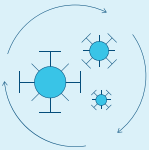
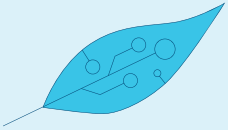
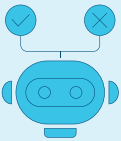
MAR2PROTECT





MAR2PROTECT Innovation Portfolio



Funded by
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November 2026

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Five complementary solutions for cleaner, safer and climate-resilient groundwater recharge.

MAR2PROTECT brings together five innovations that address nutrient losses from agriculture, micropollutants in wastewater effluent, water-quality monitoring, climate- and global-change impacts on groundwater, and decision-making across the full managed aquifer recharge (MAR) lifecycle.

The MAR2PROTECT approach

Challenge	Solution	Main users
Prevent **Agricultural nitrogen and phosphorus leaching**	FERT-ROOT	Farmers, irrigation suppliers, MAR operators, water utilities, groundwater authorities
Treat **Pharmaceuticals and persistent PFAS in wastewater effluent**	JM-Bioadsorbent	Water utilities, water-treatment companies, farmers, authorities
Monitor **Variable contaminant loads and insufficient high-frequency monitoring**	EcoTox-Sensor	Water utilities, MAR operators, industrial facilities, monitoring companies, regulators
Forecast **Climate- and global-change impacts on groundwater**	REACH Tool	Water authorities, basin managers, MAR operators, consultancies, researchers
Decide **Fragmented MAR lifecycle data and late identification of operational risks**	M-AI-R DSS	Water utilities, MAR operators, authorities, consultancies, international organisations

MAR2PROTECT

Online real-time ecotoxicity

Problem Solved

Contaminant loads can vary considerably over time and conventional grab sampling is often insufficient to assess the quality or effluents, surface water, or groundwater. Environmental waters contain complex mixtures of chemicals although targeted analyses can be performed to evaluate ional or contaminant loads, frequent testing using methods is expensive, labour-intensive, and methods provide an integrated estimate of for specific modes of biological action and being incorporated into environmental works. However, these methods generally says requiring specialised personnel and

ides an alternative approach through ar real-time biological monitoring. rients and toxicants generating ata that supports rapid detection

rity as an indicator of

uously replenished system. Light and lgae-dominated abolism affect hamber, and l activity

Unique Value Proposition

A comprehensive visualisation and decision-support tool for MAR operators. Addresses MAR performance through: risks mitigated by MAR, innovative pre-treatment technologies and operational risk identification.

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solves th
real-time
intuitive
policym
water
operato
recharg

Online real-time ecotoxicity biosensor.

Lead Partner
Stellenbosch University (SU), South Africa.

Work Package / Task Related Deliverables
The development of the device was part of WP3 contributing to tasks 3.1 and reported in deliverables D3.1 (Bio and chemical optical-based sensors), D3.5 (Optimization of the integrated sensing system for reliable operation under field conditions), D3.6 (Report on the optimization of the integrated sensing system for reliable operation under field conditions) and 3.7 (Final report on Bio and chemical optical-based sensors).
The use of the sensor and pilot installation forms part of WP5 and contributing to task T5.6 and reported in D5.4 (Final assessment of the implementation of the MAR2PROTECT technologies in the demo sites).

Current TRL
TRL 5. An initial prototype of the device was tested in the laboratory setting. A field deployable prototype was subsequently developed and installed at an experimental site. Testing remains ongoing.

KER Type
ool → Sensor System.

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Discover a
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Target Markets & Users

Segment	Description
Water utilities, drinking water/ water suppliers	Public and private water u managing recharge schem stressed regions
Government and international organisations	Local, regional and national w responsible for groundwater n planning and climate-adaptatio
Industrials (SMEs and large companies)	Environmental and hydrogeologi integrating the DSS into assessme advisory services
Government and international organisations	International and multilateral organi water-security and climate-adaptation
Foundations, NGOs and environmental organisations	Organisations supporting groundwate water-security initiatives
Academia and research community	Research institutions using the platform f development, validation and advanced gro studies

Exploitation Route & Business Model Outline

Exploitation route	
Revenue model	SaaS (Software as a Service): annual licence per utility / MAR research use
IP strategy	SaaS licence fees; consultancy and site-specific model customis workshops; maintenance contracts
Next steps	Software copyright protection and trademark under assessment Finalize platform for November 2026; develop commercial SaaS offe

Contact **Isabel Gamallo** (isabel.gamallo@cetaqua.com) and **Sara Espinosa Martínez** (sara.espinosa@cetaqua.com) from **CETAQUA** for pilot testing and guides/technical discussions. For project coordination matters, please reach out to **NOVA**, coordinator of the MAR2PROTECT project. Collaboration, exploitation, and technology transfer opportunities are supported by **FEUGA**, project's Technology Transfer Entity.

