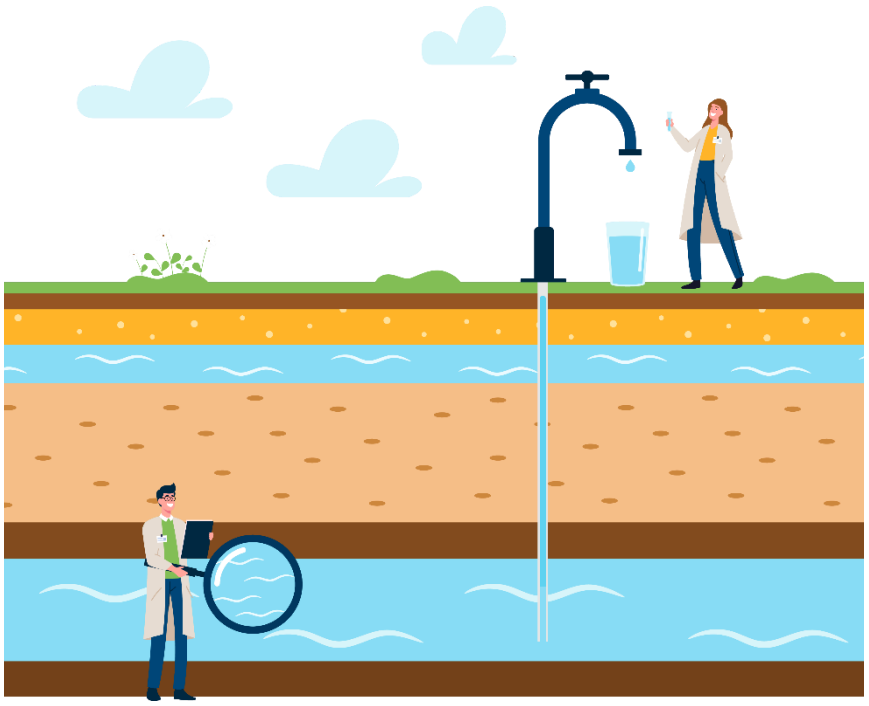
MAR 2 PROTECT

M-AI-R DSS USER GUIDE. How to use and navigate in the platform

CETAQUA ANDALUCÍA



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Project title: "Preventing Groundwater Contamination Related to Global and Climate Change through a Holistic Approach Based on Managed Aquifer Recharge"

Project Duration: 1st December 2022 - 30th November 2026 (48 months)

Website: https://mar2protect.eu/

Partners and Associated Partners Acronyms

Acronym	Partner
AdTA	Águas do Tejo Atlântico
AQUATEC	Affiliated Entity of CETAND. Water private company (Veolia group), Spain
CETAND	Centro Andaluz de Investigaciones del Agua
CIIMAR	Centro Interdisciplinar de Investigação Marinha e Ambiental, Portugal
CT	City of Cape Town
DU	Dunea Duin & Water
FEUGA	Fundación Empresa Universidad Gallega, Spain
FHNW	University of Applied Sciences and Arts Northwestern Switzerland
HERA	Holding Energia Risorse Ambiente
IHE	IHE DELFT Institute for Water Education, The Netherlands
IT	Instituto de Telecomunicaçoes, Portugal
ISSBAT	Inst. Supér. des Sciences Biologiques Appliquées de Tunis
KTU	Kaunas University of Technology, Lithuania
NOVA	NOVA ID FCT – Associação para a Inovação e Desenvolvimento da Faculdade de ciências e tecnologia da universidade NOVA de Lisboa, Portugal
SU	Stellenbosch University, South Africa
UNIBO	University of Bologna, Italy

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Executive Summary

M-AI-R DSS is a decision support system designed to support Managed Aquifer Recharge (MAR) throughout the entire project lifecycle, from initial planning and site selection to implementation, monitoring, and operation. This document will guide you navigating through the platform and its main results.

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1 WHAT IS THE M-AI-R DSS PLATFORM

M-AI-R DSS is an AI-enhanced integrated platform that supports decision-making across the full MAR lifecycle:

- Site suitability assessment: GIS- and Earth Observation (EO)-based mapping to identify optimal MAR locations considering hydrogeological, climate, and land-use data.
- Design and planning: Integration of REACH Tool (groundwater quality prediction), DRONE (data driven modelling for climate impacts in GW) and RAINREC (recharge dynamics) modelling tools to support MAR scheme design under CC scenarios.
- Operational management: Real-time sensor data integration for monitoring water quality, clogging risk and aquifer performance.
- Risk assessment: Proactive quantification of clogging, salinity, and scarcity risks before they occur, enabling preventive action.
- Visualization and reporting: Decision-ready dashboards for MAR operators, regulators, and civil society.

The results presented in the M-AI-R DSS platform are from all MAR2PROTECT demo sites, especially Frielas – Portugal, Emilia-Romagna – Italy, Cape Flats – South Africa and Marbella – Spain.

The operational section of the DSS has a restricted access as it has been specifically designed for a MAR scheme operating in Marbella, Spain.

2 WHO CAN USE THE PLATFORM

Anyone can access the platform through this link and through the MAR2PROTECT site.

The platform has been designed with the intention to provide support regarding Managed Aquifer Recharge to civil society, policy makers, public administrations, private entities, and academy.

3 WELCOME PAGE

Once you access the platform in the first page that opens you have to make the first decision: to choose between 3 main blocks:

1. Explore the platform
2. MAR planning DSS
3. MAR Operational DSS (restricted access).
4. About MAR2PROTECT

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Figure 1: M-AI-R DSS main page.

In the following sections, we will show you what you will find detailed guidelines on how to navigate on each of them.

4 EXPLORE THE PLATFORM

Explore the platform is the section where you can find all MAR2PROTECT tools, results and resources and navigate through each of them at their own pace. Once you click on the "explore the platform" box, a main page with all the results will appear. You can select the tool or result by either clicking on the main menu that will display when entering the section (Figure 2) or by clicking on the upper bar and selecting the result you are most interested in (Figure 3).

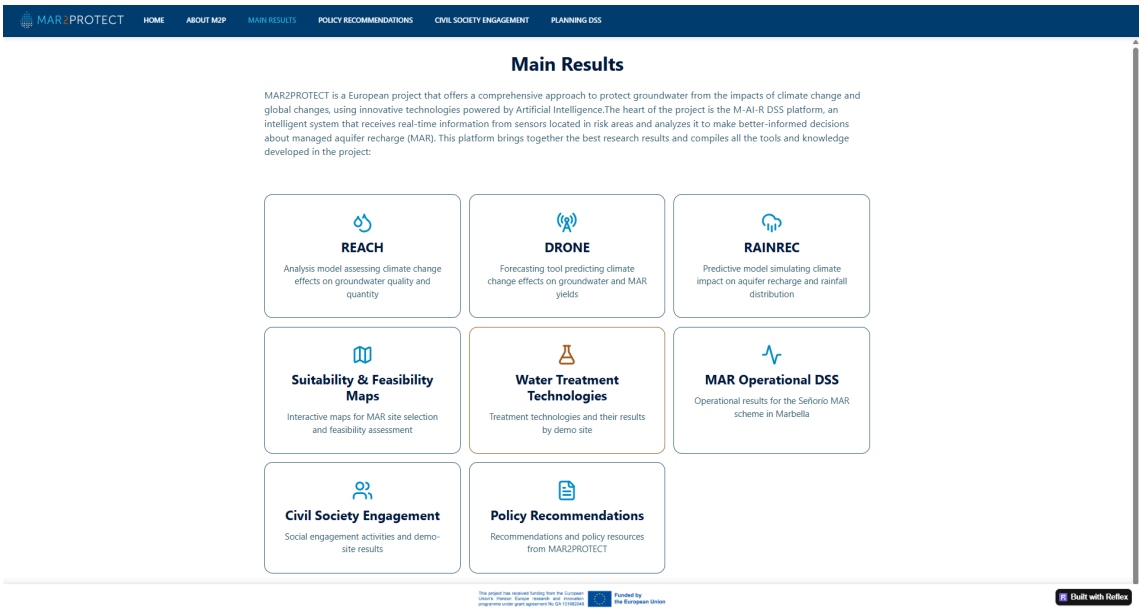

Figure 2: Main page of “explore freely”.

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Figure 3: Access to main results through the upper bar.

Let's explain now each of the results that you will find and how to navigate through each of them:

4.1 REACH

The REACH Tool is a predictive analysis model developed under the MAR2PROTECT project to evaluate how climate and global change impact the chemical and quantitative status of groundwater. It is organised in 3 pillars: MOD-REACH, DATA-REACH and GIS-REACH and the main results have been developed for the Señorío Aquifer in Marbella and the Costa del Sol Occidental, Spain. When clicking in the REACH block you will access to the REACH Tool main page:

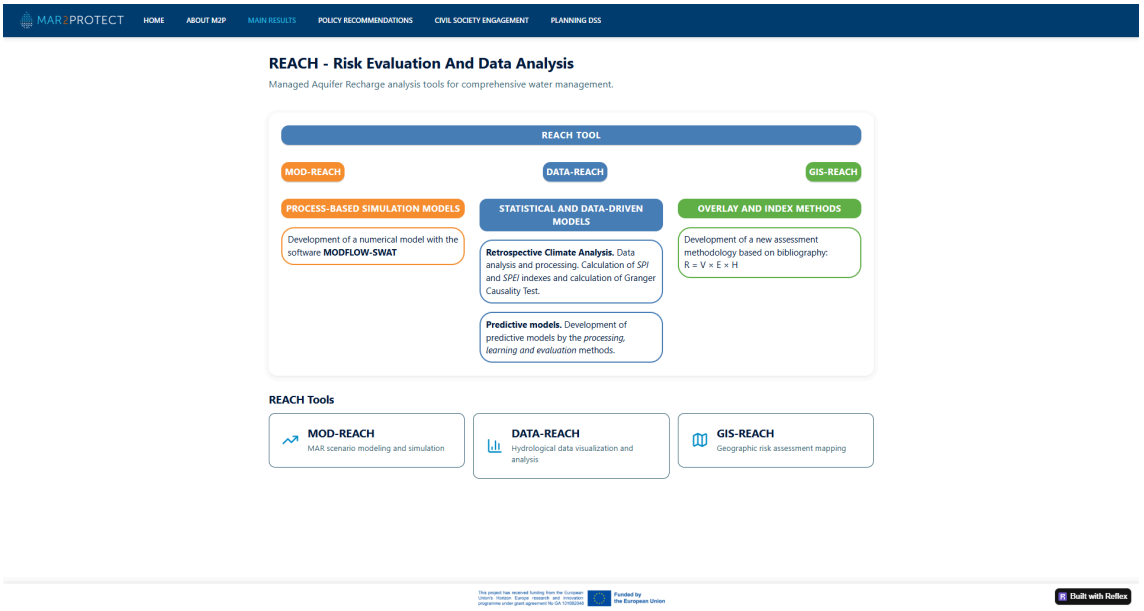

Figure 4: REACH Tool main page.

You have information about the REACH Tool and its three modules: MOD-REACH, DATA-REACH and GIS-REACH. You can access to each of them by either clicking on the name tags in the scheme (1) or in the links of the lower part of the page (2):

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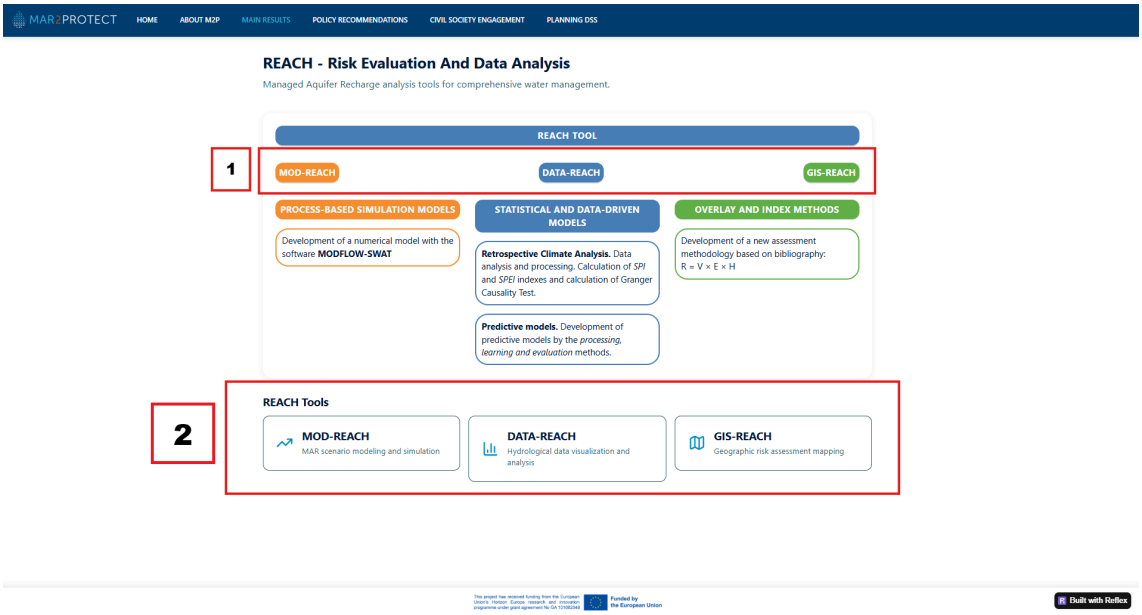

Figure 5: Access to the REACH Tool modules results

4.1.1 MOD-REACH

The MOD-REACH module is a physical modeling-based approach within the REACH tool, is designed to simulate groundwater flow and understand the hydrogeological dynamics of aquifers, particularly in the context of Managed Aquifer Recharge (MAR) and climate change impacts.

When entering the MOD-REACH results you will find explanations about the MOD-REACH and its results. The page is structured as follows:

1. Explanation about the REACH Tool,

2. Dropdown menu with the evolution of the piezometric levels.

3. Two videos with the simulations of the evolution of the piezometric levels and the salinity of the aquifer in order to understand the possible saline intrusion in the Señorío Aquifer, Marbella. The videos will start automatically but you can stop them by clicking in the middle of the video.

