DEEPWATER-CE
WORKPACKAGE T3

PILOT FEASIBILITY STUDY FOR MAR SCHEMES WITH INTEGRATED ENVIRONMENTAL APPROACH IN KARST GEOLOGICAL CONDITIONS IN SEMIARID KARST REGION (CROATIA)

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CROATIA

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Contents

1. Summary

This report documents the feasibility study for MAR schemes in karst geological conditions in the semiarid karst region in Croatia conducted within the DEEPWATER-CE Interreg project.

Through the process of MAR site selection, the island of Vis was selected as the Croatian pilot area. Vis is a small remote island in the Croatian part of the Adriatic Sea. The island's area is 89.7 km^2 and it is approximately 45 km away from the Croatian mainland. Favorable geological and hydrogeological conditions enabled the formation of high-quality karst aquifers from which the groundwater is abstracted, hence the island of Vis is not connected to the mainland or any other island by water supply pipelines. With the increasing tourism activity, there is a pronounced need for alternative solutions in the management of freshwater resources on the island due to increased seasonal demands, climate change, and high variability of seasonal precipitation.

The concept of applying the MAR scheme on the island of Vis is primarily focused on the two most prospective methods: (i) infiltration pond (IP) and (ii) aquifer storage and recovery (ASR).

The island of Vis is suitable for the application of MAR according to all the criteria that are analyzed in detail in the desktop analysis *(document D.T3.6.1 Report on the Desk Analysis of the pilot feasibility study for MAR deployment in fractured and karstified aquifers located in semiarid karst areas; see Annex 2)*, as well as in field work report (document *D.T3.6.2 Report on the field work of the pilot feasibility study for mar deployment in Split-Dalmatia County; see Annex 3)*.

These are other essential specifications of the island of Vis that make it an excellent example for the implementation of the MAR pilot project in the Republic of Croatia:

- There is a significant water supply problem on the island, which cannot be solved by connecting the island to another water supply system. The island of Vis is located 44 kilometers from the nearest mainland point (Vinišće on the Trogir coast) and 53 kilometers from Split.
- The island of Vis has its groundwater resources in karstic aquifers. The water level is often dangerously low in the summer months, which leads the island's water supply system to the risk of water salination. Therefore, existing aquifers need to be protected, whereby managed artificial recovery (MAR) is an option that needs to be explored.
- In the summer months in 2019 (this is the year the highest annual water consumption on the island), the extraction of water from the existing aquifers achieved the maximum amount of water currently available on the island.
- The island's future development (mainly tourism) depends on providing additional quantities of drinking water available. On the island of Vis, there are continuous research and shooting of the underground carried on to find new sources of drinking water. Connecting to the land water supply system is extremely expensive.

The feasibility study was prepared for a basic and alternative option. The basic (proposed) option represents the implementation of the pilot project according to the infiltration pond method. The alternative option represents implementing a pilot project according to the aquifer storage and recovery method (ASR). Both options are assessed at the same pilot location, i.e. at the area of the Korita aquifer in the central part of the island of Vis. Given the appropriateness of the methods at the selected pilot site, both methods were identified as technically appropriate.

Total investment costs, including VAT, are estimated at **3,142,851.20 HRK** to implement the pilot MAR pilot project on the island of Vis according to the infiltration pond method. According to the alternative MAR scheme, i. e. the ASR method, the total investment for implementing the pilot project is **4,689,559.70 HRK**, including VAT, which means that the investment is about 50 % higher than the basic (proposed) option.

The infiltration pond method compared to the ASR method requires less intervention in the natural environment, is less risky (but still high-risk), is less demanding in terms of capital investment and operating costs, the required infrastructure intervention is smaller, the amount of equipment installed is significantly lower, with the same final effect achieved. Therefore, in terms of elaborating a feasibility study, the infiltration pond method was defined as the primary and the ASR method as an alternative method.

The infiltration pond method proved to be justified in financial and economic (social) terms. On the other hand, the ASR method is not financially justified, whereas, in social terms, it is, but with lower economic NPV than the primary option. Given that investments in public infrastructure must not only be seen in financial terms, but firstly in economic (social), the financial non-acceptability of the pilot project under the ASR method should not be a reason for rejecting the project. However, the Water Framework Directive (2000/60/EC) requires the financial sustainability of all investments into water infrastructure, which entails the necessary price alignment towards final beneficiaries in case of implementing a financially non-feasible project. Given the already high water prices on the island, this option would be challenging to accept by the inhabitants of the island of Vis.

By comparing the options among themselves, the conclusion is that the primary option, i.e. the infiltration pond method, according to all parameters, is better.

2. Introduction

Managed Aquifer Recharge (MAR) refers to a suite of methods that are increasingly being used to maintain, enhance, and secure the balance of groundwater systems under stress. MAR techniques offer promising solutions for water management, also with regard to tackling future climate change impacts (Casanova et al., 2016; Dillon, 2005; Dillon et al., 2019; Sprenger et al., 2017).

Within the DEEPWATER-CE project, we investigate the potential to implement MAR schemes in four partner countries: Hungary, Poland, Slovakia, and Croatia considering these socio-economic, geological, hydrogeological, technical, regulatory, and human health aspects. In the frame of the DEEPWATER-CE project during the previous work transnational decision support toolbox has already been developed, which primarily addresses site selection (DEEPWATER-CE, 2020a) and the guidance and methodology of the feasibility study of MAR schemes were described (D.T3.2.5, DEEPWATER-CE, 2020b).

According to these methodologies, suitability maps were compiled for Croatia to designate potentially suitable MAR locations (D.T3.1.2., DEEPWATER-CE, 2021a). Based on suitability maps (general and specific level) and the realistic need for implementation of new solutions to enhance fresh water availability, the island of Vis was chosen as the optimal location (i.e. pilot area) for further investigations. Firstly, the pilot area was characterized by the desk analysis of existing data (D.T3.6.1.; DEEPWATER-CE, 2021a). Detailed field investigations were carried out in the period from September 2019 to September 2021, to collect geological, hydrogeological, hydrochemical, and hydrological data (D.T3.6.2.; DEEPWATER-CE, 2021b). Furthermore, comprehensive risk analyses were performed to evaluate risks during the construction phase and the operational phase of the MAR facility on the island of Vis (D.T3.6.3.; DEEPWATER-CE, 2021c).

This feasibility study is prepared in the DEEPWATER-CE project as output O.T3.4, INTERREG Central Europe Transnational Cooperation Programme 2014-2020.

The feasibility study is prepared for the selected pilot area on the island of Vis. Still, the procedures and results can be applied to other MAR systems in aquifers located in similar areas, i.e. karst areas of Croatia, with possible application also beyond. The financial and economic analysis of the pilot project has taken into account prices on the Croatian market. They should be adjusted to other markets if the study is applied to a different geographical area.

The purpose of this feasibility study is to get an insight into the total costs and benefits of the pilot project establishing a MAR system in aquifers located in semiarid karst areas of Croatia, specifically at the selected pilot site on the island of Vis, and to analyze the financial and economic feasibility of implementing this pilot project. The feasibility study assesses the feasibility of the MAR system on the island of Vis in two different technical options (the proposed and an alternative option), checking the technical, financial, and legal feasibility of the project and its social and environmental acceptability.

Firstly, the methodology of the feasibility study will be described. Then, relevant regulatory frameworks regarding water management and MAR on EU, national, regional, and local levels will be shown, as well as specific constraints related to MAR implementation in Croatia. After that, a detailed characterization of the pilot site will be shown, followed by the risk management, and ultimately, a cost-benefit analysis. The last chapter is a compilation of various Annexes that are relevant for the feasibility study but are too large to be fully included in the presented work.

3. Feasibility study methodology

3.1. Application and adaptation of a developed DEEPWATER-CE MAR methodology

As part of the DEEPWATER-CE project, common methodological guidelines for developing pilot feasibility studies have been developed. This methodology is a basis for analyzing the feasibility of establishing a MAR system at all pilot sites in the DEEPWATER-CE project (D.T3.2.5 Common methodological guidance for Deepwater-CE MAR pilot feasibility studies; 2020b)(MAR methodology).

The developed methodological guideline (MAR methodology) relates to the specific areas of the pilot project concerned, which are, due to their specificities, not covered in general guidelines for the preparation of feasibility studies (Guide to Cost-benefit Analysis of Investment Project - Economic appraisal tool for Cohesion Policy 2014-2020 (2014), with the latest updates: Economic Appraisal Vademecum 2021-2027 - General Principles and Sector Applications (2021)).

MAR methodology has been developed for the specific needs of this project. It describes detailed the specific procedures according to which we are addressing the following chapters of the feasibility study:

- the legislative frameworks of the pilot project;
- desktop analysis of pilot areas,
- detailed definition of the pilot site, including detailed methodologies for supply and demand analysis (existing situation and future projections);
- defining, analyzing, and managing risks;
- cost-benefit analysis;
- comparison of alternative options.

Additionally, the full intervention logic of the project DEEPWATER-CE can be seen in Annex 1.

MAR methodology proposes a 30-year reference period for the cost-benefit analysis, which has been accepted and applied. This reference period is consistent with the reference period recommended by the EU CBA methodology (EU, 2015) for water supply projects.

In the MAR methodology, different discount rates that have been applied in the various MAR studies and projects are mentioned and are in the range between 3 % and 8 %. The EU CBA methodology defines discount rates for projects in the EU Member States: 4 % financial discount rate and 5 % economic (social) discount rate. We use the financial discount rate in the financial analysis and the economic (social) discount rate in the economic analysis of the project. We apply a 4 % financial discount rate and a 5 % economic (social) discount rate in this feasibility study.

The MAR methodology defines the net present value indicator (NPV) as the main indicator in the cost-benefit analysis. In this feasibility study, we calculate two more indicators in the cost-benefit analysis in addition to the net present value, namely the internal rate of return (IRR) and the benefit-cost indicator (B/C).