Innovation Factsheet

onditioning and

Result Identification

Technology Short Name
FERT-ROOT.

Full Name
FERT-ROOT
conditionin
system.

Lead Partner
Stellenbosch Uni
Africa.

Work Package / Task
Deliverables
WP2, Task 2.4: Mitigation of
agricultural N/P leaching to GW
through FERT-ROOT (TEC6). Related
deliverables: D2.3, D2.4, D2.5, D2.6,
D5.4.

Current TRL
TRL 8. Comm
technology.

KER Type
Product → Tech

Find out more at:
www.mar2protect.eu/knowledge-center/solutionshub/

Target Markets & Users

Segment	Description
Water utilities, drinking water/water	Utilities managing wastewater treatm and MAR schemes

nt and environmental-tec
e to manufacture. Integrate
the bioadsorbent
med water requiring appropria
ore irrigation
al and water authorities overseein
ischarge and groundwater-protec
anisations supporting optimisation
formance assess
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nths; pilot upscalin
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anab@fct.unl.pt) from **NOVA**, for licensi
rtunities, pilot testing, technical inte
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es are supported by **FEUGA**

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The five technologies

FERT-ROOT

Integrated soil conditioning and nutrient retention system

The challenge

Subsoil compaction restricts root penetration and suppresses rhizosphere microbial activity, reducing nutrient uptake efficiency in vineyards, orchards, and row crops. Excess fertiliser leaches beyond the root zone, becoming a major source of diffuse groundwater nitrogen and phosphorus pollution while increasing production costs through over-fertilisation.

The solution

FERT-ROOT combines the **HumeFlo™ Water Treatment System** and soil biostimulants delivered through existing irrigation systems. Cold plasma photocatalytic oxidation generates H_2O_2/O_3 nanobubbles; **MacroPlex™** prevents calcium and magnesium from binding phosphate into unavailable precipitates; **AminoFix-3000™** provides slow-release carbon and nutrients for microorganisms; and **Nitro-15™** delivers organic nitrogen through protein hydrolysates. Together, these components improve nutrient uptake, reduce fertiliser leaching, and support healthier root systems.

Benefits for users

- **Efficiency:** improves nutrient availability, root development, microbial activity, and fertiliser uptake efficiency.
- **Cost:** reduces fertiliser losses and dependence on costly mechanical remediation measures such as soil ripping.
- **Safety:** non-invasive technology installed directly in irrigation systems with no specialised operators required.
- **Sustainability:** reduces nitrogen and phosphorus leaching into groundwater, supporting sustainable agricultural production and groundwater protection.

Value for adopters

An integrated solution combining nanobubble water treatment, nutrient sequestration, and biological soil stimulation to improve fertiliser uptake, reduce nitrogen and phosphorus leaching, alleviate soil compaction, and enhance root development.

Maturity and route to market

TRL 8. Commercially available technology, currently commercialised in South Africa through irrigation-system integration and distribution networks. Revenue comes from the sale of HumeFlo equipment and recurring supply of MacroPlex™, AminoFix-3000™, and Nitro-15™ consumables.

JM-Bioadsorbent

Novel adsorption biomaterial based on residual biomass from *Juncus maritimus* for the removal of micropollutants from wastewater effluent

The challenge

Groundwater contamination by pharmaceutical compounds and persistent PFAS is a growing threat to safe MAR operations. Reverse osmosis is energy-intensive, costly, and generates secondary waste, while impurities and coexisting pollutants in real matrices can adversely affect adsorption performance.

The solution

JM-Bioadsorbent uses the salt marsh plant *Juncus maritimus* as a bio-based raw material to produce a novel biosorbent capable of absorbing and removing pharmaceuticals and PFAS from aqueous solutions. Residual post-harvest biomass is processed and functionalised to enhance adsorption capacity.

