Innovative and Sustainable Groundwater Management in the Mediterranean

D1.2 MID-TERM TECHNICAL REPORT

PART B

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Glossary

ANN	Artificial Neural Network,
AOP	Advanced Oxidation Processes,
BU	Boğaziçi Üniversitesi,
CERTE	Centre de Recherches et des Technologies des Eaux,
CDP	Communication and Dissemination Plan,
D	Deliverable,
DOI	Digital Object Identifier,
DSS	Decision Support System,
DMP	Data Management Plan,
EGU	European Geosciences Union,
FAIR	Findability, Accessibility, Interoperability and Reusability,
HRMA	High-Resolution Monitoring Approach,
ISARM	Internationally Shared Aquifer Resources Management,
IST-ID	Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento,
M	Milestone,
MED	Mediterranean,
NGO	Non-Governmental Organizations,
RCM	Regional Climate Model,
RCP	Representative Concentration Pathway,
RF	Random Forest,
SHW	State Hydraulic Works of Turkey,
SWOT	Strengths, Weaknesses, Opportunities and Threats,
TUC	Technical University of Crete,
UFZ	Helmholtz-Zentrum für Umweltforschung,
UNIPR	Università degli Studi di Parma,
UPV	Universitat Politècnica de València,
WP	Work Package.

Executive Summary

The overall objective of the InTheMED project is to implement innovative and sustainable management tools and remediation strategies for MED aquifers (inland and coastal) in order to mitigate anthropogenic and climate-change threats by creating new long-lasting spaces of social learning among different interdependent stakeholders, NGOs, and scientific researchers in five field case studies. These are located at the two shores of the MED basin, namely in Spain, Greece, Portugal, Tunisia, and Turkey.

InTheMED will develop an inclusive process that will establish an ensemble of innovative assessment and management tools and methodologies including a high-resolution monitoring approach, smart modelling, a socio-economic assessment, web-based decision support systems (DSS) and new configurations for governance to validate efficient and sustainable integrated groundwater management in the MED considering both the quantitative and qualitative aspects.

The Mid-term technical report for the first period contains the description of the work progress carried out by the seven scientific teams from different countries: Portugal, Spain, Germany, Italy, Tunisia, Greece and Turkey, from the beginning of the project, March 2020, until August 2021. The objectives of the project and the degree of fulfilment of each of them are analysed. Furthermore, this document also includes a revision on the expected impacts, the Exploitation and Dissemination Plan and the Data Management Plan. Finally, the deviations from the proposal submitted are detailed and a revised Gantt chart is provided. As anticipated at the beginning of the project, all the tasks have been delayed approximately six months with respect to the original Gantt chart of the proposal.

1. Explanation of the Work Carried Out by the Beneficiaries and Overview of the Progress

The Mid-term technical report describes the work carried out by the seven scientific teams that form InTheMED from the beginning of the project, March 2020, until August 2021. The specific objectives and the degree of fulfilment of each of them are analysed, including the work carried out to achieve it. The work carried out by each WP is thoroughly highlighted individually and the interconnection between the different teams is clearly displayed.

It is worth mentioning that all the tasks have been affected by the situation derived from the SARS-CoV-2 pandemic, producing a generalized delay in the entire project of approximately six months. Tables with completed and in-progress deliverables and milestones are shown below. At the end of this report the revised Gantt chart is included with the expected submission date for the deliverables and milestones in progress.

Table 1. List of completed deliverables, including the first periodic report

Code	Deliverable Name	WP	Submission date to MEL
D1.1	Consortium Agreement	1	2021/05/14
D1.2	First periodic report	1	2021/10/28
D1.3	Documentation of kick-off meeting	1	2021/09/15
D1.4	Data Management Plan. Version 1	1	2021/05/06
D2.1	Report on the integrated and innovative high-resolution monitoring strategies in the different case studies	2	2021/09/07
D3.1	Identification of the surrogate models to be applied in the case studies	3	2021/09/03
D4.1	Report on the social-economic system characterisation, stakeholder mapping and water governance for selected case studies	4	2021/09/21
D5.1	Report on site characterisation and hot spot identification	5	2021/09/03
D7.1a	Project website	7	2021/05/14
D7.1b	Communication and Dissemination Plan	7	2021/05/07

Table 2. List of completed milestones

Code	Milestone Name	WP
M1.1	Consortium agreement drafted	1
M1.2	Kick-off meeting first, second and third periodic reports completed	1
M2.1	Knowledge exchange about each aquifer and main groundwater issues, existing datasets and further needed monitoring in each case studies drafted	2
M3.1	Choice of the typology of the surrogate models to be tested in the five study cases	3
M5.1	Inventory of existing water resources degradation assessment methodologies for use in InTheMED case study sites	5
M7.1	Project website launched online	7
M7.2	Final version of the communication and dissemination plan (CDP) finished	7

Table 3. List of deliverables in progress

Code	Deliverable Name	WP
D1.4	Data management plan. Version 2	1
D4.2	Report on the participatory systems mapping and the conceptual model	4
D6.1	Report on the development of the innovative DSS tool	6
D7.4	Report on mid-term workshop	7

Table 4. List of milestones in progress

Code	Milestone Name	WP
M3.2	Evaluation of the performance of the surrogate models implemented in the study case	3
M4.1	First Living Lab guiding problem identification and system characterization	4
M4.2	Second Living Lab scrutinizing and refining the conceptual model	4
M6.1	Initial DSS algorithm at an operational level	6
M7.4	Mid-term conference reports drafted	7

1.1. Objectives

Pillar 1: Strengthening the Understanding of Groundwater Functioning and Trends

OBJ-P1-1 Identification of the most important groundwater problems in the MED region

To identify the main groundwater problems, work packages had iteratively updated the initial Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses regarding quantitative and qualitative groundwater aspects for the entire MED region and for each case study. New studies were performed by considering the experiences while doing the literature review, the results of survey and interviews between all the project partners and with relevant stakeholders. Field trips were organized (mainly in Spain, Tunisia and Turkey) to observe the current situation, get acquainted with the relevant stakeholders and close information gaps from the literature review with field data. In addition, inputs and experiences from all members of the consortium regarding data management and sharing were also considered.

OBJ-P1-2 Investigation of the long-term groundwater trends

At the current time, groundwater level data for each partner country of the project has been collected. The availability of time series and the processing needed to analyse each country and region is very contrasting. Statistical analysis has been performed on the longest time series to identify trends, their spatial and temporal distribution, and their magnitude. For most of the assessed piezometers in the region, there are no significant overall trends, but over 20% of them show a significant increase in the water table depth over the years. When looking at specific decades within long and relatively complete time series, it was found that between 1985 and 1994 over 23% of the selected wells had an increasing depth trend. For the decade between 2005 and 2014, the percentage of wells with increasing depth was only 13%, suggesting a possible recovery across the region. Investigating the drivers for these trajectories is of significant importance and is the focus of WP2 for the coming months.