The MAR methodology proposes a “willingness to pay” method to calculate the social benefits of the MAR project, which is applied in this study. To assess the willingness to pay, we have performed a survey. The prepared survey from the MAR methodology was translated into the Croatian language, and values were transformed into Croatian kuna. The survey was distributed to the inhabitants of the island via the online form.

3.2. Application and adaptation of the EU CBA methodology

General guidelines for feasibility studies of EU-funded projects are given in the document Guide to Cost-benefit Analysis of Investment Project - Economic appraisal tool for Cohesion Policy 2014-2020 (EU, 2015).

The 2014 general guidelines have recently been upgraded in the new document Economic Appraisal Vademecum 2021-2027 - General Principles and Sector Applications (EC, 2021).

Since both documents together form a whole, we call them both together the EU CBA methodology in the following text.

The EU CBA methodology defines a cost-benefit analysis approach in an open way that allows the application of a general methodology to all kinds of projects. The EU CBA methodology is sufficiently open and allows a complete adaptation of all the specific procedures foreseen by the MAR methodology. This feasibility study is completely aligned with the EU CBA methodology.

In addition to general guidance, the EU CBA methodology develops a tailor-made approach to cost-benefit analysis for specific areas that are most often funded by EU funds and which have certain specificities. Among these specific areas, we can also find the area of water supply. The tailor-made approach for the water supply area is completely applied in this feasibility study.

In this feasibility study, we use discount rates as they are defined by the EU CBA methodology: 4 % financial discount rate and 5 % economic (social) discount rate. Member States may define national discount rates by themselves; the Republic of Croatia has not defined its discount rate. Therefore, general discount rates determined in the EU CBA methodology are used for the projects in Croatia.

The financial discount rate expresses the opportunity cost of capital. The opportunity cost of capital is the cost resulting from the decision to invest in one project rather than another (alternative). The loss on the first project compared to the second (alternative) represents an opportunity cost. Conversely, the gain on the second project compared to the first represents an opportunity gain of capital. Thus, the financial discount rate is used in the procedures for assessing the benefit of a particular investment option.

We use the social discount rate in the economic (social) analysis of the project. Public investment impacts GDP and the value of the social discount rate draws attention to the necessary (or target) difference in future inflows and outflows to be achieved by exploiting public investment. In this respect, the higher value of the social discount rate requires a greater difference in future public inflows and outflows to justify the public investment. In comparison, the lower value of the social discount rate requires a smaller future difference in public inflows and outflows. Different countries apply different social discount rates, but most agree that it is necessary to apply its lower value for developed countries. In comparison, developing countries need a higher discount rate value. A method is based on the economy's long-term growth rate and has been adopted in the European Union. The following parameters are used to calculate it: the growth rate of public expenditure (g), demand elasticity (n), and the money time preference rate (p), based on which the social discount rate (SDR) is calculated: $SDR = ng + p$.

For the new programming period, 2021-2027, the social discount rate has been recalculated. Accordingly, the latest EU CBA guidance proposes to the Member States, which do not have defined a national social discount rate, to apply a 3 % social discount rate to projects in 2021-2027.

Given the numerous assumptions and estimates that we had to use due to the uniqueness of this pilot project, this feasibility study is prepared based on a previous, more conservative 5 % social discount rate.

3.3. Other methodological approaches

To develop this economic and ecological part of the pilot feasibility study, we have two high-quality methodologies (EU, 2015; EC, 2021; i.e. EU CBA methodology) that complement each other, covering all the elements of the feasibility study and cost-benefit analysis, including all the specificities of the pilot MAR project.

In assessing the economic (social) costs and benefits, we have additionally used methodological guidance "Evaluating the Impact of Nature-based Solutions - A Handbook for Practitioners" and appendix to the manual: "Evaluating the Impact of Nature-based Solutions - Appendix of Methods" (European Commission, Directorate-General for Research and Innovation, March 2021).

In addition, the study uses the insights from scientific papers that describe experiences and provide data on individual projects and/or research results, for example:

- Damigos et al., 2016: Demonstrating Managed Aquifer Recharge as a Solution to Water scarcity and Drought — Economic Analysis of MAR Technologies;
- Damigos et al., 2016: Revealing the economic value of managed aquifer recharge: Evidence from a contingent valuation study in Italy;
- Dandy et al., 2013: Managed Aquifer Recharge and Stormwater Use Options: Net Benefits Report;
- Khan et al. (2008): Estimating potential costs and gains from aquifer storage and recovery program in Australia;
- Todd (1964): Economics of ground water recharge;
- Maliva (2014): Economics of Managed Aquifer Recharge;
- Megdal et al. (2015): Policy and Economics of Managed Aquifer Recharge and Water Banking;
- Hunt et al. (2006): Sustainable water supplies? A feasibility study for Birmingham Eastside;
- Ross et al. (2018): Factors affecting the cost of managed aquifer recharge (MAR) schemes.

Another study carried out as part of the MARSOL project was used as a methodological framework: "Demonstrating Managed Aquifer Recharge as a Solution to Water scarcity and Drought - Economic Analysis of MAR Technologies" (Final Report, Deliverable D15.2; 2016.).

4. Regulatory framework

4.1. Legislative and strategic framework

EU level

- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy,
- Decision 2455/2001/EC of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC
- Commission Decision of 17 August 2005 on the establishment of a register of sites to form the intercalibration network in accordance with Directive 2000/60/EC of the European Parliament and of the Council (C(2005) 3140) (2005/646/EC)
- Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment
- Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption
- Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast)
- Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration

National level

- Water Act (OG 66/19, 84/21)
- Law on Water for Human Consumption (OG 56/2013, 64/15, 104/2017, 115/18, 16/20)
- Regulation on water quality standards (OG 96/19)
- Ordinance on conditions for determination of wellfield area sanitary protection zones (OG 66/11, 47/13);
- Ordinance on limit values of wastewater emissions (OG 26/20)
- Ordinance on compliance parameters, methods of analysis, monitoring and safety plans for human consumption, and procedure for keeping a register of legal entities performing public water supply activities (OG 125/17, 39/20)
- Ordinance on sanitary, technical and hygienic, and other conditions to be met by water supply facilities (OG 44/14)
- Regulation on cost-effective criteria for water suppliers (OG 112/10)
- Regulation on the minimum basic price of water services and the type of costs covered by the price of water services (OG 112/10)

Strategic framework

EU level

- Europe 2020 strategy;
- The Green Deal;
- The European Union Recovery Plan (Next Generation EU);

- Communication from the Commission to the European Parliament, the Council, the European Economic, and Social Committee, and the Committee of Regions – forgoing a climate-resilient Europe – the new EU Strategy on Adaptation to Climate Change; Com(2021) 82 final, 24.2.2021.

National level

- National Development Strategy of the Republic of Croatia up to 2030;
- National Recovery and Resilience Plan of the Republic of Croatia 2021-2026;
- Spatial Development Strategy of the Republic of Croatia (2017);
- Water Management Strategy (2009);
- Climate change adaptation strategy in the Republic of Croatia for the period up to 2040 with a view to 2070;

Another crucial strategic framework will be the Operational Programmes 2021-2027, but they have not been adopted yet. At its session on 5 November 2020, the Government of the Republic of Croatia adopted a Decision on Operational Programmes related to Cohesion Policy for the EU programming period 2021-2027 in the Republic of Croatia and the authorities in charge of their preparation:

- Operational Programme (OP) Competitiveness and Cohesion 2021-2027; funded by the European Regional Development Fund and the Cohesion Fund,
- Operational Programme (OP) Efficient Human Resources 2021-2027; funded by the European Social Fund Plus,
- Integrated Territorial Programme 2021-2027 (ITP) funded by the European Regional Development Fund, the Cohesion Fund, and the Just Transition Fund.

OP Competitiveness and Cohesion 2021-2027 and OP Efficient Human Resources 2021-2027 represent a continuity from the previous programming period. The establishment of the Integrated Territorial Programme 2021-2027 (ITP) in the new programming period brings new possibilities to financing local and regional initiatives according to the identified needs. The main characteristic of this programme is the focus on regional growth and development.

In addition, a Partnership Agreement for the programming period 2021-2027 between the Republic of Croatia and the European Commission is under preparation.

The pilot project is also aligned with the following national strategic frameworks from the previous programming period, which are still relevant due to the delay in adopting the new ones:

- The Regional Development Strategy of the Republic of Croatia for the period up to the end of 2020,
- Strategy for the development of entrepreneurship in the Republic of Croatia 2013-2020,
- Industrial Strategy of the Republic of Croatia 2014-2020,
- The Tourism Development Strategy of the Republic of Croatia up to 2020 (the Sustainable Tourism Development Strategy for 2030 is under development).

Regional and local level

- Development strategy of the city of Vis 2021-2027;
- Strategic Development Programme of the city of Komiža for the period 2015-2020;
- Komiža - Smart City, Smart City Development Strategy (draft, the final version of the document is under development);

- Strategic documents of water supply company on the island of Vis (Vodovod i odvodnja otoka Visa d.o.o.);
- Development and business strategy of the company Vodovod i kanalizacija d.o.o. Split for the period from 2019 to 2030.

5. Characterization of the pilot site

Under the DEEPWATER-CE project, a transnational toolbox to support decision-making on identifying potentially suitable MAR locations in Central Europe has been developed (document D.T2.4.3 Transnational Decision Support Toolbox for designating potential MAR locations in Central Europe). Based on this toolbox, suitable pilot sites with the appropriate MAR methods can be identified (document D.T3.6.1 Report on the Desk Analysis of the pilot feasibility study for MAR deployment in fractured and karstified aquifers located in semiarid karst areas).