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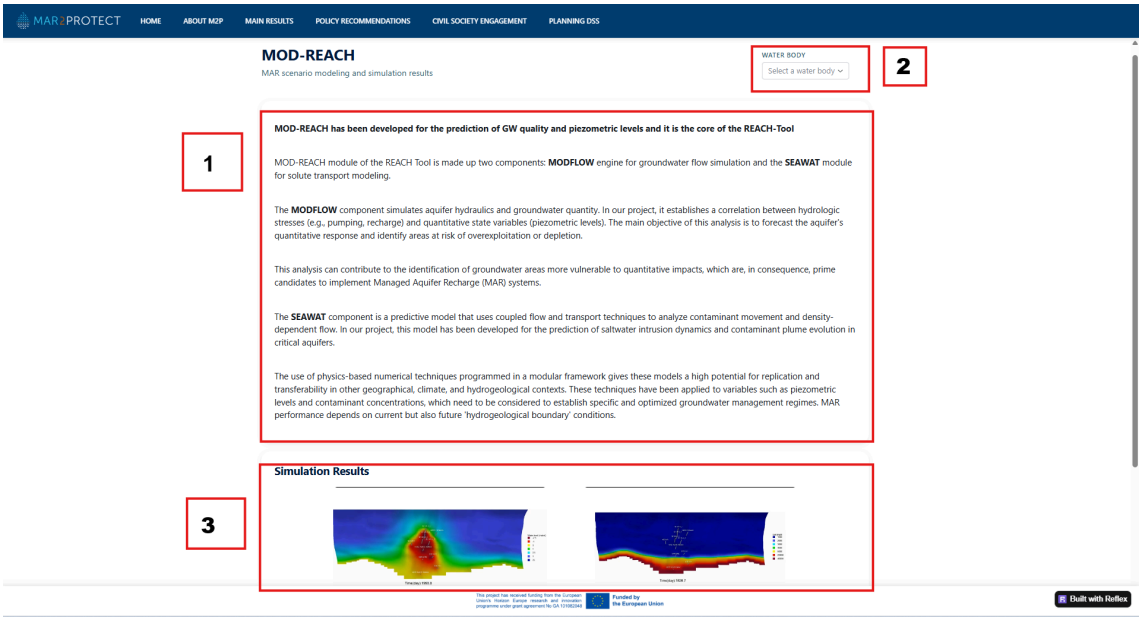

Figure 6: MOD-REACH page

The dropdown menu displays all the evaluated piezometers and wells used for modeling the Señorío aquifer.

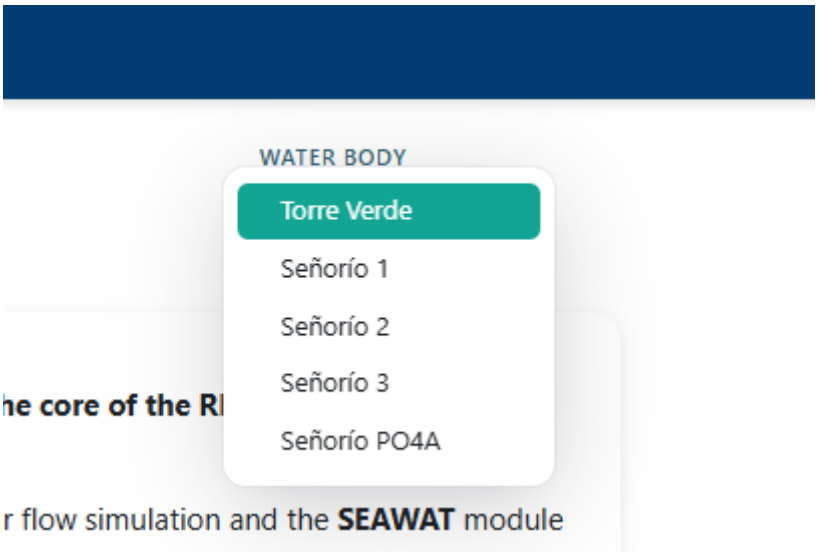

Figure 7: Wells and piezometers of MOD-REACH results.

Clicking in each of the "water bodies" a graph with the evolution of the piezometric levels will be displayed. You have to select them one by one to see each of the results. The graphs will be displayed on the upper part of the page. They show the interpolated evolution of the piezometric levels since the year 2000 of the MOD-REACH module. You can adapt to the timeframe they want to visualise by moving the bar under the years.

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Figure 8: Display of the MOD-REACH results of the interpolation of the piezometric levels. In the lower part, you have information about MOD-REACH and the videos.

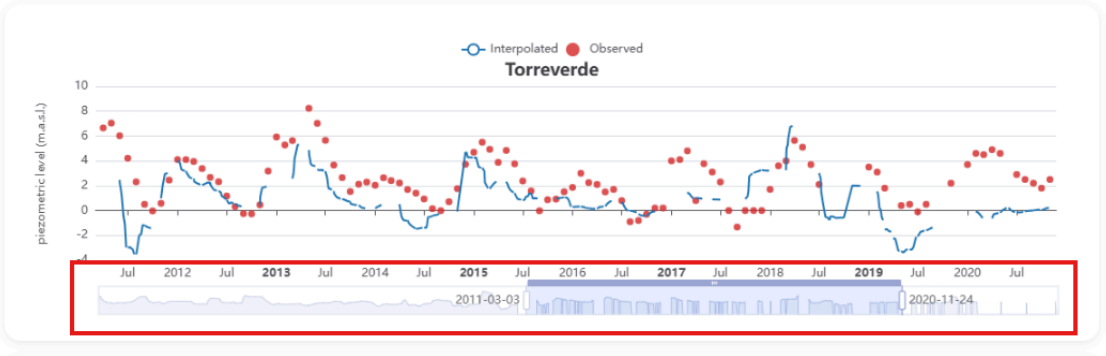

Figure 9: Scale bar adaptable to the timeframe that you want to see. To modify it, click on each side of the coloured bar.

4.1.2 DATA-REACH

The DATA-REACH module is a data-driven based approach within the REACH tool, focuses on analyzing past climate data and predicting future groundwater conditions using advanced statistical and machine learning techniques. It shows two key results: Retrospective Climate Analysis and predictive models.

The main page of DATA-REACH displays a map with different control points distributed in the western Costa del Sol area, Spain. Below the map, the page shares an explanation of the main results of the DATA-REACH module. On the right side there is a dropdown menu to select all the wells, reservoirs and piezometers where the DATA-REACH predictive analysis has been done.

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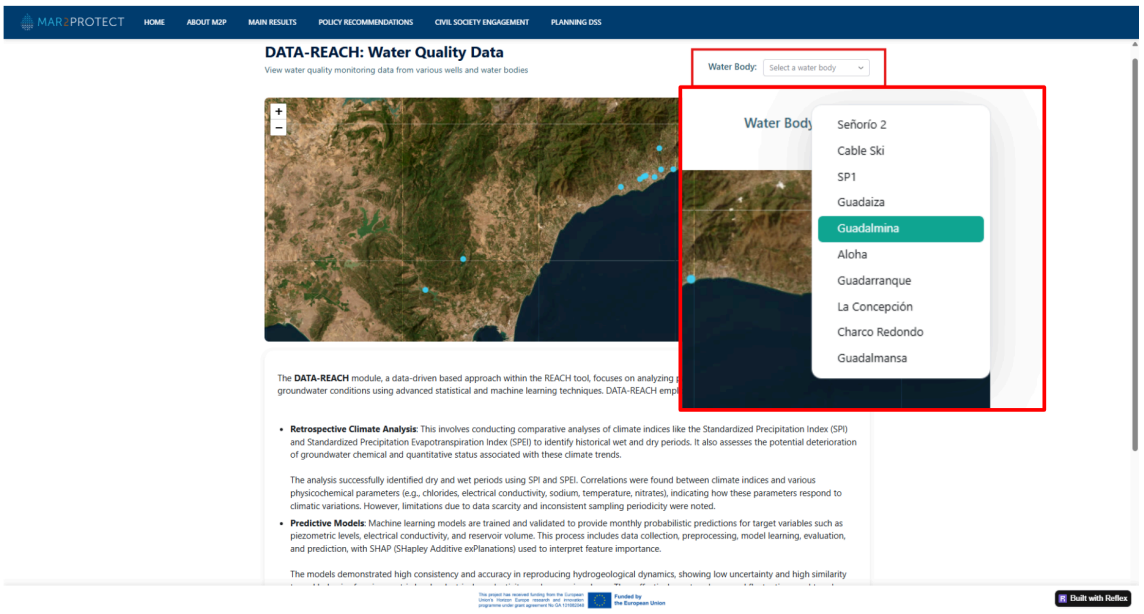

Figure 10: Visualization of the DATA-REACH results page and dropdown menu of the control points of the predictions.

You can click the control points either on the map or in the dropdown menu. When clicking in each of the control points you will find the prediction for the evolution of the water levels in the reservoirs, the prediction of the evolution of the piezometric levels and, in selected wells, the prediction of the evolution of the salinity.

As in the MOD-REACH, the lower bar can be adjusted, to modify it you have to click on the sides of the cloloured bar, the Figure 11 has been highlighted in yellow.

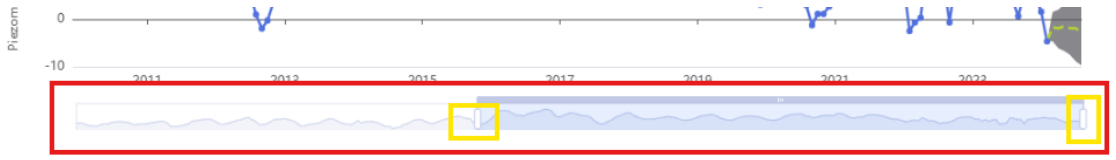

Figure 11: Lower bar scale of each graph; the yellow boxes indicate where you have to click to move the bar and adapt the timeframe they want to visualise.

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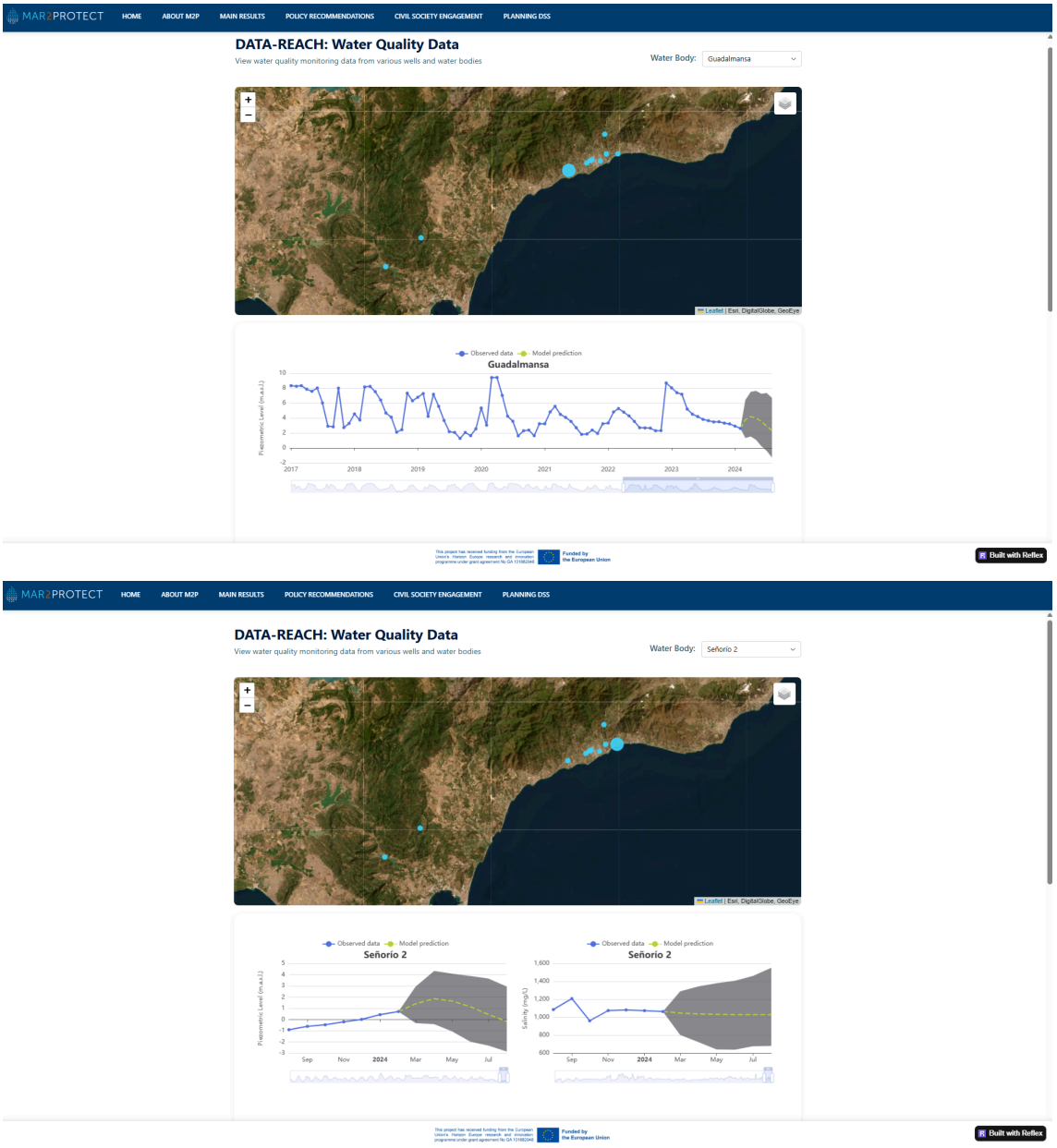

Figure 12: Examples of the visualization of the DATA-REACH predictive results.

4.1.3 GIS-REACH

The GIS-REACH module is the geospatial approach within the REACH tool, and it is dedicated to assessing groundwater pollution risk through comprehensive vulnerability, hazard, and exposure mapping. This module is crucial for identifying optimal areas for Managed Aquifer Recharge (MAR) implementation and guiding groundwater protection actions. GIS-REACH develops a groundwater risk assessment methodology by integrating three core components: vulnerability, hazard, and exposure.