It is worth mentioning that the implementation of the high-resolution monitoring approach for all case studies was affected by the situation derived from the SARS-CoV-2 pandemic. Nevertheless, initial work was carried out in order to assess the potential of the proposed methods and their benefits.

To date, three high-resolution monitoring sensors have been purchased by the Tunisian case study and the site selection for the sensor implementation has been done. An innovative monitoring and characterisation scheme was suggested to control better groundwater quantity and quality for each case study. This new monitoring strategy was designed combining historical grab-sampling (biweekly), High-Resolution Monitoring Approach (HRMA, very tight measures: sampling interval lower than one hour) and geostatistical geophysical inversion procedure. Preliminary tests of geostatistical geophysical inversion were applied to a data set available at the Portuguese case study and the results have shown the potential of these methodologies to characterize complex groundwater systems and advances the current knowledge about their case study. In addition, detailed analyses regarding beneficial aspects of using HRMA, consideration for selecting groundwater monitoring sensors (type of parameters, locations of the sensors and monitoring frequency), budget calculation and distribution, and geophysical data for aquifer modelling and characterization were also conducted.

Pillar 2: Improvement of Groundwater Resilience and Security in a Social Learning Process

OBJ-P2-1 Incorporating groundwater management within a broader socio-economic context to improve water resources resilience through stakeholder workshops and dynamic simulation modelling

IntheMED scientific teams have promoted the incorporation of groundwater management within a broader socio-economic context by engaging stakeholders throughout the different phases of the project to improve understanding of the challenges in water use and enhance groundwater resource resilience. Such engagement is still in course, and it comprises discussion with stakeholders and project partners about groundwater problems in the MED

region and information collection from diverse stakeholders consisting of farmers, local and state representatives, cooperatives and NGO. Various field trips were performed by UPV and BU teams to meet those parties.

OBJ-P2-2 Raising awareness in society and among concerned stakeholders to improve groundwater management through the implementation of a multi-actor participatory approach in the selected case studies in the MED region

The implementation of a multi-actor participatory approach was affected by the situation derived from the SARS-CoV-2 pandemic. However, a governance analysis was performed to better understand the operational and management systems of the groundwater resource in selected case studies. In addition, relevant stakeholders were identified and have been invited to a workshop planned in Konya on September 30th, 2021. The purpose of the workshop was to develop an endogenous multi-party participatory approach to tackle the challenges facing the groundwater resource. The work performed to date will serve as a foundation for the planned living labs as part of WP4, and that will ultimately feed a system dynamics model.

OBJ-P2-3 Identification of groundwater problems and implementation of the appropriate feasible preventive mitigation options through sustainable learning processes

The first part of this objective is consistent with OBJ-P1-1. After a thorough survey of the five field case studies, each scientific team performed a detailed SWOT analysis of their particular case study and identified the hotspots. Presently, WP5 is developing the appropriate and feasible preventive mitigation options through sustainable and social learning processes with the collaboration of WP4. This task also includes capacity reinforcement of water users based on scientific approaches i.e., evaluation of cost benefits of different remediation strategies and the impact of sustainable practices to preserve groundwater quantity and quality.

Pillar 3: Development of Sustainable Management and Remediation Strategies

OBJ-P3-1 Establishment of adaptable and sustainable management strategies through the combination of HRMA, tailored model results, socio-economic assessments, bottom-up management and remediation strategies, an innovative Fuzzy WebDSS tool, and effective communication dissemination strategies

The project has simultaneously progressed on all issues related to the development of adaptable and sustainable management strategies. High-resolution data collection equipment has been installed at selected case studies and an innovative monitoring and characterisation scheme was suggested to control better groundwater quantity and quality for each case study (WP2). Smart models, tailored to the needs and available data of each case study were selected and are under development (WP3 and WP1). Stakeholder participation was encouraged in all phases, from problem identification to solution development (WP4). Bottom-up remediation strategies are being developed for selected case studies (WP5). DSS system tools are being developed to effectively manage vulnerable groundwater resources according to information given by the partners responsible for each case study site (WP6). Also, a detailed communication and dissemination plan was developed (WP7). All activities are being documented and shared with relevant stakeholders through virtual brochures, posters and factsheets, papers and oral presentation in conferences, webpages, and social media.

OBJ-P3-2 Prediction of the effects of future climate and anthropogenic changes, and how they can be mitigated by stakeholder-suggested preventive options using smart modelling

In order to forecast climate changes at each pilot site, about 20 Regional Climate Models projections were collected. The RCMs have been selected among a wide set of models for their finer resolution of 0.11 degree (EUR-11, 12.5 km) and their data coverage from the 70s up to 2100. The data related to two different Representative Concentration Pathways (RCPs) were considered: RCP4.5 and the RCP8.5. The bias correction of the model outputs for each case studies is being carried out. In addition, information was solicited from stakeholders to know if they were aware of the threat of climate change. Such information served as a foundation for planning stakeholder workshops that will ultimately feed a system dynamics model through smart modelling (WP3) and a socio-ecological assessment model (WP4).

OBJ-P3-3 Advice to the most polluting industries at selected sites to reduce their discharge loads through the adoption of a local water management concept and the implementation of the best available technologies in the market for the appropriate treatment of their effluents

The diagnosis of the local water management in the industrial sector aims to propose innovative treatment technologies to: (i) control and reduce the polluting discharges into receiving environments; (ii) promote the reuse of treated wastewater. Training and demonstration for industrials will be oriented taking into account the 4R principles (Reduce, Recycle, Reuse, Recover). The results of the cost/benefit analysis developed for the novel treatment scenarios will be presented and disseminated in the training sessions for an application on the real sites. These last activities were affected by the situation caused by the SARS-CoV-2 pandemic.

Pillar 4: Reinforcement of the DSS, Communication and Dissemination Activities

OBJ-P4-1 Development of an innovative and easy-to-use Fuzzy WebDSS tool benefiting from the real-time measured data using specific sensors and modelling results to reinforce early-warning and ensure the real-time groundwater characterization and optimal decision making

At the current time, the development of the DSS tool concerns the conceptual design of the decision-making problem for each case study area and, especially the Greek case study site (Tympaki), that will serve as the area to first implement and validate the algorithm that is in the stage of design. The next steps include the integration of the algorithm in a web platform, which will enable the connection among the real-time measured data and the modelling results. The results will be published in maps in order to inform the stakeholders in a more understandable manner. For this purpose, two possible platforms to publish online the maps have been found, “Geonode” and “ArcGIS Online”, and are going to be furtherly evaluated in order to conclude which one fits best the objectives and requirements of InTheMED project.

OBJ-P4-2 Promotion of InTheMED results and improvement of its regional and international visibility through the participation in high level international conferences, reinforcement of Open Data Access – opting in the pilot Open Research Data in Horizon 2020 – and integration of different initiatives targeting the MED region.