Validation highlights

- → **80–100% PFAS removal** in laboratory and pilot-plant tests.
- → **90–100% pharmaceutical removal** in laboratory tests and **40–80%** in the pilot plant.
- → **Lower pilot-scale operating cost** than commercial activated carbon: **1.98 €/m³ vs. 2.04 €/m³** of treated wastewater.
- → **Approximately 6% reduction** in total life-cycle environmental burden compared with commercial activated carbon.

Value for adopters

A bio-based solution derived from residual salt marsh plant biomass, delivering superior pollutant removal performance at lower cost than commercial activated carbon, with a circular-economy approach based on residual biomass valorisation.

Maturity and route to market

TRL 4–5. Validated at laboratory and pilot scale. A patent application has been filed for the technology. Exploitation routes include licensing the technology to water-treatment companies and direct sales of material.

EcoTox-Sensor

Online real-time ecotoxicity biosensor

The challenge

Contaminant loads can vary considerably over time, and conventional grab sampling is often insufficient to assess effluent, surface-water, or groundwater quality. Frequent conventional testing is expensive, labour-intensive, and difficult to implement at high frequency, while effect-based methods generally rely on laboratory assays requiring specialised personnel and infrastructure.

The solution

EcoTox-Sensor provides automated, online and near real-time biological monitoring. A stable biofilm is continuously replenished with fresh algal cells from an internal nursery system. Changes in microbial metabolism affect carbon dioxide concentration inside the sensing chamber, and CO_2 measurements are used as a proxy for biological activity and ecotoxic effects.

Benefits for users

- → **Efficiency:** continuous monitoring reduces the need for labour-intensive sampling campaigns.
- → **Cost:** prototype construction cost is approximately **€1,200,** significantly lower than competing technologies.
- → **Safety:** uses naturally occurring algae, with no identified safety concerns beyond handling monitored water samples.
- → **Sustainability:** automated online monitoring reduces laboratory workload and resource consumption.

Value for adopters

Earlier identification of contamination events and operational failures compared with conventional monitoring approaches can improve environmental protection, operational efficiency, and public health protection in drinking-water applications.

Maturity and route to market

TRL 5. A field-deployable prototype has been installed at an experimental site, and testing remains ongoing. Potential routes include technology licensing, industrial partnerships, or spin-off creation, with hardware sales, maintenance services, data-management solutions, and monitoring contracts.

REACH Tool

gRoundwatEr quAlity CHange

The challenge

Water-resource managers and MAR operators lack accessible, validated tools to forecast how climate change and global change will affect groundwater quality and quantity over the coming decades. Aquifer vulnerability assessment is typically slow, expensive, and requires high specialist input.

The solution

REACH Tool combines **MOD-REACH, DATA-REACH and GIS-REACH** to integrate hydrogeological modelling with climate-change scenario analysis. It predicts piezometric levels and stored aquifer water volumes, maps risk and vulnerability for different contamination types, identifies areas susceptible to groundwater-pollution hazards, and supports groundwater-exploitation planning.

Validation highlights

- → **Reproduces aquifer hydrogeological dynamics** with low uncertainty and high precision.
- → **Includes a model of the El Señorío Aquifer** in Spain.
- → **Tested** at the Emilia-Romagna, Italy, and Frielas, Portugal, Demo Sites.
- → **Predicts the evolution of piezometric levels and electrical conductivity** with high accuracy.

Value for adopters

Virtual “what-if” scenarios, aquifer simulations, and GIS mapping help managers and policymakers forecast water levels, pinpoint pollution risks, optimise water management, and identify locations for sustainable aquifer replenishment.

Maturity and route to market

TRL 6–7. Fully developed, validated on a real aquifer and with a completed replicability study. Planned as an open-source release with commercial consultancy services and integration into M-AI-R DSS, supported by site-specific model setup and customisation, training workshops, and technical support.

M-AI-R DSS

AI-based decision support system for managed aquifer recharge in a climate change perspective

The challenge

MAR operators and water utilities lack a single integrated platform covering the full MAR lifecycle, from site selection and design to operation and performance evaluation. Data is fragmented across disconnected GIS, sensor, climate and hydrogeological systems; modelling is expensive, slow and specialist-dependent; and clogging, salinity intrusion and water-quality deterioration are often identified too late.