When clicking into the page, you will see 3 main blocks:

1. Information about the risk mapping methodologies.

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2. Dropdown menu with the demo sites where the GIS-REACH has been applied.
3. Map where you can select the site and visualise the results.

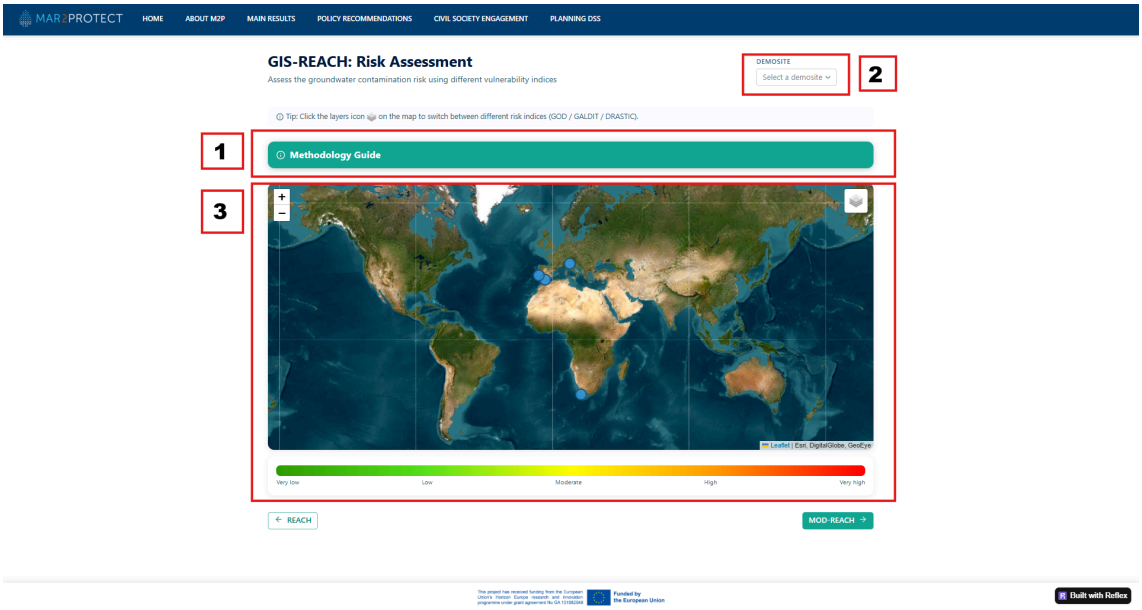

Figure 13: Display of the main GIS-REACH page.

Click on "Methodology Guide" to understand the different methodologies developed in this module. It will display an explanation of the computation of the risk mapping methodologies. All of them are common to all the evaluated demo sites.

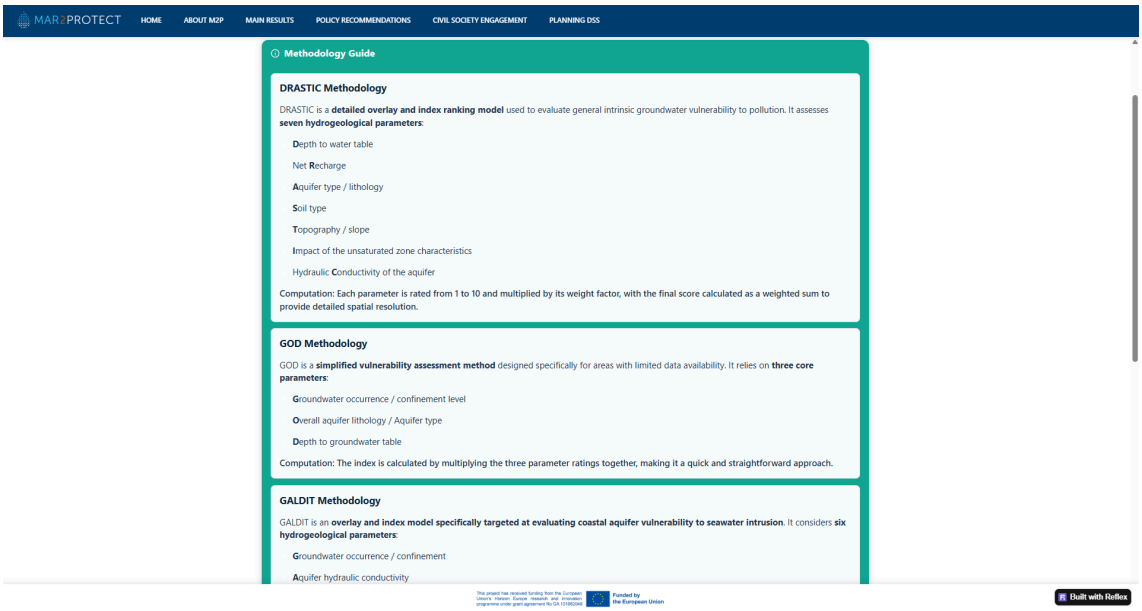

Figure 14: Methodologies information displayed.

To see the map results you can either click directly in the map the site you want to visualise or you can select the site in the dropdown menu at the right side of the page.

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Once you select the site, a coloured map will be displayed. You can zoom in and out with the mouse or with the signs "+" and "-" that are on the left map area. In the lower map area, you will find a coloured scale bar, the red colours represent the highest risk values whereas the green ones represent the lowest.

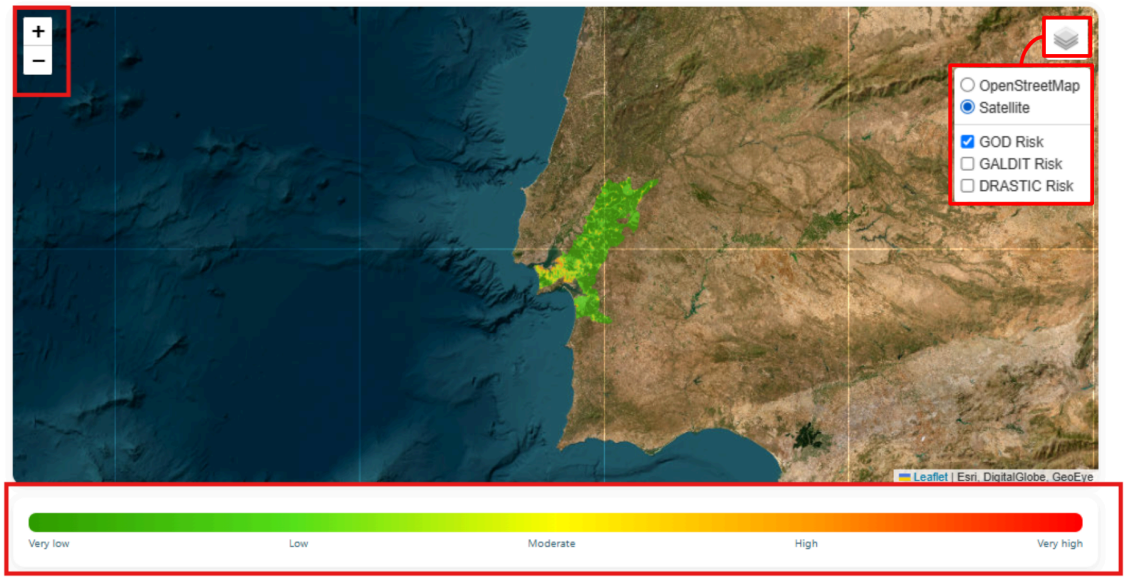

Figure 14: Map area of the GIS-REACH results.

On the right side of the map, you can modify the base map and the risk map you want to visualise based on the risk mapping methodology: DRASTIC, GOD, GALDIT.

4.2 DRONE

It is a forecasting tool designed to predict how long-term climate change and global change will affect groundwater. Its primary focus is simulating Managed Aquifer Recharge (MAR) yields and predicting climate-driven salinity intrusion in coastal aquifers.

The main page of the DRONE model results includes an explanation of the tool and three links to the different type of results:

1. Charts: time series and statistical chats for monitoring data

2. Heatmaps: spatial distribution of monitoring parameters

3. Water quality: visualisation of water quality parameters

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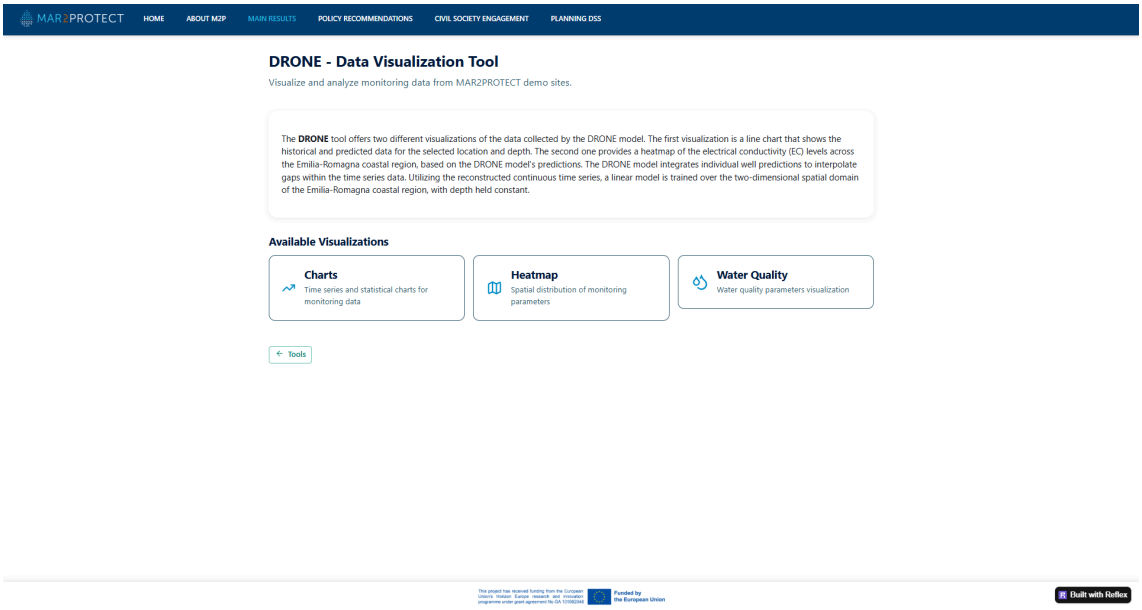

Figure 15: Drone model main page.

4.2.1 DRONE CHARTS

Displays the results of the predictions of the evolution of the piezometric levels of the DRONE model. You will see a map and different dropdown menus where they can select: the control point, the depth and the data frame. The graph area shaded in blue provides information about the behavior of the injection in a MAR scheme.

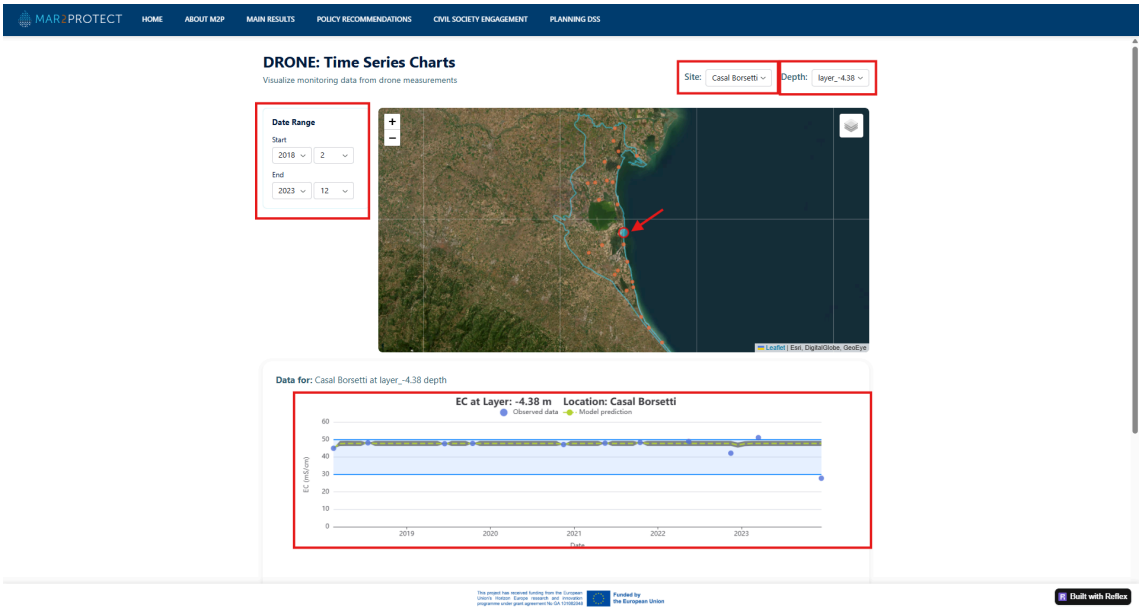

Figure 16: DRONE Charts page. The boxes highlight the areas with the dropdown menus, and the graph with DRONE results.

In order to visualise the different graphs you can either select the site in the dropdown menu or in the map (as shown with the arrow in Figure 16).

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4.2.2 DRONE HEATMAP

Displays the results of the predictions of the salinity in the aquifer in a hetmap format. The legend shows how the highest salinity (electrical conductivity) values are represented by brown colours whereas the lowest are represented by blue.

