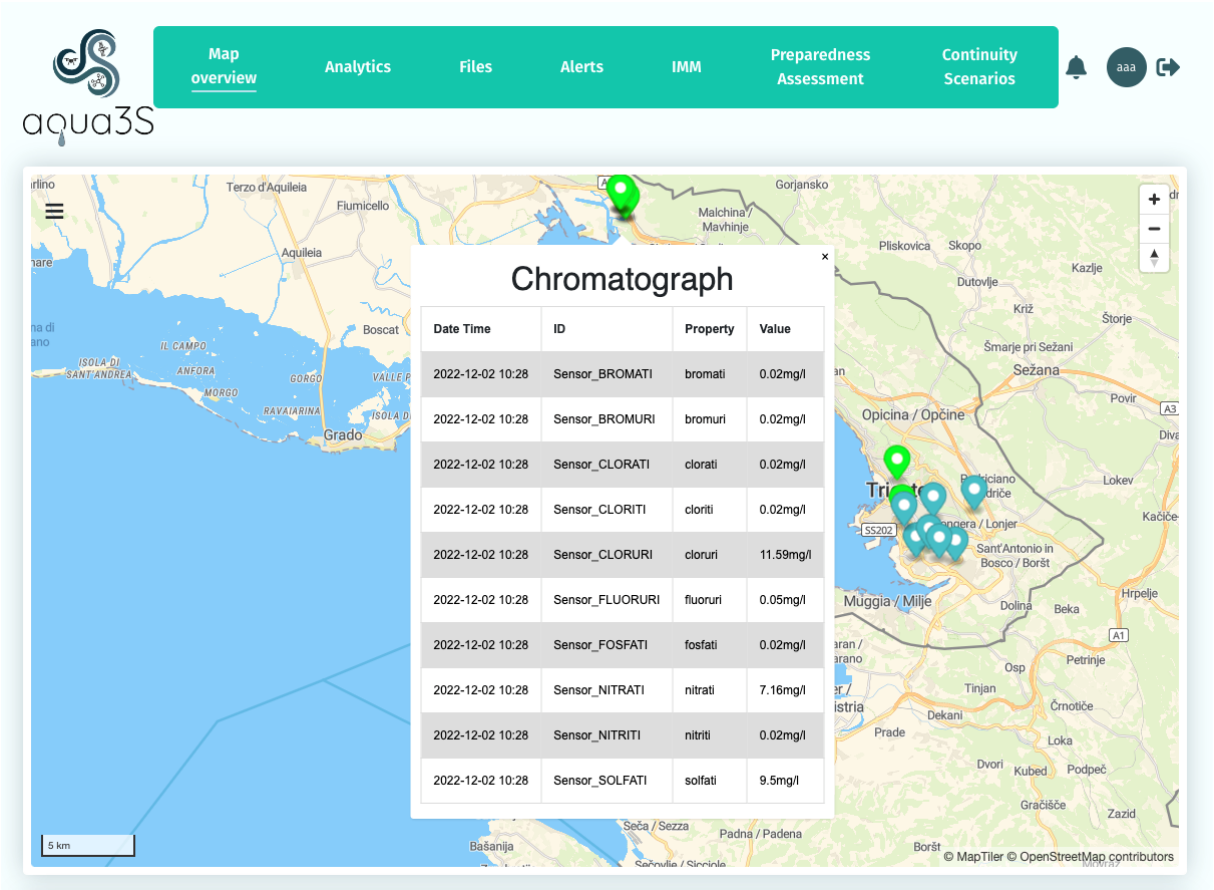


Figure 10. Map view showing pop-up sensor detail.

There is an implicit hierarchy of triggering conditions, such that if a sensor is set to deviceState 'Red', the marker will be red, regardless of the state of any other sensors in the group. Likewise, if a sensor is in the alert state, it will override all the sensors that are 'fine', 'anomaly' or 'epanet anomaly' (Figure *11*).

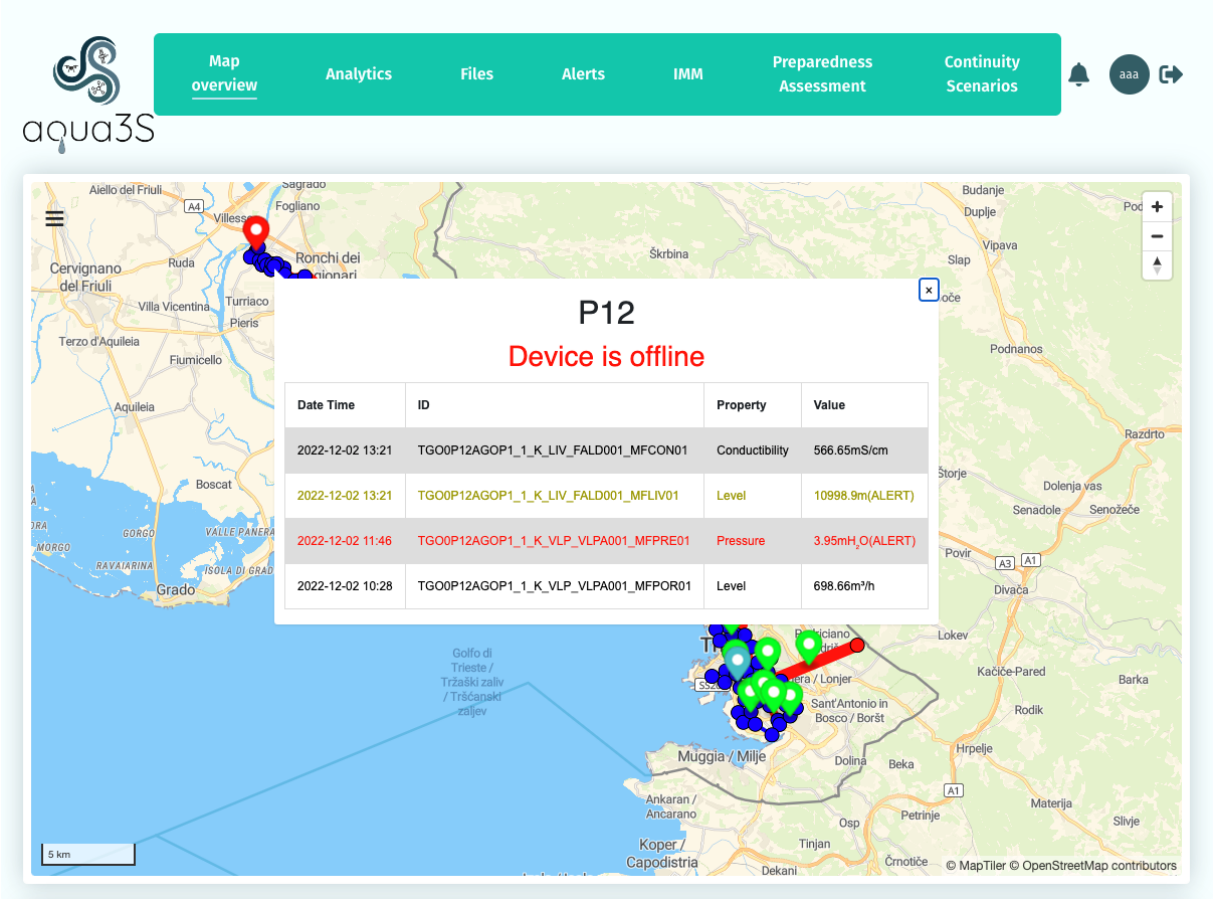


Figure 11. Map view showing sensor detail colour-coding of sensor states.

6.1.1 Hamburger Menu

The top left-hand corner of the map view contains a black hamburger menu that provides additional functionality for working with the map view. The menu is modal, such that clicking on the hamburger icon will reveal the menu and clicking on it again will hide the menu (Figure 12). The menu is data-driven and scrollable, so it will contain information and options based on the data provided by the operator.

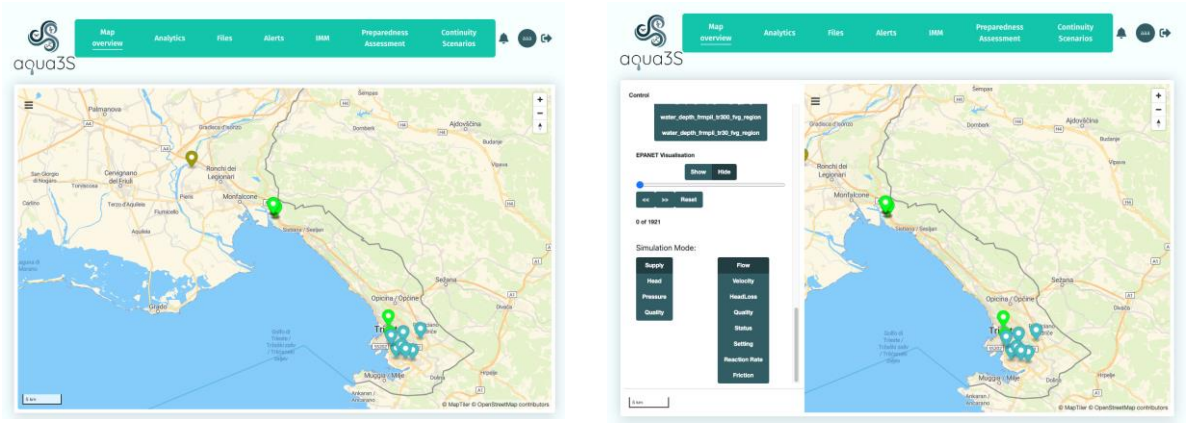


Figure 12. Hamburger menu operation

The menu comprises of the following functional groups: map mode, which allows users to choose between 'street view' and 'satellite' map backgrounds for the slippy map, device / property views, which allows users to filter map markers based on the properties of the sensors they represent, user layers,

which allows users to view, or hide, overlay data and EPANET visualisation which allows users to interact with EPANET models and associated simulations.

6.1.2 EPANET

EPANET software is considered the standard when it comes to modelling hydraulics within water distribution systems. However, this software was developed over 20 years ago and the visualization side the software is lacking, with no method to integrate with sensor information and other GIS artifacts. Therefore, the aqua3S project has developed a method to integrate EPANET hydraulic models into the overall aqua3S platform, improving usability and visualization.

The EPANET mapview (Figure *13*) allows users to visualize the hydraulic performance of the network within a centralized platform, allowing the user to easily compare hydraulic performance with sensor readings and visualize within a GIS framework. A user can visualize the EPANET model within a GIS framework, and toggle through time-steps to identify and visualize hydraulic performances, such as pressure, flow, velocity, etc., as well as network static properties, including pipe diameter, pipe length, etc. The user can easily compare hydraulic simulations to actual sensor readings to help identify possible issues within the water distribution system.

In case water quality parameters are provided, these can also be visualized within the EPANET mapview.

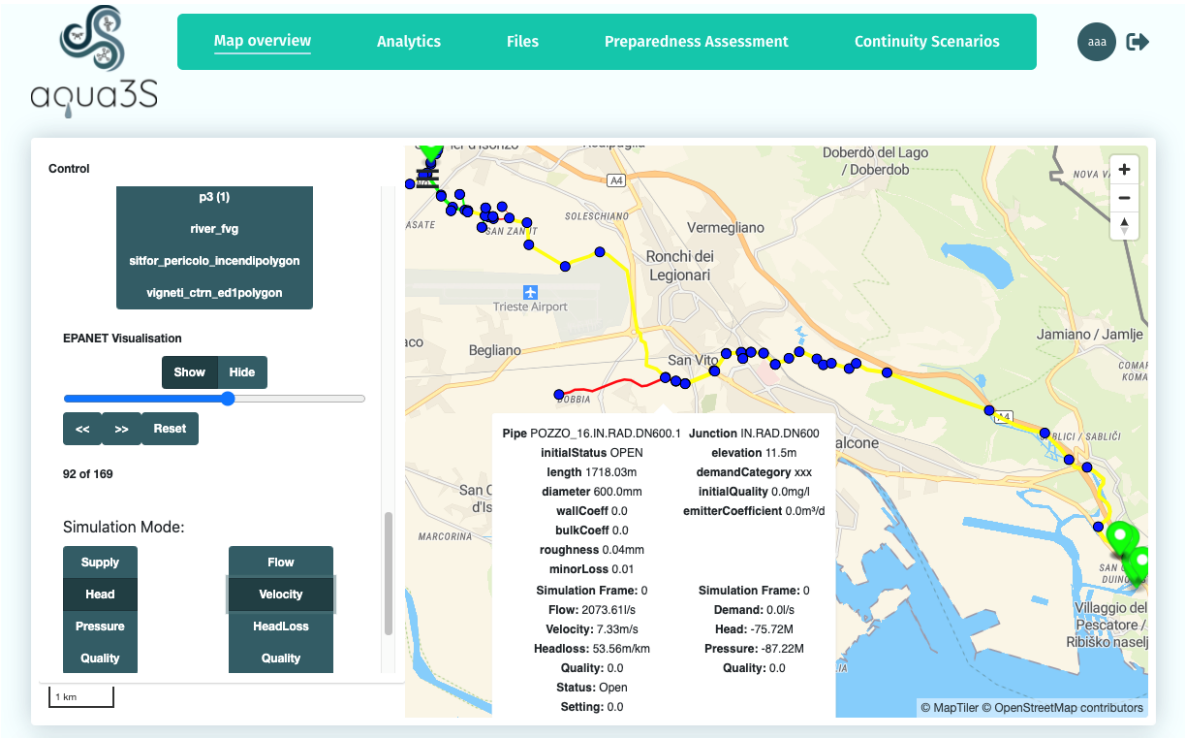


Figure 13. EPANET visualisation.

6.1.3 User layers

User layers are described as any type of visualisation data that can be added to the slippy map. For Maplibre, layers are presented in geoJSON format; therefore, if data can be converted into geoJSON from whatever source format is provided, it can be displayed. The main limiting factor is the complexity

of data, though through tests, it was proven that data with as many as 100,000 layers could be visualised through Maplibre without any obvious performance issues.

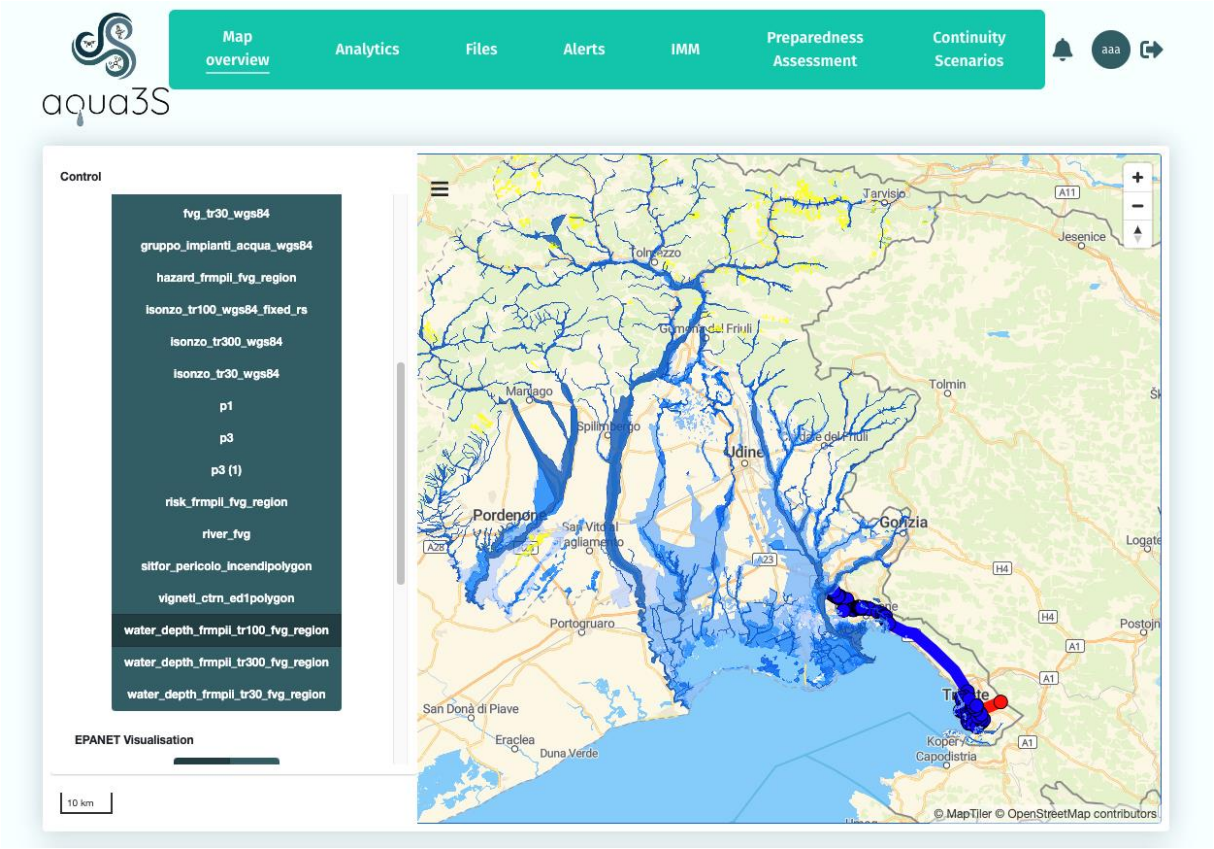


Figure 14. Flood map user layer.

Figure *14* shows flood map data for the Monfalcone region of the Trieste pilot. The source data came from WMS and was exported to a Shapefile and then to GeoJSON. The region of the flood map is fairly large, at around 100km x 100km and comprises around 100,000 features. Figure *15* depicts the flood map in Figure *14* being interrogated by a user, with the platform presenting feature-specific data in the form of a pop-up, in this case detailing the feature metadata and a bespoke look up of water depth to feature colour.

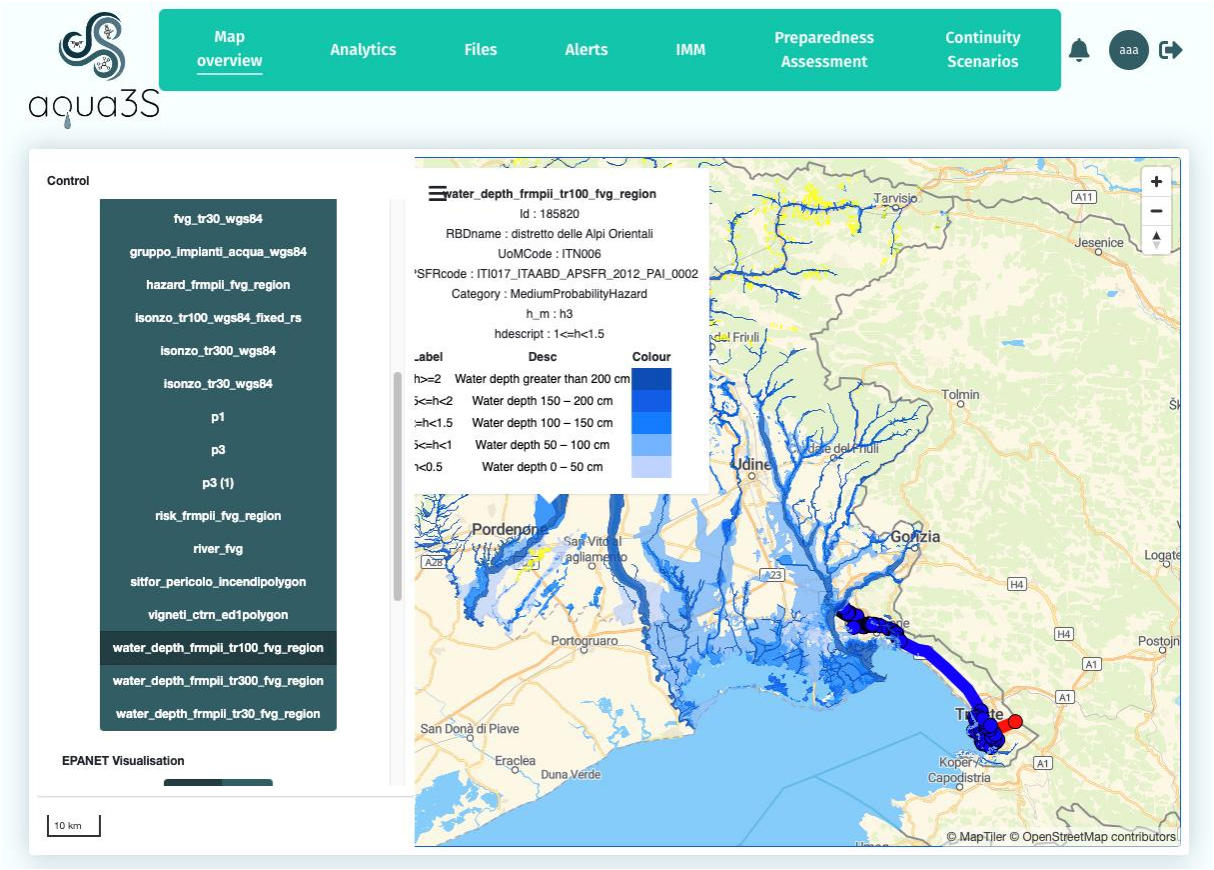


Figure 15. User layer data.

In comparison, Figure *16*, details user layer data constructed from multiple Google Earth KMZ files, with data presented either as points or lines (depending on the content of the KMZ file). Like the flood map example, selecting visualisation data results in the associated metadata being presented as a pop-up. In this instance, the metadata was fairly sparse, though this is pilot defined, however pilots did report some issues in authoring and editing metadata.

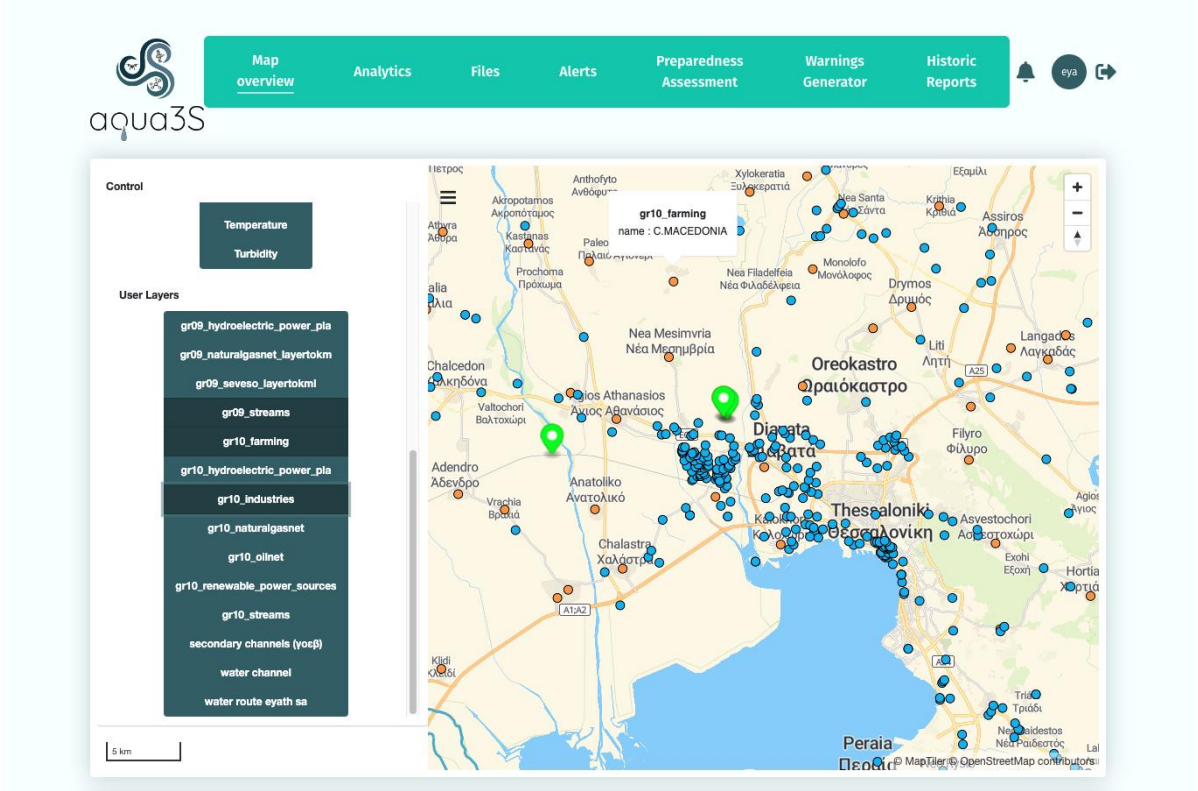


Figure 16. KMZ user layer data.

6.2 Multi – source map

This map is used for visualising data from satellites, social media platforms, call complaint centres, UAVs and CCTVs. Apart from visualising the aforementioned data, the map itself provides some basic functionality like the zoom in and zoom out. It also has two basic modes that users can select regarding the display of the map – the satellite and the street mode. Moreover, users can change the orientation of the map by clicking and holding their right mouse button and move the mouse around simultaneously. They can also move to another region of the map by clicking and holding their left mouse button and move the mouse to the direction that they want to be displayed at the centre of their screen. On the left part of map, there is the menu panel, which is organized based on the categories and subcategories of the available data that contains filters with toggle buttons so users can set the visibility of the data.