The MAR site selection process has been based on the assessment of geological and hydrogeological conditions, current and future (modeled) climate conditions, and the exposure and sensitivity of different MAR types to climate extremes. In order to find suitable MAR sites, detailed information on geological, hydrogeological, and climatological criteria have been collected and implemented within geographical information system (GIS) databases.

A four-step procedure has been developed for the decision-support toolbox for the investigation of MAR suitability (document O.T2.1 Transnational Decision Support Toolbox for designating potential MAR locations in Central Europe).

In Croatia, the pilot area of the island of Vis has been selected. This is a semiarid karst area, which, due to its specificities, is a perfect area for establishing MAR. The available groundwater resources cover the water demand of the domestic population. However, demand increases significantly during the summer due to intensive tourism (by five to as many as six times). Vulnerable and limited groundwater resources, together with increasing seasonal demand and uncertain climate future, make this island an excellent candidate for assessing the suitability of MAR. In addition to increasing tourist activity, there is a strong need for alternative solutions in the water resources management on the island due to increased seasonal demand, climate changes, and high seasonal rainfall variability.

The concept of applying the MAR scheme on the island of Vis is primarily focused on the two most promising methods: infiltration ponds method and aquifer storage and recovery (ASR) method which have been identified by applying the toolbox O.T2.1. The suitability maps developed by the application of the toolbox and related methodology can be accessed via the IGRAC platform (https://ggis.un-igrac.org/maps/2171/embed). Other MAR methods are not suitable for application on the island of Vis because there are no surface water bodies on the island.

The island of Vis is suitable for the application of MAR according to all the criteria that are analyzed in detail in the desktop analysis (document D.T3.6.1 Report on the Desk Analysis of the pilot feasibility study for MAR deployment in fractured and karstified aquifers located in semiarid karst areas; see Annex 2).

The Korita wells supply the entire island of Vis. Therefore, in this pilot study, the whole island of Vis is defined as a pilot area (Figure 1). The Korita well field is located in the central part of the island of Vis. The Korita pumping site is conveniently located in terms of having enough land availability on-site for the potential construction of an accumulation structure, which would be utilized as a source of water for MAR. Furthermore, the availability of essential infrastructures such as roads, telecommunications, electrical power, and water distribution, and a high degree of security in terms of potential pollution sources are secured. This makes this site potentially very suitable for the application of the proposed MAR scheme.

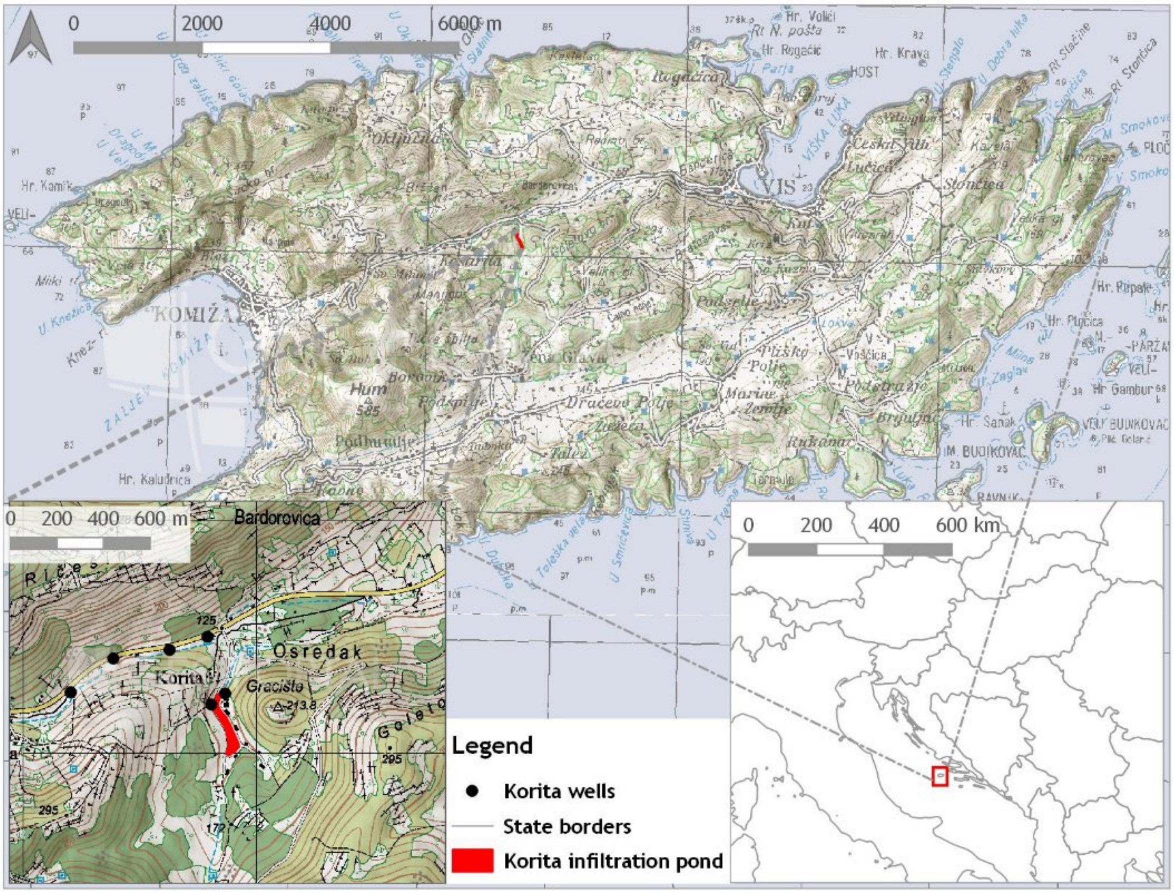

Figure 1. Location of the Korita area on the island of Vis

The analysis of the suitability of the pilot area within the DEEPWATER-CE project (report D.T3.6.1 “Report on the desk analysis of the pilot feasibility study for MAR deployment in fractured and karstified aquifers located in semiarid karst areas”, see Annex 2) has shown that the proposed location of the Korita area is appropriate according to all the analyzed criteria:

- surface topography,
- climate conditions,
- land use and potential sources of surface and groundwater contamination,
- hydrology,
- geology,
- hydrogeology and water supply.

Nevertheless, the authors of the desk analysis highlighted in the conclusions the complexity of investigating the suitability of MAR in the karst environment, which is mainly due to the high anisotropy and heterogeneity of karstic systems and also due to the relatively low number of implemented schemes on the global scale when compared to MAR schemes in the alluvial environments with intergranular porosity aquifers. Although it is possible to achieve a high degree of certainty related to the MAR suitability assessment, it is hard to provide a definitive judgment on suitability and efficiency in a karst environment without the operating test site or facility. As a consequence of their high heterogeneity, it is practically impossible to quantify the karst aquifer’s response (changes in chemical composition, flow and discharge patterns, and groundwater levels) to the injected/infiltrated water without detailed high-resolution monitoring of the numerous parameters.

5.1. Territorial, demographic, climatic, and economic aspects of the pilot area

Territorial aspects

The island of Vis is located in Split-Dalmatia County, which covers 14,106.40 km^2, of which the mainland with the islands is 4,523.64 km^2, and the sea area 9,576.40 km^2. The island of Vis spreads on 89.72 km^2, which ranks it in ninth place according to the size of the Croatian islands.

The island of Vis is located in the island area of Split-Dalmatia County, along with the islands of Palagruža, Biševo, Brusnik, Jabuka, and St. Andrew (Figure 2). This islands group belongs to the central part of the Adriatic coast of the Republic of Croatia. Along the island of Vis, the islands of Biševo, Jabuka, Svetac, Brusnik, Ravnik, Budikovac, Galiola, Palagruža, etc., are the furthest points of the Adriatic Sea, and their geographical position reduces their possibility in greater freedom of movement and transport connections.

Figure 2. The geographical position of the island of Vis

There are two larger cities on the island of Vis; the city of Vis in the northeast and the city of Komiža on the western part of the island. Other settlements are situated in the island's interior at the edges of the field, mainly along the old road Vis-Komiža: Podselje, Marine Zemlje, Podšpilje, Podstražje, Žena Glava, Podhumlje. In the southeastern part of the island, settlements Milna, Brgujac, and Rukavac are situated. The city of Vis consists of 11 settlements: Brgujac, Dračevo Polje, Marinje Zemlje, Milna, Plisko Polje, Podselje, Podstražje, Rogačić, Rukavac, Stončica and Vis. The settlements of the city of Komiža are: Komiža, Biševo, Borovik, Duboka, Oključna, Palagruža, Podhumlje, Podšpilje, Sveti Andrija and Žena Glava. The nearest sailing point from the city of Vis is towards the island of Hvar at a distance of 16 kilometers in the southwest direction. Vinišće on the Trogir coast is the nearest land point from the city of Vis, at a distance of 44 kilometers. From the county headquarters - the city of Split, the city of Vis is on a distance of 53 kilometers, with good traffic connections by ferry and catamaran lines that take place several times in the day.

Like all Dalmatian islands and coastline, the island of Vis belongs to the Mediterranean climate with hot summers. On average, the island of Vis has 2,650 hours of sun per year. This type of climate is also called the “Adriatic type” climate. Winters are mild and humid, while summers are hot and dry. The mean annual temperature, measured at the Hum weather station, is 16.8 °C. The warmest month of the year is July, while the coldest is January.

Small quantities of rainfall during the year are associated with a mild climate. The majority of the precipitation is in the autumn and winter period of the year, in which 2/3 of the total annual rainfall falls. Due to the small amount of rain, summer droughts are common. They cause damage to agriculture, which is one of the primary economic activities on the island. The lowest rainfall is recorded in the months of peak water consumption, which may cause difficulties in the drinking water supply.

Monthly precipitation data on the island of Vis (Komiža measuring station) in the last ten years are presented in Figure 3.