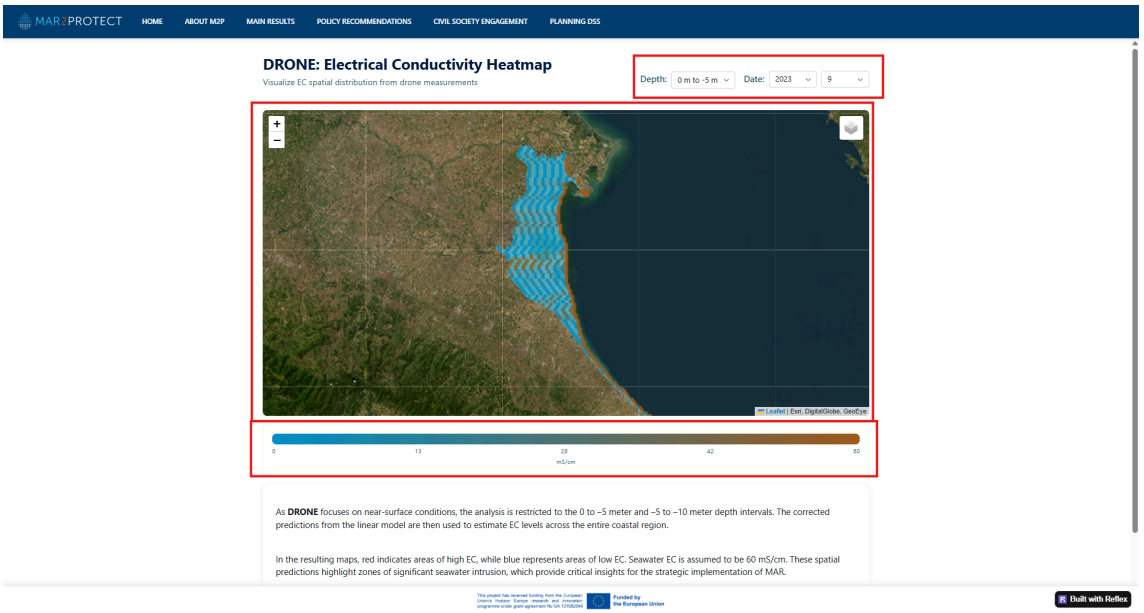

Figure 17: DRONE heatmap page. The boxes highlight the areas with the dropdown menus, and the map with DRONE results.

4.2.3 DRONE WATER QUALITY PARAMETERS

Displays the results of the distribution of the concentration for selected chemical parameters from DRONE measurements in a map format. The highest values are represented in red and the lowest in green. In the dropdown menu at the right, you can select the parameter they want to visualise and the date.

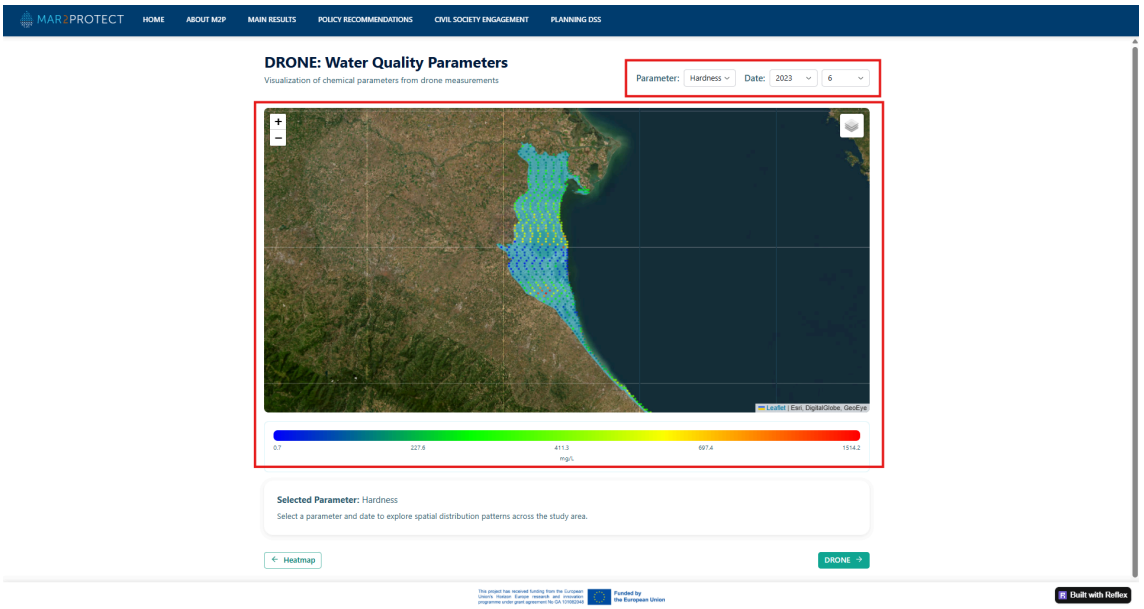

Figure 18: Example of a DRONE water quality parameter map. The boxes highlight the areas with the dropdown menus, and the map with DRONE results.

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4.3 RAINREC

RAINREC is a predictive modeling tool which primary purpose is to evaluate the impact of climate change on aquifer recharge by accurately simulating how changes in weather patterns redistribute rainfall. This module contains detailed explanations with all the methodology, results and model calibration and validation.

The main RAINREC page displays the location of the study area in the Cape Flats and information about the model evaluation. To see RAINREC results you have to click on the right-side dropdowns: first about the type of information, and second the variable. By defect, the tool shows future projection results.

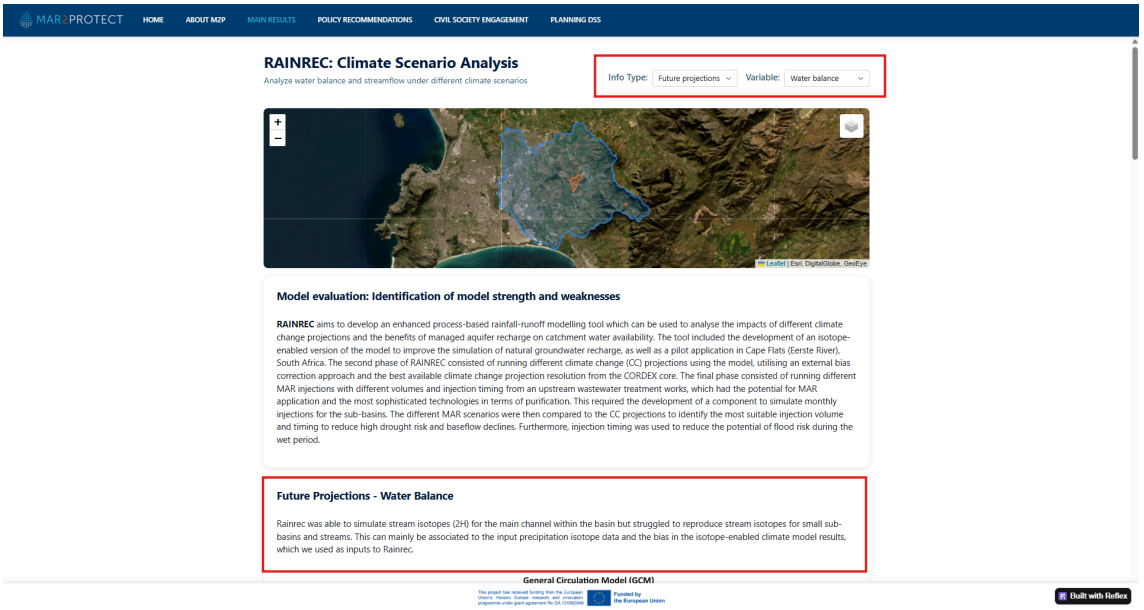

Figure 19: RAINREC main page. The red boxes show the dropdown menus and the area where the results are displayed.

4.3.1 RAINREC FUTURE PROJECTIONS CHARTS

By defect, when opening the RAINREC page it will show the results for the water balance of the future projections. There are three variables that can be selected:

1. Water balance
2. Flow components
3. Streamflow.

4.3.1.1 RAINREC FUTURE PROJECTIONS CHARTS – WATER BALANCE

By defect, when opening the RAINREC page it will show the future projections of the water balance. It displays different graph images of the water balance for future projections of the RANREC model in a matrix format. To see more details, you can click on the graph you want to evaluate, and it will appear bigger substituting the main figure.

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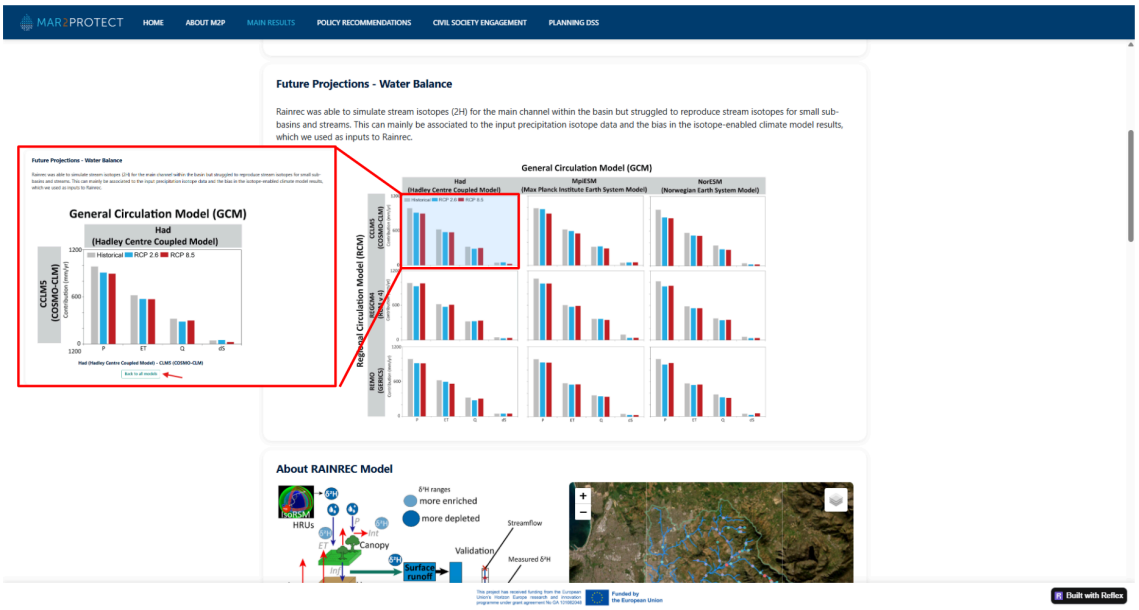

Figure 20: RAINREC water balance in the future projection's visualization.

To go back to the main figure, you can click on "Back to all models."

4.3.1.2 RAINREC FUTURE PROJECTIONS CHARTS – FLOW COMPONENTS

When selecting "Flow components" the results section of the page will display graphs for 3 time periods in a matrix format combining regional circulation models with global circulation models. In this case, the objective is to compare the three global circulation models so when you click in one model of one line, it will be displayed bigger (Figure 21). Just above the graphs, you can select the Global Circulation Model (GCM) you want to visualise from these 3: HAD (Hadley Centre climate models), MpiESM (Max Planck Institute Earth System Model) and NorESM (Norwegian Earth System Model).

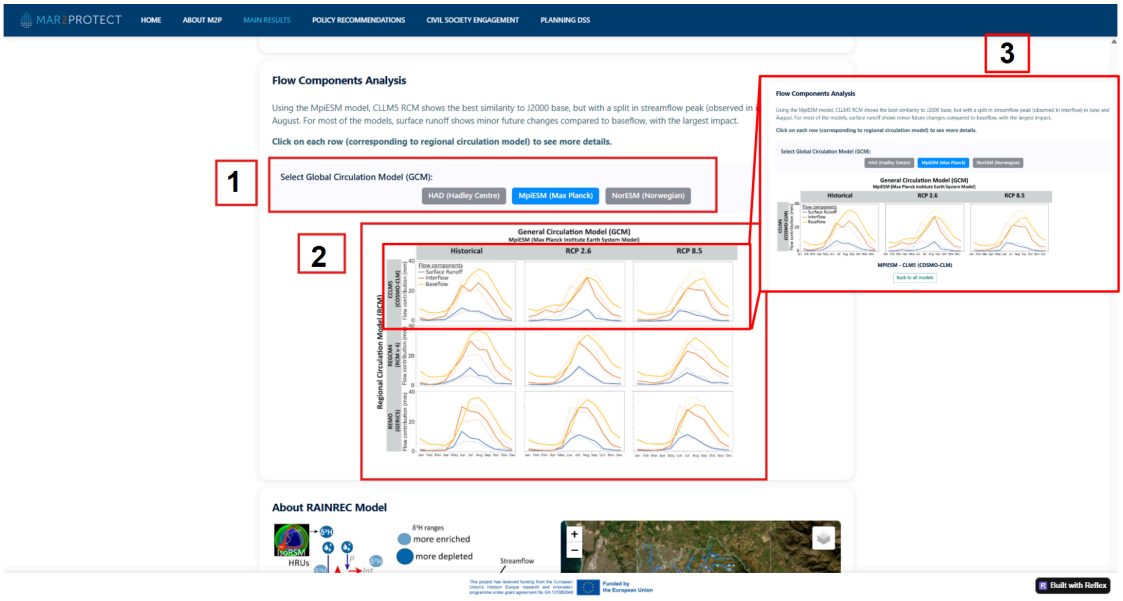

Figure 21: RAINREC Future projections – flow components. Number 1 represent the

GCM to select, number 2 the matrix with the model results and number 3 is the bigger picture of the figure.

To go back to the main figure, you can click on the "Back to all models".

4.3.1.3 RAINREC FUTURE PROJECTIONS CHARTS – STREAMFLOW

When selecting "Streamflow" the results section of the page will display graphs for 3 Global Circulation Model (GCM) you want to visualise from these 3: HAD (Hadley Centre climate models), MpiESM (Max Planck Institute Earth System Model) and NorESM (Norwegian Earth System Model): the results display the evolution of the streamflow in 3 regional climate models for each GCM.