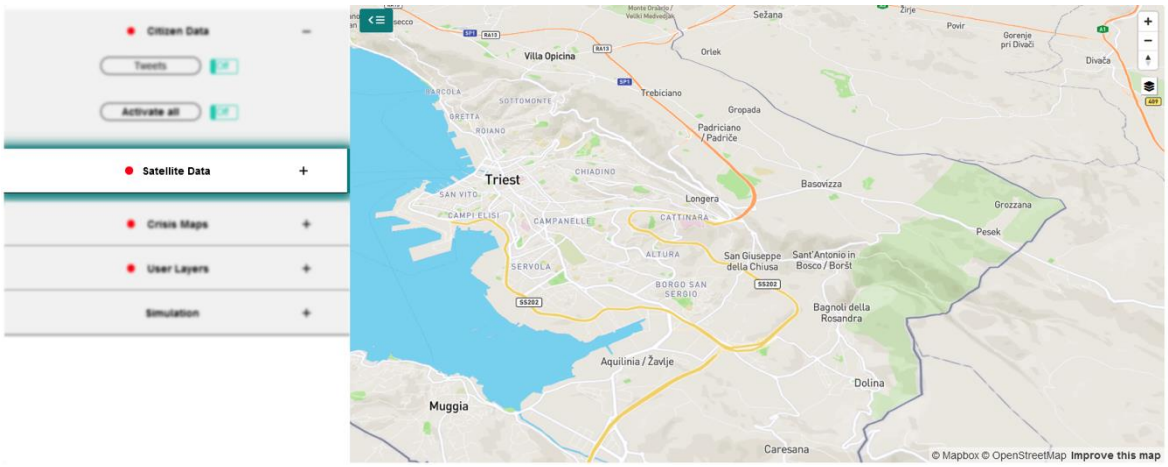


Figure 17. Changing map's orientation.

On the bottom part of the menu there is the simulation functionality tool that gives the user the ability of chronological simulations with a timeline slider tool in order to filter and return historical data of all the available data categories.

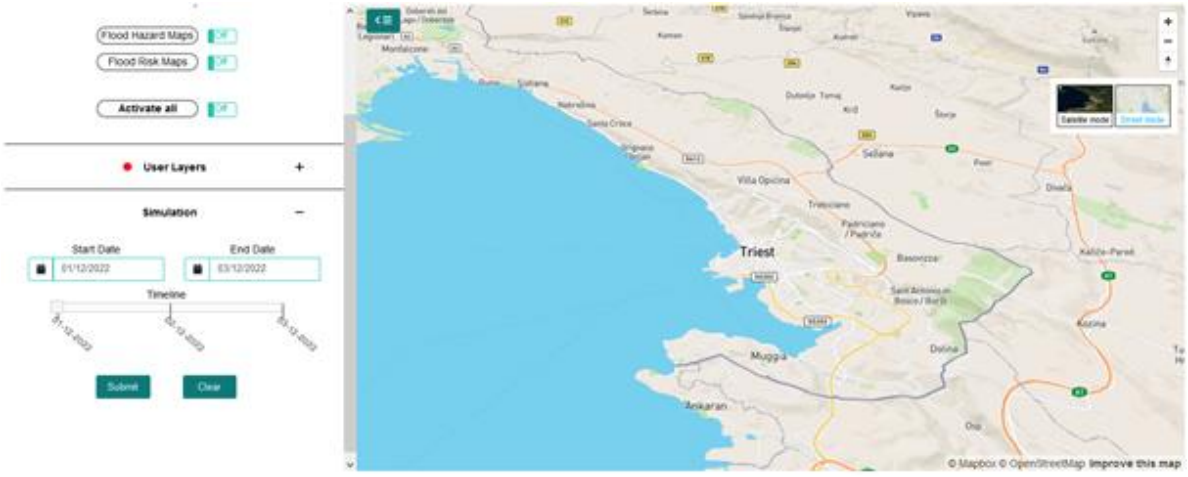


Figure 18. Simulation functionality.

Users have the ability to left click on all visualized data on the map, which opens an infoWindow on the right side of the screen that contains more detailed info of the data. In the case of satellite data (Water

Bodies ,Flood Detection, Water Depth, Water Velocity, Oil spill, Algae Bloom, Flood Hazard Maps, Flood Risk Maps , UAV flights), a button labeled "download shapefile" displays at the bottom of the infoWindow, allowing users to download the shapefile of the visible satellite data that was clicked.

6.2.1 Citizen data

Two types of citizen data are considered and ingested in aqua3S platform, i.e., Tweets and Call Complaints. The aim of using such citizen data is to collect either through social media or via dedicated centres the opinion of citizens regarding water quality and flood related events, and thus support the creation of social awareness in a water distribution network.

It should be noted that the collection of data from Twitters respects and abides to the recent General Data Protection Regulation (GDPR) and focuses on the event and the creation of social awareness, rather than monitoring specific user communities.

6.2.1.1 Tweets

The use of data from Twitters aims at detecting events in near real time that refer to floods / droughts or water quality issues. This information can be used to warn the users for the start of an incident or provide them with more details about the incident and thus, raise the situational awareness. The social media data are retrieved in real time based on keywords that are defined from the expert users. The component developed incorporates several analysis methods that extract further knowledge from the posts and enhance the original information coming from Twitter. Specifically, it includes automatic extraction of geo-information from the text of the posts for location detection, estimation of tweet reliability, and estimation of tweet relevance with the aqua3S use cases (i.e., floods/ droughts, water quality). Then, the relevant tweets are grouped based on their posting time and their geo-information. The groups of tweets that contain more than a predefined number of tweets are considered as events and depending on the number tweets they may alerts indicating that something abnormal happens in the detected area.

Figure 19. Social media visualisation.

Tweets are visualized with markers that include the Twitter logo on the map (Figure 19), based on their geotags and users can see the whole tweet text data by hovering over a specific marker. A pop-up window appears on top the marker that contains the tweet's text. Users can also left click on the tweet marker, the marker's icon changes into the light blue colour that indicates that the marker is being

selected and an infoWindow appears on the right side of the screen that contains information such as the coordinates of the tweet and the entire tweet as well. If the tweet data contains an image, it will be displayed as well. Users can close the infoWindow by left clicking the button with the X mark on the top left side of the infoWindow.

6.2.1.2 Call Complaints

aqua3S platform can ingest and visualise complaints from citizens as another type of crowdsourced information. These complaints are submitted to the official call centres of the water operators in the form of emails or phone calls and concern water quality problems. They typically contain the date and time that the complaint was submitted, a description of the water quality incident and the coordinates where the problem has appeared. All the personal details of the individuals that fill in the complaint form have been properly removed based on the data minimization principle (GDPR, Art. 5 (1) c).

Call Complaints are represented visually by markers that each have a distinct colour to help them stand out and they also have a phone symbol (Figure 20). The provided functionality is identical to that which is detailed in section 5.2.1.1

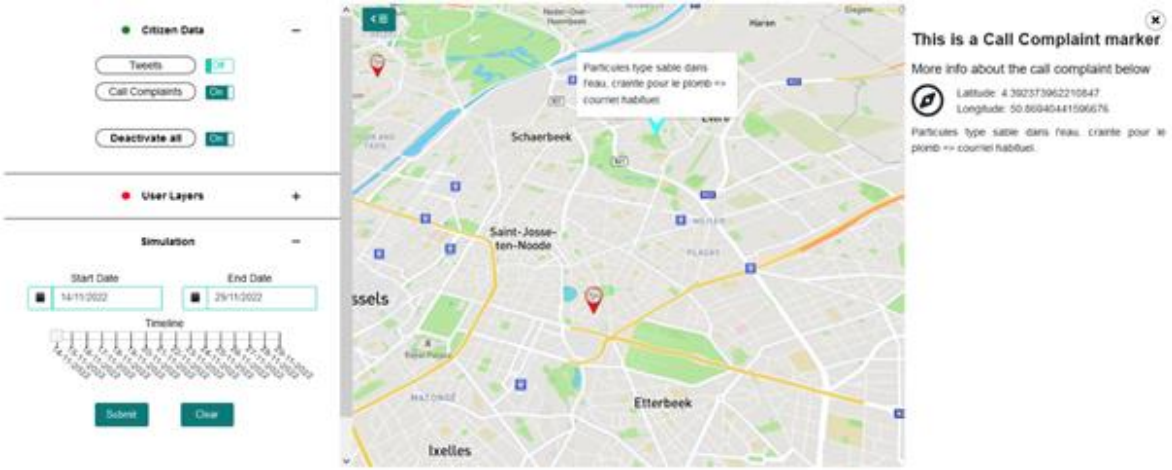


Figure 20. Call complaints visualisation.

6.2.2 Cameras' data

Two types of Camera data are considered and ingested in aqua3S platform, i.e., data from cameras on Unmanned Aerial Vehicles (UAV) / drones and data from Closed-circuit television (CCTVs). The images of the aforementioned sources are analysed by computer vision techniques, and detection of specific objects is realised including humans, land vehicles and boats mainly for security purposes. Thus, the detection of the discussed concepts is realised in order to identify objects that could possibly pose a threat to water safety and support operators in real-time crisis event monitoring.

6.2.2.1 UAV

aqua3S ingests, analyses and visualises images from UAV flights. Specifically, aqua3S platform users upload on a dedicated SFTP server, the UAV recording, along with accompanying metadata, following a specific naming convention that includes the timestamp of the flight. As soon as the platform detects a new UAV flight, the UAV analysis module is invoked that performs visual analysis on individual frames in order to detect objects such as humans or vehicles near water resources, via deep learning techniques. Object recognition is performed using Faster R-CNN architecture, pre-trained on Microsoft COCO dataset, along with Inception Resnet in atrous mode for the extraction of deep features. Analysis results

include an output video file, containing detected objects annotated with their bounding boxes, and several JSON files with information about the flight, individual frames and detected objects. Additionally, the module provides alerts to its operator when an object is detected.

Data from UAVs is visualized in two different map entities. The identified objects are visualized on the map as markers with a unique colour and an icon of a UAV , and the UAV flights are shown as line layers (Figure 21).

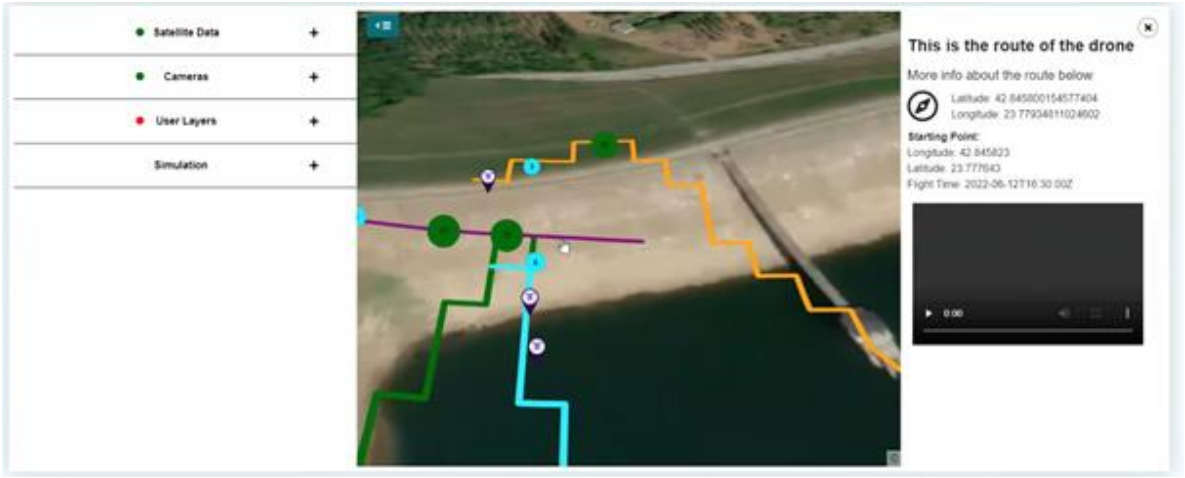


Figure 21. Visualisation of UAV flights.

Users may left-click on the line layers to bring up an infoWindow on the right side of the screen with information such as the coordinates of the point of click on the map/layer, the beginning point of the UAV's route, the timestamp of the data and the video of the entire flight (Figure 21).

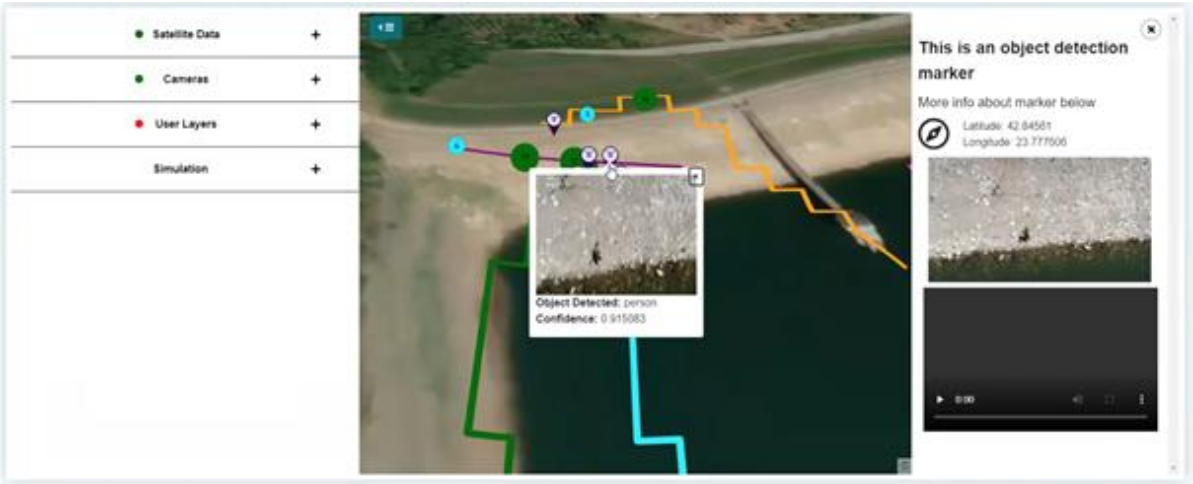


Figure 22. UAV flight information.

When hovering over the UAV markers a pop up window appears above that contains an image of the identified object, a short description of the object and the metric confidence that is a score indicating the detection confidence (i.e., probability) of the specific object into the image.

Users may left-click on the markers so that an infoWindow will appear on the right side of the screen that contains information such as the coordinates of the marker, an image of the identified object and the video of the entire flight (see Figure 22).

6.2.2.2 CCTV

CCTV data is another source of visual information supported by aqua3S platform for detecting malicious acts or unauthorized access to water resources, by visually detecting certain objects such as humans and vehicles. The system can consume images from fixed CCTV cameras, installed near water facilities, via an application programming interface, in a specified time period of interest. Every new image is forwarded to the image analysis service in order to detect humans or vehicles on it. Image analysis uses the same deep learning object recognition setup as the UAV analysis module. In case there are objects found, analysed images are stored with the objects annotated with their bounding boxes. Analysis results also include JSON files with information about the camera, individual images and detected objects. Additionally, an alert is created every time an object of interest is detected.

The CCTV cameras are visualized as markers with a unique color and an icon of a camera. When users hover over the marker a pop up window appears with information of the region that the camera is located (Figure 23).

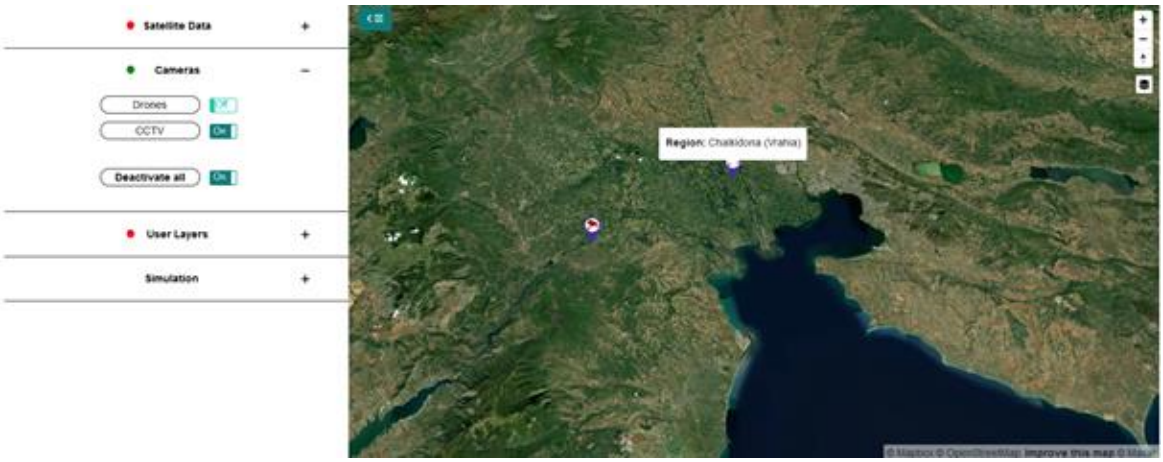


Figure 23. CCTV visualisation on map.

Users can left-click the marker and then a modal appears on the screen (Figure 24). On the top of the modal there is information on the region and ID of the camera. On the left side of the modal there is the simulation tool with two date pickers that allows the users to select the date range. Once the desired dates have been chosen, users can left-click the submit button to send an inquiry to FIWARE context broker, which causes a drop-down menu with all the chosen dates to appear below the simulation tool.

In case the fetched data contain objects that have been detected by the cameras, a blinking text labelled “Objects Detected” appears on each date menu item (see Figure 25). Users can select the date of their choice and then a sub-menu appears that contains all the hours of the specific date. New blinking texts appear on each time menu item with the labels “Photos available” in case that this time period contains images with no object detection and “Detection Photos Available” in case images that are being contained have a detected object.

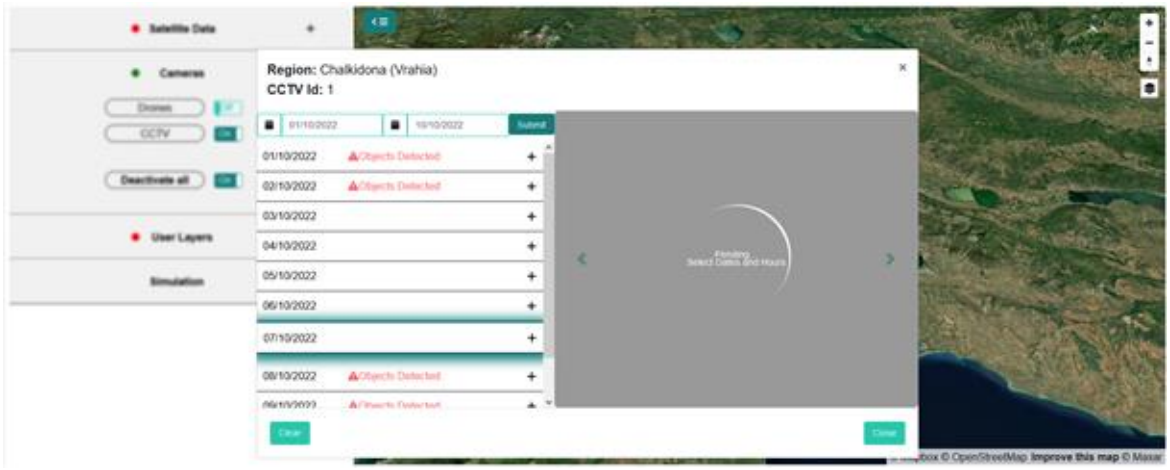


Figure 24. CCTV modal.

Users can select the time period that they want the images to be visualized on the front end by left clicking on the time period menu item and then the carousel that is on the right side of the modal will load the selected images. Users can navigate through all the images by left clicking on the left and right arrow of the carousel (see Figure 25). On the top side of the carousel, there is a sort description of the object that have been detected on the image that the user is seeing and the amount of images that were fetched for the selected time period.

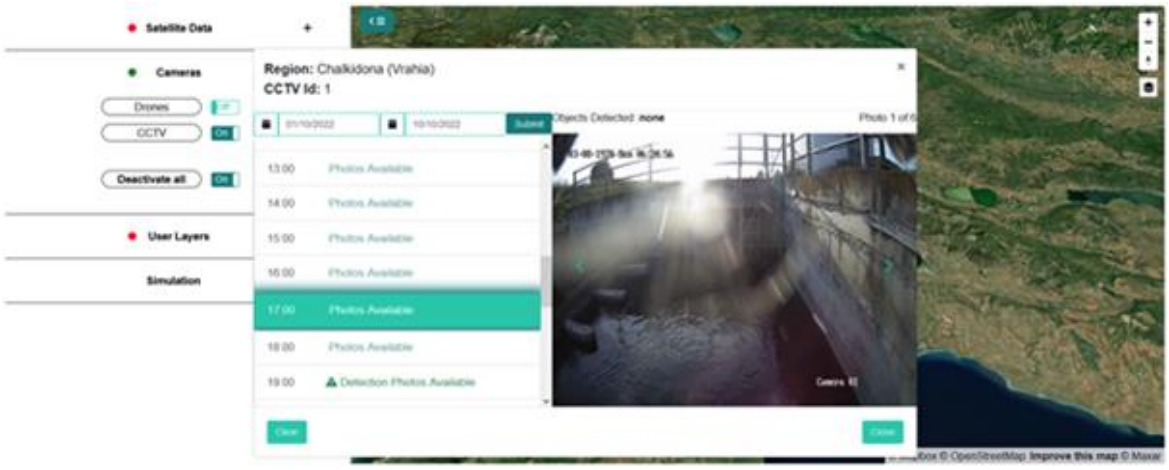


Figure 25.CCTV image carousel.

In case users want to select a new range of dates they can left click on the button labelled “Clear” that appears on the bottom left side of the modal. The modal resets and the users can repeat the actions that are reported on the previous paragraphs.

6.2.3 Satellite data

Nowadays satellite imagery is widely used to identify, localise and monitor events that affect water quality. The satellite imagery used from the aqua3S platform are provided from the Copernicus programme that freely provides radar and optical data. Specifically, radar data are retrieved from Sentinel 1, and optical data from Sentinel 2. The platform discovers and downloads satellite data on a regular basis and uses them to identify flood events, and pollution events including algae bloom and oil spills. Finally, depending on the thresholds set per type of event, alerts are produced.

6.2.3.1 Water Bodies

The Water Bodies Map captures the inundated areas using satellite imagery and visualises them onto a map. In order to produce these maps, radar data are used from Sentinel 1 and since they can penetrate clouds, they are suitable candidate for monitoring water bodies at real time. Moreover, a thresholding-based approach is used that considers as input the values of the VV band for separating between water and non-water areas.

Through the aqua3S platform, the user can activate the *Water Bodies* button from the *Satellite Data* menu list at the left and the more recent (last update) water bodies map will be illustrated on the screen in a particular region of interest, as shown in Figure 26.

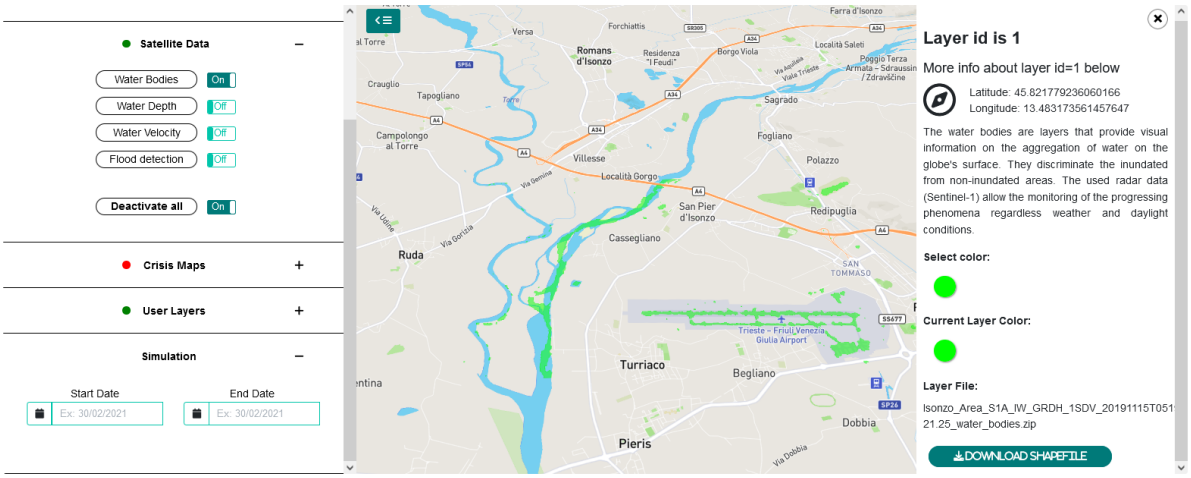


Figure 26. Water bodies layer.

Users can left click on the Water Bodies layers and an infoWindow will open on the right side of the screen that contains the following information: the coordinates of the clicked point of the layer, a short description of the displayed data, a colour-picker, an element that displays the current colour of the layer, the name of the file that was fetched from the Geoserver in order for the layer to be displayed on the map and a button labelled “Download shapefile” that provides the functionality to download and store locally the shapefile of the displayed layer.

Users have the ability to left-click on the colour-picker in order to select a colour of their choice and change the current layer colour (see Figure 27). When they click on the colour-picker a pop-up window appears on the screen that displays a colour pallet through which users can select the colour of their

choice. Once they do they can left-click on the button labelled “OK” so that the colour of the layer and the current layer colour element changes to the one that the user selected.