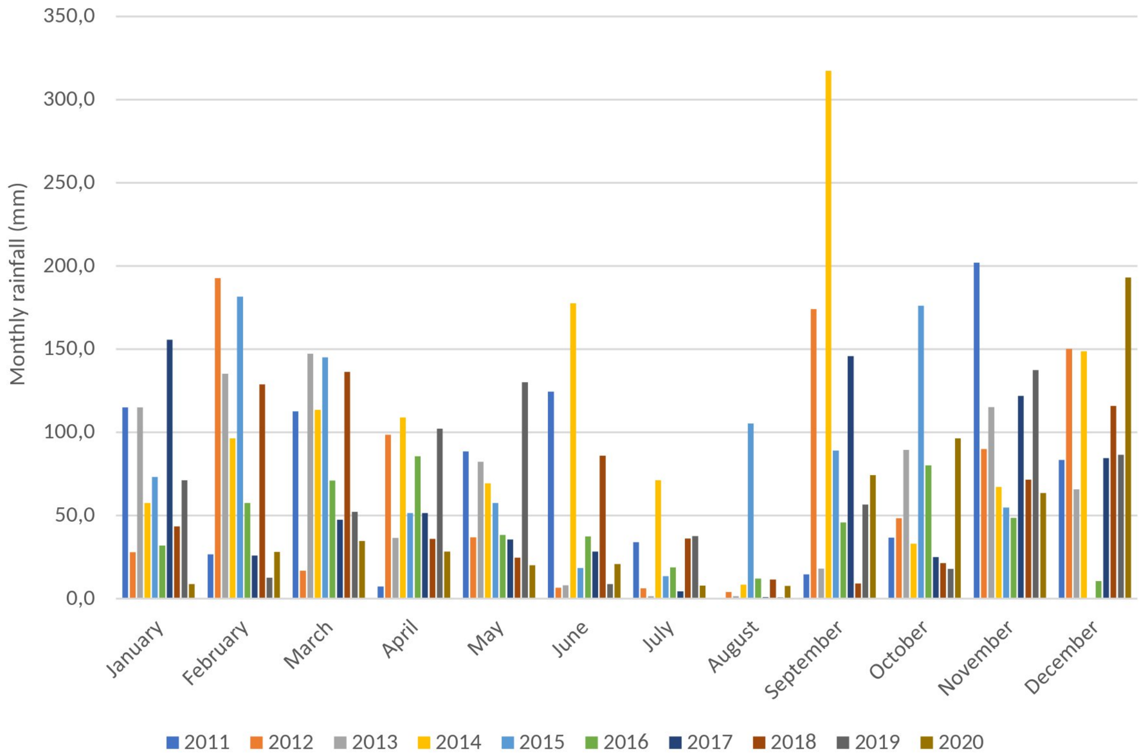

Figure 3. Monthly precipitation on the island of Vis, 2011-2021 (source: Croatian Meteorological and Hydrological Service / DHMZ)

The average annual rainfall on the island is between 600 and 700 mm in coastal areas and slightly higher in the inner parts of the island. If we look at the last ten years, we can see a decreasing trend in rainfall on the island of Vis (Figure 4).

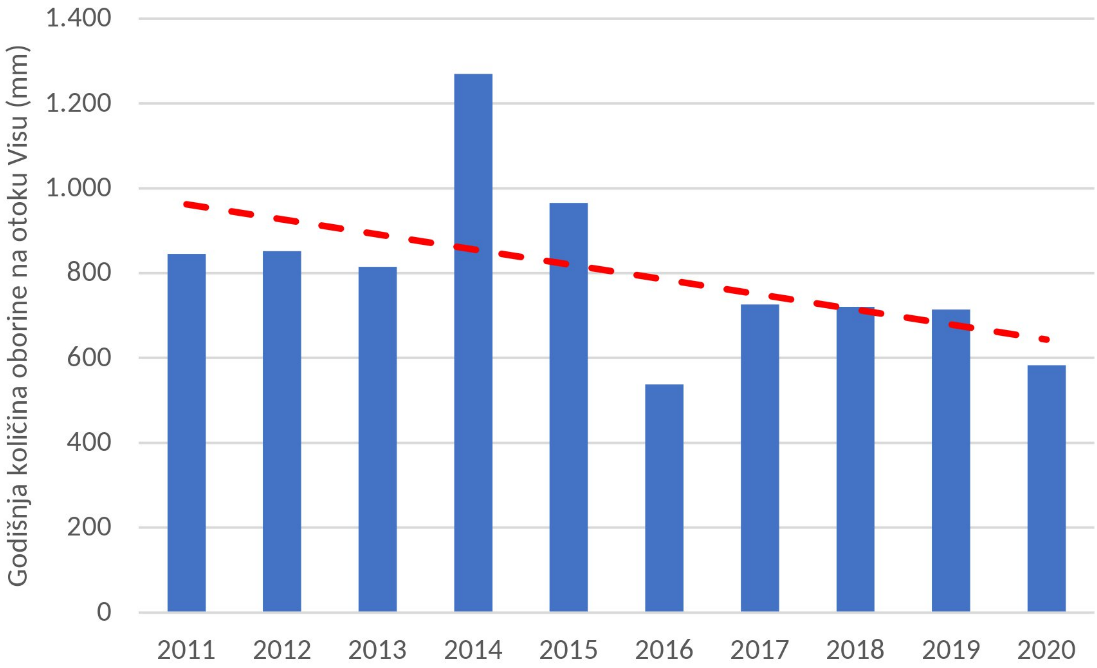

Figure 4. Annual precipitation on the island of Vis, 2011-2021 (source: DHMZ)

If we take a look at a longer period, we can see that the island of Vis is one of the areas of the Republic of Croatia with the lowest levels of rainfall (Figure 5).

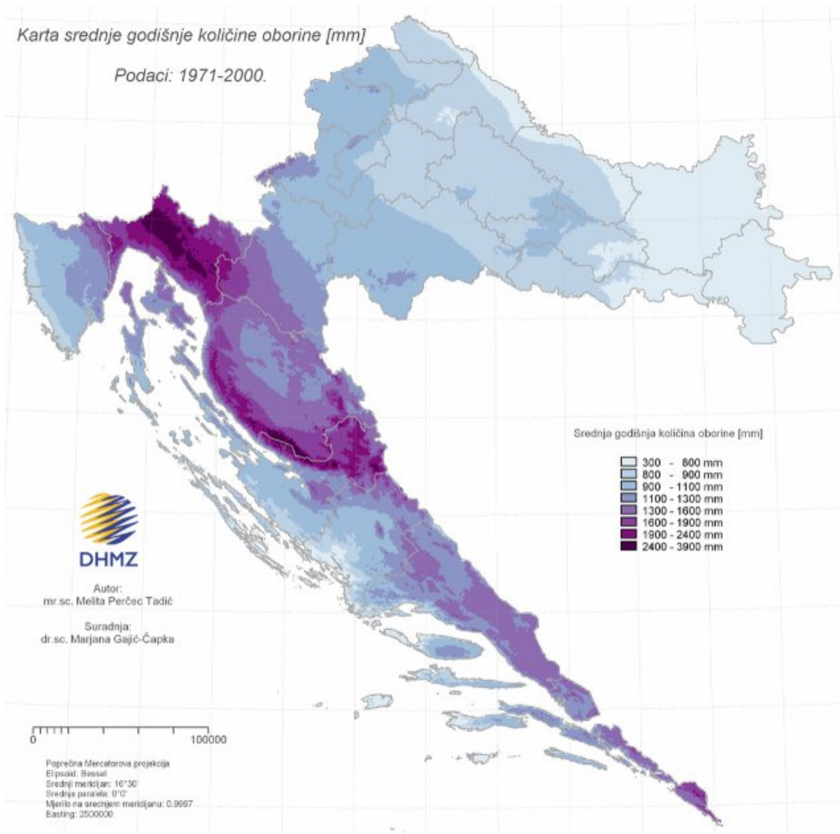

Figure 5. Map of average annual rainfall (mm), 1971-2000 (source: DHMZ)

On the maps of minimum and maximum annual air temperature in the Republic of Croatia, the island of Vis is one of the warmest areas in the country (Figure 6).

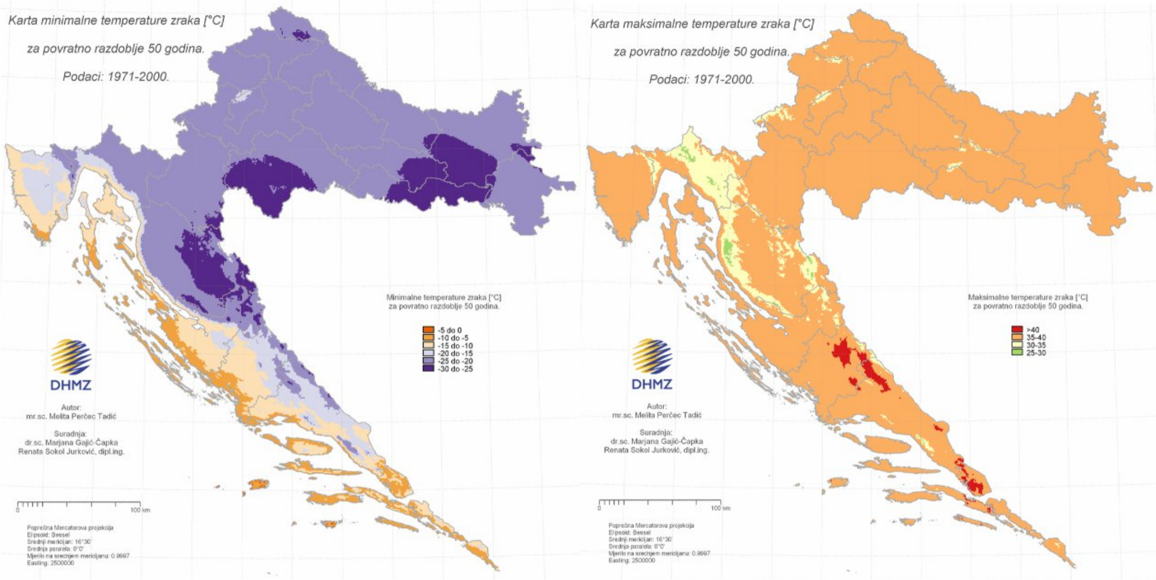

Figure 6. Maps of minimum (left) and maximum (right) air temperature (°C) in Croatia, 1971-2000 (source: DHMZ)

In the warm (summer) months of the year, a hot wind from the sea (south) usually blows, with occasional precipitation. Along with the south, another typical wind is *bura*, which generally occurs during the winter period and brings cold air while moving the cold winter front across the Adriatic to the southeast.