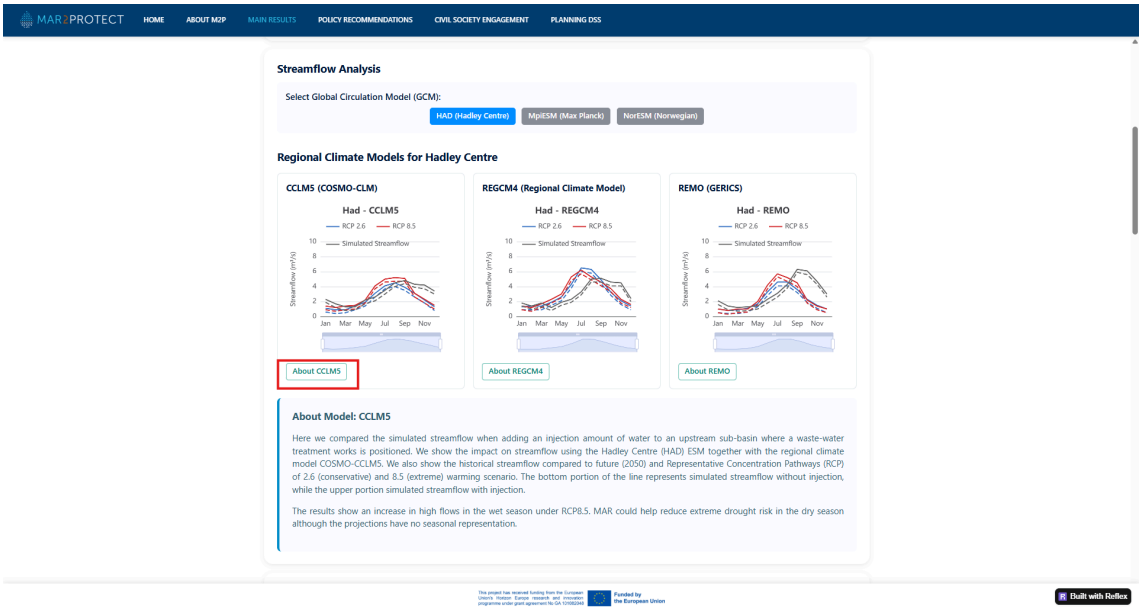

Figure 22: Example of the display of the results for the RAINREC Future projections of the streamflow. When clicking in the red box, information about the model and the results is displayed.

4.4 SUITABILITY & FEASIBILITY MAPS

MAR Suitability (SUIT) and Feasibility (FEAS) maps essentially comprise a set of maps that, together with the risk maps, will allow to:

- Identify the optimal physical location for implementing infiltration ponds and injection wells as MAR systems.
- Assess the water availability and demand of a specific region, taking into account different water sources and consumers.
- Allocate the optimal location for infiltration ponds and injection wells as MAR systems based on land suitability and water demand, and availability.

These maps have been produced for four demo sites for infiltration ponds and injection wells. These demo sites are Frielas, Portugal; Emilia-Romagna, Italy; Cape Flats, South Africa and Marbella, Spain.

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Figure 22: SUIT&FEAS main page. The red boxes highlight the sections where you can select the site to visualise the results.

In order to visualise the mapping results, you can either select the location of the map or in the upper right dropdown menu. The bar scale under the map indicates that the most suitable and feasible locations are shown in blue and the lowest, in red.

4.5 WATER TREATMENT TECHNOLOGIES

These technologies aim to prevent groundwater pollution through different approaches, primarily before Managed Aquifer Recharge (MAR) application or for mitigating agricultural leaching. To address the diverse water quality challenges in MAR projects, MAR2PROTECT has compiled several treatment technologies.

When entering the main page, you will find a description of what you can find and a dropdown menu where you can select technologies from the MAR2PROTECT Demo sites.

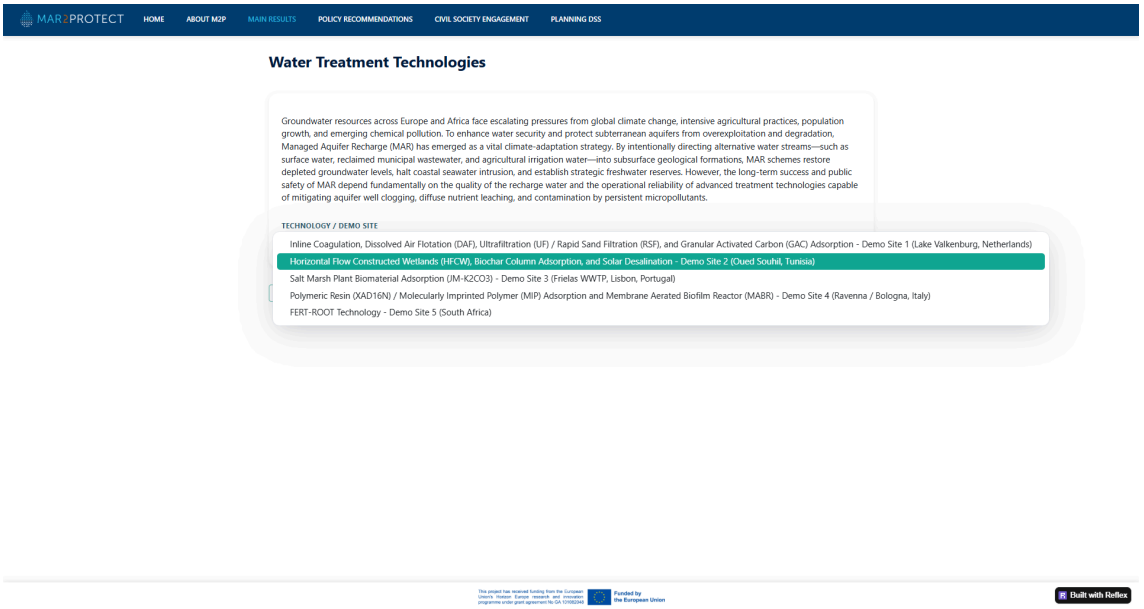

Figure 23: Water treatment technologies main page.

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When you select a technology you will find detailed information about it. All of them share the same structure:

1. Name and main description of the technology.

2. System Architecture & Process.

3. Process Flow Diagram.

4. Performance & Key Results.

5. Connection to the GW-PREV platform.



Figure 24: Example of the visualisation of one of the treatment technologies.

4.6 CIVIL SOCIETY ENGAGEMENT

MAR2PROTECT enables the engagement of stakeholders in adopting innovative digital technologies as solutions for strengthening and enhancing the sustainability of the European water industry.

The civil society engagement strategy of MAR2PROTECT embraces the need for an increasingly active role of societal actors in preventing water contamination through changes in daily practices and global warming management. In this project, we therefore engage diverse stakeholders in a variety of ways throughout the project activities.

The main page of civil society engagement activities shares information about civil society engagement and the co-design of civil society engagement developed in the MAR2PROTECT project. You can explore results by demo site or by filtering from a catalog of 50 activities.

To filter the activities by demo site, you have to select one of the MAR2PROTECT demo sites boxes (Figure 25) and it will show you information about the social context of the site and it will filter from the catalog the activities developed there.

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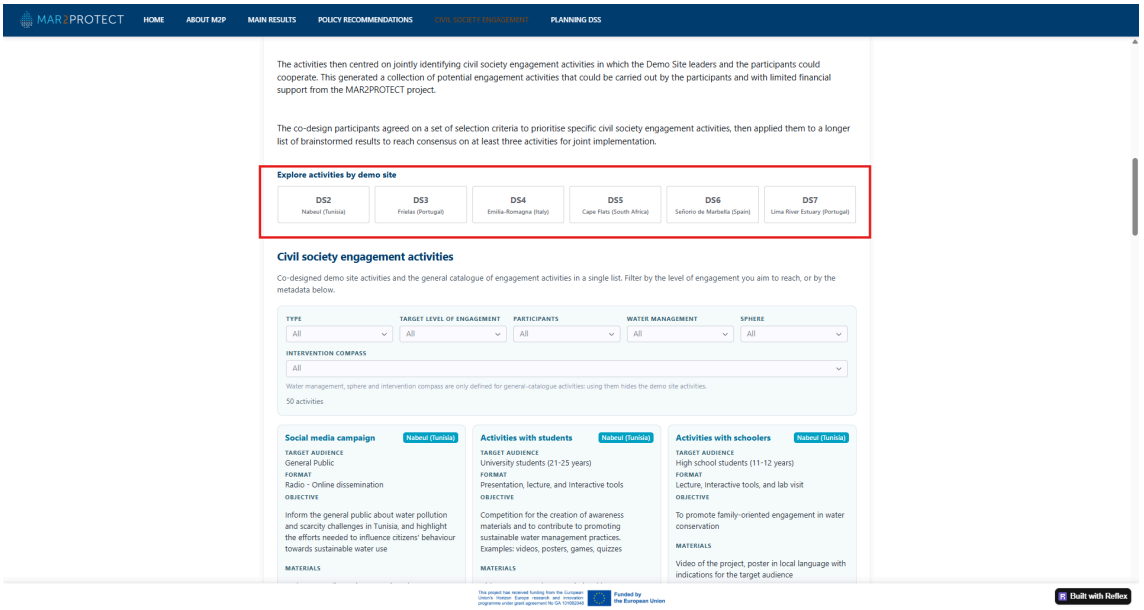

Figure 25: Menu to filter de activities by demo site.



Figure 26: Example of the visualisation of the filtered activities by demo site.

To deselect the demo site, you can move to the upper right side and click "back"

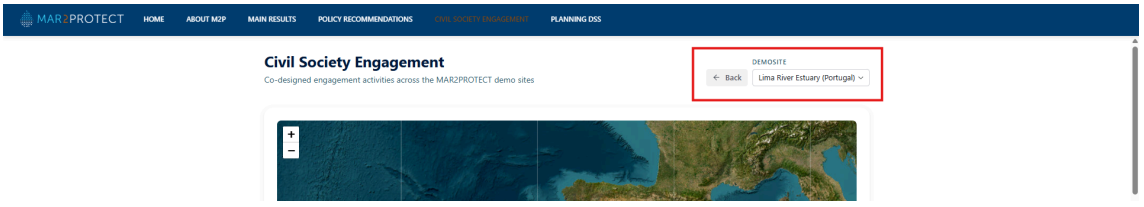

Figure 27: Location of the "back" bottom to deselect the demo site.

You can also filter the activities by type, target level of engagement, participants, water management (water quality, quantity, or both), sphere (private, public) and intervention compass.

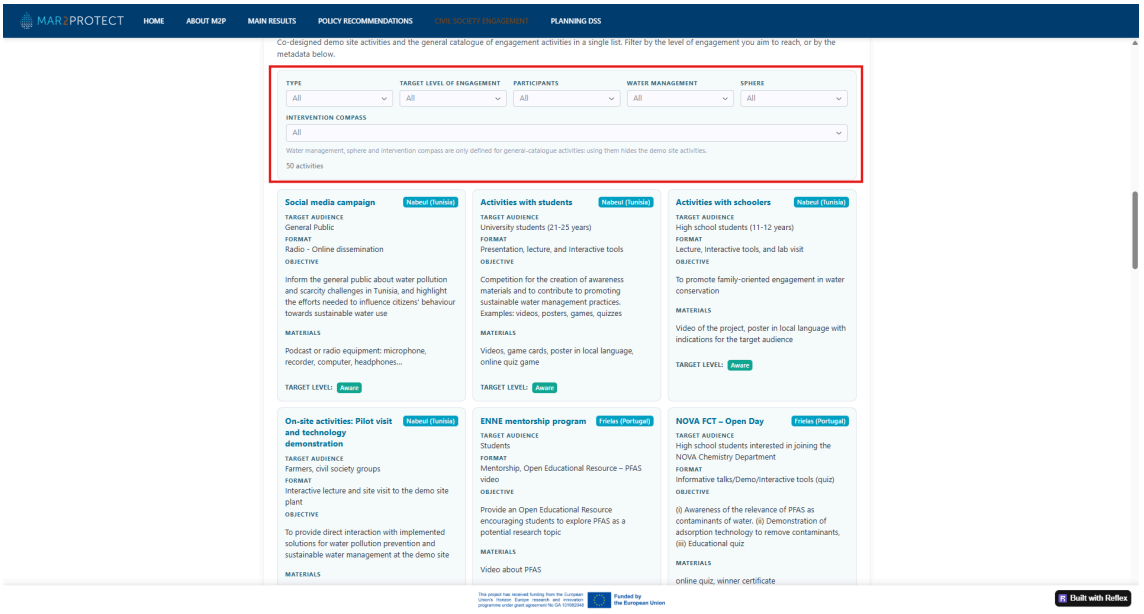

Figure 28: Filter the activities by different conditions.

4.7 POLICY RECOMMENDATIONS

The platform shares the main general framework for MAR in the European Union and in the countries of MAR2PROTECT demo sites. This page shares the legal framework in relation to MAR and policy briefs.

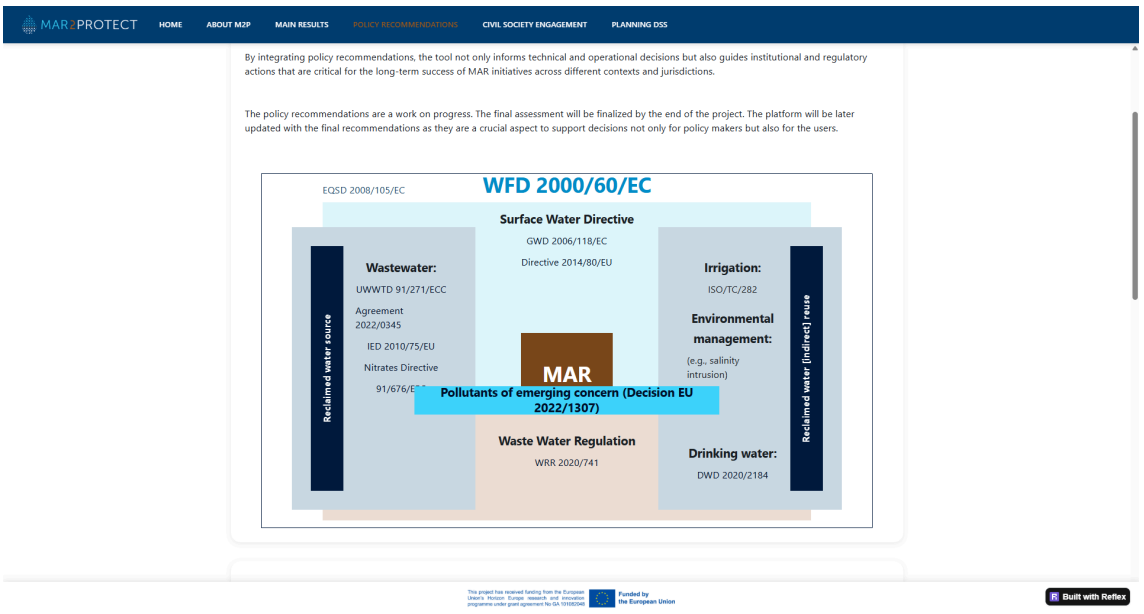

Figure 29: Main page of Policy recommendations results.