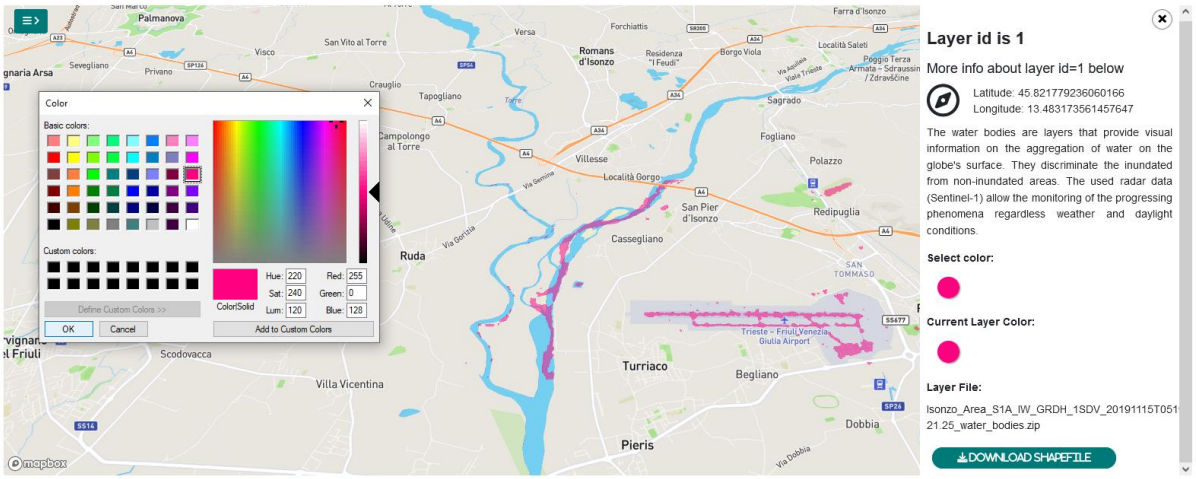


Figure 27. Satellite layer colour-picker.

6.2.3.2 Water Depth

By employing the Water Depth Maps, the platform users can be informed about the level of the water depth in the inundated areas onto a map. For each separate sub-area of a water body, the water level is assumed horizontal and defined using the Digital Elevation Models (DEM), as the value that the maximum elevation of the terrain at the boundary of the sub-area has. Then, for the particular sub-area, the Water Depth is estimated by subtracting pixel by pixel the DEM value from the water level. The results of this process are classified in four distinct categories as shown in Figure *28* where the darker colours map higher water depth levels in meters.

Water Depth Range (meters)	RGB Color	Hex coding
0.5 - 1.0	(204, 204, 25)	#CCCCFF
1.0 - 2.0	(153, 153, 255)	#9999FF
2.0 - 3.0	(102, 102, 255)	#6666FF
4.0+	(51, 51, 255)	#3333FF

Figure 28. Water Depth categories.

In aqua3S platform, the user can activate the *Water Depth* button from the *Satellite Data* menu list at the left and the more recent (last update) water depth map will be illustrated on the screen in a particular region of interest, as depicted in Figure 29.

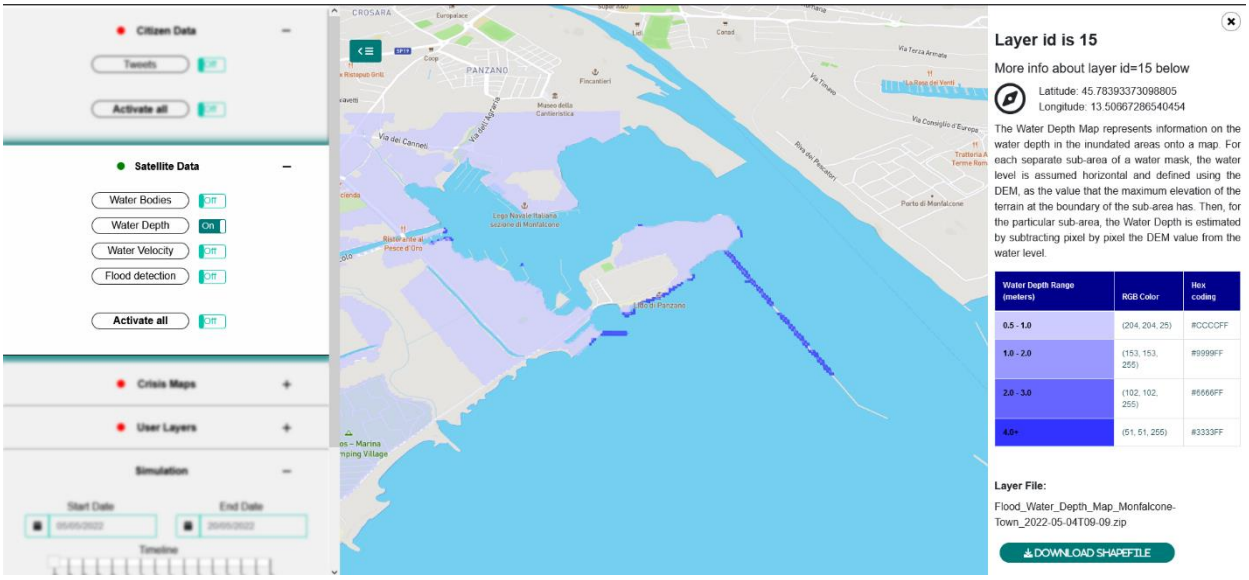


Figure 29. Water Depth Layer.

Users can left click on the Water Depth layers and an infoWindow will appear on the right side of the screen that contains information including the coordinates of the clicked point of the layer, a short description of the displayed data, a map legend that defines features of the selected layer, the name of the file that was fetched from the Geoserver in order for the layer to be displayed on the map and a button labelled “Download shapefile” that provides the functionality to download and store locally the shapefile of the displayed layer.

6.2.3.3 Water Velocity

The Water Velocity Map represents information on the water velocity in the inundated areas onto a map. Water Velocity is another factor that along with water depth directly affects the flood occurrence. It is determined per pixel by combining the Water Depth, Slope, Manning Roughness coefficient and pixel Resolution, based on a mathematical formula. Similar to Water Depth, it can be classified into four distinct categories which illustrate the intensity of the water velocity (Figure *30*).

Water Velocity Range (m/s)	RGB Color	Hex coding
0 - 0.5	(128, 255, 0)	#80FF00
0.5 - 2.0	(255, 255, 0)	#FFFF00
1.0 - 2.0	(255, 128, 0)	#FF8000
2.0+	(255, 0, 0)	#FF0000

Figure 30. Water Velocity categories.

In aqua3S platform, the user can activate the *Water Velocity* button from the *Satellite Data* menu list at the left and the more recent (last update) water velocity map will be illustrated on the screen in a particular region of interest, as depicted in Figure 31.

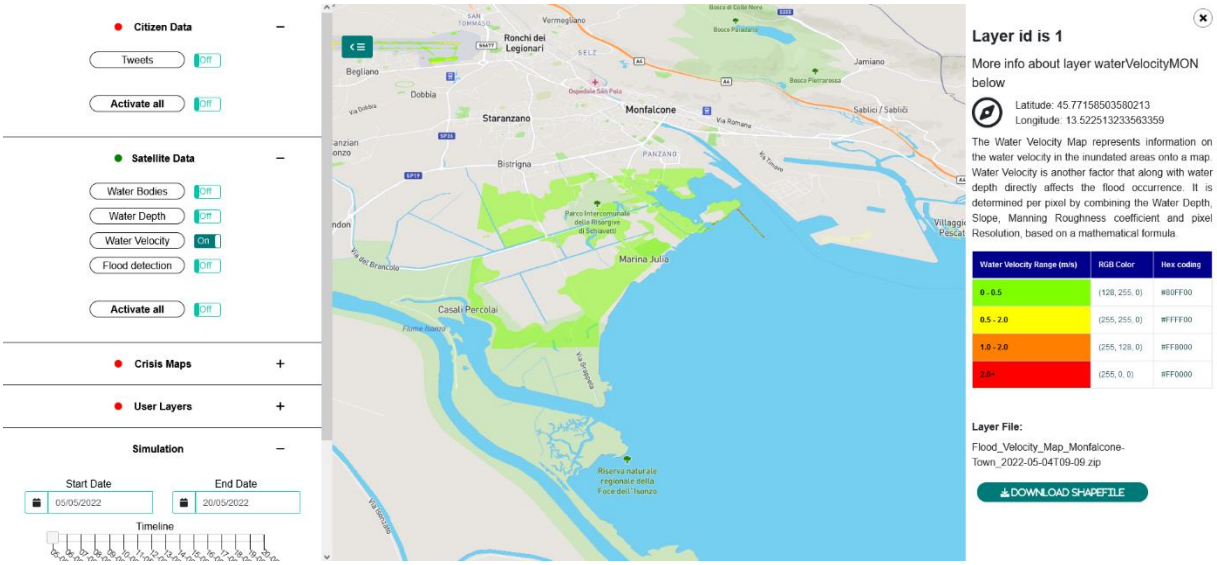


Figure 31. Water Velocity Layer.

All provided functionalities that are available regarding water velocity data on the VA map component are identical to those mentioned in the previous section (Water Depth).

6.2.3.4 Flood detection

Flood detection module is a tool of the aqua3S platform, which makes it possible to map ongoing flood events. In particular, it is focused on mapping extreme floods that occur in open-land regions, which typically comprise riverine regions and without high vegetation or buildings, among others. It achieves that in a continuous monitoring manner, which is only limited by the frequency of the satellite (Sentinel-1) pass over a given region, rather than atmospheric conditions, cloud cover or daylight. In the aqua3s platform, ongoing floods are depicted as coloured pixels. This way any user can know the location of a flood incident, in order to perform informed decision-making by having estimations of the inundated areas, which can be used in the emergency response and recovery phases of the disaster management cycle.

In aqua3S platform, the user can activate the Flood Detection button from the *Satellite Data* menu list at the left and the more recent (last update) flood detection map will be illustrated on the screen in a particular region of interest, as shown in Figure 32.

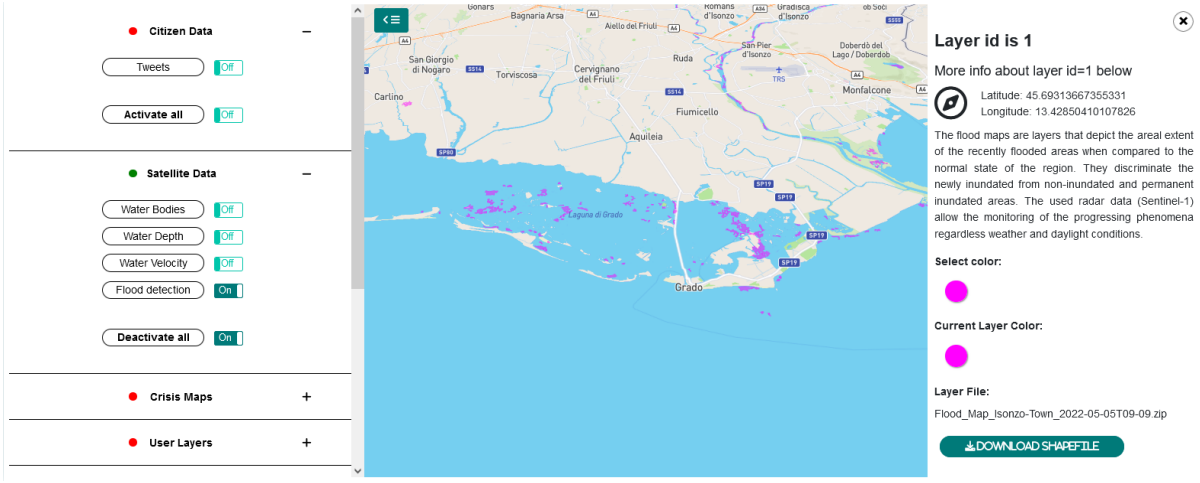


Figure 32. Flood detection layer.

All provided functionalities that are available regarding flood detection data on the VA map component are identical to those mentioned in the previous section (Water Bodies).

6.2.3.5 Oil Spills

The oil spill detection module is a tool of the aqua3S platform that allows the identification and localisation of small extent oil spill formations on the surface of inland water. For the detection of oil spills a framework is developed including a custom deep neural network model and a set of pre-processing steps that uses as input Sentinel 2 images satellite images. Through satellite imagery it is possible to scan large areas of interest on a regular basis. This way any user can track and monitor the evolution of such an event with limited resources.

Figure 33. Oil spill layer.

All provided functionalities that are available regarding oil spills data on the VA map component are identical to those mentioned in the previous section (Water Depth) (Figure 33).

6.2.3.6 Algae Bloom

The algae bloom detection module is a tool of the aqua3S platform that allows the estimation of algae bloom concentration. In general, algae blooms are dense layers of tiny green plants that occur on the surface of water bodies when there is an overabundance of nutrients on which algae depend. As more algae and plants grow, they pose a great threat to the aquatic life. The aqua3S algae bloom module uses Sentinel 2 data satellite data to estimate chlorophyll-a (Chl-a), which is the most common type of chlorophyll that is contained in algae. The algorithm used a ration-based algorithm that considers different reflectance bands, and it provides an estimation on a pixel level of the Chl-a concentration.

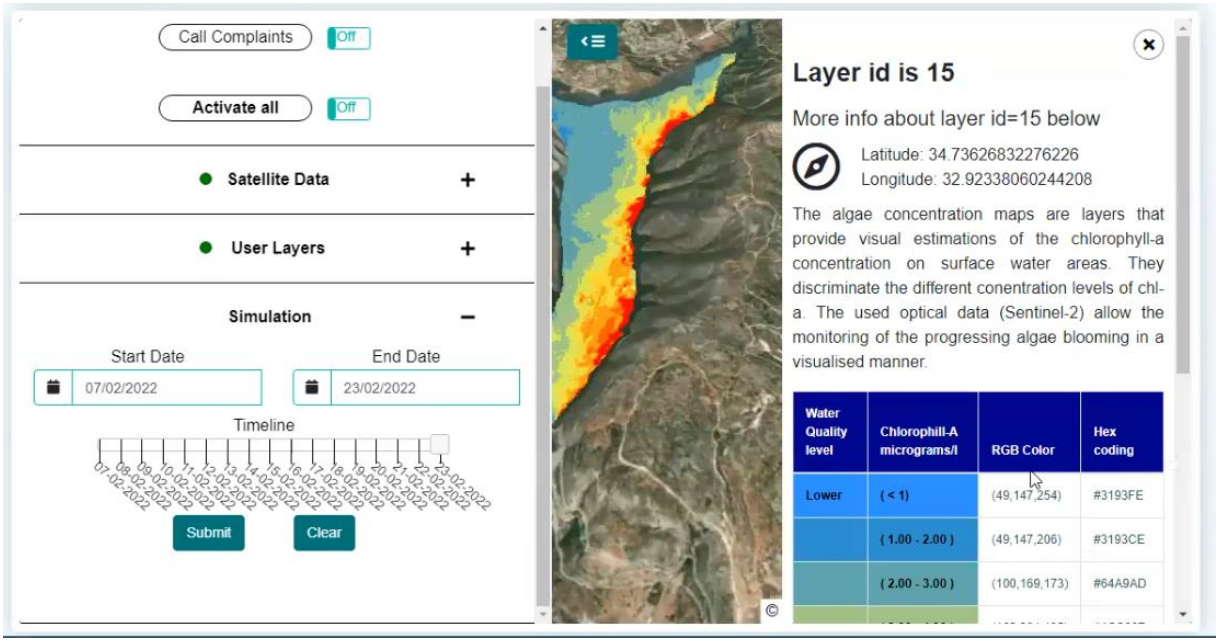


Figure 34. Algae bloom layer.

All provided functionalities that are available regarding algae bloom data on the VA map component are identical to those mentioned in the previous section (Water Depth) (Figure 34).

6.2.4 Crisis maps

Nowadays, flood disasters are intensified, become more frequent and more destructive comparing with the old ones, especially in developing countries, causing loss of human lives and properties worldwide. Climate changes along with anthropogenic factors play a significant role to escalate flood events to disasters, which have severe implications in terms of economic loss, social disruptions, and damage to the urban environment. Therefore, the proper monitoring to identify areas prone to floods and the effective mitigation countermeasures are considered very important to risk reduction. ***Flood mapping*** is a process that describes the expected extent of water inundation into dryland as a result of intense precipitation or river water level rise driven by natural or anthropogenic factors. Although, flood mapping basically comprising of flood hazard maps and flood risk maps, however, the flood mapping processes vary considerably from project to project, and/or country to country, depending on specific project requirements and country-specific guideline, legislation etc. Flood mapping provides the baseline for a good understanding of historical flood trends, future expectations, and identification of locations likely to be impacted by flooding. Hence, flood mapping can help water operators, emergency responders and all related stakeholders to be better prepared in order to increase the flood resilience of the study area.

6.2.4.1 Flood hazard maps

Flood Hazard map is a map that graphically provides information on predicted inundation areas and highlights areas that are affected by or are vulnerable to a potential flood hazard. Flood Hazard maps help prevent serious damage and deaths. Also, they can help people become aware of the dangers they might face from an extreme flooding event in a specific area. The *flood hazard* is the occurrence of a physical event, which can happen with a certain probability and intensity. A flood hazard is expressed as a combination of water depth, velocity, flow and the probability of occurrence of the event concerning three scenarios (low probability, medium probability, high probability). A flood Hazard map highlights the areas that are affected by or are vulnerable to a potential flood hazard, by mapping its levels of severity in those predicted inundation areas.

In aqua3S, the severity level of the flood hazard is dynamically assessed by employing machine learning techniques that are able to fuse multimodal data generated by the analysis of Sentinel-1 images and GIS-based data. Specifically, the water mask, water depth and velocity of the water body, which are derived from the analysis of satellite imagery, are combined with GIS-based flood conditioning factors, such as the elevation, slope, aspect, land use land cover, topographic position and terrain ruggedness indices, by using machine learning techniques aiming to estimate the flood hazard. The outcome of this process is to produce the following flood hazard map (Figure *35*).

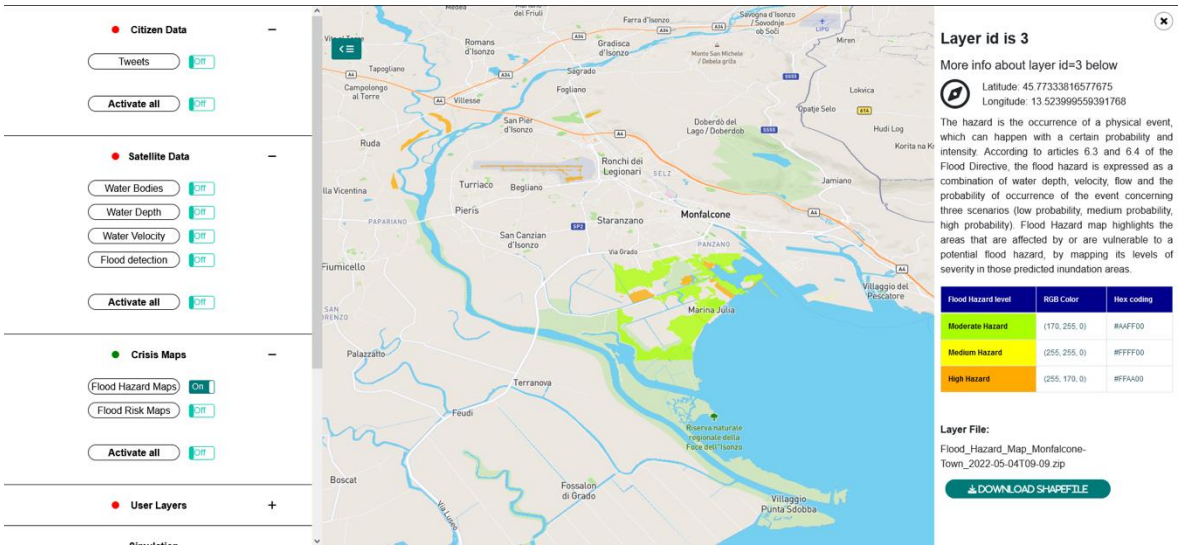


Figure 35. Flood Hazard map layer.

The user can open the Crisis Maps section in the aqua3S dashboard and click on the corresponding activation button (Flood Hazard Maps) to be informed about the flood hazard assessment situation in the region of interest based on the analysis of the most recent satellite available product.

All provided functionalities that are available regarding flood hazard data on the VA map component are identical to those mentioned in the previous section (Water Velocity).

6.2.4.2 Flood Risk maps

Flood Risk map graphically provides information, on a map, concerning areas at risk of flooding. Flood Risk is the combination of the probability of a flood's occurrence and the potential negative effects on human health, the environment, cultural heritage and economic activity associated with floods (European Flood Directive - Article 2.2). Flood Risk involves a conducting detailed assessment of the risk elements (hazard, exposure and vulnerability) by considering economic loss and harm or loss to persons. In aqua3S, the flood hazard is estimated by the aforementioned approach (section 6.2.4.1). The other

two parameters are the Vulnerability and Exposure of socioeconomic elements in the impacted area. The flood risk assessment algorithm presented in the aqua3S framework has been developed in collaboration with AAWA, as an adaptation of the procedure presented in AAWA's Flood Risk Management Plan (FRMP) of the Eastern Alps River Basin District. The outcome of this process is to produce the following flood risk map (Figure *36*). The flood risk has been categorized into the four categories presented in Table 3.

Labels	R	G	B	Hex	Color
Moderate Risk (0 ≤ R < 0.2)	130	255	130	#82FF82	Very light lime green
Medium Risk (0.2 ≤ R < 0.5)	250	250	128	#FAFA80	Soft yellow
High Risk (0.5 ≤ R < 0.9)	250	189	128	#FABD80	Soft Orange
Very High Risk (0.9 ≤ R < 1.0)	255	128	128	#FF8080	Very light red

Table 3. Flood risk categories.

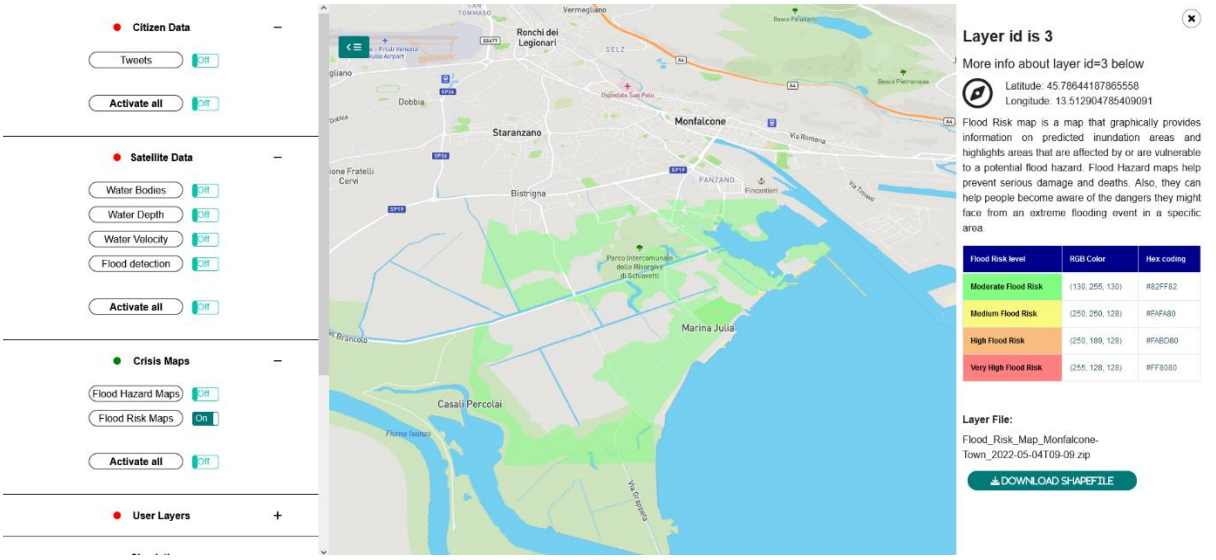


Figure 36. Flood Risk Map layer.

The user can open the Crisis Maps section in the aqua3S dashboard and click on the corresponding activation button (Flood Risk Maps) to be informed about the flood risk assessment situation in the region of interest based on the analysis of the most recent satellite available product.

All provided functionalities that are available regarding flood risk data on the VA map component are identical to those mentioned in the previous section (Water Velocity).

6.2.5 User layers

The VA module may visualize layers that are either provided in advance by the end user partners and appear on the menu panel, or uploaded by the end users real-time as GeoJSON or shapefiles. It should

be noted that in case the layers are preloaded in the VA map component, the users have the ability to change the visibility of the layers via the menu.

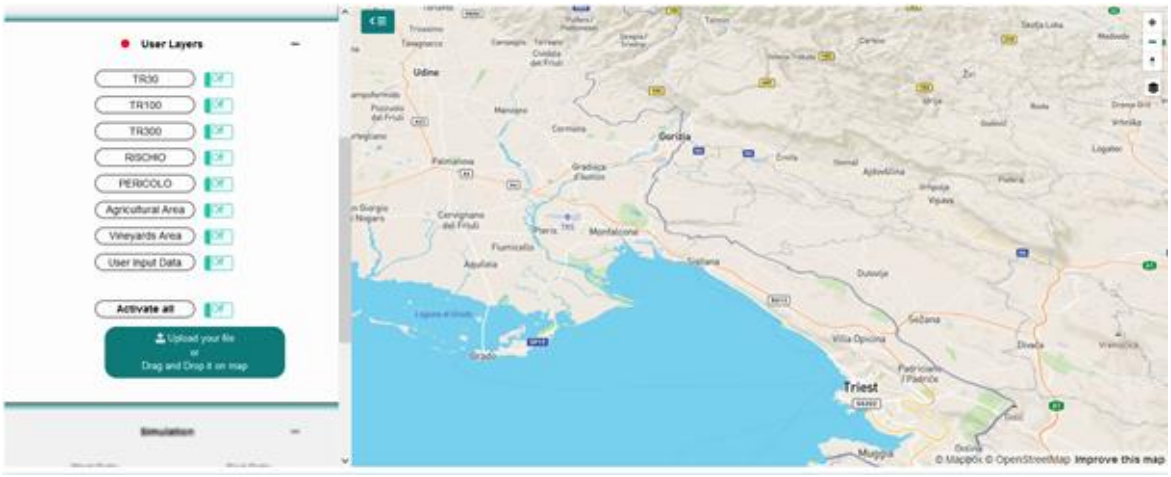


Figure 37. GIS layers.