Demographic aspects

The last census in the Republic of Croatia was carried out in 2011, and according to these data, in 2011, the island of Vis had 3,460 inhabitants. The Croatian Bureau of Statistics continuously provides annual estimates about population. The estimates are based on the data from the last census and are upgraded with annual birth, death, and migration statistics. According to these estimates, the population of the island of Vis has been stable in recent years, and it is slightly increasing.

Figure 7. shows the data collected in the last two national censuses (2001 and 2011) and the Croatian Bureau of Statistics estimates for the years between both censuses and after the last census.

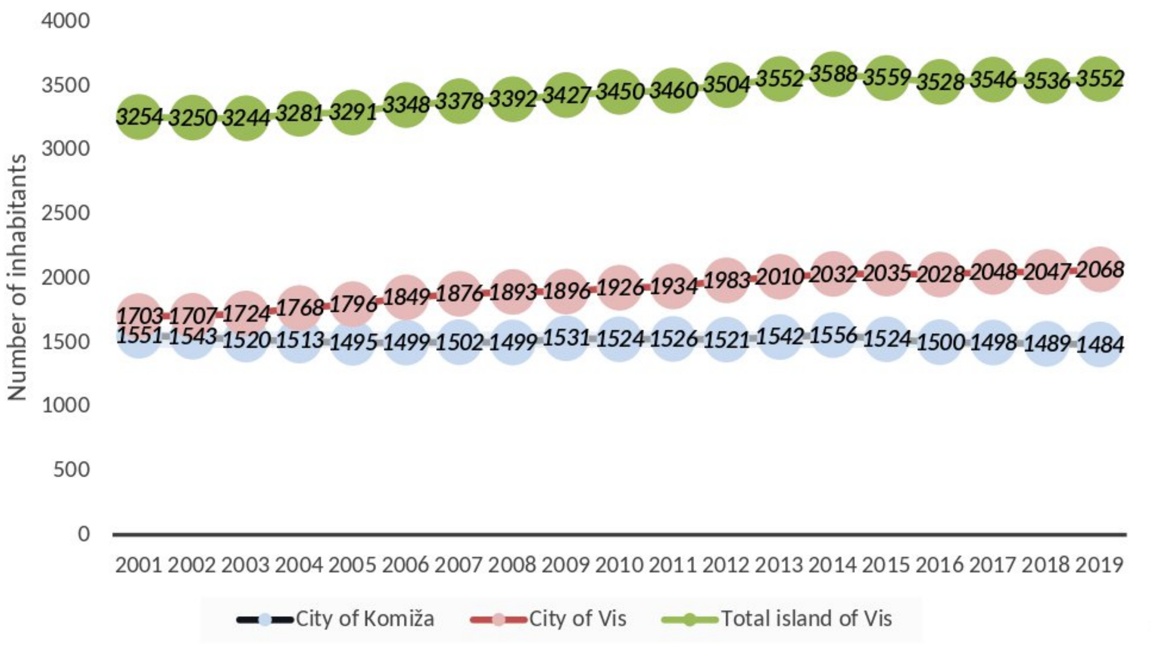

Figure 7. Number of inhabitants of the island of Vis, 2001-2019 (source: Croatian Bureau of Statistics / DZS)

According to the latest estimates of the Croatian Bureau of Statistics, at the end of 2019, the island of Vis had 3,552 inhabitants, which represents an increase of 9.16 % compared to 2001 and 2.66 % compared to 2011. On the other hand, in 2001-2019, the Republic of Croatia recorded an 8.55 % population decline. Split-Dalmatia County had a 3.35 % population decline in the same period.

According to available historical statistics, the island of Vis had almost 10,000 inhabitants during the greatest prosperity of the island, i.e. during the Austro-Hungarian period (from 1900-1921) (source: Settlements and Population of the Republic of Croatia 1857–2001, CBS, Zagreb, 2005).

The population density on the island of Vis is below average (Table 1), compared to national and regional statistics.

Table 1. The population density in Croatia

Geographical area	Population per km^2
Republic of Croatia	72.0
Split-Dalmatia County	99.0
Island of Vis	39.6

Due to the age structure of the population, the island of Vis has negative demographic statistics with negative birth rates (Figure 8).

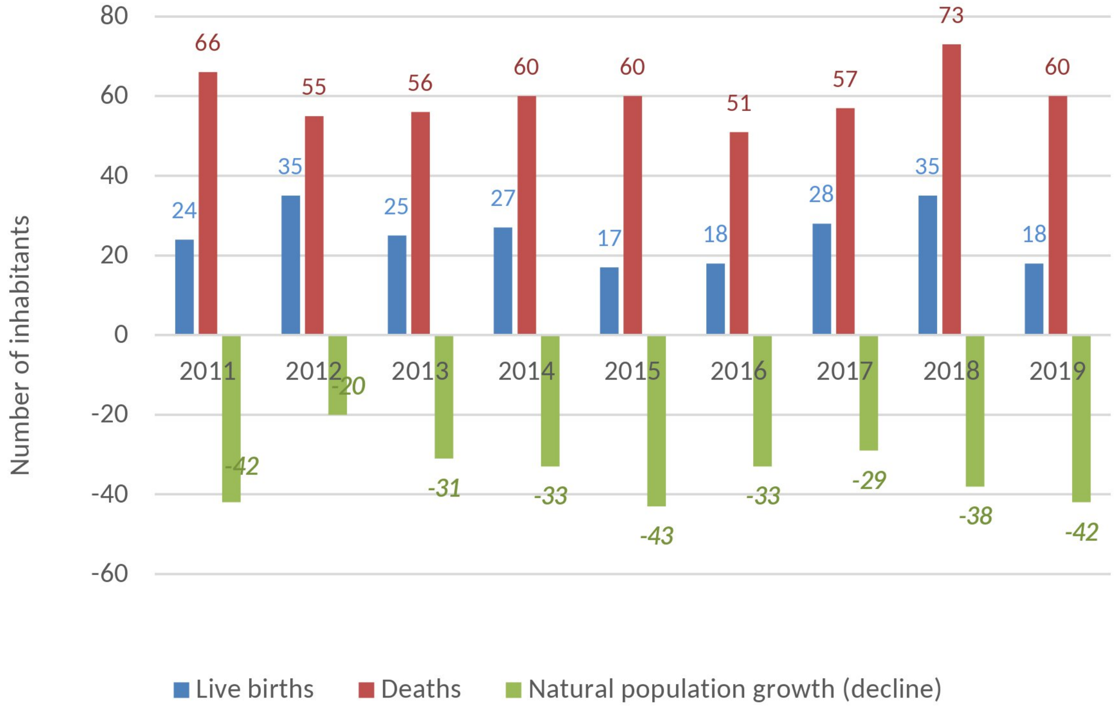

Figure 8. Negative natural population growth on the island of Vis

We have analyzed the population's age structure using the following indicators: aging index, age coefficient, and average age of the population. We have compared the data for the island of Vis with the data for the Republic of Croatia and Split-Dalmatia County. The results are shown in Table 2.

Table 2. Population age indicators

Geographical area	**Aging index**	**Age coefficient**	**The average age of the population**
Republic of Croatia	2001: 90,7 2011: 115,0	2001: 21,6 2011: 24,1	2001: 39,3 2011: 41,7
Split-Dalmatia County	2001: 77,8 2011: 102,3	2001: 19,9 2011: 23,1	2001: 38,1 2011: 40,8
Island of Vis - City of Komiža	2001: 141,9 2011: 186,5	2001: 29,2 2011: 30,7	2001: 43,5 2011: 46,0
Island of Vis - City of Vis	2001: 174,9 2011: 203,3	2001:.32,9 2011: 34,8	2001: 45,2 2011: 46,8

The aging index shows the proportion of inhabitants over 60 years old compared to those under 20 years old.

The age coefficient shows the share of inhabitants over 60 years of age in the total population.

The city of Komiža has about 40 %, and the city of Vis has about 60 % of the island's total population.

The island of Vis does not have such a problem with migration statistics as it has with age statistics. Both towns, Komiža and Vis, have recorded positive migration statistics, also with the rest of the world; however, populations' age structure does not change into a positive trend. We could explain this in a way that the majority of the immigrated population are older ages and/or that the intensity of the immigration is too small to impact the overall age structure positively.

The pilot MAR project primarily aims to raise the quality of life of the local population and encourage people to see their future on the island of Vis. With the improvement of the quality of life on the island, young families will also be stimulated to come and organize their lives on the island of Vis.

Economic aspects

Development index

According to the Decision on the classification of local and regional governments (OG 132/17), Split-Dalmatia County belongs to group III of regional governments, which are, according to the value of the development index, located in the second half of the above-average regional governments by their development.

According to the Decision on the classification of local and regional governments (OG 132/17), the city of Vis belongs to group VII of local governments, which are, according to the value of the development index, located in the second quarter of the above-average local governments by their development.

According to the Decision on the classification of local and regional governments (OG 132/17), the city of Komiža belongs to group V of local governments, which are, according to the value of the development index, located in the last quarter of the above-average local governments by their development.