The solution

M-AI-R DSS is an AI-enhanced integrated platform that supports decision-making across the full MAR lifecycle. It consolidates advanced AI forecasts, real-time sensor monitoring, and policy guidelines into a single online platform, providing long-term foresight for policymakers and real-time alerts for operators.

Core capabilities

- → **Identify optimal MAR locations** using GIS- and Earth Observation-based mapping and hydrogeological, climate and land-use data.
- → **Support design and planning** by integrating REACH Tool, DRONE and RAINREC modelling tools under climate-change scenarios.
- → **Integrate real-time sensor data** to monitor water quality, clogging risk and aquifer performance.
- → **Quantify clogging, salinity and scarcity risks** before they occur, enabling preventive action.
- → **Provide decision-ready dashboards** for MAR operators, regulators and civil society.

Value for adopters

A comprehensive visualisation and decision-support tool that addresses MAR performance through risks mitigated by MAR, innovative pre-treatment technologies and operational risk identification.

Maturity and route to market

TRL 5. The demo version with key functionalities was delivered in November 2025, and final improvements are ongoing. The planned model is SaaS, with annual licences per utility or MAR site, consultancy and site-specific model customisation, training workshops, and maintenance contracts.

Five complementary solutions, one shared approach

The five innovations address complementary points across groundwater protection and the MAR lifecycle.

PREVENT AT SOURCE
Reduce agricultural nutrient losses to groundwater

FERT-ROOT improves nutrient uptake, reduces fertiliser leaching, and supports healthier root systems.

TREAT BEFORE RECHARGE
Remove pharmaceuticals and PFAS from wastewater effluent
JM-Bioadsorbent removes micropollutants using functionalised residual Juncus maritimus biomass.

MONITOR CONTINUOUSLY

Detect nutrients, toxicants and water-quality deterioration

EcoTox-Sensor provides automated, online and near real-time biological monitoring.

ANTICIPATE FUTURE RISKS

Forecast groundwater conditions and assess future vulnerability and risks

REACH Tool combines hydrogeological modelling, climate-change scenarios and GIS mapping.

SUPPORT DECISIONS

Integrate data and forecasts to support MAR planning and operation

M-AI-R DSS combines site assessment, modelling, real-time monitoring, risk assessment and dashboards.

The solutions can be deployed for agricultural nutrient management, wastewater-effluent treatment, continuous biological monitoring, groundwater forecasting and vulnerability mapping, and integrated MAR planning and operation.

Technology uptake opportunities

The five factsheets identify opportunities involving water utilities and MAR operators; farmers and irrigation actors; environmental and hydrogeological consultancies; water-treatment and environmental-technology companies; public authorities and international organisations; academia and research organisations; NGOs and foundations.

Opportunities include:

- → **Pilot testing, additional deployments and validation** in new crops, soils, regions, aquifers and monitoring contexts.
- → **Co-development, technical integration and industrial partnerships** and integration into assessment, advisory and monitoring services.
- → **Licensing, manufacturing, distribution, material-supply and SaaS opportunities.**
- → **Site-specific model setup and customisation, training, maintenance, technical support and data-management services.**

Contact and further information

Technology contacts:

- → **FERT-ROOT & EcoTox-Sensor:** Ludwig Brocker (ludwig@humefert.com).
- → **JM-Bioadsorbent:** Ana Belén Pereiro Estévez (anab@fct.unl.pt).
- → **REACH Tool:** Isabel Gamallo (isabel.gamallo@cetaqua.com), Sara Espinosa Martinez (sara.espinosa@cetaqua.com) and Lidia Barbero (lidia.barbero@veolia.com).
- → **M-AI-R DSS:** Isabel Gamallo (isabel.gamallo@cetaqua.com) and Sara Espinosa Martinez (sara.espinosa@cetaqua.com).

For project coordination matters, contact **NOVA** (anab@fct.unl.pt), coordinator of MAR2PROTECT. Collaboration, exploitation and technology-transfer opportunities are supported by **FEUGA** (fgomez@feuga.es), the project's Technology Transfer Entity.

www.mar2protect.eu

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