Users can upload and visualize their own data by using the "Upload or drag and drop your shapefiles on the map" button, which is located in the "User Layers" category or just drag and drop their shapefile or GeoJSON on the map. Users may choose the GeoJSON/shapefile to be uploaded by left-clicking on the button, which brings up a local area browser on the screen. Users can also view pre-loaded satellite data on the map using the toggle buttons of this category.

7. Analytics

7.1 Sensor graphs

aqua3S provides two graphing modes for sensor data in the 'Analytics' menu option: 'properties by sensor' and 'sensors by properties'.

7.1.1 Properties by Sensor

The properties by sensor mode, Figure 38, allows users to view historic sensor data by grouping property data for multiple sensors in a single property-specific graph. Users can set the timeline for their graphs by using the time radio button (top left) to set timelines of intra-day, weekly, monthly, quarterly or yearly.

For each time option, sensor data is separated into buckets to ensure that the graphs are not overloaded with data, which results in severe slowdown of the graphing screen. Typically, the intra-day graph will put data into 15 minute buckets, whilst the yearly graph will put data into daily buckets.

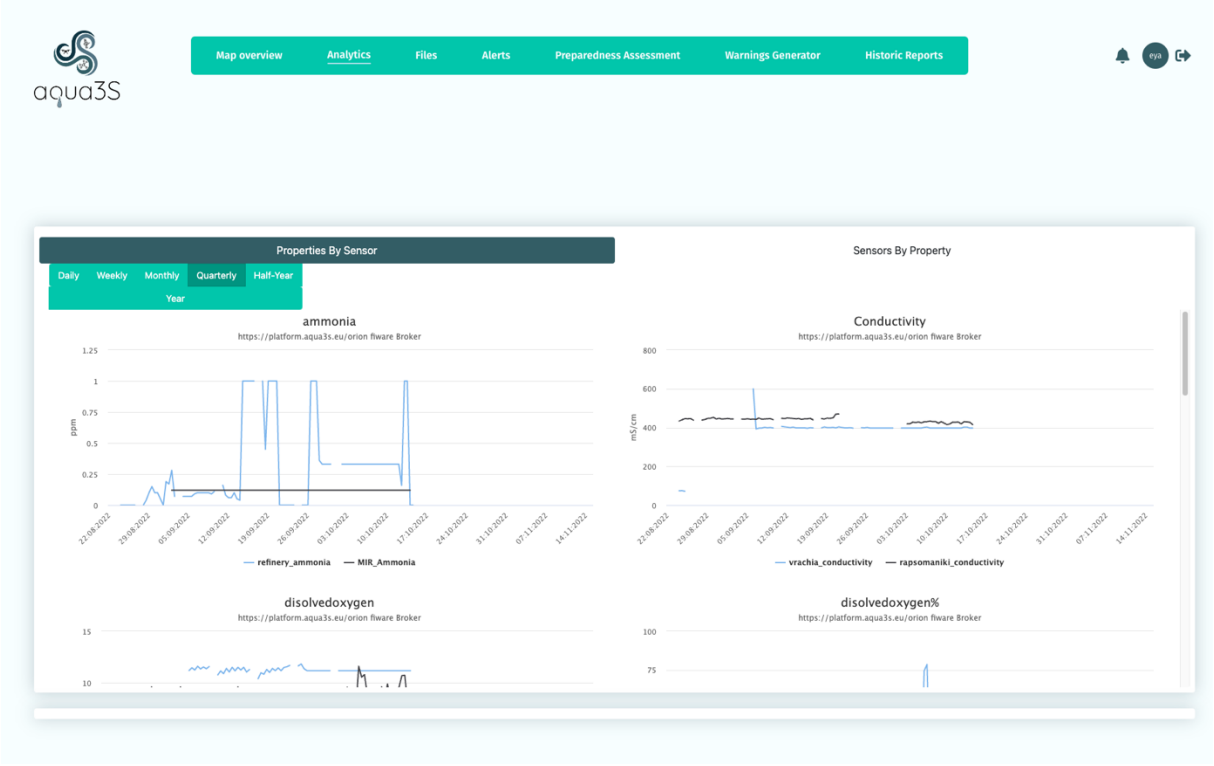


Figure 38. Properties by sensor

7.1.2 Sensors by properties

The sensors by properties view, Figure 39, is superficially like the properties by sensor view, but includes an extra radio button, allowing users to choose a specific property to view. On selecting a property, only sensors of that property are displayed, with one sensor per graph, unlike the 'all sensors of a property' display of the properties by sensor view.

Like the properties by sensor view, this view contains the timeline radio button allowing users to set an appropriate timeframe for their graphing.

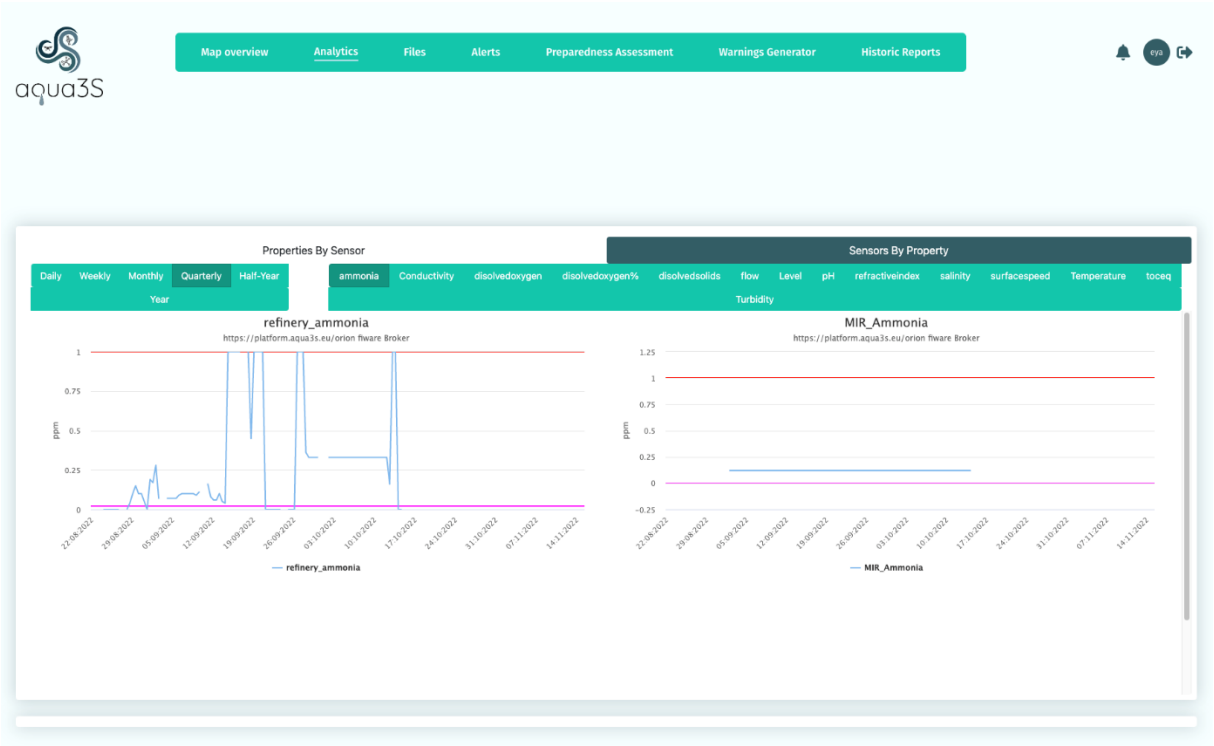


Figure 39. Sensors by property

7.2 Citizen data graphs

The graph based visualization component provides some basic functionality such as the ability to view the graphs into full screen mode, print them, download the loaded data into various formats and toggle buttons that control the visibility of data. The menu that provides all the basic functionality can be found on the top right corner of the graphs (Figure 40).

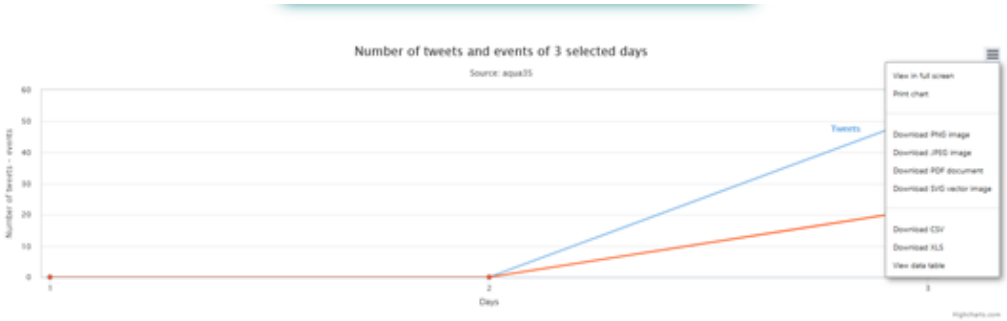


Figure 40. Graph menu.

It also provides toggle buttons so users can set the visibility of data. The simulation tool is located in the upper portion of the graph component and allows users to run chronological simulations using a date picker tool to filter and get historical data. Users can select through the date pickers a range of dates that they want to fetch data for (Figure 41). Once the date range is selected, users can left on the button labelled “Submit” so that a query to the historical service is triggered in order to fetch the desired data.

Figure 41. Graphs and simulation tool.

Users can hover over the graph line so that a pop-up window appear in order to see how many tweets, events or call complaints were posted on a certain date (Figure 42).

Figure 42. Zoom on graph points.

8. Alerts and Warnings

This section discusses the alerts and the warnings, and how they are shown by the aqua3S platform. Although the content is the same, what differs is the place where the information is available. Thus, alerts are accessible in the specific Alerts tab, while the warnings are visible in any of the tabs as they part of the Navigation Menu. Finally, it should be noted that the alert information can be available to the users via email.

8.1 Alert types

The alerts screen is data-driven and based on entities defined on a pilot-by-pilot basis. This allows information for 'devices', 'satellites', 'social media', 'cctv' and 'drone' (UAV) to be visualised on-demand, which results in the top selections of the alerts screen changing on a pilot-by-pilot basis, Figure 43.

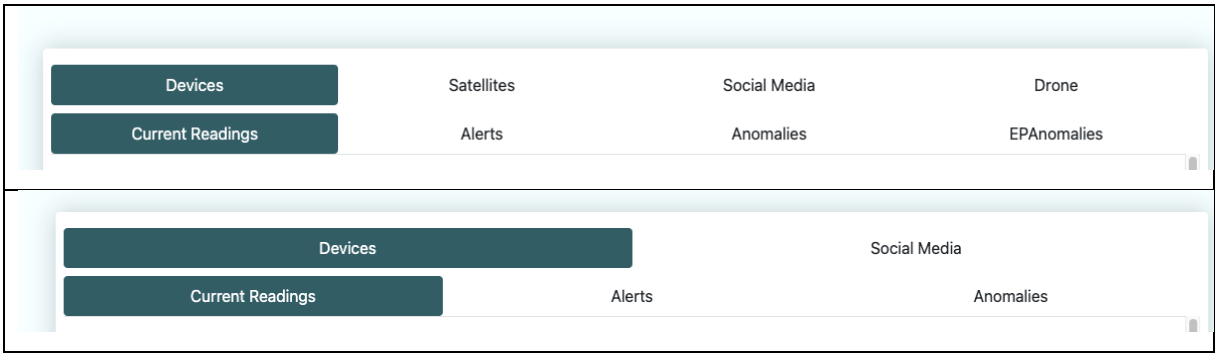


Figure 43. Alert screen headings for two different pilots (top and bottom)

8.2 Devices

This section details functionality for devices.

8.2.1 Current Readings

The device current readings tab presents the user with the current readings of the devices for the pilot. The data is taken from the smart device model and is the same data as used in the map view, unlike the map view, the current settings view is presenting device data in a tabular textual format so that all the sensors can be seen in one place and without using marker colour-coding to show device state (see Figure 44).

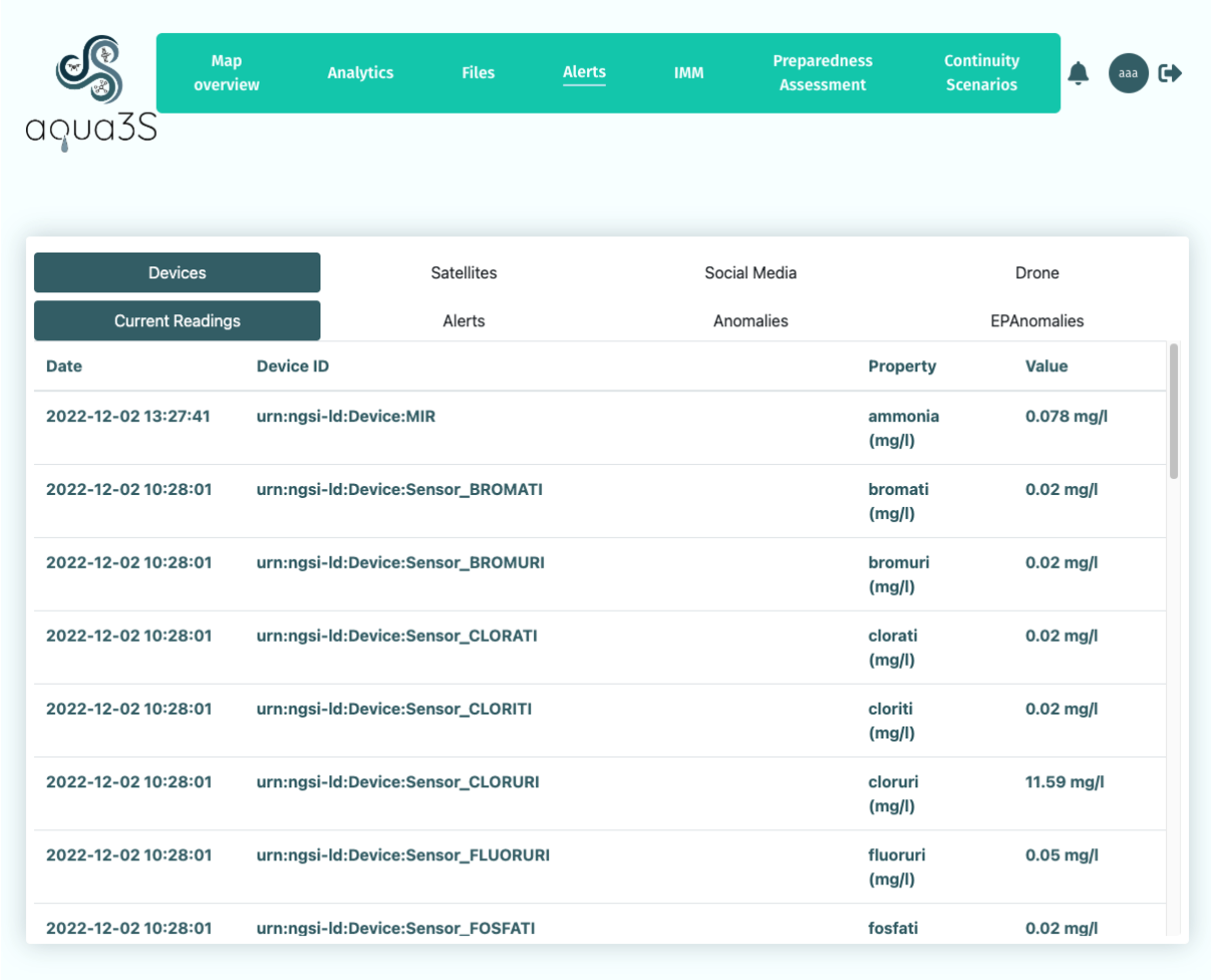


Figure 44. Device alerts – current readings.

8.2.2 Alerts

The sensor alert screen comprises of two components: 'set alerts' (Figure *45*), and 'current alerts' (Figure *46*). As indicated by its name, the 'set alerts' screen allows users to set the minimum and maximum alerts values, with the minimum value being used for under-bottoming, i.e., if a value is recorded below this value an alert is triggered, and over-topping, i.e., if a value is recorded above this value an alert is triggered. There is also an 'active' tick box which allows users to 'de-activate' alert checking for given devices.

The 'current alerts' screen (Figure *46*), displays a list of devices that are currently triggering alerts and is ordered by recency, i.e., the most recent alerts are displayed first. Like the map view, the current alerts screen will report devices that are 'offline' (deviceState set to red) as triggering alerts.

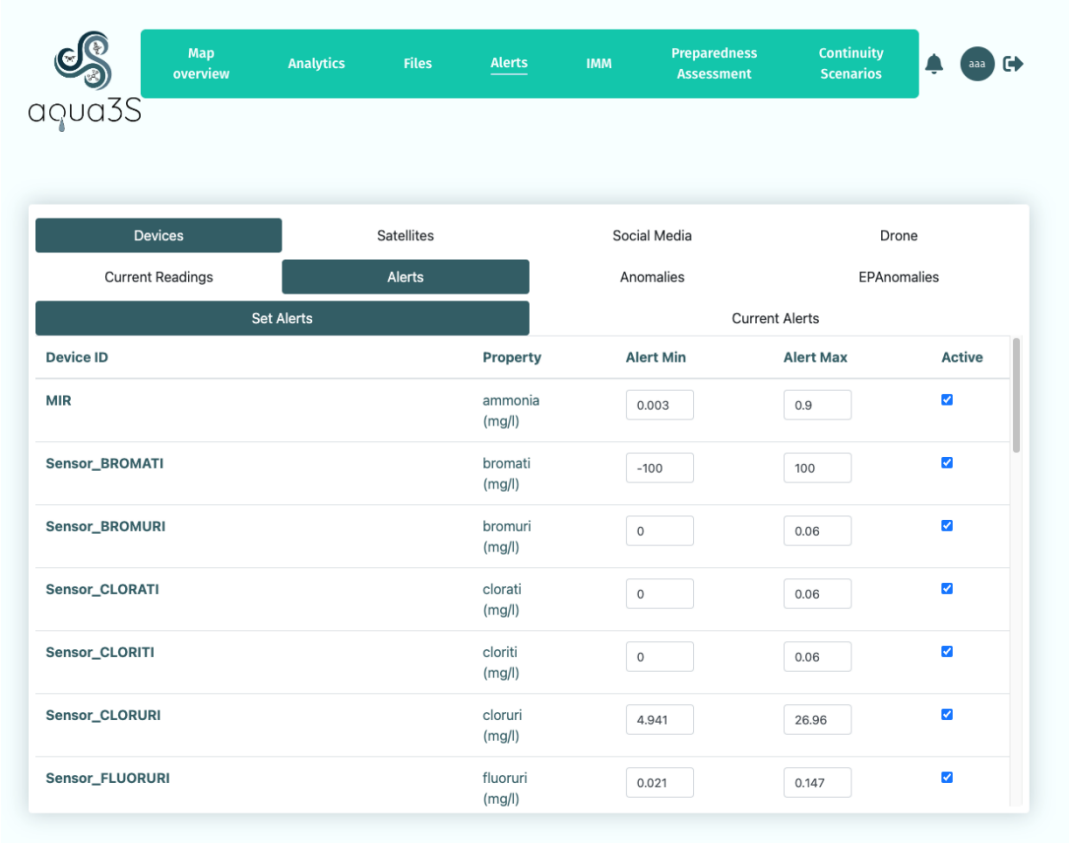


Figure 45. Devices set alerts screen.

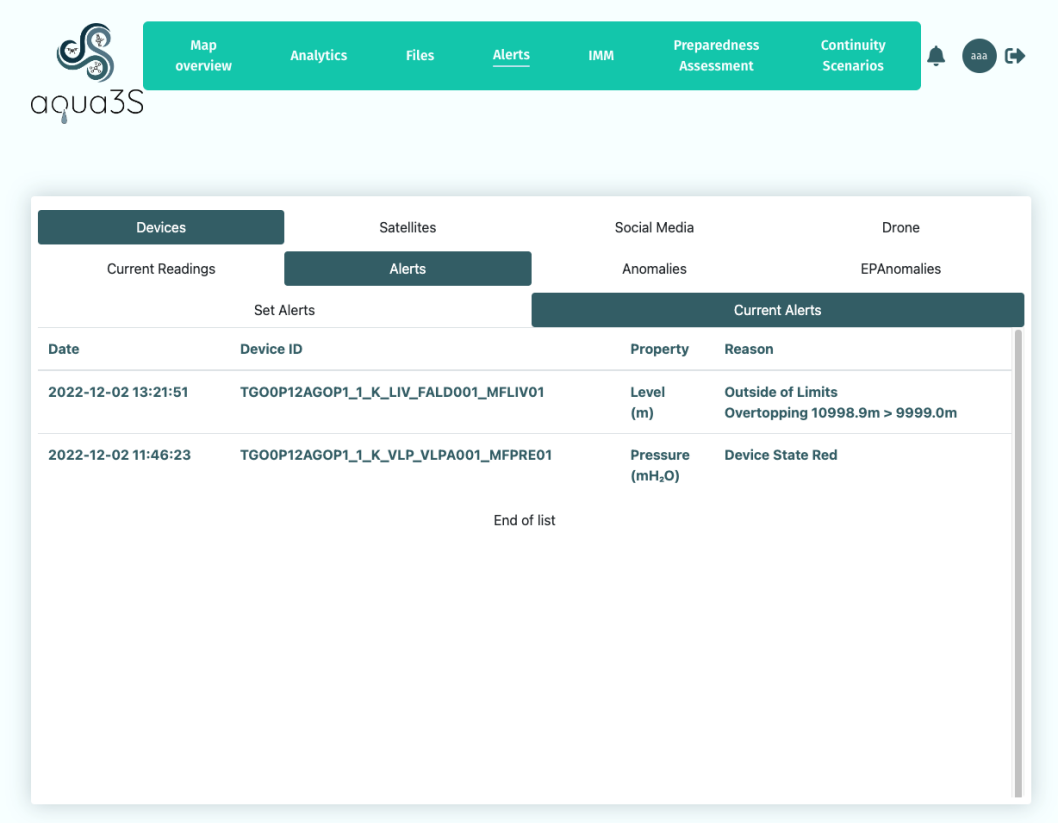


Figure 46. Devices current alerts screen.

8.2.3 Anomalies

The anomalies screen is comprised of four components: anomaly ranges (Figure *47*), current anomalies (Figure 48), historic anomalies (unused) and anomaly settings (Figure 49). To fully understand the operation of anomalies, it is best to start by looking at the anomaly settings. On-demand, anomaly ranges can be determined for devices using historic device readings stored in the historic service to create a 7-day set of limit ranges, as displayed in the charts in Figure 49. This bucketed data can be thought of in a similar way to the alert settings for the devices, except it is far more granular, with 3 readings per day over a 7-day period, rather than the single alert data point.

Like the alerts, when new data is collected for a device, it is processed against the relevant anomaly setting data and, like the alerts, a table of current anomalies is maintained in (Figure 48). Given the relative complexity of anomalies, the anomaly ranges page (Figure *47*), maintains a list of devices with their current anomaly ranges, as lower and upper values. This data is interpolated from the anomaly bucket data and is identical to the values used for anomaly processing.

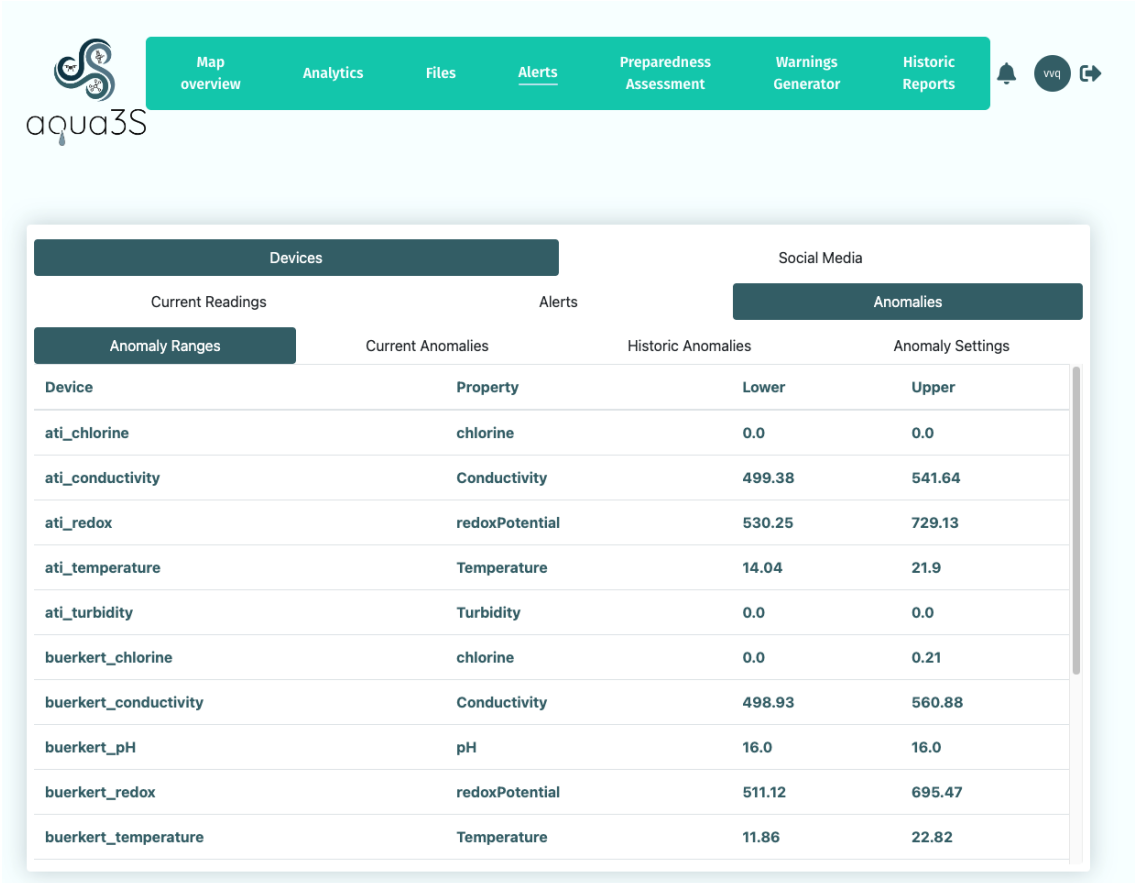


Figure 47. Anomaly ranges.