Following the Regulation on the development index (OG 131/2017), the following indicators are used to calculate the development index:

- the average income per inhabitant;
- the average original income per inhabitant;
- the average unemployment rate;
- the overall population migration,
- the level of education of the population (tertiary education);
- the aging index.

According to the latest calculations of the Ministry of Regional Development and EU Funds in 2018 (the calculations are for the period 2014-2016), the development index of the city of Vis is 106.270, which ranks the city of Vis at 84th place according to the development of local governments in the Republic of Croatia.

According to the latest calculations of the Ministry of Regional Development and EU Funds in 2018 (the calculations are for the period 2014-2016), the development index of the city of Komiža is 101.499, which ranks the city of Vis at 210th place according to the development of local governments in the Republic of Croatia.

For the period 2010-2012, the development index of the city of Vis was 101.81 and 93.95 for the period 2006-2008.

For the period 2010-2012, the development index of the city of Komiža was 86.60 and 87.83 for the period 2006-2008.

The comparison of the index values in time shows that both cities achieved significant growth in all indicators used to calculate the development index of local governments in the observed period (Table 3).

Table 3. Indicators of the development level of the city of Vis and city of Komiža and comparison to Split-Dalmatia County (reference period 2014-2016)

	city of Vis	city of Komiža	Split-Dalmatia County
Average income per capita	29,537.02	28,120.00	28,190.12
Average original income per capita	4,871.18	2,976.69	3,476.57
Average unemployment rate	0.1760	0.2086	0.1923
Overall population migration	109.68	100.07	99.75
Ageing index	203.3	186.5	102.3
Level of education (tertiary, age 20-65)	0.2383	0.1642	0.2472
Development Group	VII (local government)	V (local government)	III (regional government)

Source: Ministry of Regional Development and EU Funds.

Economy

An overview of the state of the economy within the feasibility study is essential in terms of identifying the possible effects of the implementation of the project on the economy of the island of Vis.

The economy of the island of Vis is based on tourism and tourism-related activities, and agriculture. We are analyzing the state of the economy on the island of Vis in 2019, with a quick reference to 2020 (due to the epidemic's impact on the economy, 2020 cannot be taken for a representative year).

According to Fina (Financial Agency), in 2019, there were 227 active entrepreneurs on the island of Vis (the same number was also in 2020) who employed 568 employees (in 2020, the number of employees fell to 491) and generated a total of 240.06 million HRK revenue (in 2020 the total turnover was 152.37 million HRK). All economic entities on the island of Vis are classified, according to their size, as micro and small enterprises. The largest number of active entrepreneurs on the island of Vis is registered in accommodation and food services (group I), i.e. 53 economic entities. By the number of entities in the individual group, a group I is followed by group G (wholesale and retail trade; repair of motor vehicles and motorcycles), group A (agriculture, forestry, and fisheries), group N (administrative and ancillary services), group L (real estate business) and C (manufacture industry) and others (Figure 9).

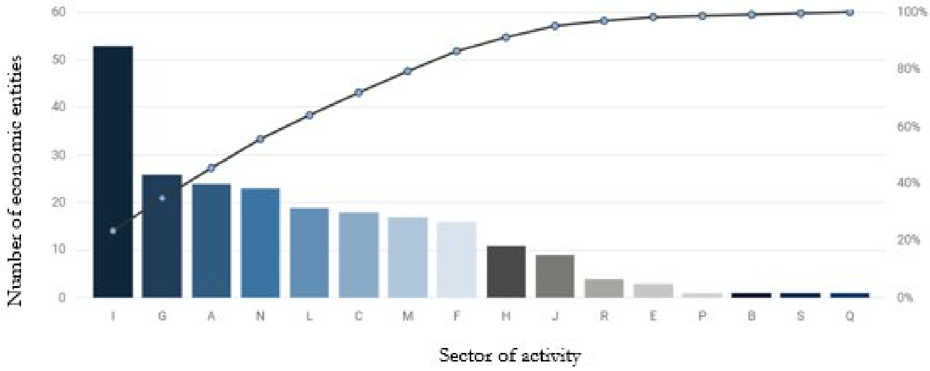

Figure 9. Number of economic entities on the island of Vis by the sector of activity, 2019

In 2019, economic entities in group I (accommodation and food services) generated the highest revenue, followed by group G (wholesale and retail trade; repair of motor vehicles and motorcycles) (Figure 10).

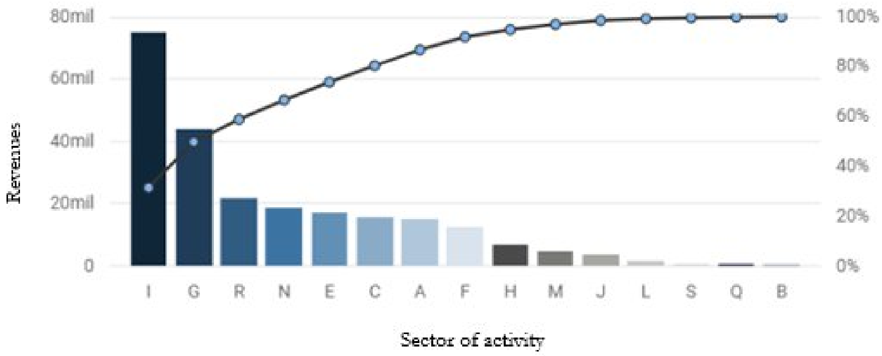

Figure 10. Generated revenues of economic entities on the island of Vis by the sector of activity

The highest number of people on the island are employed in group I (accommodation and food services). This activity employs one-third of all persons employed on the island of Vis. Group I is followed by a group that we can also, to a large extent, directly relate to tourism, namely the trade (wholesale and retail) and repair of motor vehicles and motorcycles (group G). In the third place, there is a water supply, wastewater disposal, waste management, and environmental remediation (group E). The manufacturing activities (group C) employ 42 people, and agriculture and fisheries (group A) only 37 people (Figure 11).

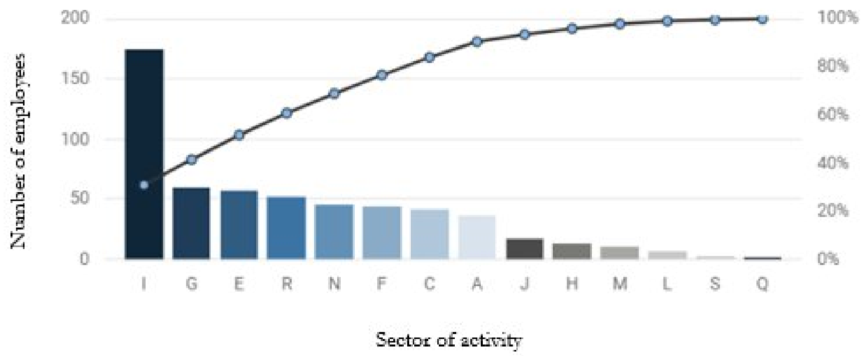

Figure 11. Number of employees in economic entities on the island of Vis by the sector of activity

Table 4. provides the overall data on the economic activity on the island of Vis.

Table 4. Overall data on economic activity on the island of Vis

Sector of activity		Number of economic entities	Number of employees	Revenues (million HRK)
A	Agriculture, forestry, and fisheries	24	37	15
B	Mining and quarrying	1	0	0.192
C	Manufacturing industry	18	42	16
E	Water supply; wastewater disposal, waste management and remediation activities	3	58	17
F	Construction	16	44	12
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	26	60	44
H	Transport and storage	11	14	7
I	Accommodation and food service activities	53	175	75
J	Information and Communications	9	17	4
L	Real estate business	19	7	2
M	Professional, scientific and technical activities	17	11	5
N	Administrative and support service activities	23	46	19
P	Education	1	0	0
R	Arts, entertainment and recreation	4	52	22
S	Other service activities	1	3	0.839
Q	Human health and social work activities	1	2	0.657

In economic terms, the implementation of this pilot project aims to encourage or even facilitate further tourist development on the island of Vis by improving the quality and comfort of stay. Tourism is one of the most interdisciplinary branches of the economy. It affects many other sectors; development reflects in sectors such as trade, construction, passenger transport, arts, entertainment and recreation, real estate, information, and communications, financial and insurance activities, administrative and supporting service activities, and other service activities.

It is important to emphasise that further development of tourism on the island is practically impossible without providing additional quantities of drinking water on the island.

The state of the economy on the island of Vis is generally positive, as evidenced by several indicators. Economic entities on the island of Vis generate cumulative net profits (in recent years, the exception is 2020, when the cumulative net loss of 2.80 million HRK was generated). Cumulative net profit in 2019 amounted to 25.88 million HRK. The total annual revenues of economic entities are steadily increasing by 61 % in 2019 compared to 2015. At the same time, the total expenditure of economic entities has grown by 42 %.

Agriculture

The agricultural activity and capacity of agriculture should be analysed mainly to find answers to two questions:

- First, is there a local unused agricultural capacity that can be activated through this project?
- Can the residents that are active in agriculture activities or will be in the future expect some benefits if this pilot project is implemented?

On the island of Vis, agriculture is an important economic branch. The spatial plans of the city of Vis and the city of Komiža protect agricultural areas from construction that could endanger their primary agricultural purpose. Similarly, on particularly valuable land, any construction other than the construction of hydro-melioration buildings and essential accompanying infrastructure is prohibited. It is possible to perform melioration works and implement agrarian parcelling measures to consolidate the property. Neglected agricultural areas are encouraged to be used while maintaining their traditional and natural structure, especially neglected terraced vineyards and olive groves.

The economic potential in this area is driven by the traditional agricultural activities (vineyards, building, olive growing, and to a lesser extent, the cultivation of southern fruit) and fisheries.