Preliminary results of the project were already disseminated and communicated in different forms. One peer-reviewed paper was published in Water Resources Research[1], two oral presentations took place at the EGU General Assembly 2021[2] and at the 48th International Association of Hydrogeologists Congress, held from 6th to 10th of September, 2021, in Brussels, Belgium[3]. Further works are being promoted at the ISARM2021 – 2nd International Transboundary Aquifers Conference[4].

To communicate the main concepts and results of the project to the society, the CERTE team participated in the event "Researcher Night"[5] in November 27th, 2020. Several news about the project were published in official communication channels from the different participating institutions. The project showcased in a Portuguese radio show devoted do science outreach, 90' de Ciência[6].

Efforts were also developed to link with other MED initiatives despite the challenges faced with the travel restrictions. One example of the dissemination of the results obtained under the scope of the project was the participation of UPV team as the InTheMED project coordinator in the workshop 'Groundwater: facing a common challenge' promoted by CETAQUA – Water technology Centre. This webinar is the result of a joint venture of several PRIMA projects: GOTHAM, RESERVOIR, eGROUNDWATER and InTheMED.

Furthermore, a bilateral discussion and collaboration was established with another PRIMA-funded project, the Sustain-COAST project (https://www.sustain-coast.tuc.gr/en/home). These joint-force efforts aim to collect historical groundwater level data in the MED region, water policy examination and better groundwater assessment using regional modelling and data-driven analysis. So far, the gathered database contains more than 10,400 wells with historical time series of groundwater levels covering seven countries of the MED. To the best of our knowledge, this effort will result in the first long-term and, possibly, the most

[1] Katzourakis, VE, Chrysikopoulos, CV (2021). Modeling the transport of aggregating nanoparticles in porous media. Water Resources Research, 57, e2020WR027946
[2] https://www.egu21.eu/
[3] https://iah2021belgium.org/
[4] https://en.unesco.org/conference/isarm2021
[5] https://www.green-night.tn/e-green-night/project-in-the-med
[6] https://www.90segundosdeciencia.pt/episodes/ep-853-leonardo-azevedo/

comprehensive groundwater-level database in the MED region connecting groundwater status to its drivers, pressures, impacts and responses.

The methods already developed under the scope of the project were shared with the community, through its upload under FAIR principles into the project data repository at ZENODO platform[7].

OBJ-P4-3 Upscaling of the InTheMED concept to the whole MED region and replicability of its methodology to other MED countries through cross-country dissemination tools based on participatory workshops and public communication

One of the most ambitious goals of InTheMED is to achieve the replicability and transferability of the solutions and methods developed during the project to other MED countries. At this point, all scientific teams are investigating such solutions and applying them to the selected five field case studies, as well as the regional groundwater assessment of the whole MED region, which is crucial to adapt local solutions to the broader groundwater context of the MED region. Thus, the participatory workshops with agents from the MED region will be held at the end of the second half of the project. To reach this objective efforts will be put in the strengthen of links with other international research projects related to sustainable groundwater management.

1.2. Explanation of the Work Carried per WP

1.2.1. WP1: Innovative Project Management

The overall goal of WP1, led by UPV team, the project Coordinator, is to ensure sound management of the InTheMED project. For that, active, frequent and efficient communication has been promoted and maintained through cloud-based collaborative tools, such as Slack, and by email with all project partners, ensuring and monitoring everyone's participation. Each team has contributed to the smooth execution and management of the project at national

[7] https://zenodo.org/communities/inthemed/

level in its financial, administrative and scientific aspects, which supported the integral management of the project.

UPV team created a template for project documents, deliverables, milestones and any other type of report, so that all documents keep a coherent and representative format for the InTheMED project and to maintain a general uniformity and good image. A revision of all deliverables has been carried out, to ensure scientific consistency and compliance with the design format. Completed deliverables and milestones have been collected and uploaded to the MEL web platform. Additionally, these and the rest of InTheMED results are guarded following the instructions of the Data Management Plan. UPV team ensures that all partners comply with the provisions of the Data Management Plan and currently is in the process of drafting the second version of it. More details on this can be found in section 3.

During the first year and a half of the InTheMED project, the following virtual meetings have been held, where all the project partners discussed and exchanged ideas and knowledge, maintaining a fluent communication:

- Kick-off meeting: April 28th,2020.
- Project Management Board meeting: May 6th, 2020.
- Steering Committee Meetings: October 7th, 2020 and May 15th, 2021.
- Scientific Advisory Meeting: April 12th, 2021, with the presence of Andrés Sahuquillo, Daoud Slim, Encarnación Taguas, Gerald Corzo and Pier Paolo Roggero as the members of InTheMED Advisory Board.
- First InTheMED Annual Meeting: September 16th and 17th, 2021.

Moreover, the InTheMED UPV team has met several times with the Spanish team of eGROUNDWATER project, which is also funded by PRIMA. The coordinator of eGROUNDWATER is part of the Water and Environmental Institute (IIAMA), at the Technical University of Valencia, just like the Spanish team of InTheMED, and they have also selected the Requena-Utiel aquifer as their case study. Therefore, to avoid duplication, the MODFLOW model of said aquifer built by the Spanish team of InTheMED was lent to the eGROUNDWATER

team. Moreover, both teams have jointly conducted multiple interviews with stakeholders in Requena-Utiel region, including Irrigation Communities and municipalities.

1.2.2. WP2: Innovative Monitoring and Data Analysis in the MED

The German team leads WP2, which has a threefold objective: the acquisition of historical MED data, the analysis and sharing of collected data and the enrichment of data availability, using the HRMA in case studies characterized by limited data conditions. During the reporting period and concerning Task 2.1: "Implementation of an Innovative High-Resolution Monitoring", a strategy for implementing High-Resolution monitoring in the five case studies was developed. The benefits of HRMA were presented to the other partners, also explaining the necessary considerations to select the equipment most fit according to the monitoring objectives. Furthermore, a range of equipment devices and companies were provided to the other teams, along with guidance about the potential costs of equipment, installation and maintenance.

Innovative methods to characterize aquifer properties from geophysical data were developed and applied to a data set available at the Portuguese case study. These data were provided by the project's partner SOMINCOR and comprise a set of resistivity profiles and sparse direct measurements of the water properties. Due to delays in the data transmittal, SOMINCOR was closed for three months in 2020 after the outbreak of the SARS-CoV-2 pandemic, the activities planned for WP2 were affected. This delay affected the implementation of the innovative modelling tools and therefore only preliminary results are available. Also, the Greek team explored inverted resistivity profiles, along with borehole data using spatial data science techniques (3D Kriging and Sequential Gaussian Simulation) to provide the hydraulic conductivity in the coastal aquifer system and identify regions associated with higher uncertainty. Relevant parts of the profiles were used to generate 3D models after anisotropy and detailed variogram analysis. Statistical error techniques were used to select representative models of the true subsurface while allowing the exploration of the uncertainty space.