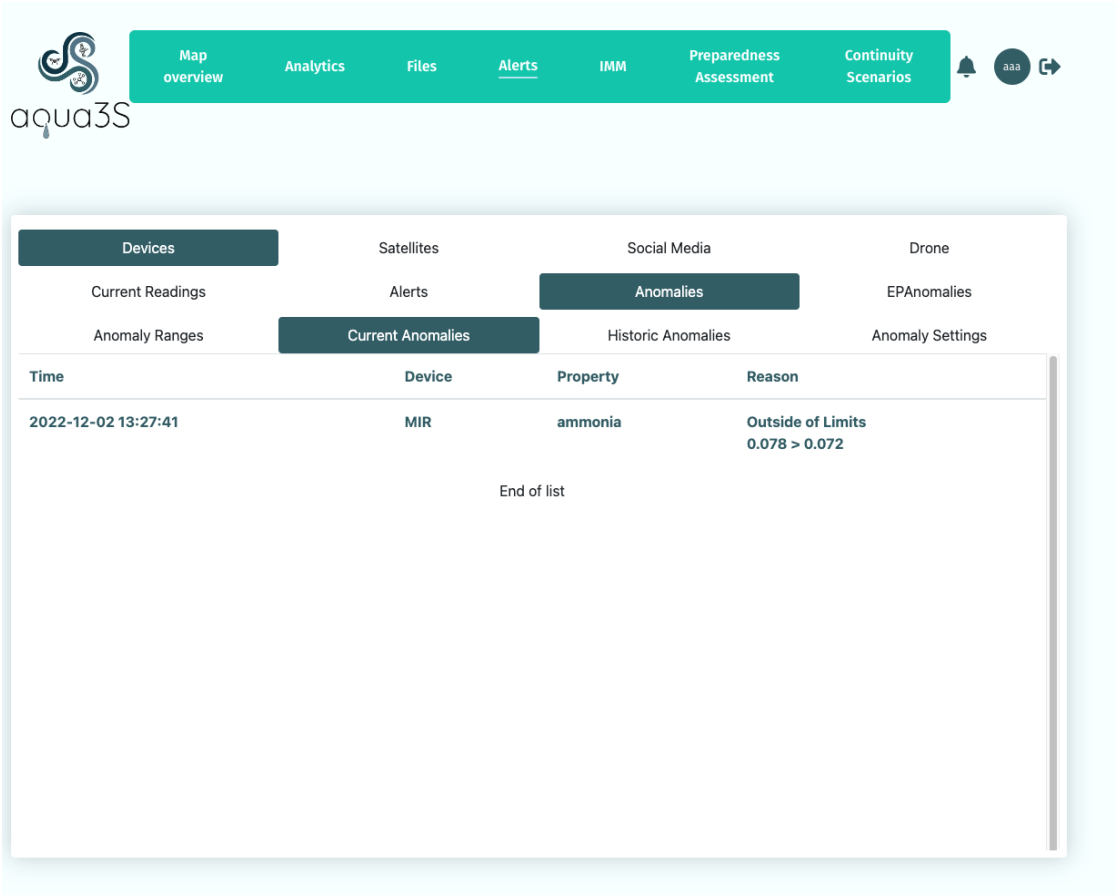


Figure 48. Current Anomalies

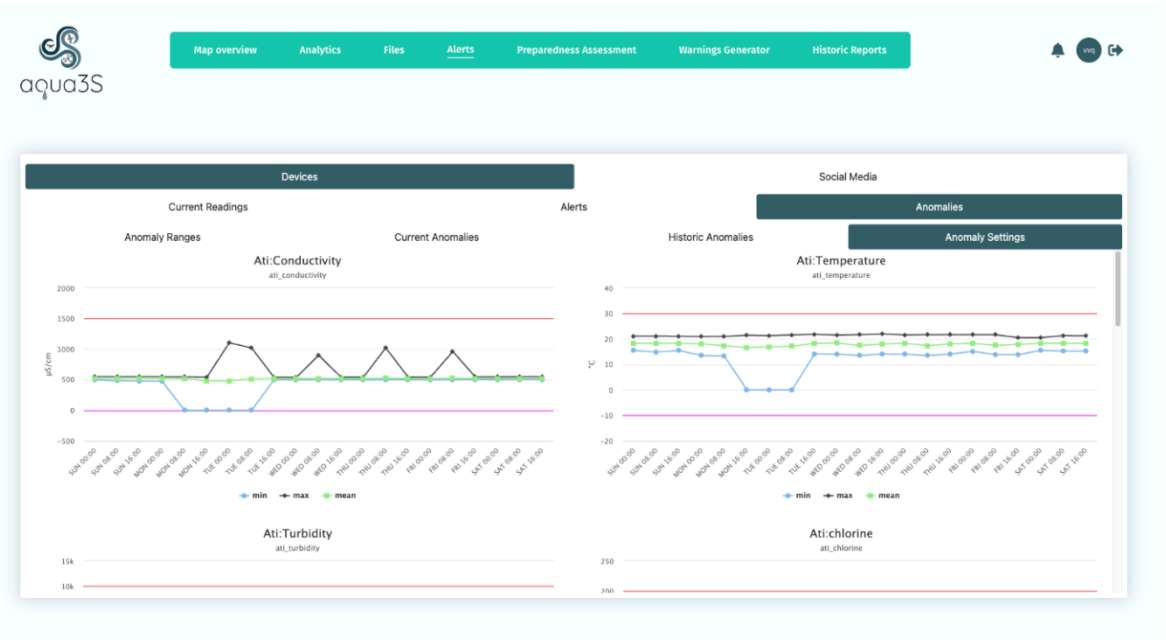


Figure 49. Anomaly settings

8.2.4 EPANET Anomalies

EPANET Anomalies are a unique set of anomalies that can be calibrated using hydraulic model simulations, to improve anomaly detection and reduce false positives. Specifically, the EPANET anomalies integrated into the aqua3S platform are designed to improve pipe-break detection. The EPANET anomaly model uses hydraulic simulations and statistical process control algorithms to identify pressure and flow sensor readings associated with pipe breaks within the water distribution system.

EPANET anomalies are visualized within the aqua3S platform in the same method as other sensor anomalies. However, a specific warning message would distinguish the EPANET anomaly from other anomalies.

Associated with the EPANET Anomalies are a localization model that can assist in predicting the preferred search areas for leak detection crews. The localization model uses hydraulic simulations of leaks to calibrate a machine learning and geographical coverage model to predict search areas that maximize the likelihood of containing the pipe break.

The localization model is automatically triggered four hours after the EPANET anomaly is triggered. The localization model visualizes the ideal search area(s) on the map view based on the specific case studies preferred search radius and number of search areas. The user can then click on the search area to identify the predicted likelihood it contains the pipe break and can send leak crews to search the area and overall reduce the impact of the pipe break by improving the utilities search time (Figure *53*).

Like the anomalies screen, the EPANET anomalies screen consists of four components: ‘current readings’ (Figure *50*), ‘current anomalies’ (Figure *51*), ‘historic anomalies’ (unused) and ‘anomaly settings’ (Figure *52*).

Again, like the anomalies screen, the EPANET anomaly settings screen (Figure *52*), is the best starting point, containing the EPANET simulation data each device. This data is used by the EWMA algorithm as the core of EPANET anomalies to determine anomalous behaviour in the network, and the results are presented in Figure *50*, again as a recency-ordered list of devices that are out of range. Like the devices screen, the EPANET anomalies contains a screen of current readings (Figure *50*), though this is limited to EPANET devices and was primarily implemented to make it easier to separate ‘normal’ devices from those using EPANET.

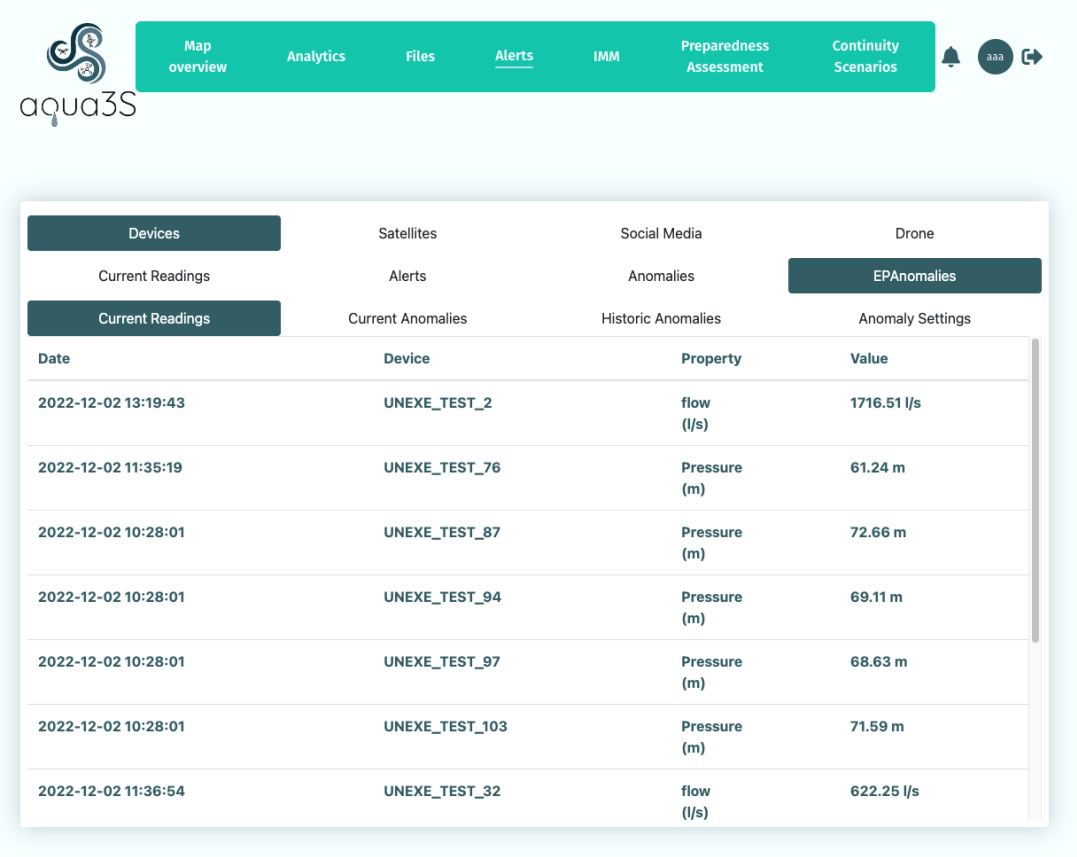


Figure 50. EPANET anomalies - current readings.

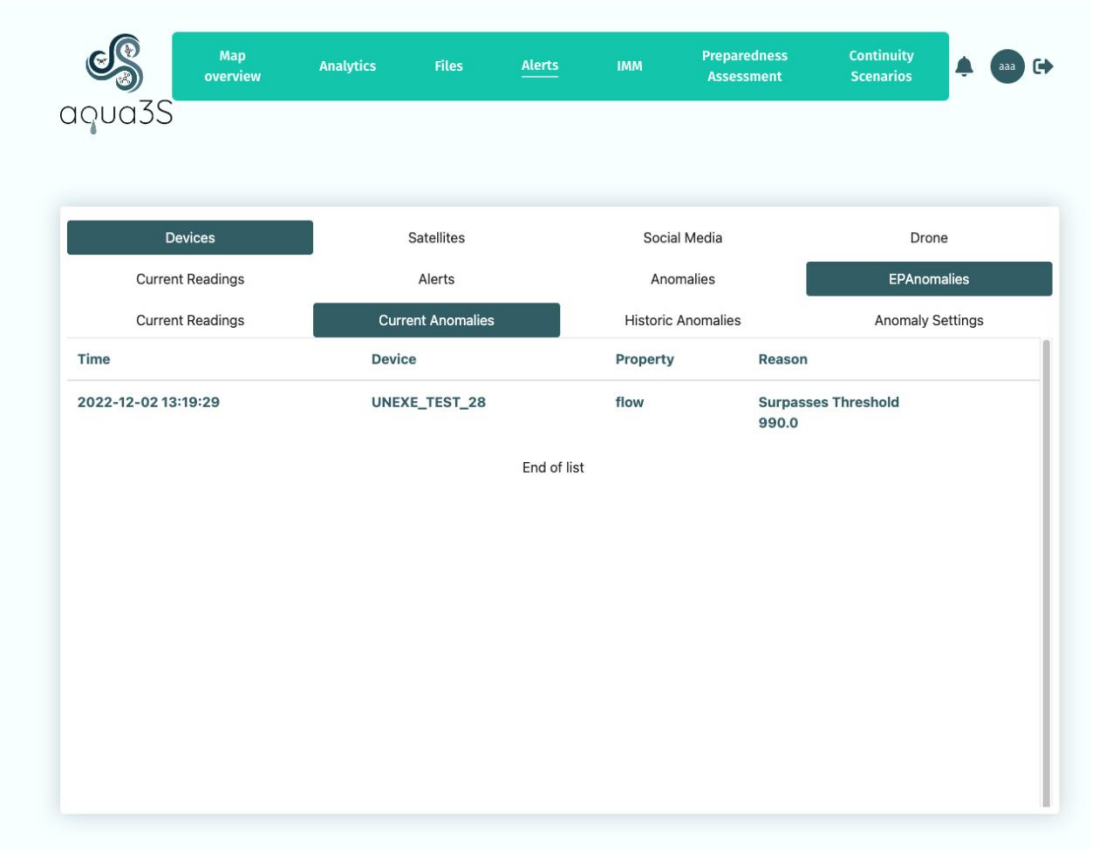


Figure 51. EPANET anomalies - current anomalies.

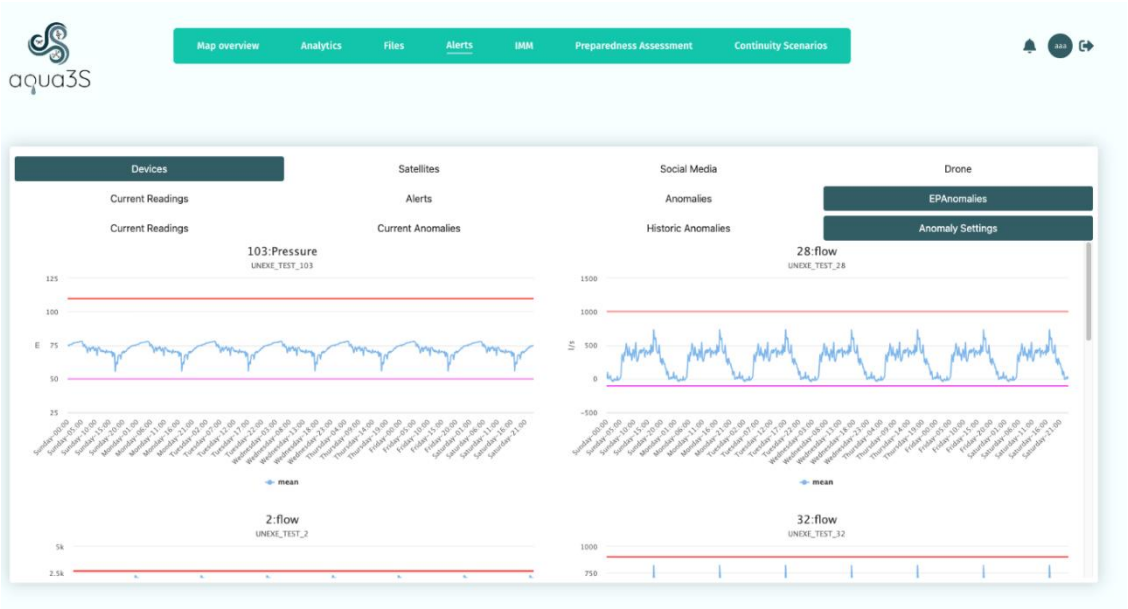


Figure 52. EPANET anomalies - anomaly settings.

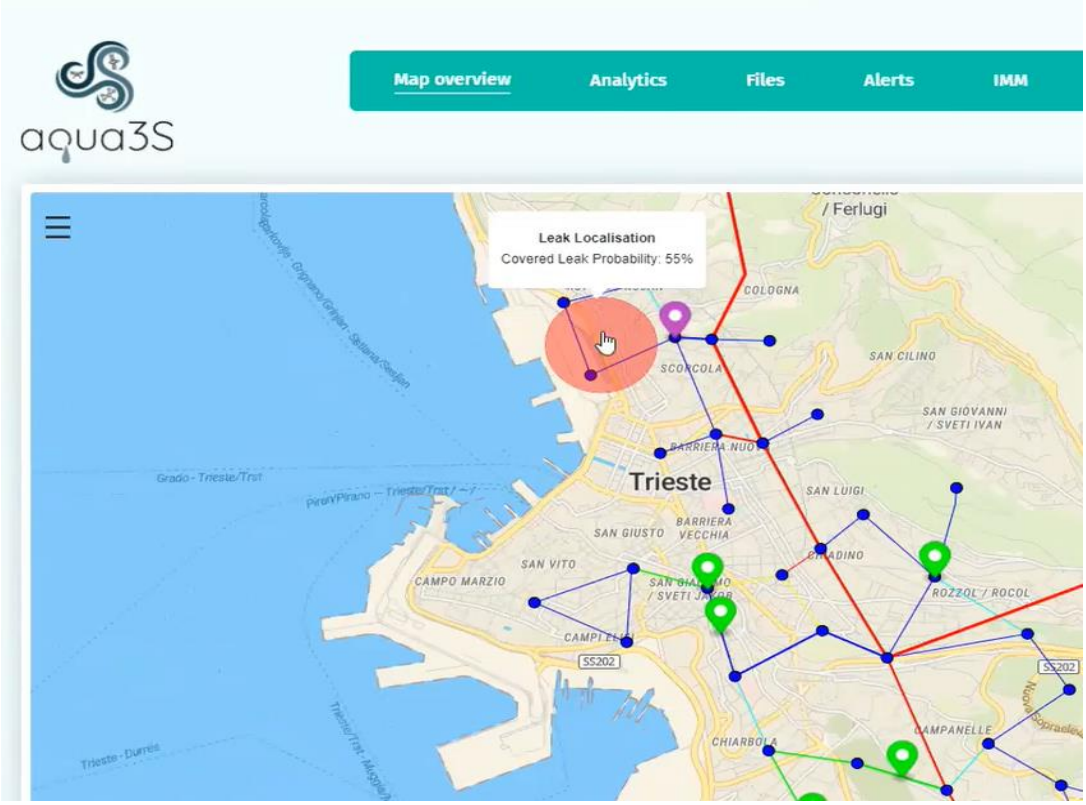


Figure 53. EPANET anomaly leak localisation (in map view).

8.3 Satellite Alerts

The Satellite alerts display whether there is any current alert from the Satellite data. As current alerts (see Figure 54), we consider the alerts that have been triggered no later than 12 days ago for the Flood detection and 5 days from Sentinel-2 from Oil spill/ Algae bloom/ Waterbodies data.

Different time periods are considered for each type of data for which an alert is considered as current depending on the how often data are available (e.g., Sentinel 1 data are available every 12 days while Sentinel 2 every 5 days).

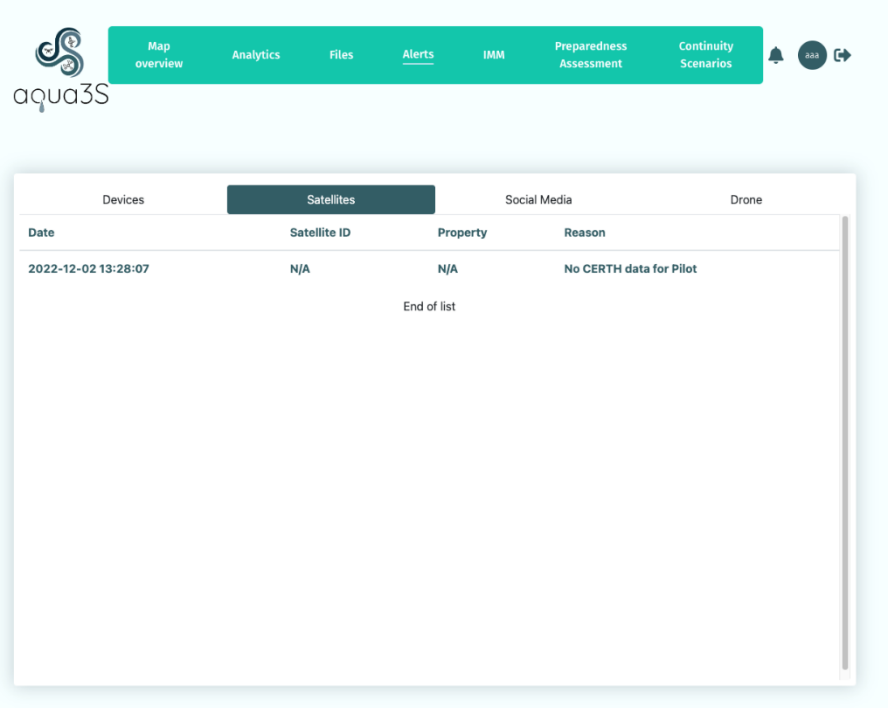


Figure 54. Satellite alerts.

8.4 Social Media Alerts

The Social media alerts display whether there is any current alert from Twitter. As current alerts (Figure *55*), we consider the alerts that have been triggered no later than 4 days ago.

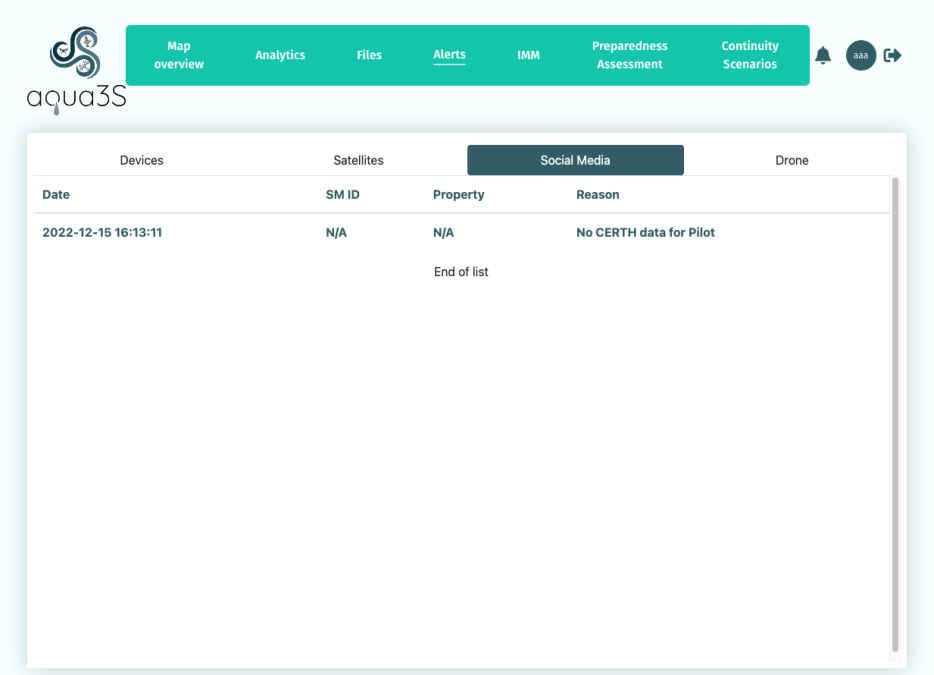


Figure 55. Social media alerts.

8.5 CCTV Alerts

The CCTV alerts display whether there is any current alert from the CCTVs. As current alerts (Figure 56), we consider the alerts that have been triggered 1 day ago.