Each of the Directives, norms, etc. Is connected by a link to the official page of each of them.

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The platform also shares the links to pdf versions of MAR2PROTECT policy recommendations and the joint policy recommendations from the ZeroPollution4All Cluster.

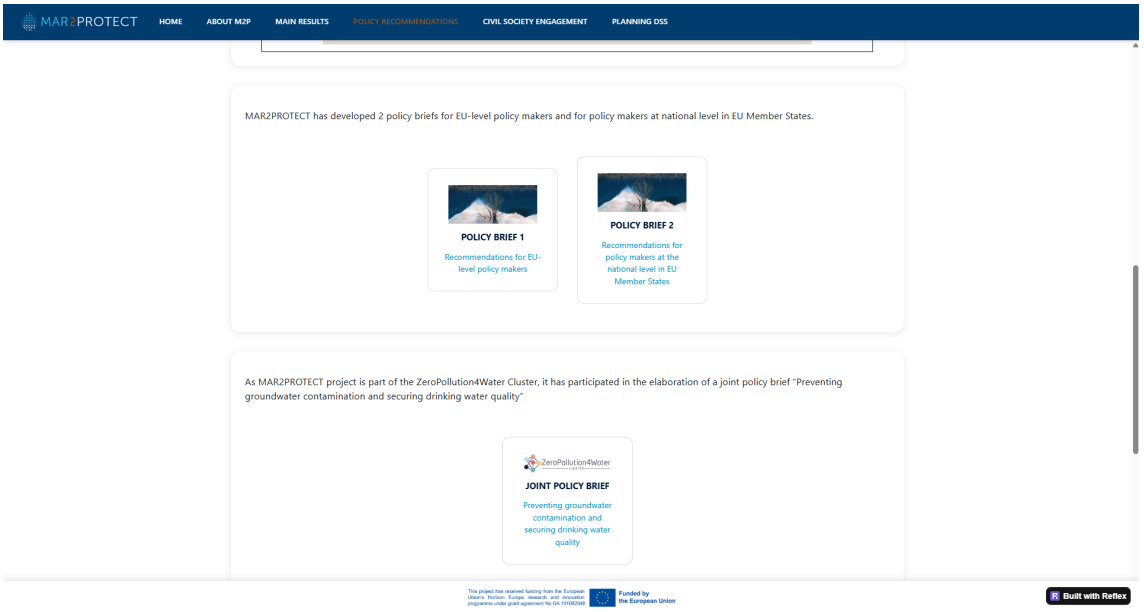

Figure 30: Links to the policy briefs of MAR2PROTECT and eroPollution4All Cluster.

5 MAR PLANNING DSS

MAR2PROTECT project proposes a 5-step guided workflow for the planning phase of a MAR project. Following this structured approach will help you develop a robust MAR project that delivers reliable water security benefits while safeguarding valuable groundwater resources for future generations:

When entering the "MAR Planning DSS" block, it will appear on a main page with information on the importance of this planning phase in a project and the 5 steps to follow.

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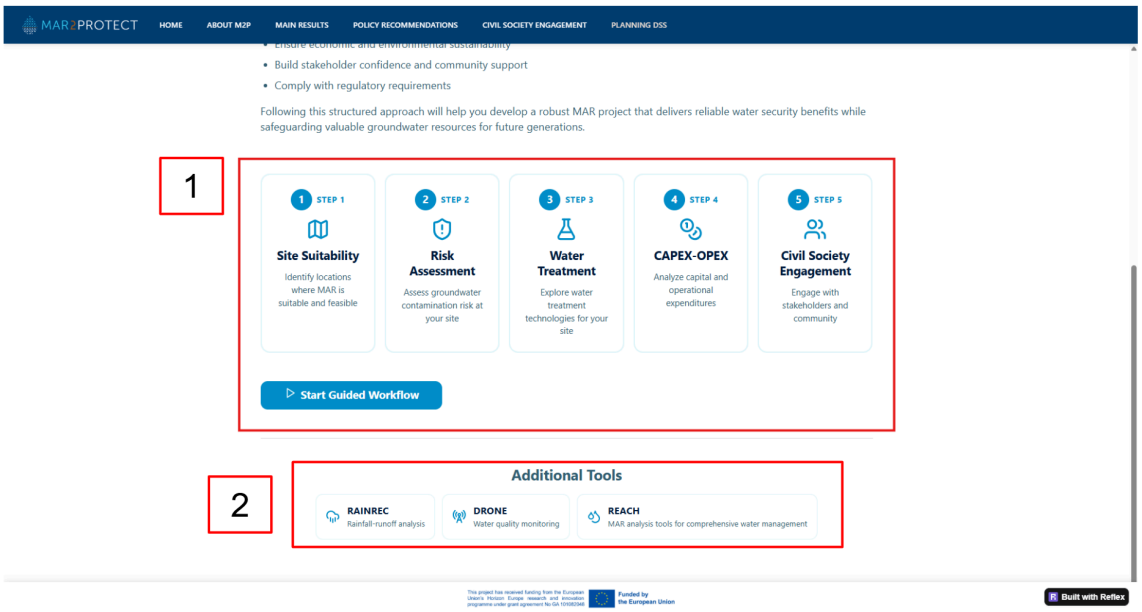

Figure 31: Main page of the “MAR Planning DSS” module.

In Figure 31, number 1 highlights the guided steps and the bottom to go directly to the MAR planning. Number 2 highlights links to the additional tools: RAINREC for Cape Flats (South Africa) site, DRONE for Emilia-Romagna (Italy) site and REACH for Marbella (Spain) site. The explanation for each of these tools is presented in sections 4.1, 4.2 and 4.3.

When clicking in "start guided workflow" it will direct you to the first step.

5.1 STEP 1 – SITE SUITABILITY AND FEASIBILITY

Identify locations where MAR is both suitable and feasible. Read carefully all the guidance on the page.

When you enter to step 1, you have to first select the study area from 4 MAR2PROTECT demo sites: Frielas, Portugal; Emilia-Romagna, Italy; Cape Flats, South Africa or Marbella, Spain. These are the areas where it was possible to develop the Suit&Feas methodology. To select a site, you can either click on the dropdown menu on the right side or click directly into the map.

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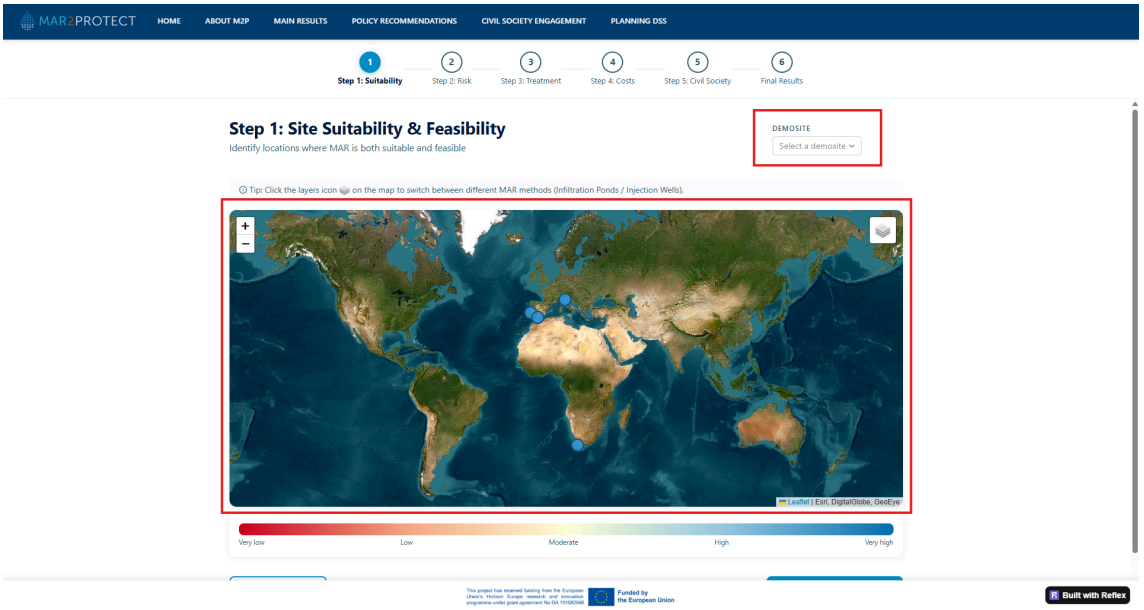

Figure 32: Areas where you can select the demo site to start with step 1 evaluation.

Once you have selected a site, it will appear a box where you have to choose your MAR method: Infiltration ponds or injection wells and the map will be automatically displayed for the selected site. You can zoom in and out on the left side of the map using "+" or "-" or you can use the mouse.

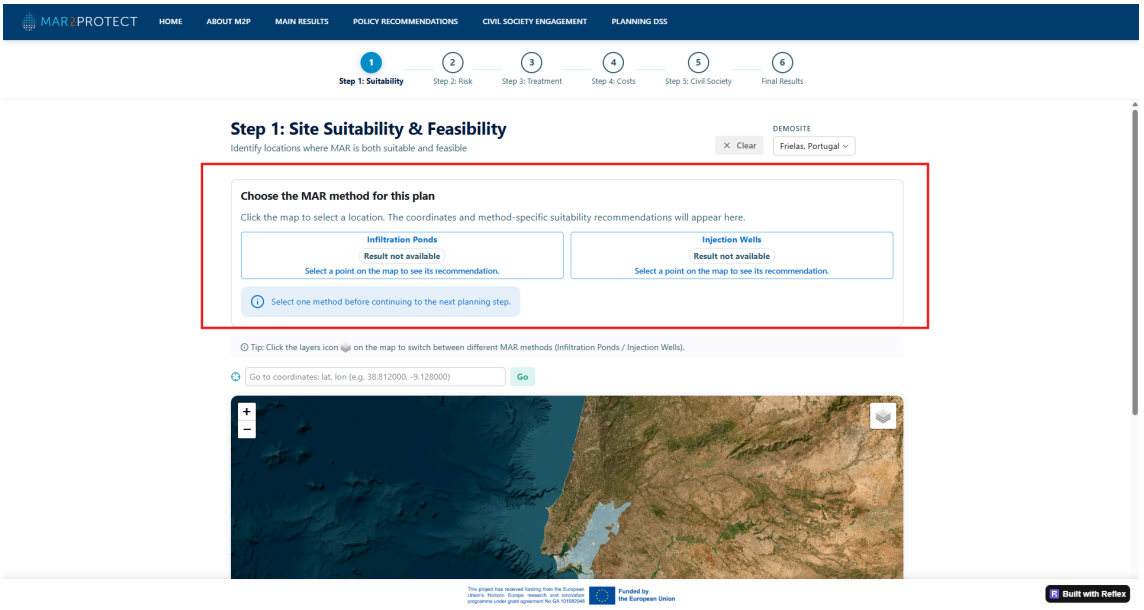

Figure 33: Areas where you can select the demo site to start with step 1 evaluation.

To receive a recommendation you have to select a location in the map. To do so, you can click directly into the map or you can write the coordinates in the search bar just above the map.

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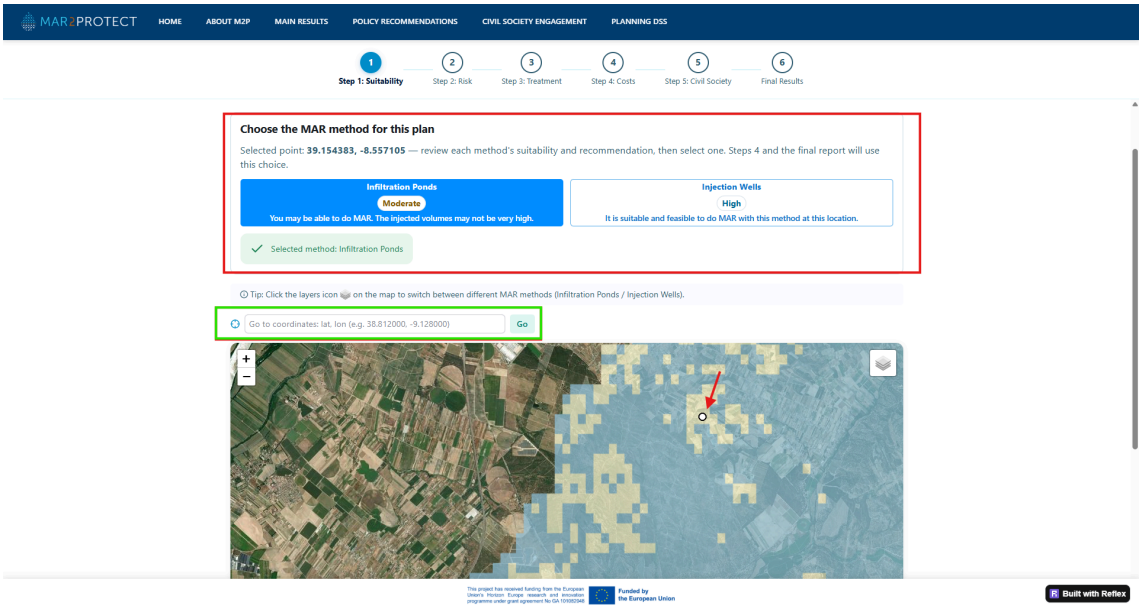

Figure 34: Recommendations for the site selected. The red box highlights the area with the recommendation for the selected method and site. The green box highlights the search bar where you can introduce the coordinates. The red arrow points to the selected point for the recommendation.