Regarding Task 2.2: "Review and Collect the Available Groundwater Quantity and Quality Data Sets in the MED Region", at the moment this report is being written, groundwater level data have been collected from 10,400 piezometers across the region, including all the countries in

study cases of the InTheMED project and, additionally France. Furthermore, scientific teams will continue collecting data, knowing that the availability and completeness of the groundwater quality time series might be less than with the groundwater level. A strategy was also tailored for each country with the common rationale to obtain the longest possible time series from official sources. Currently, WP2 is searching for contacts to help in data acquisition strategies and collection, especially in countries in the southern and eastern region of the Mediterranean Sea.

The data collection has faced challenges proper to any data collection process, based on the access and data sharing policies, existence of digital data, language barriers and having the right contacts to get data. Challenges related to the SARS-CoV-2 pandemic have also slowed the pace of this task.

Once the groundwater data was collected, it was processed. Raw data was first imported and restructured into a common format. Most of the processing was done using Pandas library from Python. After import, data was analyzed for quality, and a report was written. Finally, they were put in a common format for analysis and comparison between countries. The work carried out so far by all participating partners is summarized in D2.1: Report on the Integrated and Innovative High-Resolution Monitoring Strategies in the Case Studies.

1.2.3. WP3: Innovative Smart Modelling in the MED

The WP3, led by the Italian team, has the objective to develop innovative smart models to be used by stakeholders for the analysis of alternative scenarios and future climate conditions. The Italian team discussed in detail with each project partner about the case studies and the list of necessary/available data in one-by-one meetings from July 7 to July 12, 2021. The main outcomes, useful for the development of Task 3.1, Task 3.2 and Task 3.3, are reported in the Deliverable 3.1.

To accomplish Task 3.1: “Selection of the Smart Model Types Suitable for Application to Groundwater Systems” several activities were carried out. First, a detailed literature review of recent documents related to surrogate modelling in groundwater has been carried out and it has been presented in D3.1. The choice of the most suitable models is related to the purpose

of the investigation and to the problem at hand. With this aim, the UNIPR team submitted to each partner a survey regarding the study sites, model objectives and state of the art. The survey results have been reported in Milestone 3.1. Three surrogate models have been identified as the most suitable ones for pilot sites: artificial neural network (ANN), random forest (RF) and linear regression. To evaluate the applicability of these methods, ANN and RF have been applied for the solution of two cases found in the literature. The first example deals with groundwater flow and it investigates the effect of different recharge and pumping rates on hydraulic heads at monitoring points. The second one deals with groundwater transport: the aim is to estimate concentrations at monitoring wells starting from different releases. The results have been presented during the meeting of May 7th 2021 and in D3.1.

The activities related to Task 3.2: "Training and Validation of the Models in the Case Studies" are still in progress. Each pilot site needs a model that can address the specific problem of the study area. On the basis of the survey, the sites have been divided into two groups: sites with numerical models: Requena-Utiel (Spain), Tympaki (Greece), Castro Verde (Portugal), Konya (Turkey), and without numerical model: Grombalia (Tunisia) and Mediterranean Sea region. The numerical models are still under development by project partners. In addition, the Greek team has developed a novel mathematical model to describe the transport of nanoparticles in water saturated, homogeneous porous media with uniform flow and the results have been published in the journal Water Resources Research. Besides that, a study of the interaction of titanium dioxide with formaldehyde in the presence of quartz sand under static and dynamic conditions was also performed by them. Finally, field data (such as rainfall, temperature, water depth) and geological information to set up a surrogate model are still being collected by partners.

Regarding Task 3.3: "Downscaling of Future Climate Projections at the Case-Study Scale and their Transfer to the Partners", different activities have been carried out: literature review about future climate analysis on the Mediterranean Area; a collection of climate models for the Mediterranean Area (EURO-CORDEX) and data collection by project partners.

1.2.4. WP4: Innovative Governance and Socio-Economic Assessment in the MED

The WP4, led by the BU team, is in charge of the socio-economic assessment of the groundwater resources and the agents involved. First, to accomplish Task 4.1: "Systems characterization, stakeholder mapping and governance analysis", a detailed literature review has been conducted to familiarize BU, UPV and CERTE research teams with their local and national groundwater policies, stakeholders and main groundwater-related issues in Konya Closed Basin (Turkey), plain of Requena-Utiel (Spain) and Grombalia region (Tunisia), respectively.

The stakeholders are classified according to scale (local, regional and national) and characteristics (state, market and civil). Following the literature review, missing information was identified regarding the Turkish case study. The missing information was related to agricultural irrigation practices in the basin, agricultural crop pattern, the information flows and social networks among various stakeholder groups, the level of enforcement of the existing legislation and the level of congruence with the basin management plans, water allocation plans, and groundwater action plans. Regarding the Spanish case study, the main information gaps were related to agricultural practices and the functioning of the irrigation communities.

BU team, created a semi-structured interview template with the intention of both closing the information gap related to the current situation and getting to know the current stakeholders. This template was translated to English and shared with the partners from Spain and Tunisia as guiding material for the interviews with stakeholders involved in their areas of study. The classification of stakeholders was taken into consideration while preparing the interview template; the questions are distinctive of the different roles of the actors. Then, a survey for socio-economic assessment was prepared by the BU team and filled out by all three participant partners (BU, UPV, CERTE).

From March to July 2021, both BU and UPV teams organized various field trips; each team conducted interviews with relevant stakeholders in their case studies. CERTE team has adapted the questionnaire to the Tunisian case study and will be conducting the interviews with a sample of actors and stakeholders managing groundwater in Grombalia basin in the following months. The main objectives of the field trips were to observe the current situation, to get

acquainted with the relevant stakeholders, to close information gaps from the literature review with field data, and to prepare for the M4.1, the first workshop of the Living Lab, strengthening the research teams' communication with the relevant stakeholders, selecting potential invitees who would be willing and suited to contribute to the living lab and starting to identify key variables and their behavior over time for the conceptual model (prior to the living lab).

Overall, field trips were successful as the majority of the stakeholders were welcoming the research teams and interested in the topic and the project. The outputs of the interviews were included in the governance analysis of the three case studies. The BU team met a total of 32 people from 11 different stakeholder groups during their last field trip. Of the 32 people, 9 were revisited after the first field trip. The UPV team met 6 irrigation communities and representatives of the city councils of Requena and Utiel. The report D4.1 Stakeholders Questionnaire: Irrigation Communities and city councils of Requena and Utiel compiles the information obtained in these meetings (it is a restricted access document). It was a successful exercise to strengthen the relationship with stakeholders.

The work carried out so far by all participating partners is summarized in D4.1: Report on the Social-Economic System Characterization, Stakeholder Mapping and Water Governance for Selected Case Studies and it reviews the initial stage of the research to be completed within WP4 of the project. The content of this document paves the way for the participatory systems mapping and conceptual modelling in the next stage of the research.