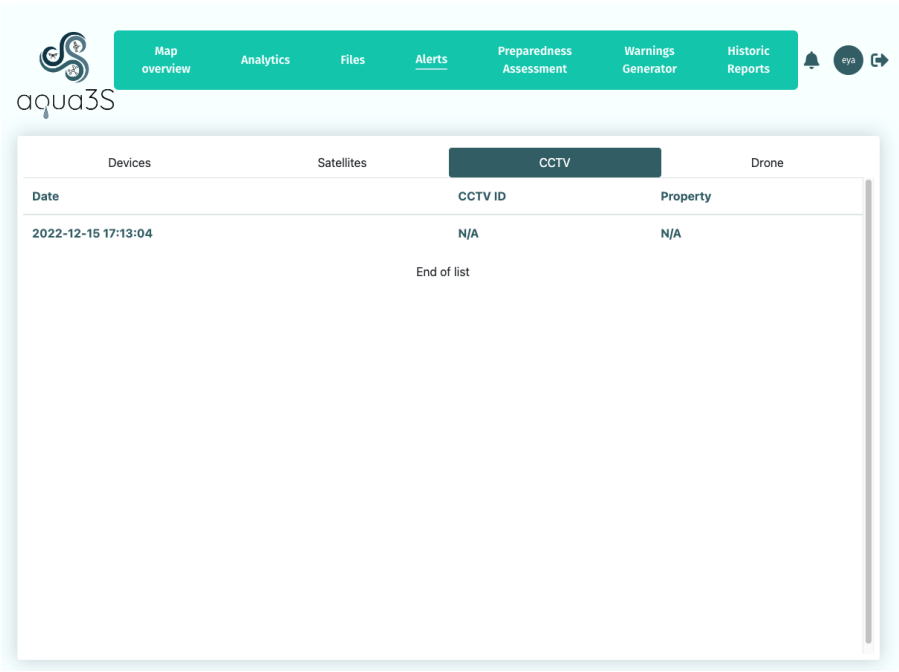


Figure 56. CCTV alerts.

8.6 Drone Alerts

The Drone (UAV) alerts display whether there is any current alert from the UAV data. As current alerts (Figure 57), we consider the alerts that have been triggered 1 day ago.

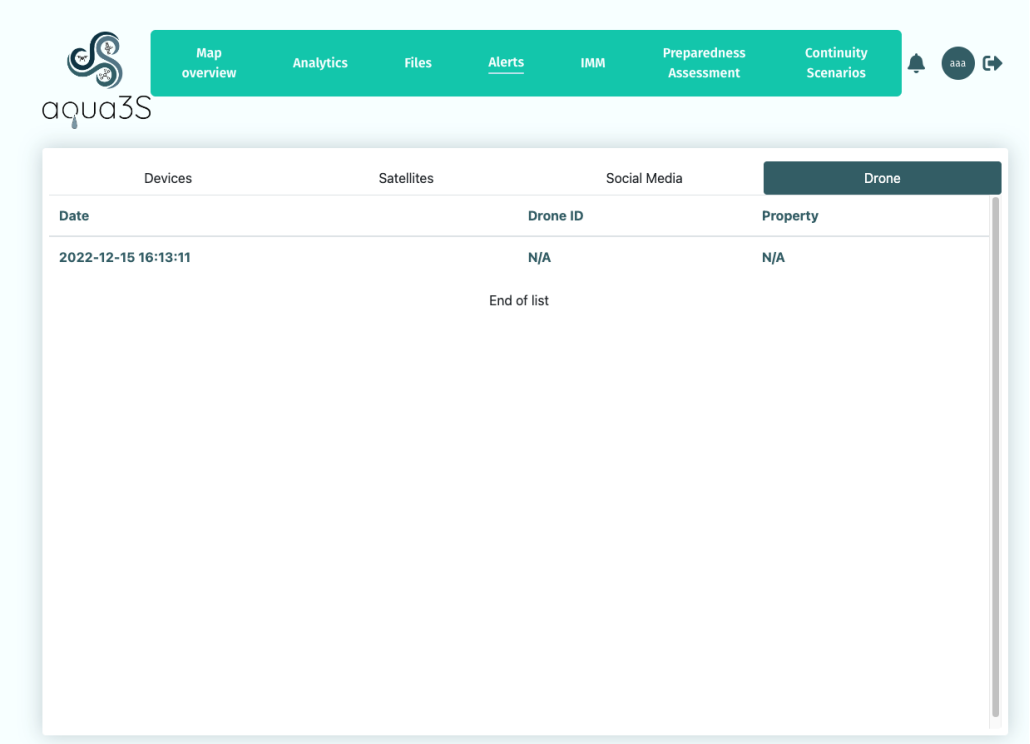


Figure 57. UAV alerts.

8.7 Warnings

In order to inform the users regarding the new or updated alerts that are made available via alert sources (i.e., Devices, CCTVs, UAVs, Social Media and Satellites), the Warning module service detects the current alerts and provides this information in real-time. For every pilot area, the warning service collects all the alerts from relative alert sources, populates them in Knowledge Base and semantically retrieves the relevant information. Table 4 show when these alerts have been triggered in order to be considered as current alerts from different types of sources:

Source	Current Alerts
Device	Based on the latest value of the device
UAV	1 day ago
CCTV	1 day ago
Satellite data (Sentinel 1)	12 days ago
Satellite data (Sentinel 2)	3 days ago
Social Media	4 days ago

Table 4. Current Alerts per source.

The results of this process are visualized via the Dashboard in order to inform stakeholders to act accordingly. This will facilitate the decision-making process as the decision-makers will be able to identify new situations where there may be danger and decide the best solution for handling different alerts.

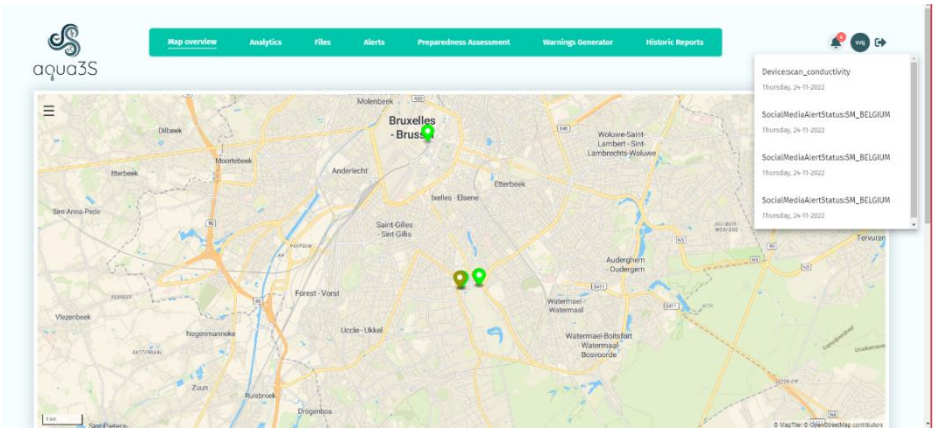


Figure 58. Warnings example.

8.8 Alerts Email

Warning emails are sent out by the workhorse component whenever a change is noted in the alert state of a device in a pilot. Typically, this occurs when at least one device enters an alert state or leaves it and returns to normal operation. Regarding sensors and in order to limit the scope for email spamming, alert emails are only sent when there is a change in device alert state.

Regarding satellite, UAV, CCTV and Social Media data, alerts emails are send whenever an alert is raised and thus when an event/ abnormal value happens within the time period indicated in Table 4.

For all type of data, alert emails are sent from the xxx@gmail.com account with recipients defined in a FIWARE alert emailing smart model.

Figure 59 and Figure 60 depict examples of emails send in case of device alerts and satellite alerts respectively.

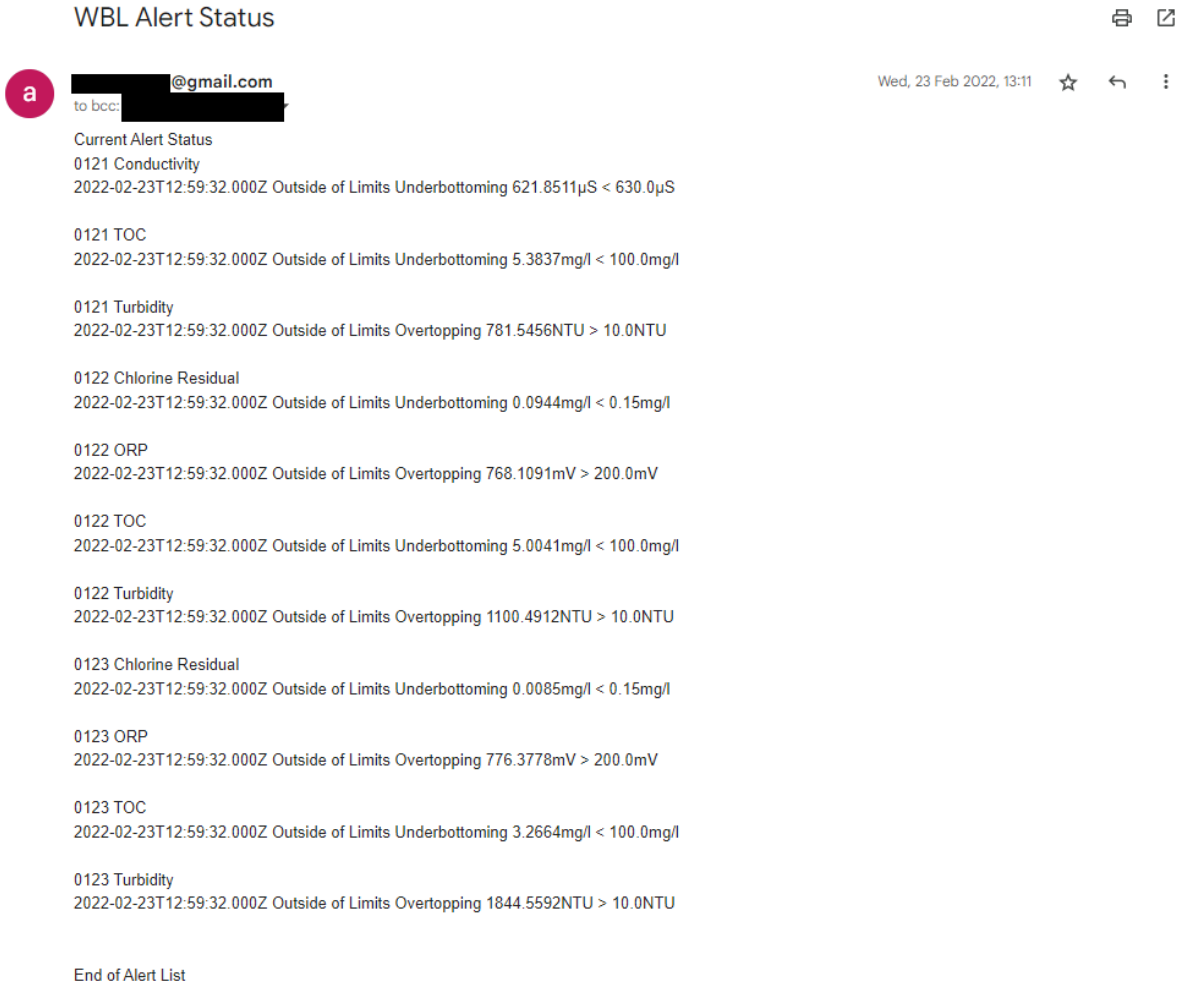


Figure 59. Example of email with sensor alerts.

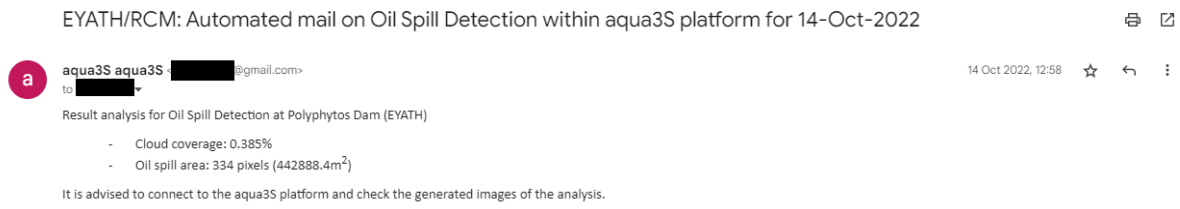


Figure 60. Example of email with satellite alert for oil spill case.

9. Files

The file management component acts as the place where a water infrastructure operator can store and have available at once all the files that are related to crisis management. Through this component a user can i) have access to the files that have been uploaded by members of their organization and ii) upload a new file. As shown in Figure 61, the user can download, edit or delete an uploaded file. Figure 62 presents the information needed to be filled when a file is uploaded to the platform. These fields are i) the title of the file to be displayed in the platform and ii) an optional short description for this file.

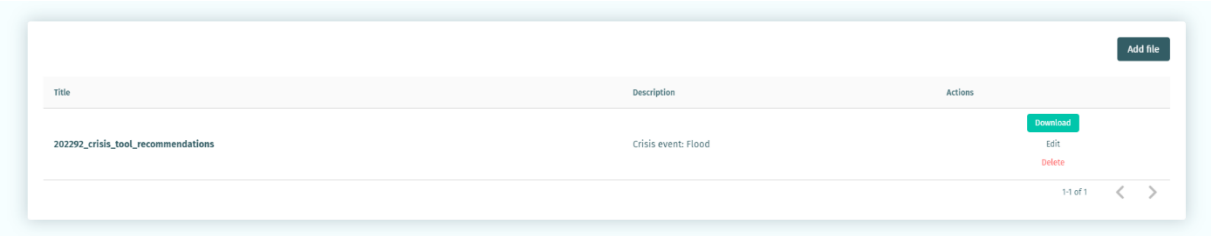


Figure 61. File management module

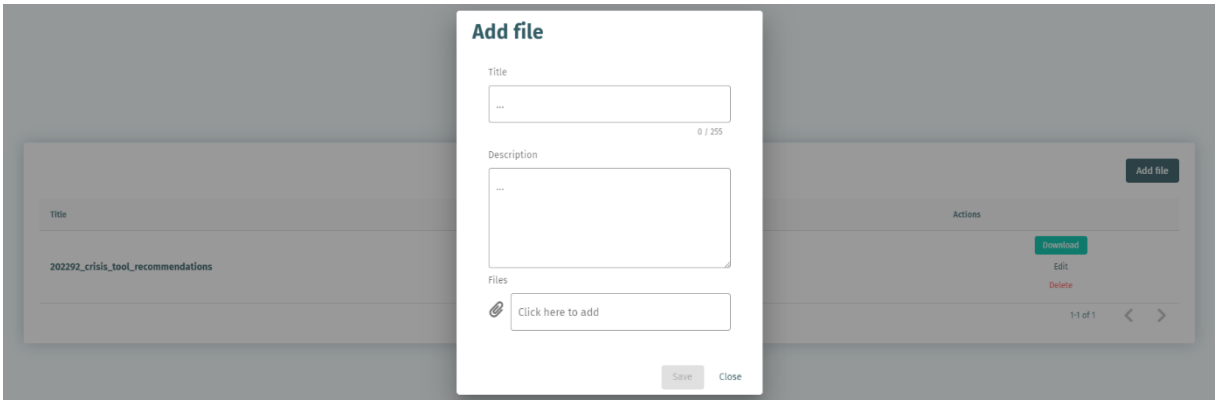


Figure 62. Functionality for adding files in the platform

10. Preparedness assessment

The “Preparedness against hazardous events” tool is a crisis management tool that aims to support stakeholders that are responsible for a water infrastructure, in assessing their preparedness level against a series of hazardous events and helps them improve their level of preparedness by providing high-level recommendations. In more detail, the tool’s scope is not specialized risk assessment; such assessments are carried out by specific simulation software, e.g., hydrological modelling, seismic modelling etc.; but the identification of areas of strength and weakness in the crisis management plan of a water organization.

The primary end users of the tool are asset owners and/or operators, however, the use can be extended to broader stakeholder groups that involve actors engaged in some capacity in the crisis management chain of actions in water utilities. The aforementioned users can use the “Preparedness against hazardous events” tool either as part of their daily routine or after a crisis event has occurred and the organization’s level of preparedness needs to be evaluated. As part of their daily routine, the tool can highlight the gaps in the established crisis management approach of the organization in a potential water crisis event while when the tool is used after a crisis has occurred, it can provide an insight on how well the organization tackled the crisis and in general its overall level of preparedness.

The tool is divided in four sections i) the *hazardous events section*; where the user selects a specific hazardous event from a list of predefined events, ii) the *crisis management section*; where the user selects all the crisis management actions that their organization is implementing for the selected hazardous event, iii) the *preparedness assessment section*; where the level of preparedness is qualitatively evaluated and areas of strength, of improvement and weakness are identified and iv) the *recommendations* section; where recommendations are provided to the user, which can serve as guidance for the user towards enhanced preparedness.

The tool’s features, that are available to the users, are presented in detail below:

1. Introductory page

At the first, introductory page of the tool (Figure *63*) the user can be informed about the different functionalities that are provided, such as the identification of areas of strength or weakness and how the preparedness evaluation is going to be performed, as well as the ability to create a new session or proceed with a previous one (Figure *64*). The five most recently created sessions are available for selection and each stored past session includes all the actions that have been selected in Section 2.

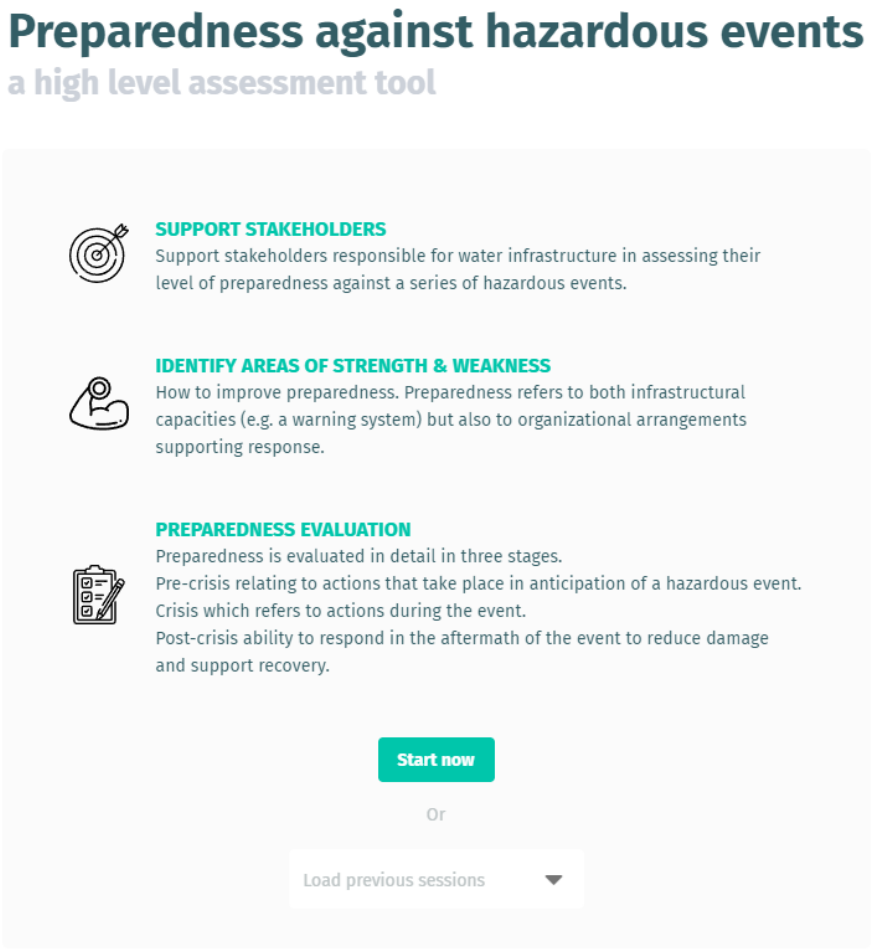


Figure 63. The introductory page of the "Preparedness against hazardous events" tool.

Figure 64. Availability to select from previous/older sessions.

1. Selection of hazardous event

In this page the user can select the hazardous event that is under evaluation. As shown in Figure 65, 16 hazardous events are available for the users to choose from.

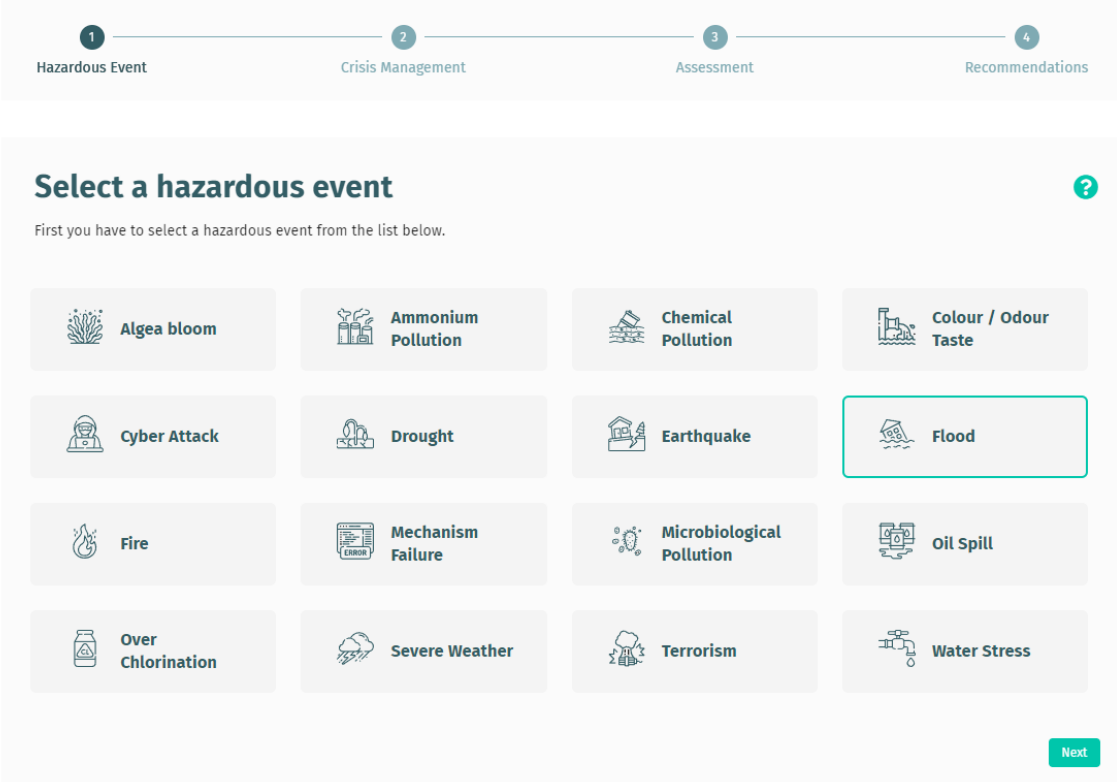


Figure 65. Hazardous event selection section.

2. Crisis Management section

The crisis management section includes the 3 main stages of a crisis event; the *pre-crisis*, the *crisis* and the *post-crisis*. Each stage is separated to predefined functional areas and each area includes the actions that can be deployed by an organization towards crisis management, as shown in Figure *66*. The user can either (i) select the actions that are performed by their organization at the moment or (ii) by including some actions that are not currently implemented, so the user can examine their contribution to the organization's overall level of preparedness. The user can select an action by clicking on the relevant button and the selected actions are shown with a different colour.

After the completion of the selection, the user verifies their selections and proceeds to the next section of the tool.

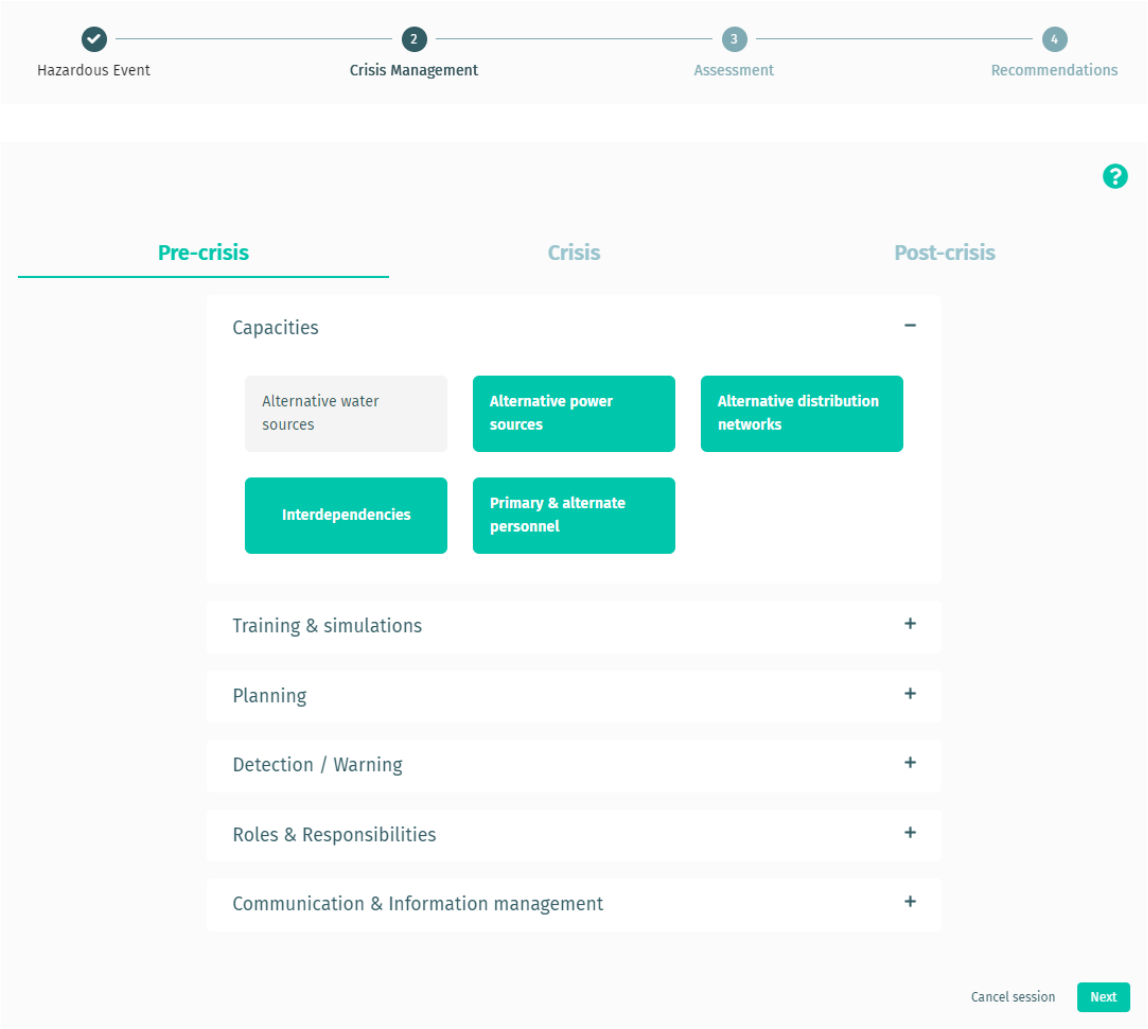


Figure 66. Crisis Management Section.