According to the Paying Agency for Agriculture, Fisheries, and Rural Development (PAAFRD), 13 farms operate in the form of a company on the island of Vis, 10 in the form of crafts, and 4 in the form of a self-supply farm (data on 31.12.2020). By the Paying Agency for Agriculture, Fisheries, and Rural Development register, on 31 December 2020, two agricultural cooperatives were active on the island of Vis. The most significant number of farms on the island are organised in the form of a family farm; according to the Paying Agency for Agriculture, Fisheries and Rural Development, there were 348 of them at the end of 2020 (there were 371 at the end of 2016).

According to the Paying Agency for Agriculture, Fisheries, and Rural Development, the total area of 1,553 available agricultural parcels on the island of Vis, which are owned by 348 individual owners, is 402.49 ha. The average size of available agricultural properties on the island of Vis is 3.86 ha (all of these data refer to 2020). According to the Paying Agency for Agriculture, Fisheries, and Rural Development, the available agricultural parcels are cultivated in a high percentage. The majority of cultivated agricultural areas on the island of Vis are vineyards (40.7 %), followed by olive groves (27.5 %) and arable land (7.7 %). In approximately equal percentages, the fruit plantations (6.6 %), meadows (6.3 %), karst pastures (5.4 %), and mixed perennial plantations (5.1 %) are present.

According to Fina's data, the economic entities in group A (agriculture, forestry, and fisheries) operate with a total net loss, which amounted to -290,749 HRK in 2019. The sector employs 37 people and generates a total of 15 million HRK of annual revenues.

The development of agriculture on the island is limited due to water scarcity when the water in agriculture is most needed. At the same time, it is a period characterised by the lowest rainfall on the island. The island has an average of 2650 hours of sun per year and exceptionally high-quality land in the mediocre parts of the island, making ideal natural conditions for growing seasonal summer fruit and vegetables. The local market is secured and is growing (local supply of increasing tourism, increasing awareness of the local population about the importance of local food).

The aim of this pilot project is not in providing water for agricultural irrigation. The project aims in providing drinking water for direct consumption by residents and guests of the island of Vis. Therefore, the project will not have a direct impact on the development of agriculture on the island.

Tourism

Both cities on the island, Vis and Komiža, are classified as tourist cities by the Law on membership fees in tourist boards (OG 152/08, 88/10, 110/15, 121/16) and the Ordinance on declaring tourist municipalities and towns and classifying settlements in tourist classes (OG 122/09, 9/10, 61/10, 82/10, 36/11, 89/11, 146/11, 141/12, 144/12, 38/13, 153/13, 126/15, 15/16, 54/16, 113/16, 26/17, 61/17, 72/17 and 78/17). Vis and Komiža (on the level of settlements) are both classified in tourist class A, while the city of Vis and the city of Komiža as a whole are classified in tourist class D. Some other settlements on the island are classified in tourist classes B and C.

The Law on membership fees in tourist boards (OG 152/08, 88/10, 110/15, 121/16) provides that municipalities and cities where at least one settlement has been classified in one of the tourist classes are designated as tourists municipality or city.

Tourist accommodation capacities on the island of Vis are based on private accommodation; out of a total of 5,683 beds in 2019, 4.563, i.e. more than 80 % of them are private accommodation. If we compare the historical data from only a few years ago, we can see a significant increase in the number of private accommodation capacities, which is a logical response to the growing demand for accommodation on the island of Vis (Figure 12).

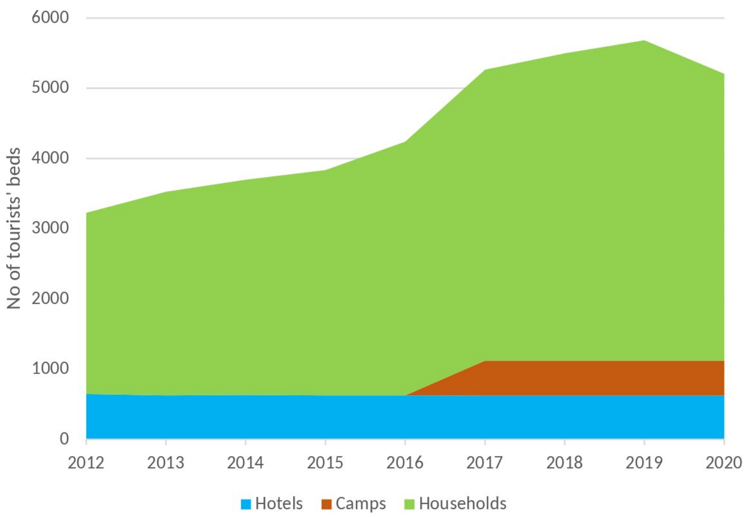

Figure 12. The tourist accommodation capacities on the island of Vis (2012-2020)(source: DZS)

The number of tourist arrivals and overnight stays on the island of Vis is steadily increasing, as shown in Figure 13.

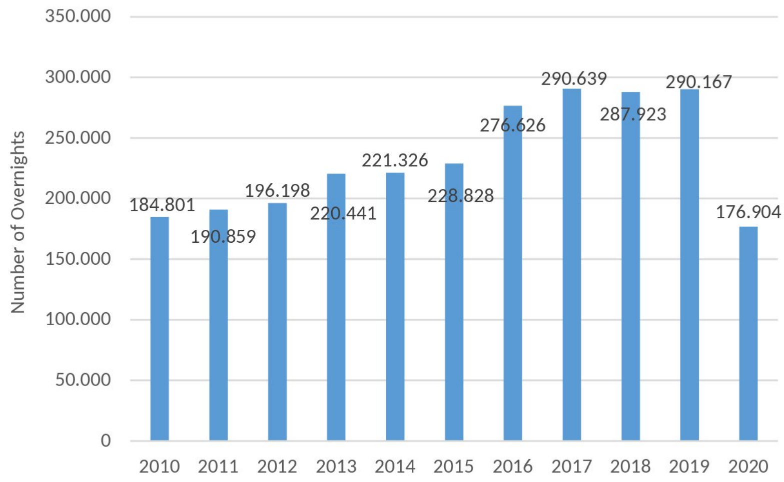

Figure 13. The number of touristic overnights on the island of Vis (2010-2020)(source: Tourist Board of Split-Dalmatia County).

Between 2010 and 2019, the island of Vis recorded an increase of almost 60 % in the total number of tourist overnight stays. In the same period, there was nearly a 90 % increase in the number of tourist arrival, shown in Figure 14.

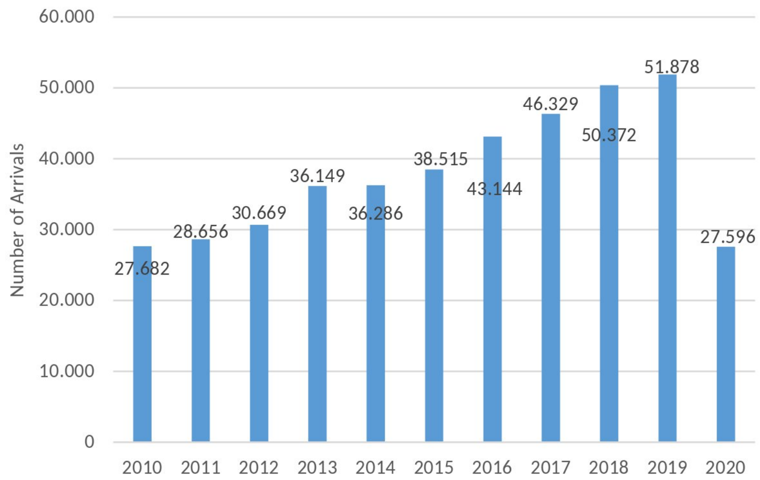

Figure 14. The number of touristic arrivals on the island of Vis (2010-2020) (source: Tourist Board of Split-Dalmatia County).

In the total number of tourist arrivals in 2019, foreign guests represent 71.5 %, and the remaining 28.5 % are domestic guests.

Throughout the observed period, the island of Vis remains a tourist destination with an average stay of about six days (Figure 15).

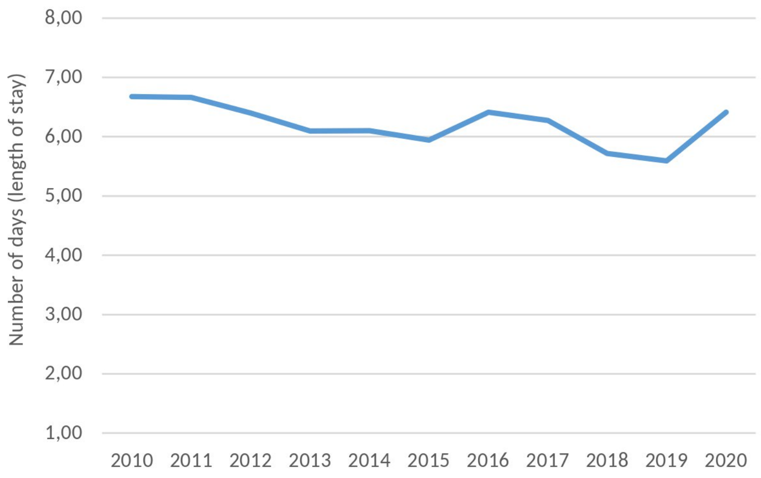

Figure 15. The average length of tourists' stay on the island of Vis (2010-2020) (source: Tourist Board of Split-Dalmatia County)

Tourism on the island of Vis is extremely seasonal. Private accommodation in households, accounting for more than 80 % of all tourist capacities, is in most cases not suitable for off-season stays. With only 11 % of the total islands' accommodation capacity, both hotels on the island are closed in the off-season.