1.2.5. WP5: Innovative Remediation Strategies in the MED

The Tunisian team leads WP5, whose main objective is to approve particular remediation strategies for the selected field case studies through a participatory system. During the reporting period and concerning Task 5.1: "Site Characterization and Hotspot Identification", the scientific teams collected and analysed all the available data for the case studies in Spain (Requena-Utiel), Portugal (Castro Verde), Tunisia (Grombalia), Greece (Tympaki) and Turkey (Konya) and assessed the baseline situation for each one of them. The data collected and assessed consists of hydraulic levels, pumping rates, quality and pollution of aquifers, rainfall, temperature, stream flows, groundwater level, groundwater problems, water threats,

hotspots, water supplies, wastewater production, water quality status, and applied governance system in each respective area. Based on the data collected and analysed, the scientific teams (CERTE, UPV, TUC, IST-ID, and BU) wrote an exhaustive report; D5.1: Report on Site Characterization and Hot Spot Identification, where the five sites were investigated through a detailed SWOT analysis to identify the main groundwater problems, hotspots, and key stakeholders, which are needed in WP2 (Task 2.1) and WP4 (Task 4.1).

Urgent remediation actions for industrial and agricultural sectors have been identified. For the industrial activity, CERTE team have proposed various treatment scenarios based on Advanced Oxidation processes (AOP) and they have carried on with the cost benefits analysis to choose the most suitable treatment scenario for each use case. Concerning the agricultural sector, it was proposed to organize a capacity building session for farmers to promote sustainable agricultural practices (irrigation, use of fertilizers and pesticide, etc.).

Regarding Task 5.2: "Capacity Building on Sustainable Integrated Water Management", the stakeholders have been selected according to the main problem identified in each case study. In preparation for the training session in the Grombalia case study, a preliminary activity related to cost-benefit analysis of various innovative technologies based on advanced oxidation processes (AOP), has been carried out. In addition, a design of an electrochemical prototype including a cell with a power supply for different wastewater treatment was performed. This prototype will be used exclusively for experiments and demonstration sessions. To implement the best available technologies to overcome the main problem in each case study, CERTE team is still studying the possibility of undertaking a social learning process to design a new water management solution through participatory interactive sessions (Living Labs) with stakeholders. This action mainly depends on the pandemic situation in all case studies.

The activities related to Task 5.3: "Development and Upscaling of Remediation Technologies" focus on the development of water remediation technologies and strategies. For this purpose, the approach of identifying the optimal treatment technologies for industry regarding economic and environmental aspects is based on the environmental cost-benefit assessment of different treatment strategies. In the Grombalia case study, three industrial activities have been selected for this assessment: textile, agri-food, and leather. In addition to the in-situ

strategy, different treatment strategies (Anodic oxidation, AO, and Electro-Fenton, EF) have been designed based on previous works and expertise.

1.2.6. WP6: Innovative Decision Support Systems in the MED

The WP6, led by the TUC team, has the mission to develop a novel decision-making tool to aid groundwater managers in the sustainable management of groundwater resources. Regarding Task 6.1: "Initial Development and Testing of an Innovative Decision Support System", for the development of the novel tailored visualization and decision-making tool, a literature research has been conducted. Based on this research, the decision support steps have been determined and a questionnaire has been designed based on Cinelli et al., (2020)[8] in order to aid the implementation of the decision support steps. The questionnaire is available in draft form and will be used in separate lateral meetings that are going to be organized between the TUC team and the partners responsible for the respective case study areas. In addition, a template for indexing the problems in each study site is designed and is going to be filled in with the information available from the previously referred meetings as well as from the D5.1: Report of Site Characterization and Hotspot Identification.

One of the decision support steps is the "evaluation model" and can be based either on the Outranking theory of Multi-Criteria Decision Analysis (MCDA) approach or on the Multi-Criteria (Multi-Objective) Optimization approach. According to the proposal, the decision-making tool will be based on the later approach (multi-criteria optimization) and the algorithm that is going to be followed is currently being developed, constituting progress for the first milestone M6.1: Initial DSS Algorithm at an Operational Level of WP6. However, special attention has also been given to the Outranking theory during the literature research in order to investigate its possible integration in the DSS according to the types of the problems that will be determined. The document for validating M6.1 is available in draft form and will be updated after the validation of the algorithm.

[8] Cinelli, M., Kadzinski, M., Gonzalez, M., & Słowinski, R. (2020). How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy. Omega.
DOI: https://doi.org/10.1016/j.omega.2020.102261

As Task 6.1 is still in progress, Task 6.2 cannot be implemented yet. Therefore, it is limited to the collection of the data available for the study cases in order to form the scenario of the current situation.

Concerning Task 6.3: "Production of Maps from the DSS According to Suggested Scenarios and Dissemination with Stakeholders", fuzzy WebDSS maps will be derived according to the suggested scenarios and shared with stakeholders and the social community in order to ensure the design of the best groundwater management practices, measures and policies against current situations with less anthropogenic and climate change pressures. In that direction, preliminary research has been made to investigate the possible options for publishing the maps derived by the DSS tool on the internet. A first option is the "Geonode" platform and a second one is the "ArcGIS Online". These options will be evaluated according to the tools provided, the cost, its interactivity with the user and other features that will be determined during the evaluation process.

1.2.7. WP7: Innovative Dissemination and Communication in the MED

The WP7, led by IST-ID, is responsible for developing novel communication strategies and dissemination materials. The activities planned under WP7 in the first half of the InTheMED project comprised the development of the project's identity in terms of logo and visual identity, the deployment of the website and the definition of a detailed communication and dissemination plan to be implemented during the three years of the project. This period was planned to finish with a mid-term workshop.

The InTheMED website[9] was released to the public at month six. Simultaneously, the Communication and Dissemination Plan (CDP) was finalized with contributions from all partners. These activities correspond to Milestones 7.1 and 7.2 and Deliverables 7.1a and 7.2b.

The CDP consolidates the communication and dissemination strategy of the InTheMED project, identify the most efficient means to communicate with partners and stakeholders and to disseminate, exploit and communicate the results. The CDP sets out the objectives, tools,

[9] https://inthemedprima.com/

materials, and channels to be exploited to effectively spread InTheMED activities, achievements and tangible results to targeted audiences and relevant stakeholder. It includes the official logo of the project and the visual identity, which was built around the main logo.

One of the components of the CDP was the creation of a virtual identity and the presence of the project in social media channels. This objective was accomplished by creating user accounts on Twitter[10], LinkedIn[11] and Facebook[12]. These platforms are regularly updated with information related to project. An effort has been made to interact with accounts from other PRIMA projects.

As part of the communication and dissemination activities the project members have been actively promoting the project and the results already obtained. These efforts included the dissemination of the project through news posted on institutional websites, see Table 1, radio shows dedicated to science outreach[13] and the participation at the GREEN NIGHT, an experience of Tunisia in the European Researchers' Night. Also, the project was showcased at the Webinar "Groundwater: facing a common challenge" promoted by CETAQUA – Water technology Centre – with support of PRIMA foundation and four PRIMA projects: GOTHAM, RESERVOIR, eGROUNDWATER and InTheMED.