Once you have selected the site and the method and you have recieved a recommendation, you are ready to go to step 2. To do so you only have to click on "Step 2: Risk assessment" bottom

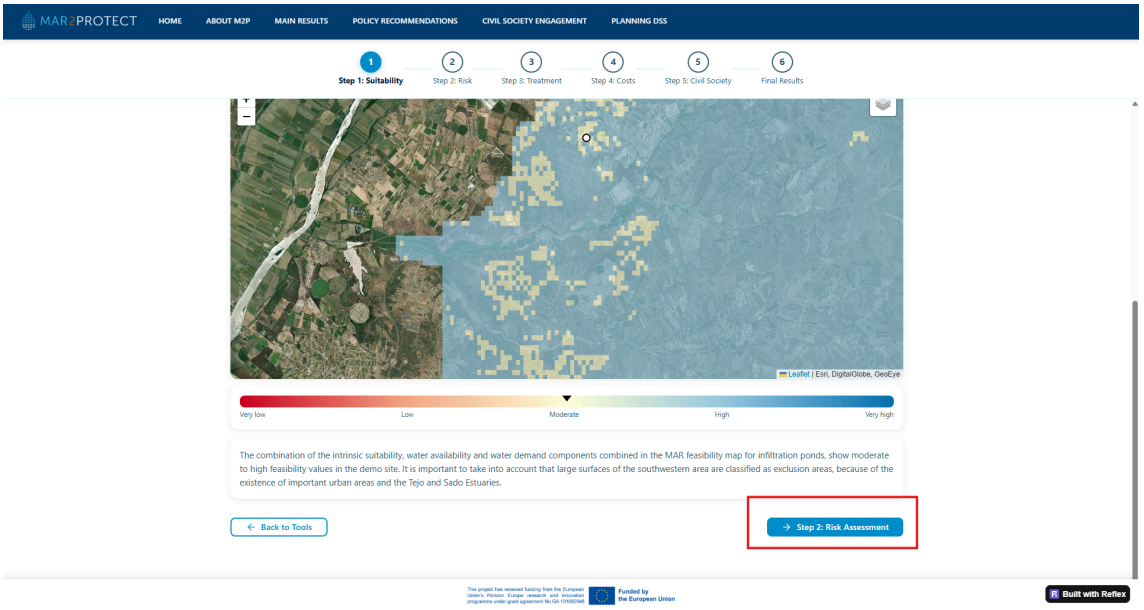

Figure 35: Location of step 2 bottom.

5.2 STEP 2 – RISK ASSESSMENT

Assess the groundwater contamination risk at your selected site.

When you go the step 2, as you will receive information from a map, you don't have to select again the desired location, it is saved from the first step.

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When you enter step 2, you will directly receive recommendations regarding MAR and how it can help prevent groundwater contamination at the site. This is linked to the REACH Tool, specifically to the GIS-REACH module. The recommendations are described for the 3 methodologies: GOD, DRASTIC and GALDIT. To know more about each of them, you can click on "Methodology guide".

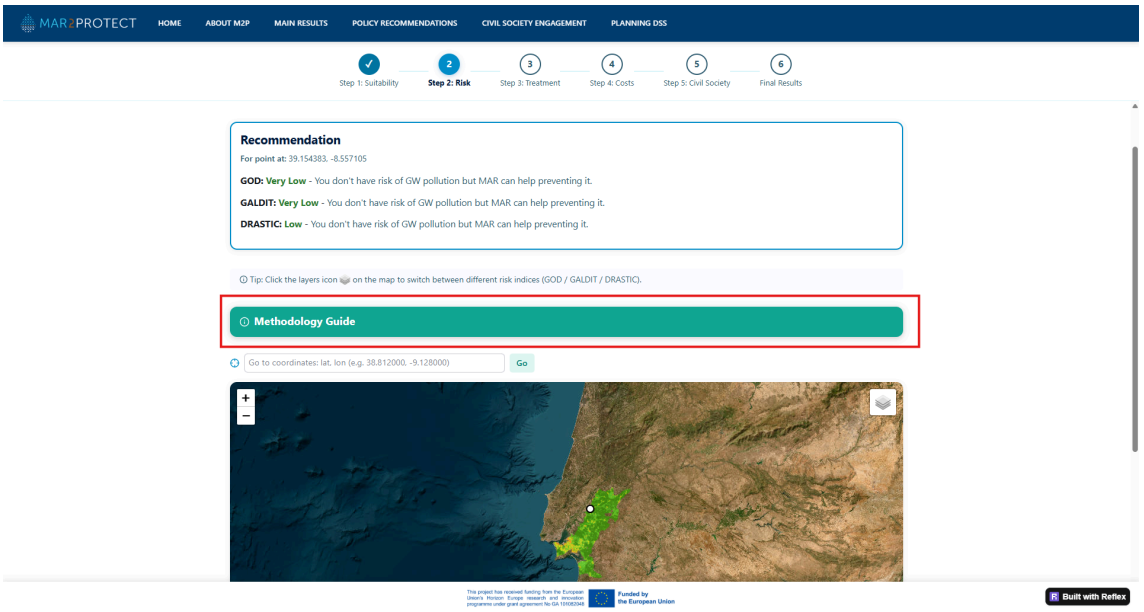

Figure 36: Visualisation of step 2 results. The red box highlight the dropdown where you can find information about each risk mapping methodology.

5.3 STEP 3 – TREATMENT

Select a water source to explore MAR2PROTECT treatment experience. Select one or more parameters to include their treatment options in your final Planning DSS report. These options support assessment and do not replace site-specific water-quality analysis.

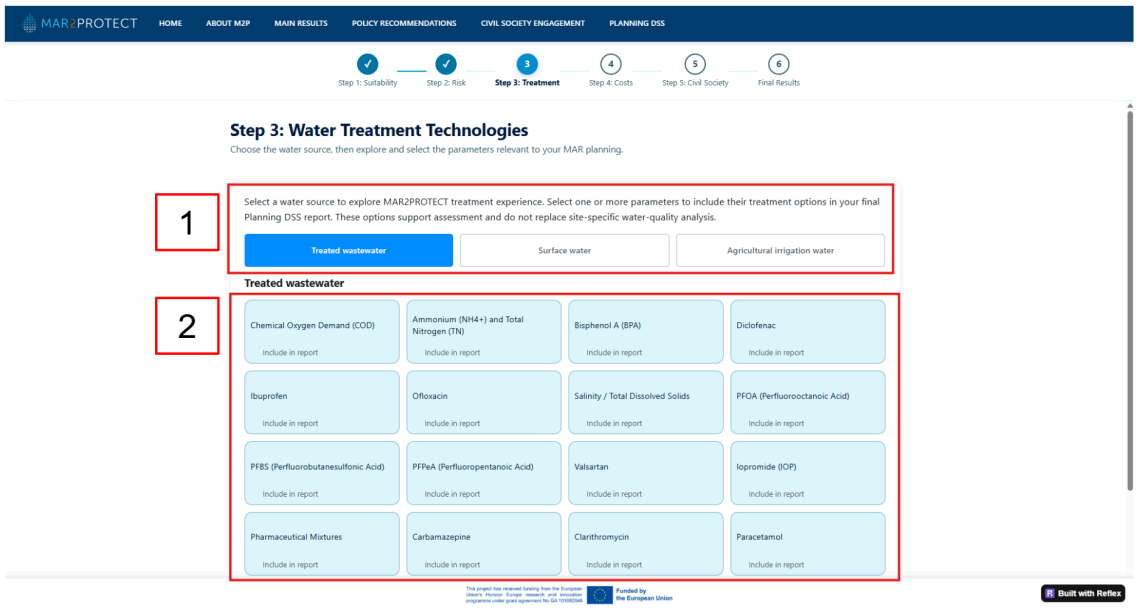

Figure 37: Visualisation of step 2 main page.

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You have to first select the type of water for MAR and you can click in each parameter to know more about treatment technologies developed in MAR2PROTECT to eliminate them or reduce their concentration.

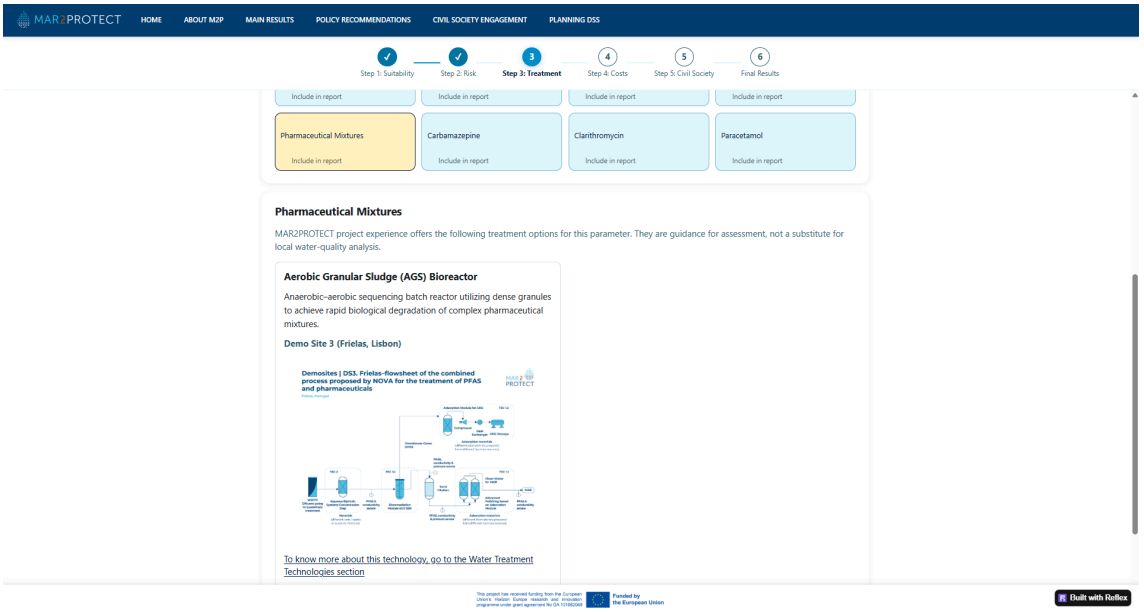

Figure 38: Selected parameters in yellow and description of the water technology below.

To include a parameter in the final assessment you have to click on the lower part of the box (Figure 39). You can select as many parameters as you want to assess.

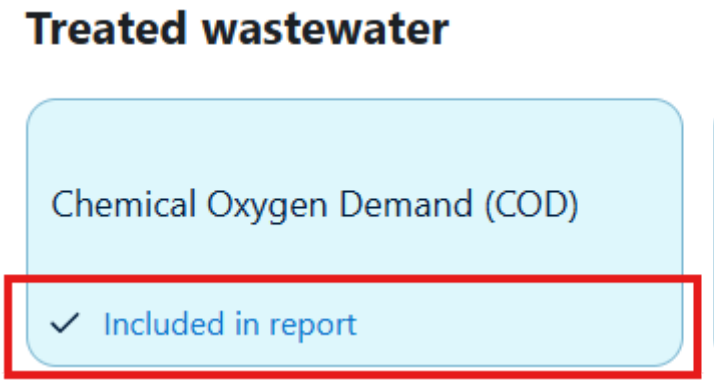

Figure 39: Detail of how to include the parameter in the report.

You can select parameters from different types of water to be included in the same report.

Once you have selected all the parameters that you need, you are ready to go to the next step.

5.4 STEP 4 – CAPEX-OPEX

In this step, we provide you with information on the costs you need to consider when doing a cost-benefit analysis. We have compiled the most important expenses for the calculation of capital and operating costs. This is a case-specific case and the final

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assessment on the benefits and costs have to be made by you, but this is a crucial step to consider when planning a MAR project.

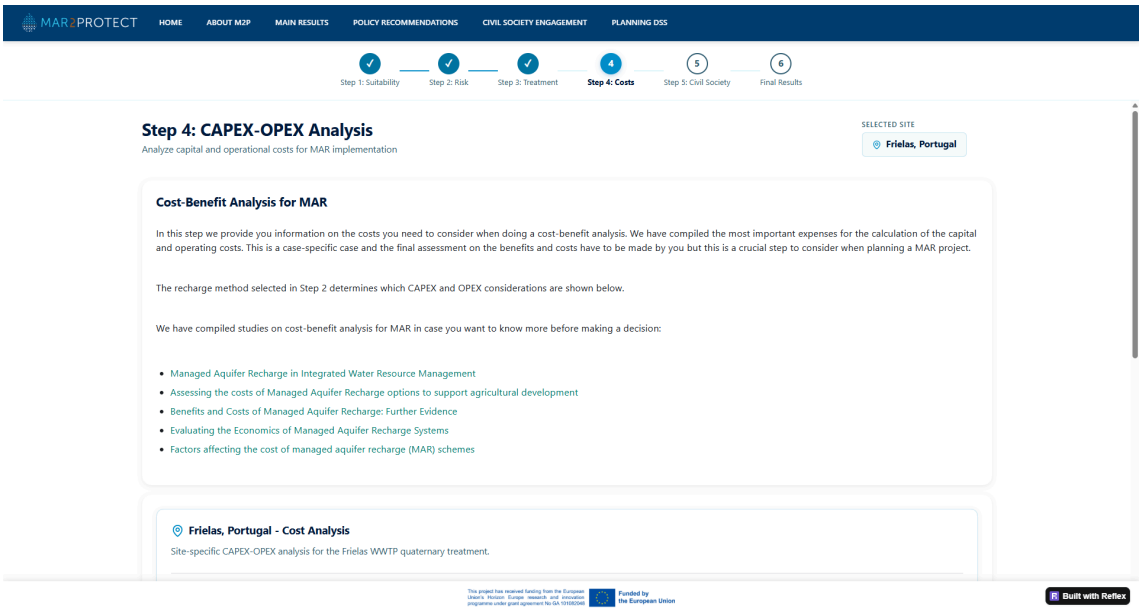

Figure 40: Main page of step 4 CAPEX-OPEX analysis.

The page displays information about what you can expect from this section and external resources to know more about cost estimation of MAR. It includes a CAPEX-OPEX calculator with a proposal of costs that can be considered when starting a MAR project. The calculator is generic but can support decissions as a starting point to the cost-evaluation. It is linked to the MAR method selected in step 1: infiltration ponds or injection wells.