3. Assessment section

In this section the user is informed about the assessment results per each stage and per functional area. As shown in Figure *67*, the assessment results include the level of preparedness, which is visualized by utilizing different colours for each level of preparedness status; green for “Highly Prepared” status, blue for “Moderately prepared” status, red for “Slightly prepared” status; different verbal expressions and graphical figures. Apart from the organization’s level of preparedness, the user is informed about the impact that a hazardous event has on the components of a water supply system (i.e., water source (groundwater), water source (surface water), treatment, storage, distribution, and administration & communication). The impact of an event is given by verbal expressions and in the help modal, at the upper and right part of the page, the user can find a more detailed description for each expression.

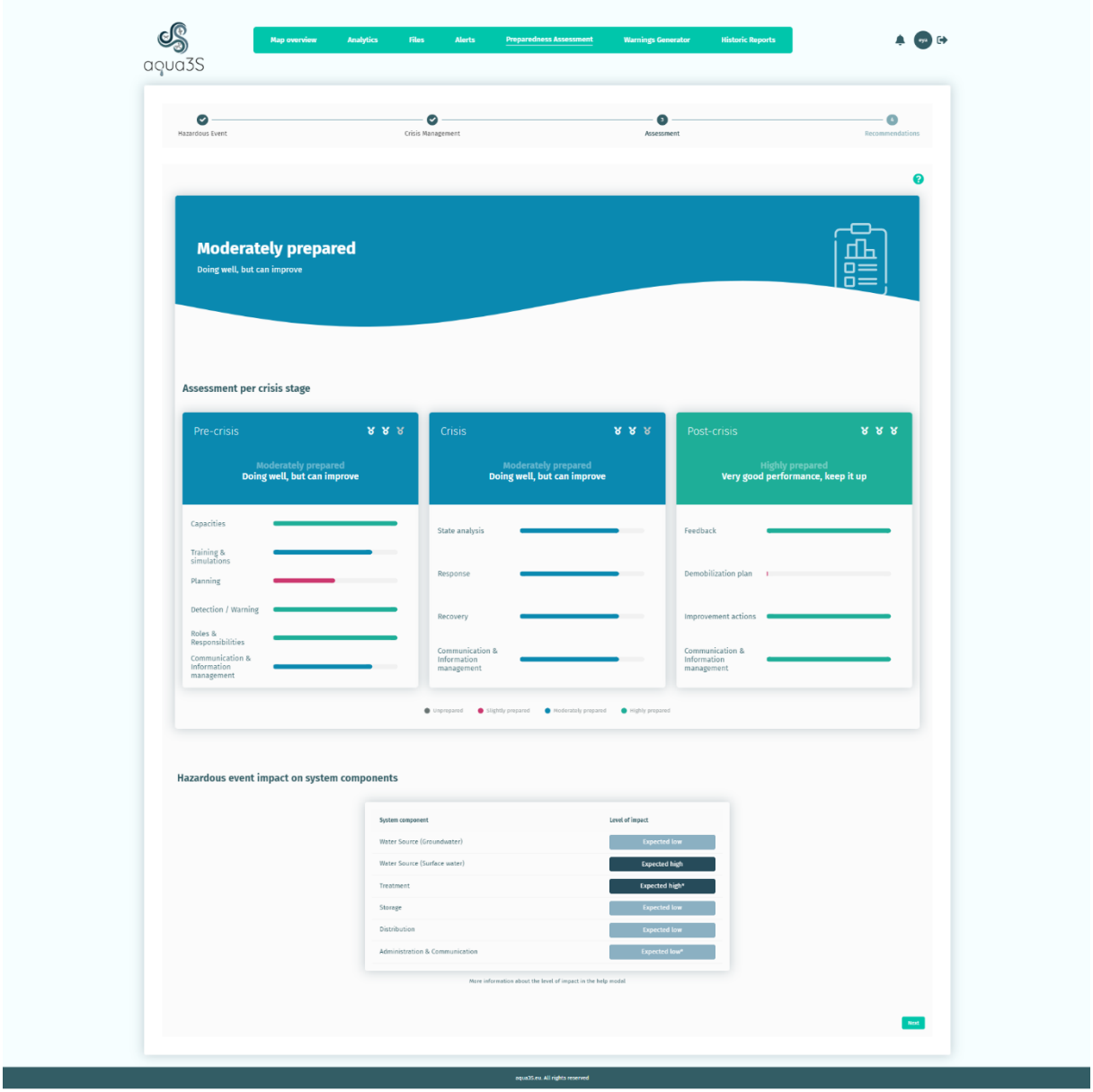


Figure 67. Assessment section.

4. Recommendations section

In the recommendations section, the user can view the recommended actions that can be implemented in order to increase their organization's level of preparedness. The proposed recommendations are divided into two categories, the "on screen" and "on paper". The first category is showcased in the recommendations section's page and includes the recommendations that are not implemented by the organization and have the most impact in increasing the level of preparedness for the selected hazardous event (Figure *68*). The second category encompass the full list of the recommended actions that can be implemented by an organization (Figure 69). This full list can be downloaded and serve as a guidance on some key aspects of crisis management.

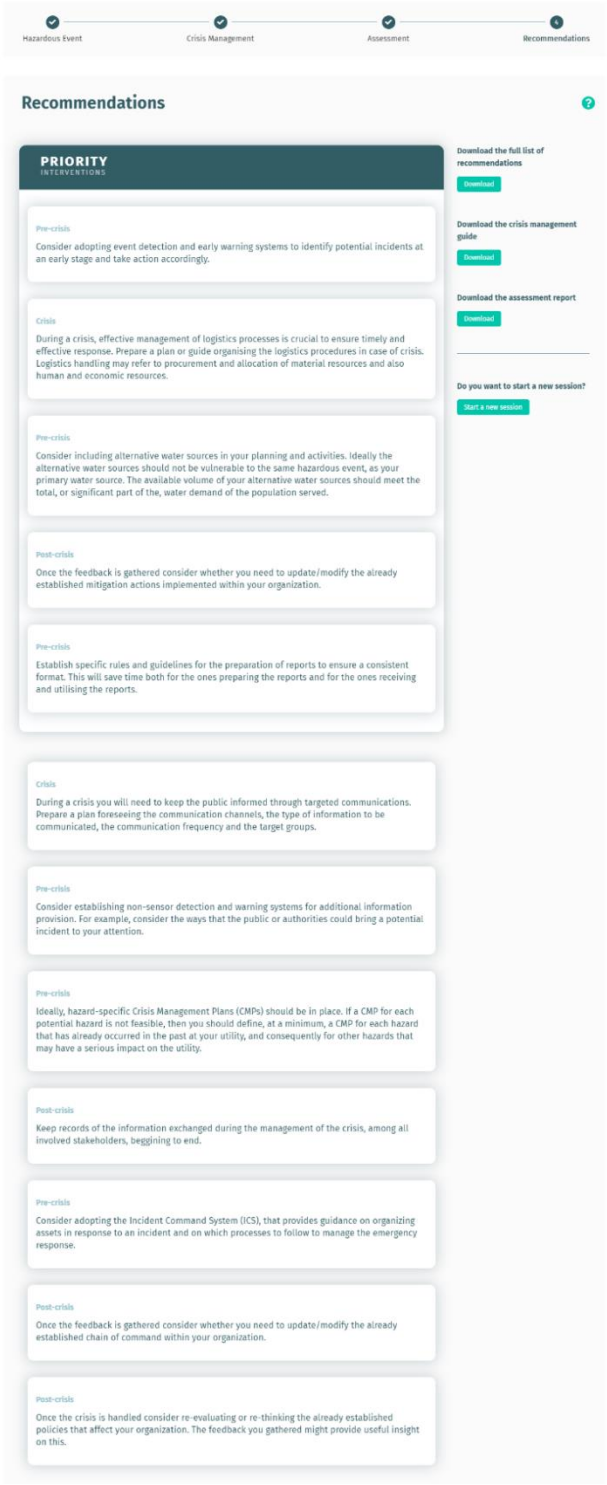


Figure 68. “On screen” recommendations.

aqua3S

RECOMMENDATIONS

Priority interventions

Pre-crisis

Detection / Warning

Consider adopting event detection and early warning systems to identify potential incidents at an early stage and take action accordingly.

Crisis

Response

During a crisis, effective management of logistics processes is crucial to ensure timely and effective response. Prepare a plan or guide organising the logistics procedures in case of crisis. Logistics handling may refer to procurement and allocation of material resources and also human and economic resources.

Pre-crisis

Capacities

Consider including alternative water sources in your planning and activities. Ideally the alternative water sources should not be vulnerable to the same hazardous event, as your primary water source. The available volume of your alternative water sources should meet the total, or significant part of the, water demand of the population served.

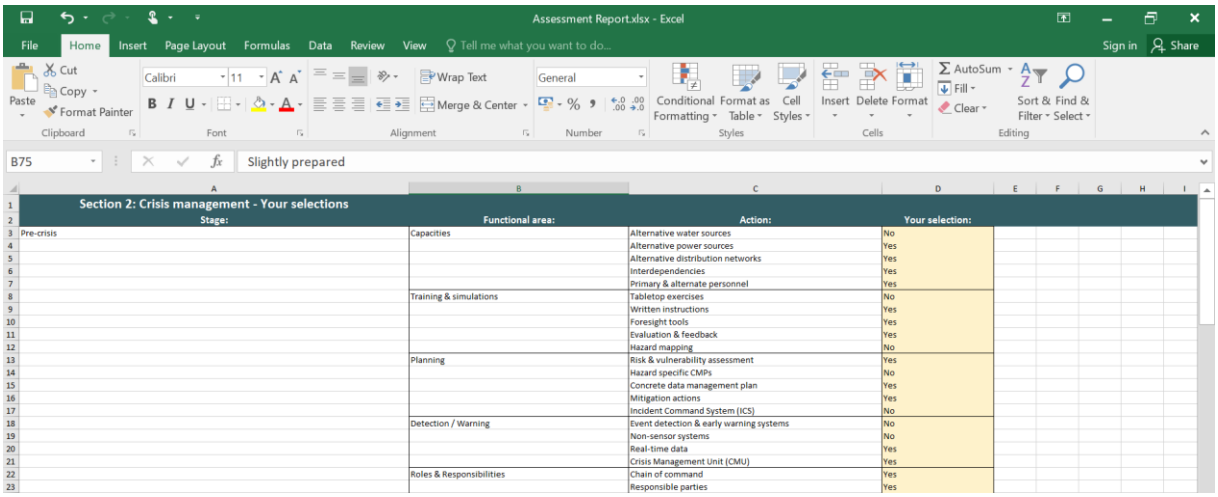
Post-crisis

Improvement actions

Once the feedback is gathered consider whether you need to update/modify the already established mitigation actions implemented within your organization.

Figure 69. Download the full list of recommendations feature

In this section, the user can also download i) the assessment report (Figure *70*) that sum up the assessment results that were generated for the created session and ii) the crisis management guide (Figure *71*) that contains extra information on the crisis management stages, their functional areas and actions, as well as the impact of the supported hazardous events on the system components.



Stage:	Functional area:	Action:	Your selection:
Pre-crisis	Capacities	Alternative water sources	No
		Alternative power sources	Yes
		Alternative distribution networks	Yes
		Interdependencies	Yes
		Primary & alternate personnel	Yes
	Training & simulations	Tabletop exercises	No
		Written instructions	Yes
		Foresight tools	Yes
		Evaluation & feedback	Yes
		Hazard mapping	No
	Planning	Risk & vulnerability assessment	Yes
		Hazard specific CMPs	No
		Concrete data management plan	Yes
		Mitigation actions	Yes
		Incident Command System (ICS)	No
	Detection / Warning	Event detection & early warning systems	No
		Non-sensor systems	No
		Real-time data	Yes
		Crisis Management Unit (CMU)	Yes
	Roles & Responsibilities	Chain of command	Yes
		Responsible parties	Yes

Figure 70. Download the selections-assessment results.

Preparedness against hazards – Guide

In the ***"Preparedness against hazards assessment tool"***, preparedness is evaluated in detail in three major stages:

i. The period before the event, i.e., **pre-crisis** preparedness relating to actions that take place anticipation of a disastrous event,
ii. The period during the event, i.e., **crisis** management, and
iii. The period after the event, i.e., readiness for **post-crisis** management, ability to respond in the aftermath of the event to reduce damage and support recovery.

Section 1: Hazardous events

Ideally, a Crisis Management Plan (CMP) should be in place for each hazardous event. The hazardous events included in the tool are presented below, along with the high-level impact each specific event may have on the water supply system components.

Table 1. Explanation of the verbal codification attributed to the impact level of the hazardous events

Verbal codification	Explanation
High	All experts indicate a high level impact.
Expected high	The majority of the experts indicate a high level impact.
Expected high*	Most experts indicate a high level impact, but there is a significant variation among the experts' opinions.
Medium	All experts indicate a medium level impact.
Expected medium	The majority of the experts indicate a medium level impact.

Figure 71. Download the crisis management guide.

11. Continuity scenarios

The continuity scenarios module is a module where specific unavailability scenarios, triggered from different events related to a water infrastructure, are displayed. The context of this module was conceptualized in collaboration with AAA and AAWA; Italian water infrastructure end-users; and the scenarios displayed, along with the mitigation actions for each scenario, were given by the aforementioned organizations.

The module has a twofold role to fulfil, i) serve as a reference procedure during the planned crisis drills of a water infrastructure and ii) act as a guide, with mitigation actions to be implemented, when an event occurs. In regards to the first part, the module helps a water infrastructure to increase its level of preparedness and tackle more efficiently a potential event, and the second part the module enables an organization to mitigate the consequences of an event that has occurred and prevent this event from turning into a crisis.

As shown in Figure *72*, the module comprises of twenty different continuity scenarios. A scenario consists of two parts i) the title of the scenario and ii) a list of mitigation actions that an organization needs to implement in order to tackle early and efficiently an occurring event (Figure *73*).

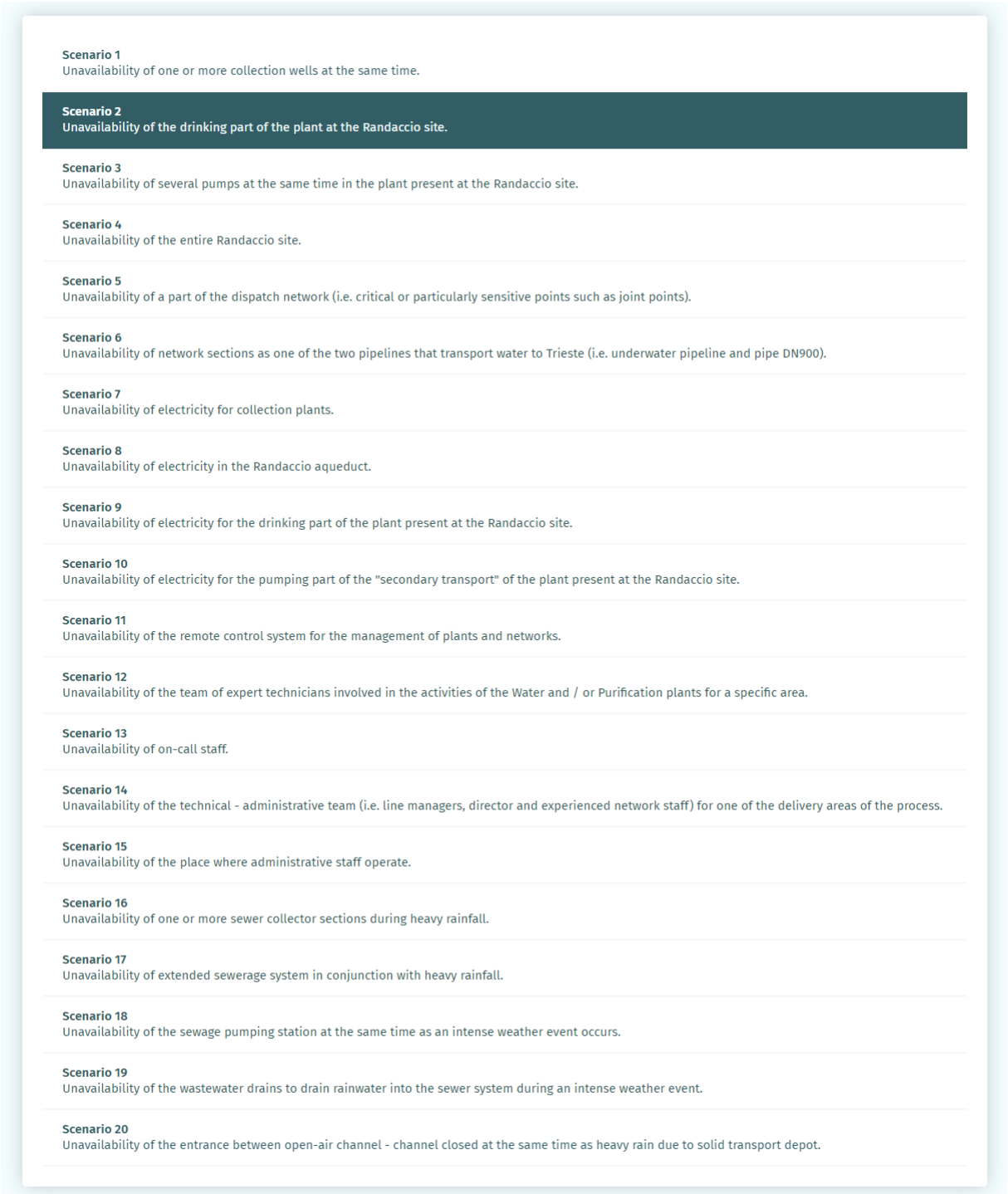


Figure 72. Available continuity scenarios.

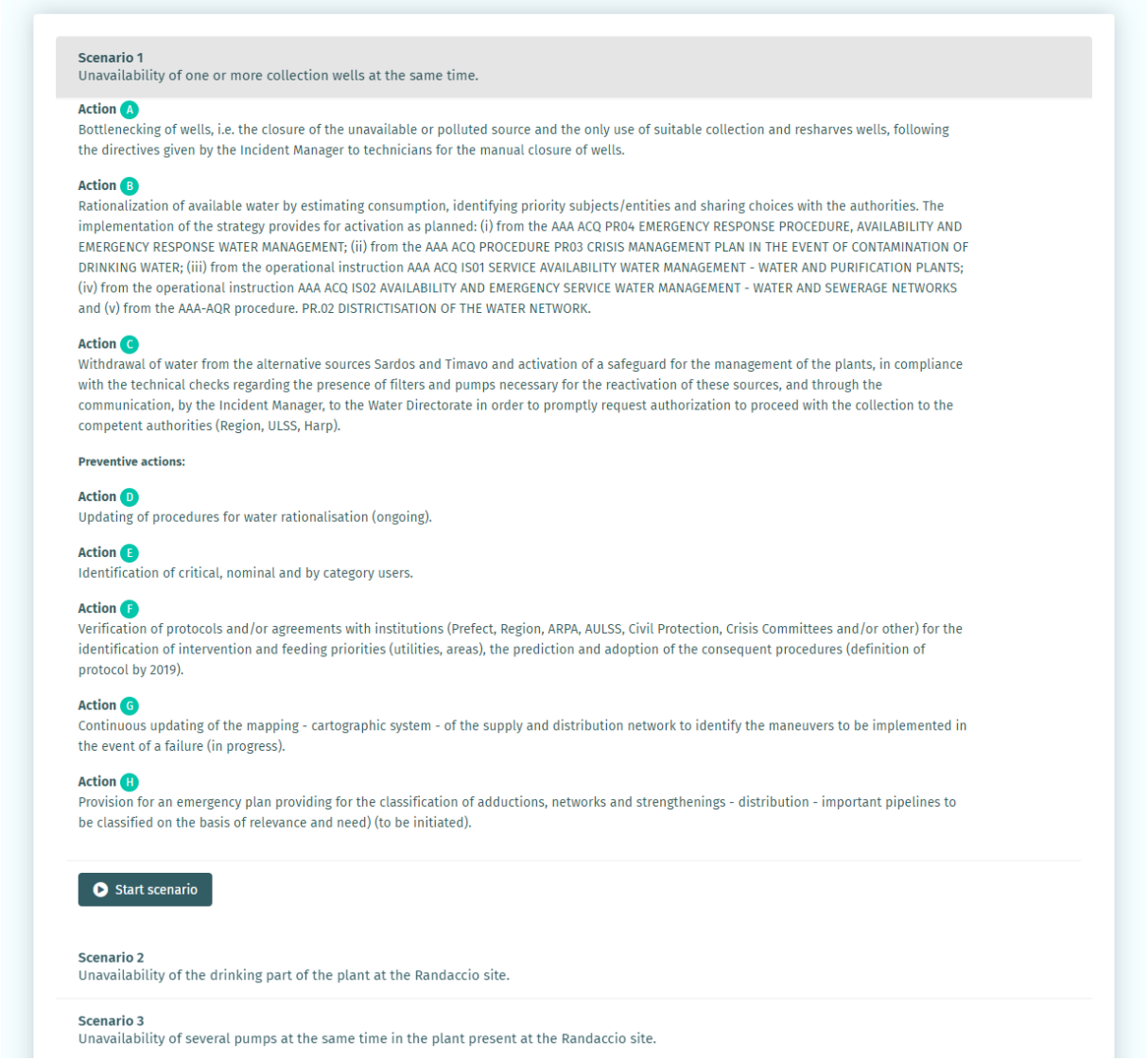


Figure 73. Extended continuity scenario 1.

In more detail, when an event occurs the water infrastructure's operators identify the continuity scenario that corresponds to the occurring event and initiate the process. When a scenario is initiated, a time countdown alert banner is displayed at the upper part of the aqua3S platform which indicates the time in which the scenario's mitigation actions should be completed (Figure 74). If all mitigation actions are marked as "completed", the event is tackled successfully and the scenario ends (Figure *75*).

Figure 74. Countdown alert banner for completing disaster recovery actions.

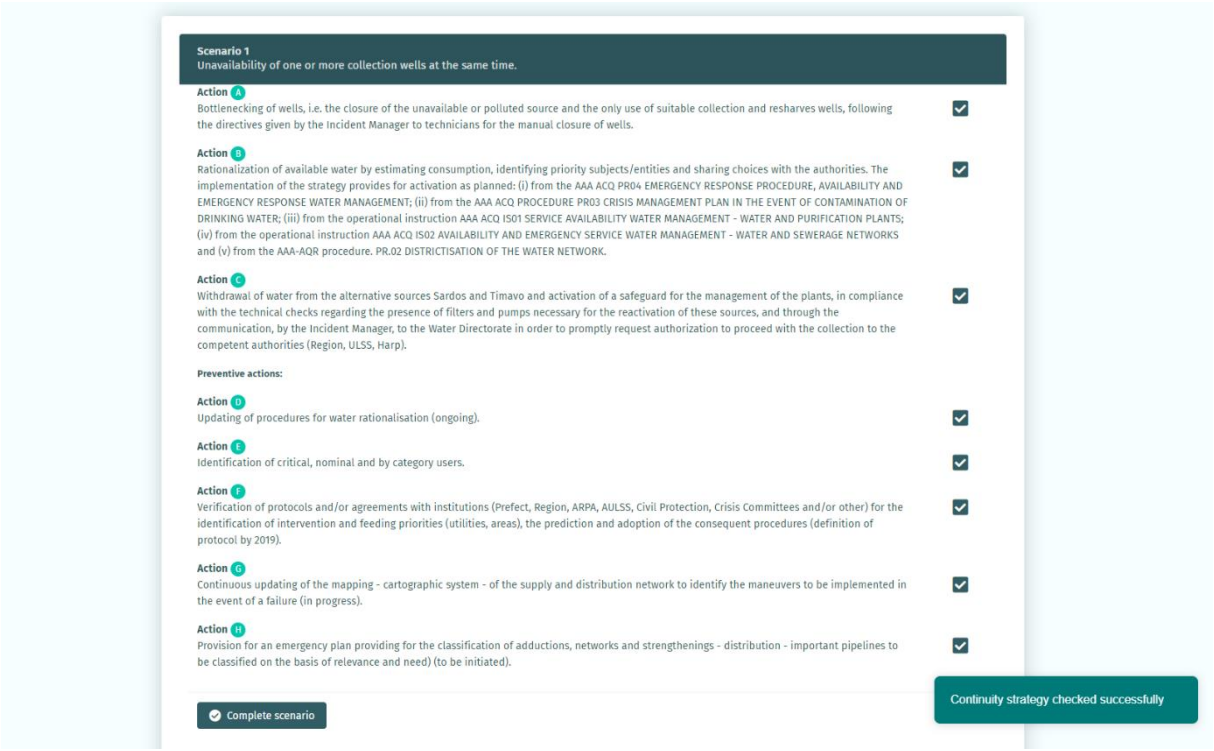


Figure 75. Completed continuity scenario.