Table 5. Summary of the dissemination of the InTheMED in official new channels

1	https://web.archive.org/web/20200522113504/http://www.upv.es/noticias-upv/noticia-12048-inthemed-es.html
2	https://web.archive.org/web/20200522113403/http://www.upv.es/index-es.html
3	https://cerena.ist.utl.pt/news/inthemed-kick-meeting-innovative-and-sustainable-groundwater-management-mediterranean
4	https://tecnico.ulisboa.pt/pt/noticias/investigadores-do-tecnico-participam-consorcio-europeu-para-gestao-de-recursos-hidricos-subterraneos-em-tempo-real/
5	https://web.archive.org/web/20200526102703/https://www.iagua.es/noticias/iiama/iiama-lidera-proyecto-gestion-sostenible-aguas-subterraneas-zonas-mediterraneo

[10] https://twitter.com/inthemed_prima?lang=en
[11] https://www.linkedin.com/in/inthemed-prima-5690461ba/
[12] https://www.facebook.com/inthemedPRIMA
[13] https://www.90segundosdeciencia.pt/episodes/ep-853-leonardo-azevedo/

The following list summarizes the works published in peer-reviewed international journals and communications in international conferences:

- Katzourakis, VE, Chrysikopoulos, CV (2021). Modeling the transport of aggregating nanoparticles in porous media. Water Resources Research, 57, e2020WR027946

- Silva, R, Reinecke, R, Varouchakis, E, Gómez-Hernández, J, Rode, M, Jomaa, S (2021). Long-term Groundwater Database and Assessment for the Mediterranean Region. European Geosciences Union, EGU General Assembly 2021, 19-30 April 2021 in Vienna, Austria (Online conference).

- Varouchakis, E, Azevedo, L, Pereira, JL, Trichakis, I, Karatzas, GP, Jomaa, S, Soupios, P (2021). 3D modelling of a hydrological structure combining spatial data science and geophysics: Application to a coastal aquifer system in the island of Crete, Greece. European Geosciences Union, EGU General Assembly 2021, 19-30 April 2021 in Vienna, Austria (Online conference).

- Ben-Salem, N, Silva, R, Reinecke, R, Jomaa, S (2021). Data-Driven Analysis and Regional Modelling for the Assessment of Transboundary Aquifers in the Mediterranean Region. Accepted as a Poster presentation at the ISARM2021 2nd International Transboundary Aquifers Conference, 6-9 December 2021, UNESCO, Paris, France (Online conference).

- Jomaa, S, Reinecke, R, Ben-Salem, N, Silva, R, Varouchakis, E, Silva, JV, Ceseracciu, C, Nguyen TPL, Cetinkaya, ID, Saysel, AK, Copty, NK, Karatzas, GP, Trichakis, I, Pasqui, M, Heggy, E, Maurizi, S, Roggero, PP, Rode, M, Gómez-Hernández, J (2021). Multidisciplinary Joint-Force Efforts towards Science-Based Management in the Mediterranean Region: A Particular Focus on Transboundary Aquifers. Accepted as an Oral presentation at the ISARM2021 2nd International Transboundary Aquifers Conference, 6-9 December 2021, UNESCO, Paris, France (Online conference).

- Godoy, V.A.; Napa-García, G.; Uribe-Asarta, J.; Gómez-Hernández, J.J. (2021). Machine learning as a tool to improve subsurface heterogeneity characterization. Proceedings of IAH2021, the 48th Annual Congress of the International Association of Hydrogeologists, page 282.

1.3. Impact

Considering the work developed by project partners to the date, the expected impacts as stated in the proposal for all WPs continues to be relevant and all the proposed objectives are expected to be achieved. However, challenges related to the SARS-CoV-2 pandemic were faced in most of the tasks and a delay of six months is to be expected for the deliverables (as detailed in section 4).

1.4. SARS-CoV-2 Effect on Progress

Major actions along the Mediterranean regarding the SARS-CoV-2 pandemic were taken on March 7th, 2020, only a week after the official beginning of the project. Italy was the first country going into confinement, but it was quickly followed by the rest of the countries involved in the project. Switching all activities online and restricting mobility and in-person interaction amounted for a reorientation on how and when things could be done. When the first wave passed, it seemed that initial activities could be recovered, although an overall delay was anticipated; unfortunately, a second wave came in, and a third one, and so on, up to a fifth wave, with imposed restrictions for each wave. It was evident that the consortium was not going to achieve all planned milestones in due time, and internally, all partners started to work counting on an overall delay of six months.

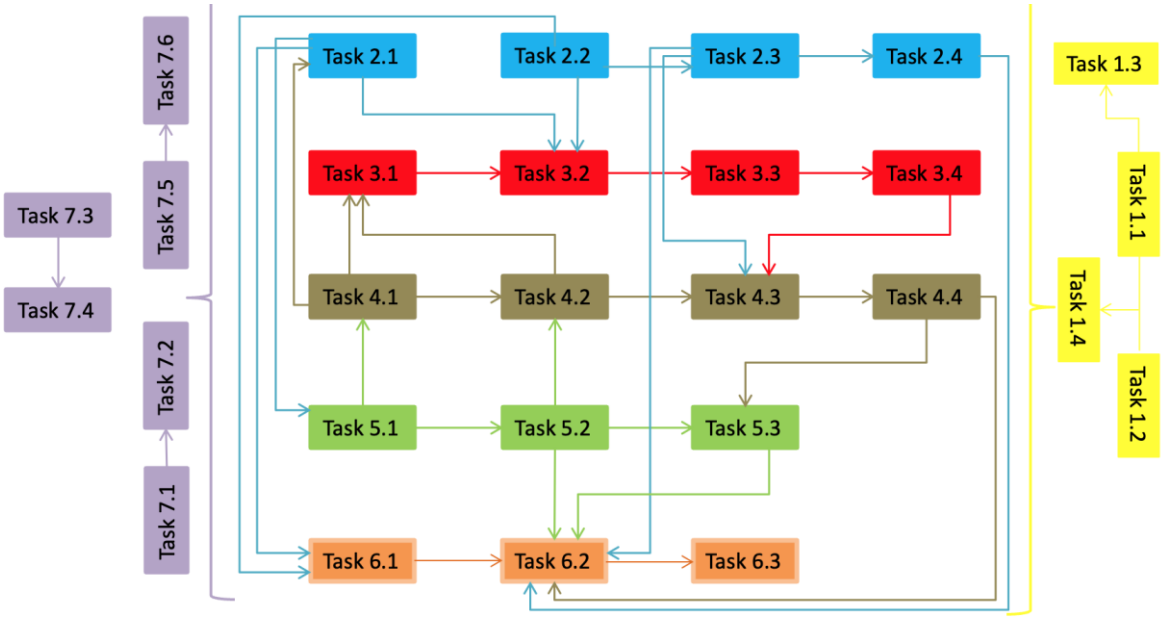

Figure 1. Diagram of interrelationships between tasks

The interconnectedness of the tasks in all work packages, sketched in Figure 1, made impossible to establish specific delays for each work package. A new Gantt chart was designed, which is included at the end of section 4. Together with this midterm report, an official request to the PRIMA foundation has been submitted requesting a revision of the Grant Agreement and an extension of the project duration from 36 to 42 months, without any request of additional funding.