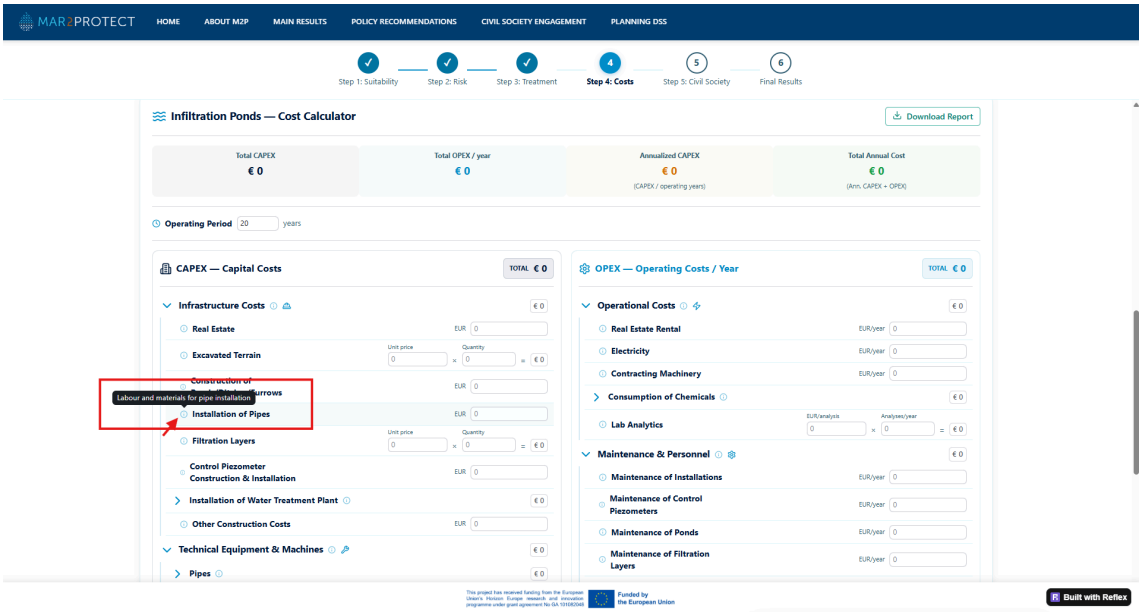

Figure 41: Visualisation of the CAPEX-OPEX calculator. To know more about each type of cost you can put your mouse on the question mark and it will give a description of the item (highlighted in the red box).

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When you have completed the costs you can go to the final step.

5.5 STEP 5 – CIVIL SOCIETY

The aim of this step is to provide you with ideas of activities to engage with stakeholders and community for MAR implementation.

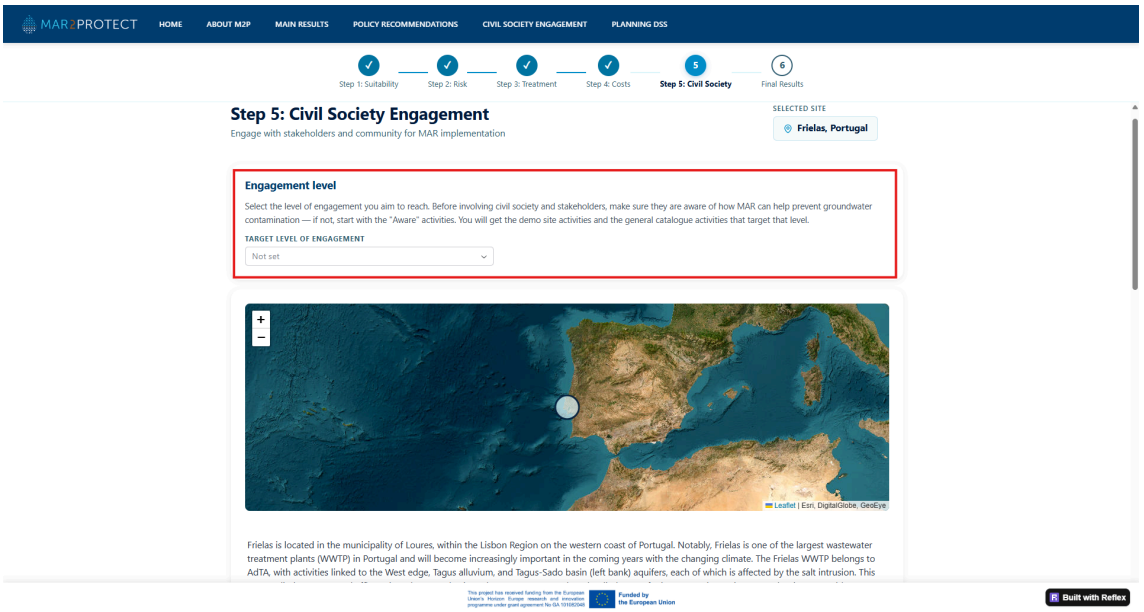

Figure 42: Step 5, civil society engagement main page. In the dropdown menu highlighted in the red box, you can select the target level of engagement you aim to reach.

The map shows the location of the site and the description below explains the social context of the site.

Once you select the targeted level of engagement a list will be displayed with different activities from a general catalog with ideas to be developed at the site and a list of the activities already developed in the MAR2PROTECT project with stakeholders and civil society in the selected site. You can select as many as you want to be included in the final report.

To select the activities you have to click on the box at the left of the title of the activity. When you select it, it will appear a green tick in the box (Figure 43).

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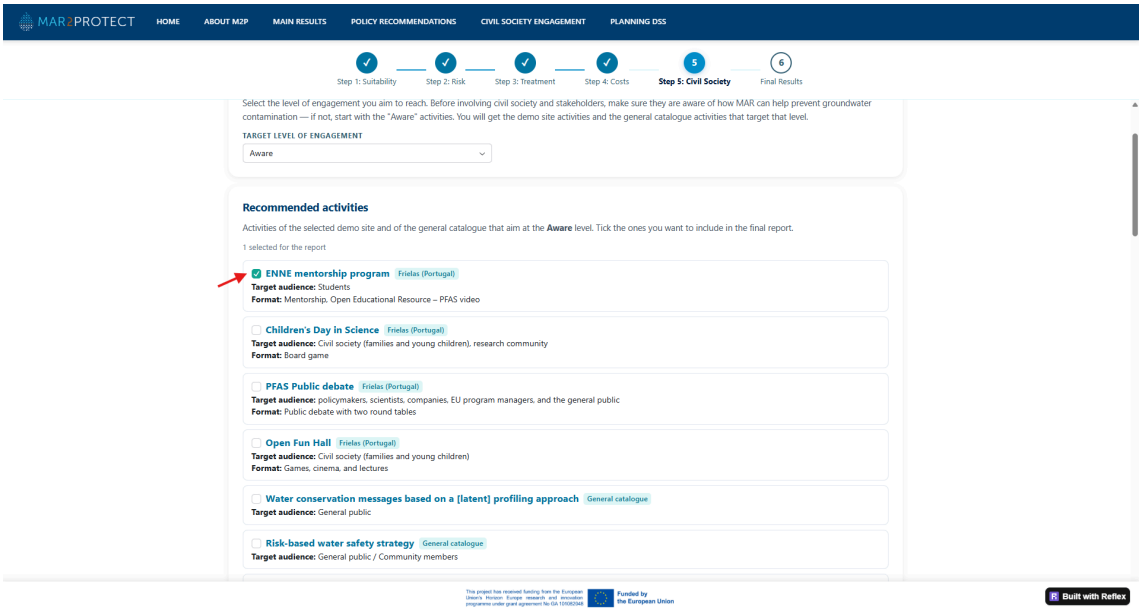

Figure 43: Selection of the civil society engagement activities.

Once you have read and selected all the activities you are interested in, you can go to the summary of the final results.

5.6 FINAL REPORT

In this step you can review your complete planning decisions and recommendations. It includes a summary of your planning decisions step by step for the location selected in step 1. It includes detailed information about the risk mapping methodologies and about the selected parameters and the water treatment technologies.

It also includes a summary of the cost estimation that you can download in Excel format to continue working with it and adding detailed information as you advance on the project. For step 5, it shows all the selected civil society engagement activities.

For Cape Flats and Emilia-Romagna, Italy Demo sites, the final report includes a link to DRONE and RAINREC models where you can deep your knowledge on these tools and also gain additional support for MAR with their predictions and simulations.

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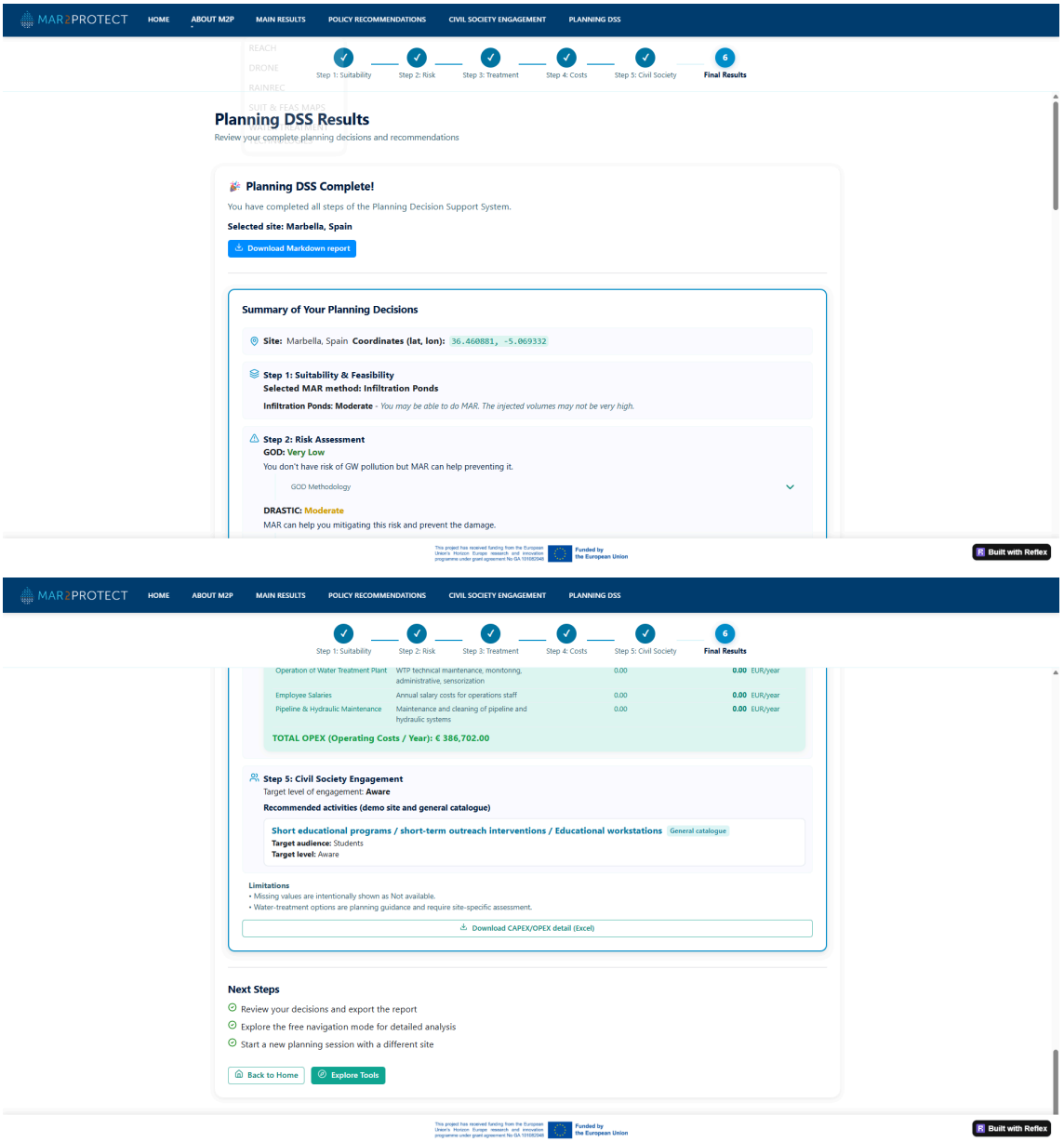

Figure 44: Examples of the report of the planning DSS process.

6 MAR OPERATIONAL DSS

This module of the platform has been specifically designed to follow the real-time operations for the Señorío MAR scheme from Marbella, Spain. It has restricted access only to MAR managers and operators to control MAR operations from the site. It includes an early warning system with alerts based on when to activate and deactivate the MAR scheme, check the sensors and anticipate the maintenance and control actions. This module can be adjusted to any site.

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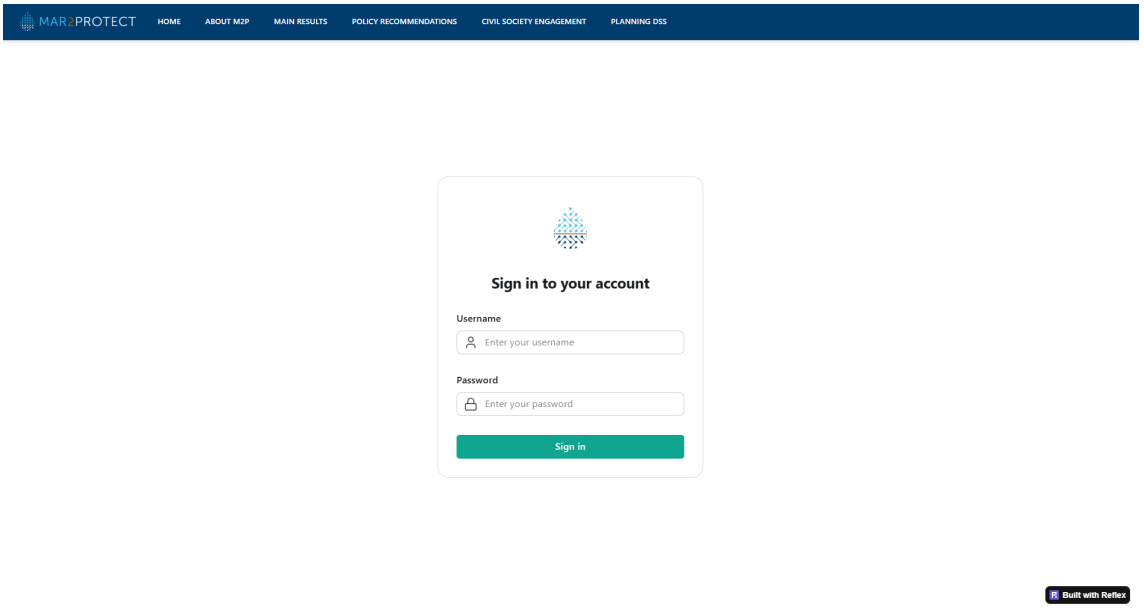

Figure 45: MAR operational DSS main page.

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