12. Intervention Management Model (IMM)

The IMM is developed to identify optimal response to possible pipe break events occurring within a water network. The IMM applies a heuristic algorithm to be able to identify the near optimal solution to pipe repair and pipe break mitigation in near-real-time. Specifically, the IMM identifies the optimal time to repair a broken pipe, as well applying possible interventions (operating closed valves, adjust PRVs, etc.).

To use the IMM, the user must select the pipe that is broken, the expected repair duration, and the preferred number of solutions to be analysed by the user (Figure *76*). The IMM then predicts several near-optimal solutions to the pipe repair based on an overall performance indicator and the number of interventions required from the utility provider (Figure *77*). The user can then toggle through these predicted solutions, visualizing the impact each solution has on various performance indicators as well as the unique step-by-step solutions (Figure *78*). The user can then identify which intervention solution works best for them and begin implementation.

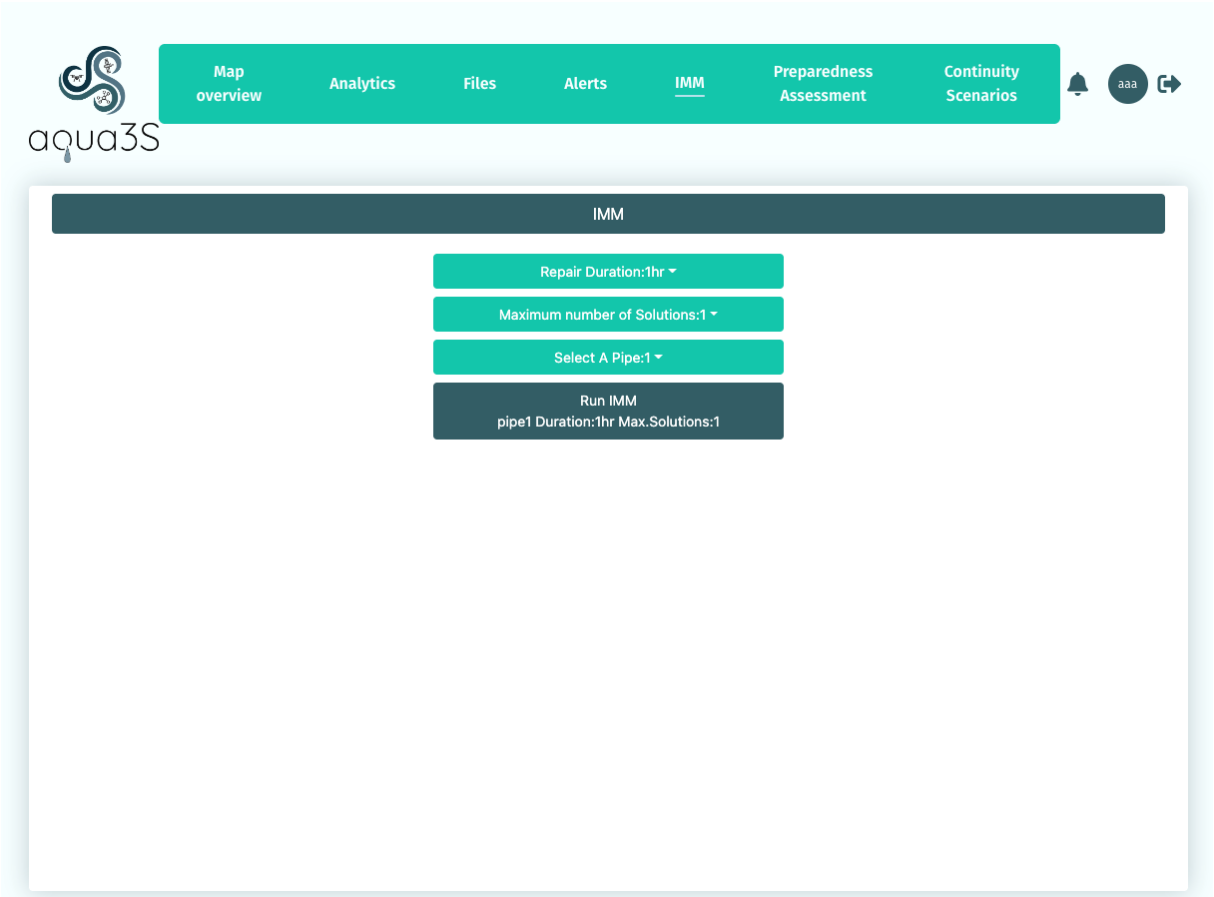


Figure 76. IMM - setting configuration.

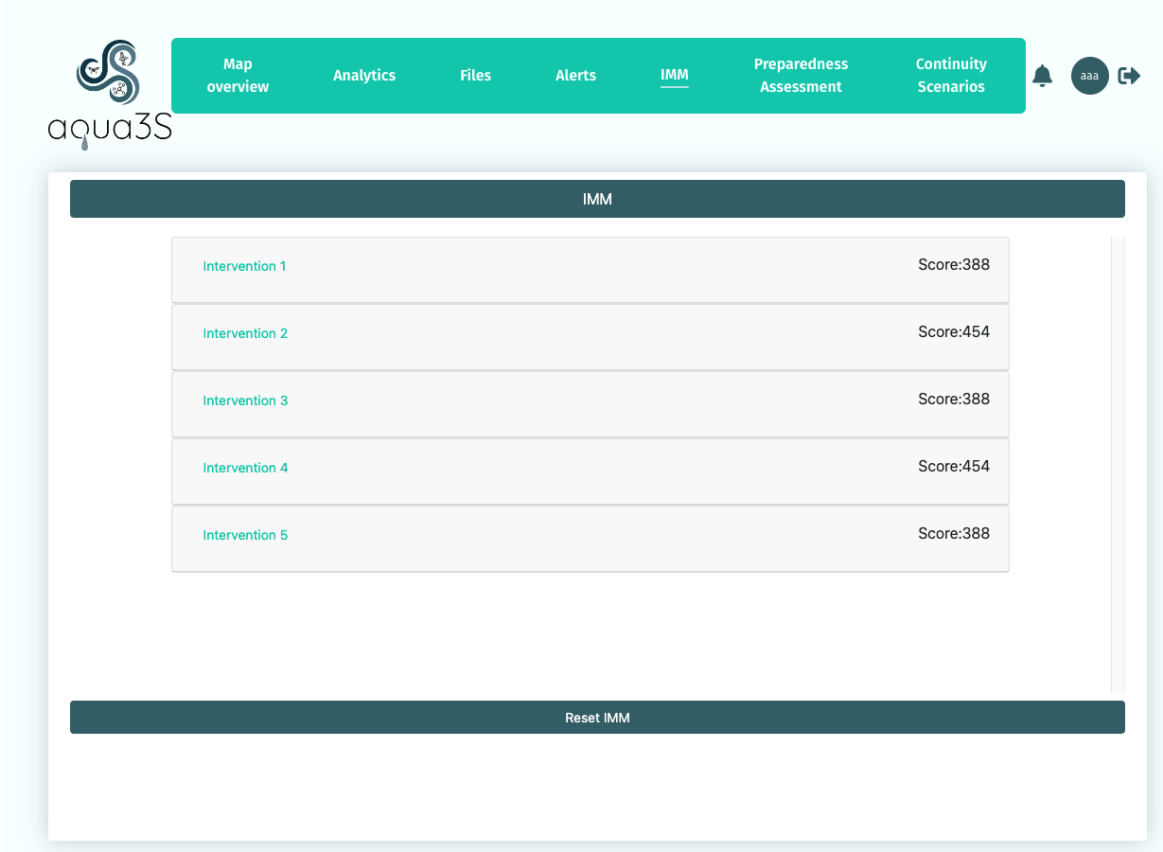


Figure 77. IMM - showing multiple results.

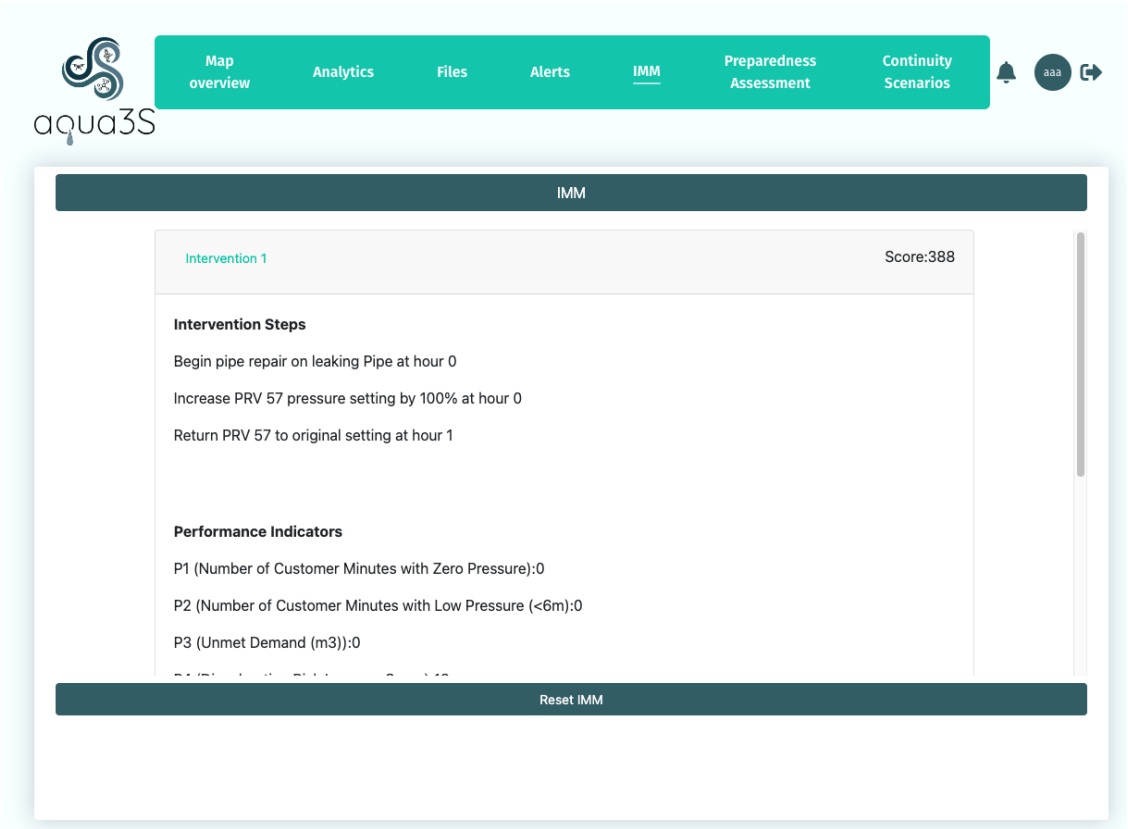


Figure 78. IMM - result detail.

13. Warning Message Generation

The main function of the Warning Message Generation (WMG) is to allow the user to promptly generate standardised warning messages which are based on the best practices in terms of the type and format of information included. The main purpose of the tool is to support various departments and teams (PR, media and social media teams, security and emergency response teams) to quickly generate and share pre-approved messages in-line with the best practices, whilst also allowing a degree of customisation, making the WMG capable of generating warning messages and alerts covering a vast variety of scenarios. The tool also allows message generation in multiple languages. Each message has the following basic structure:

[severity] [crisis] [alert] for *[location]* at *[time]* issued by *[organisation]*. *[event description]*. Responders are *[response]*. Citizens in this area should *[instructions]*. Visit *[URL]* or call *[contact number]*. *[Additional Media]*

Information about the severity, type, and category of the crisis is mandatory. This structure allows for providing information about the date and time of the crisis, affected location, issuing organisation, response of the organisation, and instructions for the audience. Alongside, an event description may be added in the message, as well as weblink, contact details, and media (photographs and video). This structure allows the generation of messages that are well-suited for various communication channels. The WMG fields have pre-loaded options as well as the option for the user to add free text.

The abovementioned message format can be used for the construction of messages disseminated during the crisis phase, as well as more complex messages shared during the pre-crisis or post-crisis phases and such that provide crisis updates.

13.1 Severity, type, and crisis

The severity, type, and crisis segments are the three core elements of the warning message. The severity indicates the seriousness of the message (e.g., *red, amber, yellow, green,* free text), the message type gives information about the type of information being provided (e.g., *alerts, warning, advisory, caution, update, notice,* free text), and the crisis describes the incident itself (e.g., *severe weather, flood, drought, pollution, etc.*). All three elements are mandatory. Figure 79 shows a generated example of a message which includes only the mandatory information.

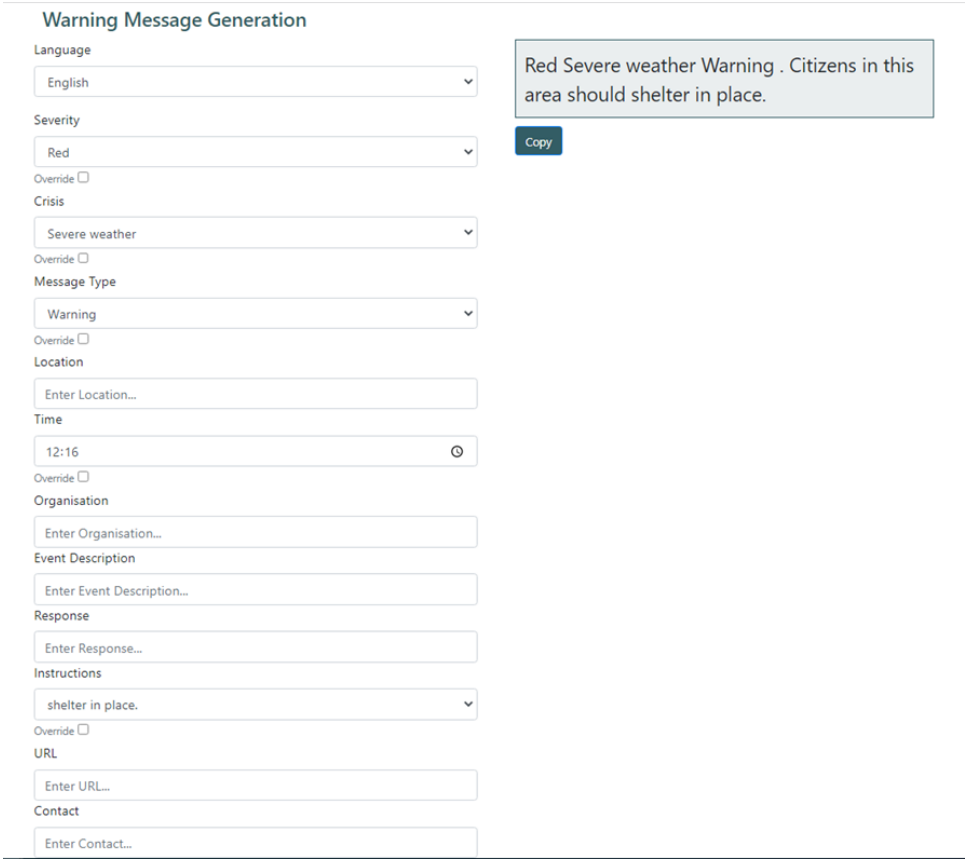


Figure 79. WMG basic dummy message.

13.2 Timings and location

Timings are an optional element which can be used to indicate when the incident started, and the field can be overridden to provide the appropriate information. Specific location and area can also be added to the message.

13.3 Instructions and event description

The tool provides a list of pre-set instructions that can be shared with the target audience in the warning message. The field also allows input of free text. In the instance of the aqua3S WMG, the target audience is the citizens. Some of the pre-set instructions are: *boil water, avoid water, shelter in place, evacuate immediately, save water, drink bottled water,* and *return to normal*.

13.4 Event description, organisation, response, URL, contact

The WMG has a field where the event can be described using free text only. The field may be used from the issuing organisation to add any further relevant information to the public.

The organisation and response fields provide spaces for adding customisable text informing about the name of the issuing organisation as well as the actions the organisation has taken to deal with the incident. Additionally, organisations may add further information, such as a link to a webpage with more detailed information about the incident or contact details. Figure 80 shows an example of a generated message where all the fields are filled in.

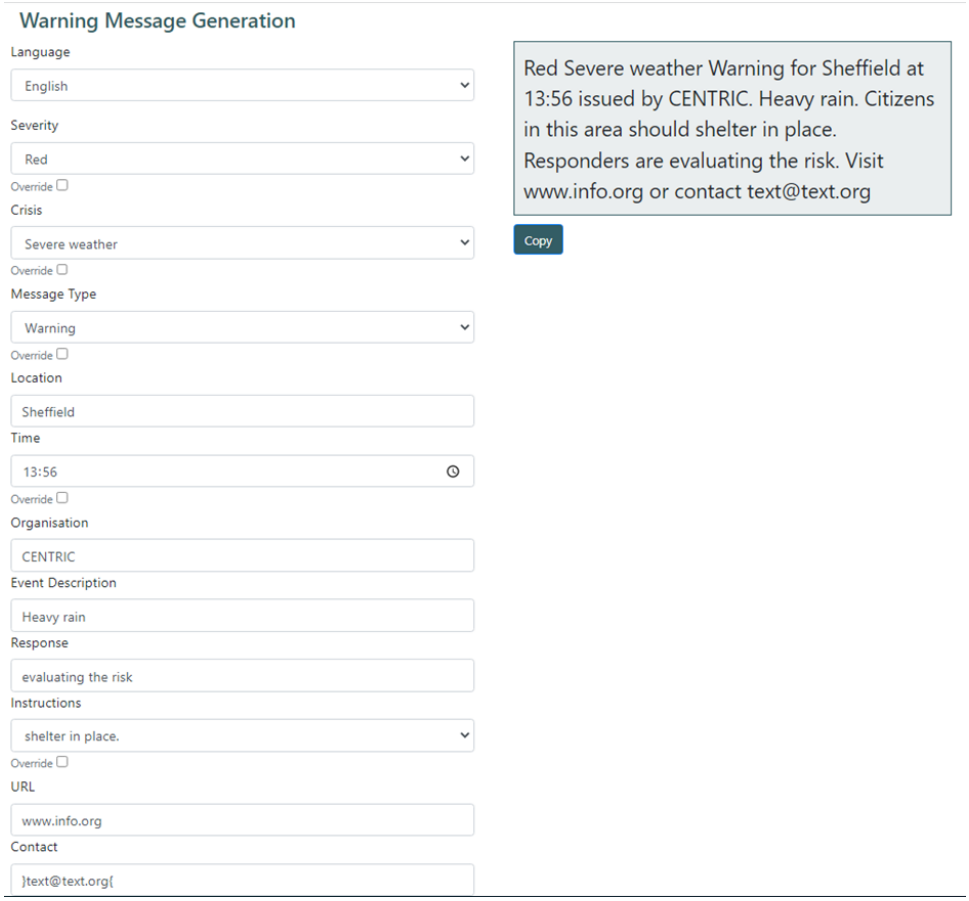


Figure 80. WMG dummy extended message.

13.5 Language

The user needs to select one of the predefined WMG languages, namely Greek, English, Bulgarian, Italian, and French. This is the language in which the generated message will be produced. Figure 81 shows an example of a warning message in French.

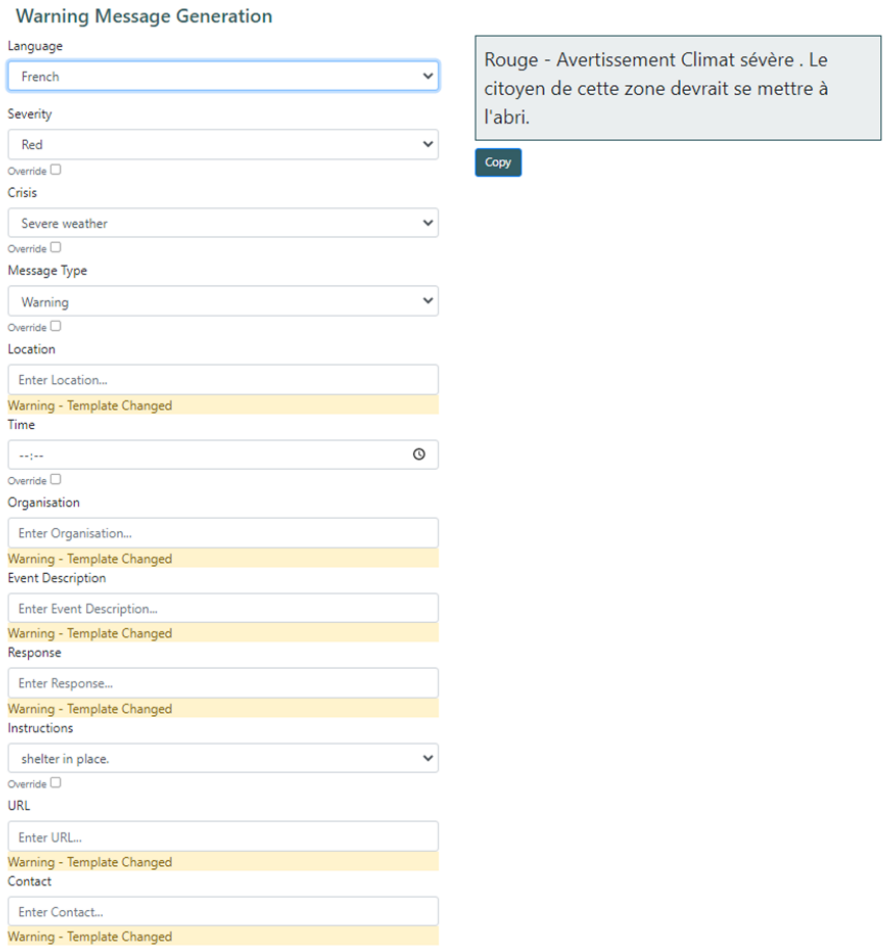


Figure 81. WMG dummy message in French.

14. Historic Reports

The Historic Report module is responsible for identifying and keeping track of the historical alerts that comply with the criteria defined in the web interface. This knowledge is useful for decision-makers that observe older events, to understand the situation, to identify correlations among alerts and eventually to come up with better solutions in terms of environmental planning and monitoring in the future. The input criteria contain the source, the location, and the time period during which the alerts will be examined. Using those, the service executes the appropriate semantic queries on the Knowledge Base, where all alerts have been already stored (Warnings service) and produces a PDF file containing information for each alert that fulfils the given requirements.

The module receives as input the following parameters (see Figure 82):

- *Type of data*: it refers to the type of data sources that will be included in the alert report. The user can select either all type of data or a single type from the following list: satellite, UAVs, CCTV, sensor.
- *Time period*: it refers to the time period that the alerts were triggered. Thus, only alerts active in the selected time period will be part of the report.

Based on the selected input parameters, a PDF report is produced that can be downloaded through the platform.

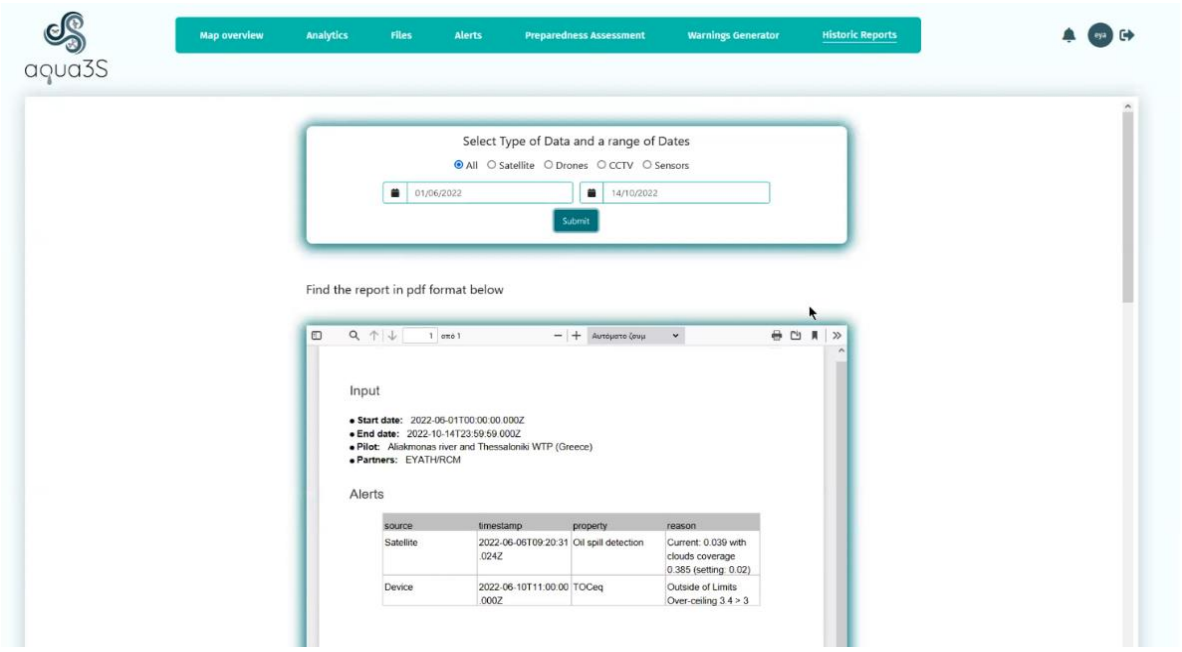


Figure 82. Historic Reports module