2. Update of the Plan for Exploitation and Dissemination of Result

Depending on the evolution of the pandemic, the InTheMED Communication and Dissemination Plan might need to be revised. Travel restrictions might impact the organization of the mid-term workshop (postponed to month 24 in the revised Gantt chart, see section 4) and the living labs. As a contingency measurement, a back-up plan is under development to host these events virtually.

3. Update of the Data Management Plan

The first version of the Data Management Plan was delivered on the MEL online platform on May 5, 2021. In this first version, the type, format and naming conventions of collected, processed and generated data and the curation and preservation of the data during and after the end of the project, indicating the dissemination level of every generated data, reports and deliverables were indicated.

Zenodo was selected as the main repository, where the InTheMED community[14] was created. The consortium is pleased with the operation of Zenodo, hence no changes are proposed on the way to guarantee the FAIR principles of InTheMED results. Additionally, the project website, https://inthemedprima.com/, also includes the project results, thus expanding the potential users interested in our results. The website is linked to the repository through the DOI assigned to each result using a hyperlink, from where they are freely available for download.

To date, all InTheMED partners have complied with the rules established by the DMP v1. Nonetheless, certain topics remained unresolved in the first version, such as those related to the size of the data, which it is intended to answer in the DMP v2. Moreover, all project partners will focus on specifying the methodologies and standards to be applied, including the general keywords to use for every InTheMED result.

Its update is in course, and it is expected to be completed by March 2022, considering the general delay of approximately six months that all tasks have suffered.

[14] https://zenodo.org/communities/inthemed/

4. Deviations from the Proposal Submitted

From the beginning of the project, a delay was predicted in most tasks due to the extraordinary situation caused by the SARS-CoV-2 pandemic. During this first year and a half, meetings with third-party agents and stakeholders have been postponed or cancelled due to lockdowns and travel restrictions measures. Additionally, it has not been possible to carry out field work, sampling campaigns and installation of new sensors. The universities, research centres and water authorities have adopted severe measures that have made certain processes lengthy, such as the hiring of personnel and the buying of equipment. Most of the tasks have suffered a 6-month deviation from the project plan as reflected by the Gantt chart submitted in the Proposal. Nonetheless, apart from the initial delay, no further deviations are expected. At the end of this section, a revised Gantt Chart can be found.

4.1. Tasks

Task 1.4: Data Management

The elaboration and submission of the D1.4 were delayed six months due to the impossibility to hire personnel, following the exceptional measures adopted by the Technical University of Valencia during the months of confinement in Spain, from March to June 2020. Furthermore, the submission of the second version of the DMP, due on the 18th month according to the proposal, is delayed 6 months given the overall delay of the project, to allow the development of the different tasks of each WP and obtain results.

Task 2.1: Implementation of an Innovative High-Resolution Monitoring

Portugal, Spain and Tunisia declared their intention to install high-resolution monitoring sensors, but they have not reached this objective. The Portuguese team has been limited due to the closing period of the mining site where their case study is located, Castro Verde aquifer, and the restrictions to access the site with the sensors. However, they expect to acquire the sensors in the second half of the project, but contingent with the evolution of the pandemic. The Spanish team not only dealt with the impossibility of carrying out field work, due to the mobility bans caused by the pandemic, but also with the impossibility of meeting with agents

from the Júcar Water Authority, the public body responsible for the management of the Spanish case study, Requena-Utiel aquifer. During this last year, the Júcar Water Authority has been immersed in the elaboration of the Hydrological Plan for the 2021-2027 term and all non-essential meetings were postponed. However, this new plan was published in summer 2021, so from now on, the communication with them is expected to be much easier. The Tunisian team explains that the delays were caused by the SARS-CoV-2 pandemic, transport problems, and logistics connectivity and its impact on the activities of the high-resolution monitoring sensors' provider.

Regarding the acquisition of historical MED data and trend analysis and sharing of collected data, German team faced various challenges related to delayed contract of the PhD student in the spring of 2020, and then further difficulties to get in contact with public officers regarding data sharing, as most places were not working at full capacity in the pandemic. The inability to travel and request data by person or form networks that could help have also hindered the task.

Field trips for sampling/monitoring campaigns and meetings with the stakeholders of the Greek case study site have been postponed many times because of national or regional lockdowns and restrictions of group gatherings that have been posed. The postponement resulted in a long-lasting unavailability of the necessary data for the modelling.

Task 3.1: Selection of the Smart Model Types Suitable for Application to Groundwater Systems

The Italian team encountered several problems caused by the SARS-CoV-2 pandemic that led to a delay in the activities carried out with respect to the planned work. The main reasons for deviations from the proposal are: (i) issues related to remote work during the first months, which limited data access and meeting, (ii) delay in hiring personnel, (iii) difficulties from project partners to acquire data as fields trips have not been established due to restrictions and (iv) complete forward model are under update or development. Therefore, Task 3.1 has been implemented with a 6-month deviation from the proposal and, consequently, this led to a delay in the activities planned for Task 3.2.

Task 3.2: Training and Validation of the Models in the Case Studies

The training and validation of the surrogate/smart models have not been fully implemented since forward models are not ready in most of the case studies.

Field trips for sampling/monitoring campaigns and meetings with the stakeholders of the Greek case study site have been postponed many times because of national or regional lockdowns and restrictions of group gatherings that have been posed. The postponement resulted in a long-lasting unavailability of the necessary data for the modelling.

Task 4.1: Systems Characterization, Stakeholder Mapping and Governance Analysis

Regarding UPV and BU teams, project recruitment and field campaigns started in September 2020 as a result of the first peak of the SARS-CoV-2 pandemic and the uncertainties related to its epidemiology and public concerns. Moreover, planning of the field trips overlapped with the second SARS-CoV-2 pandemic peak in October 2020 and was delayed until March 2021.

Additionally, the 2-week official holidays in Turkey in July 2021 made it difficult to designate a suitable date for the majority of the potential invitees in August 2021 to start the participatory process. Consequently, Living Labs had to be postponed. Therefore, M4.1 is not prepared yet; however, it is in progress.

Task 4.2: Participatory Systems Mapping and Conceptual Modelling

The situation presented in Task 4.1 created a six-months standard delay in all proposed activities for BU team in sequence, thus, Task 4.2 is still in progress. Turkish team also propose a one-month lag between M4.2 and D4.2 given that D4.2 is going to assimilate the data generated from M4.2, so this lag in between is expected to be appropriate for analysis and document elaboration.

Task 6.1: Initial Development and Testing of an Innovative Decision Support System

Meetings with the Greek case study site stakeholders have been affected by the restrictions of group gatherings due to the SARS-CoV-2 pandemic. For the same reason, the face-to-face

interactions with stakeholders were constrained; therefore, stakeholders' mapping and Living Labs have not taken place yet. Living Labs are of vital importance for the project since participatory approaches are on its primary objectives.

Task 7.4: InTheMED Mid-Term Workshop

The InTheMED mid-term workshop was supposed to happen at month 18 of the project. However, due to administrative and travel restrictions originated by the SARS-CoV-2 pandemic this event was postponed to month 25.

4.2. Use of Resources

There is some deviation in the use of resources with respect to the planned ones.

In the Spanish team, the personnel costs are higher than anticipated. This is due to the pressure imposed by the new boundary conditions under which the project had to be carried out imposed by the SARS-CoV-2 pandemic; and also to inexperience in the management on large projects. This is the first time that the principal investigator acts as coordinator of a European project. The rest of the costs are much smaller than expected given that virtually no traveling has occurred and the intended deployment of sensors and stream gauging could not be performed due to the pandemic restrictions.

In the Greek team, an amount of 3,000 € (three thousand euros) was transferred from the "Other direct costs - Travel" category to the "Other direct costs - Other goods & services" category. The reasoning behind this decision was, firstly, the inability to absorb travel costs due to the ongoing SARS-CoV-2 pandemic and the subsequent travel restrictions. Additionally, the working conditions requirements of less hours at the university lab and more working hours at home necessitated the procurement of computer accessories and parts, enabling the personnel team to remotely run the necessary software on the office computers, as well as coordinate remotely.

The Turkish team was originally planning to install three sensors for high-resolution groundwater monitoring in a safe location in the Konya closed basin. However, after field works

and contacts with the State Hydraulic Works of Turkey (SHW), it was revealed that no free and secure wells are available for installing our own sensors in their monitoring wells. Moreover, it was very difficult to find a secure farm in the basin for that purpose. Instead, SHW proposed that they can provide us with the high-resolution data from five wells recently installed in the Konya Basin. Recognizing that this would be the fastest and most reliable route to acquire high-resolution data from the Konya Basin, a protocol of mutual understanding was thus negotiated between SHW and BU. The protocol is about to be signed by both parties (Boğaziçi University and SHW) and the provided data will answer the needs of the project, for a longer monitoring history. Therefore, it is expected that about 4400 Euros will be saved from the previous budget. It is estimated that the savings from the purchase of the sensors will earn about six months of graduate student labor. Because of that, the Turkish team is planning to hire a third graduate assistant in the second half of the project, who will work on the collaborative phase of model building (WP4). This will streamline the integration of the hydrogeologic model and socio-economic model and hopefully allow compensate for some of the delays caused by the SARS-CoV-2 pandemic.

The Portuguese team planned to implement the HRMA sensors in their field case study, but that objective was not possible to reach yet. This limitation is due to the closing period of the mining site and the restrictions to access the site the sensors. The sensors are expected to be acquired in the second half of the project, but contingent with the evolution of the pandemic.

None of these deviations compromise the success of the project, given that the requested six-month extension is granted.

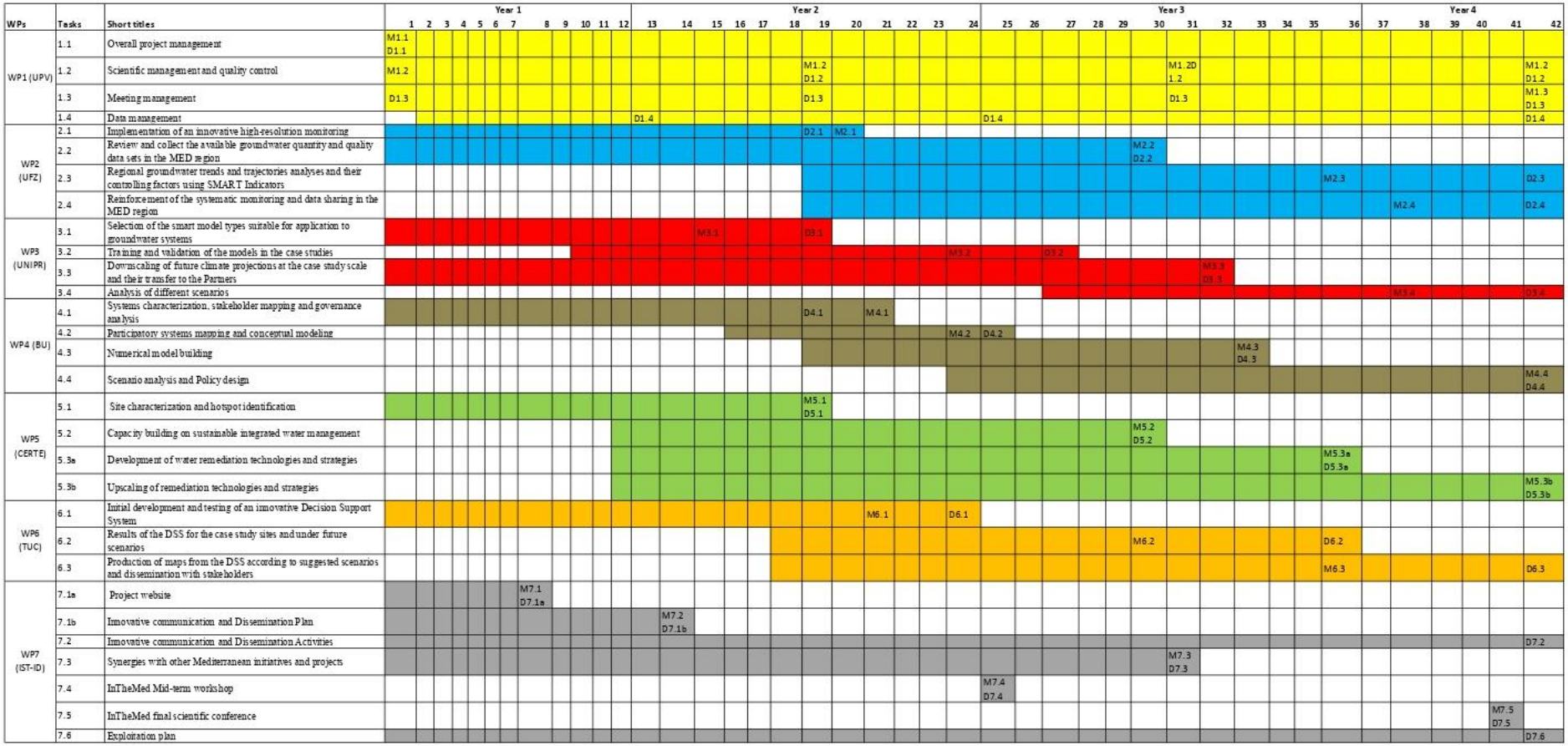

Figure 2. Revised Gantt chart, considering the initial delay of approximately six months.