In the current situation, water reductions in the summer period are expected, which is a significant obstacle to the development of tourism, especially the one that is not based on mass tourism but the quality of services. The implementation of this pilot project would ensure a certain autonomy of the island of Vis in the water supply and the elimination of difficulties in the summer months. This is necessary for the development of certain types of tourism with greater added value, and at the same time to improve the quality of stay for every tourist on the island. Increasing the attractiveness of the island as a tourist destination brings benefits that have been introduced into the benefit estimation.

Unemployment and employment

According to the latest estimates of the Croatian Bureau of Statistics, the city of Vis has 2,068 inhabitants, and the city of Komiža has 1,484 inhabitants; the total population is 3,552 inhabitants (all figures are for 2019).

The Croatian Bureau of Statistics has last observed the overall picture of the population's economic activity by the methodological rules and principles of the International Labour Organisation (ILO) in the 2011 census.

Another method of measuring unemployment refers to the evidence of unemployed registered at the Employment Service. Unemployment that is measured by this method is so-called registered unemployment. According to the Croatian Employment Service methodology, the annual unemployment data refer to the annual average calculated using the arithmetic mean method based on monthly data. Following this method, there were 231 unemployed persons on the island of Vis in 2020. One year earlier, in 2019, the number of unemployed persons was 189.

The chart in Figure 16. shows the number of unemployed persons on the island of Vis in the period 2004-2020.

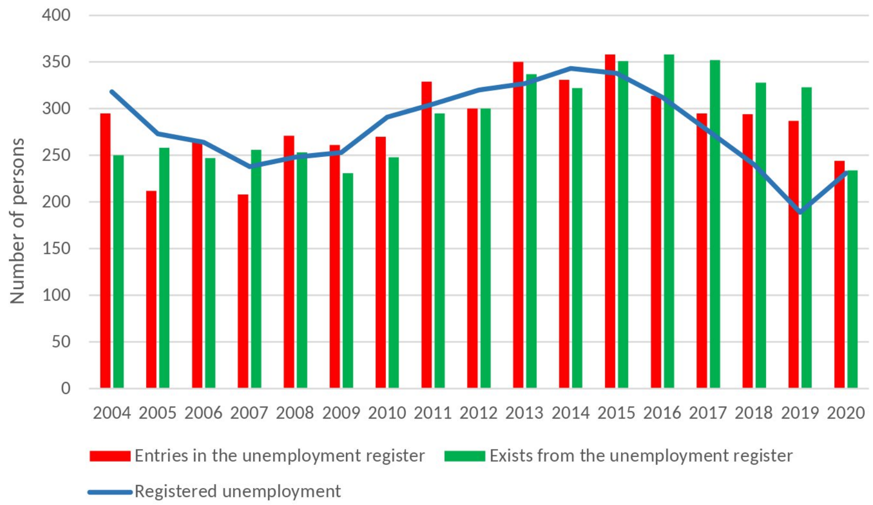

Figure 16. The number of unemployed persons (registered unemployment) on the island of Vis, 2004-2020 (source: HZZ)

The trend in unemployment is consistent with the overall economic situation; during the economic crisis, the number of unemployed is increasing, and vice versa, during the economic prosperity, the unemployment decreases. Reductions in the number of unemployed can also be a consequence of emigration.

The unemployment trend on the island of Vis is consistent with the general trend on the regional level, i.e. in Split-Dalmatia County.

According to the data that are used by the Ministry of Regional Development and EU Funds to calculate the development index at the local and regional level, the average rate of (registered) unemployment in the period 2014-2016 in the city of Vis was 17.60 %, in the city of Komiža 20.86 %, while on the regional level (Split-Dalmatia County) it was 19.23 %.

In addition to improving living conditions on the island of Vis, this pilot project's implementation can also enhance the conditions for economic activity, mainly in the tourism sector with all related activities.

5.2. Analysis of water supply and demand

5.2.1. Water supply system on the island of Vis

On the island of Vis, water is extracted from local wells in the central part of the island, which can be reached by drilling. Water capacities are critical during the summer due to drought and low rainfall, and in the same period, the island faces the highest water demand. Unlike other islands, the island of Vis (for now) meets its own need for water due to its natural water resources. Water supply is managed by the utility company Vodovod i odvodnja otoka Visa d.o.o.

The water supply system on the island of Vis is described in detail in the DEEPWATER-CE project document D.T3.4.1. “Report on the desk analysis of the pilot feasibility study for MAR deployment in fractured and karstified aquifers located in semiarid karst areas” (see Annex 1).

The water supply system on the island of Vis consists of Korita well field, K-1 well, and Pizdica spring. The main contamination source of the Vis karst aquifers and their water supply is the seawater intrusion. The sole recharge of the island's aquifer is precipitation.

Korita well field is the central object of the water supply system on the island. It was constructed in the late 1960s and consists of a pumping station and six wells (BO-1, BO-2, BO-3, BO-4, BO-5, BO-6), but only the first five are active for water supply. Figure 17. shows the basic characteristics of the Korita well field.

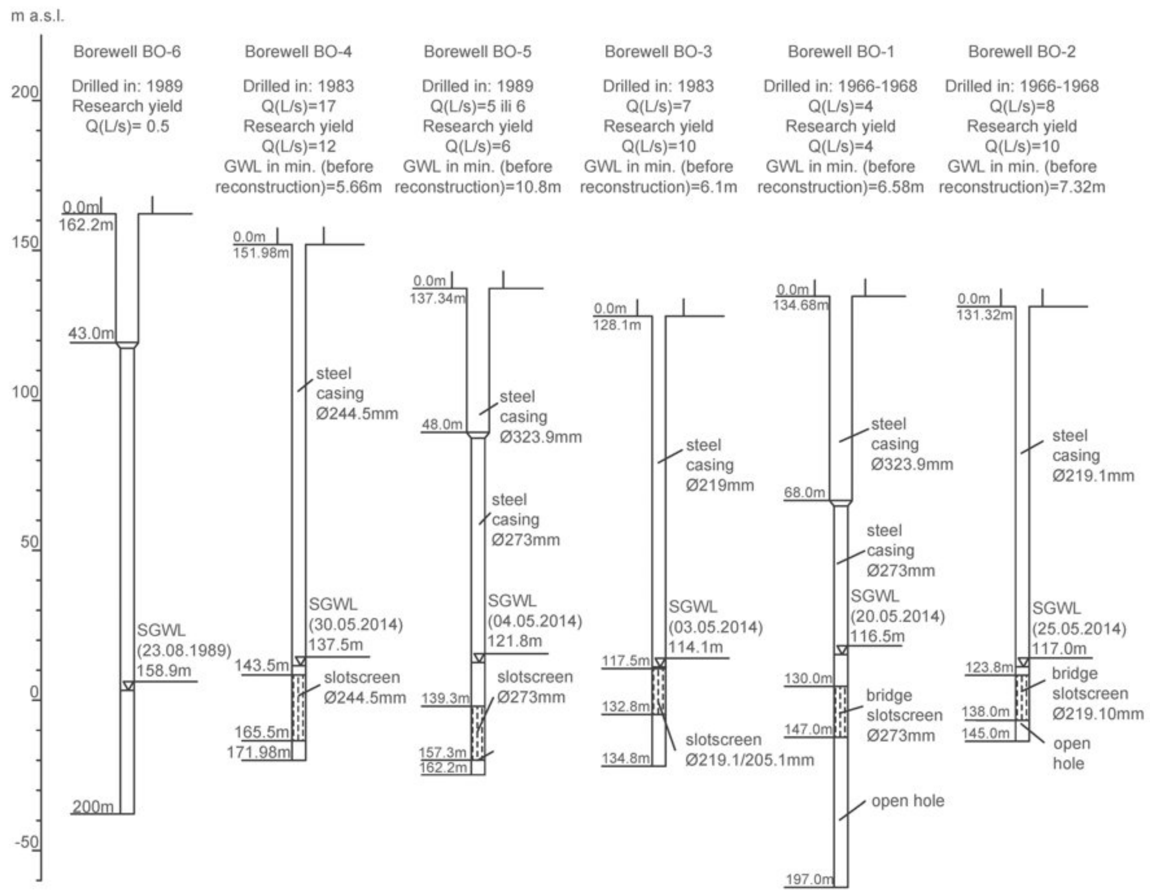

Figure 17. Schematic overview of the Korita wells (Terzić et al. 2022)

The Korita well field is located in the central part of the island along the road Vis-Komiža. The water is abstracted from the karst aquifer from a depth of approximately 120 m. The maximum pumping quantity is 42.5 l/s. The minimum overall water yield of all wells in the Korita is 27 l/s. The groundwater is abstracted with special well pumps and pressure pipelines to the pumping pool and is distributed to the consumers. Disinfection of water is carried out by chlorination on distribution pipelines at the exit from the pumping pool. Water distribution takes place in three directions:

- direction Komiža (pressure pipeline),
- direction Vela glava (pressure pipeline),
- direction Vis (gravity pipeline).

Pizdica is a small coastal source with an average pumping rate of 4 l/s. As this is the coastal spring at sea level, the spring is prone to increased salinity and concentration of chlorides. The water from Pizdica is pumped mainly during the summer months when the demand increases by a factor of five due to intensive tourism. Due to increased salinity, water from Pizdica and Korita is mixed in the ratio of ¼ before the distribution to the consumers to keep the chloride content below the maximum levels allowed for human consumption.

The K-1 well, located in the hinterland of Komiža, is the newest well and its pumping rates are up to 1.5 l/s. Despite its low yield, it is very important because it is not prone to salinization.

In the western part of the island, there are several small springs (the most relevant are Gusarica, Dragevode, and Kamenice springs) that have been utilized since ancient times.

The configuration of the terrain and the spatial layout required the construction of a water supply network with a large number of water reservoirs and braking chambers. The water supply network is built mainly of asbestos-cement tubes and partly out of steel. The water quality at the pumping station is good, and the water salinity is below the allowed value. Equipping the system with measuring and control devices makes it possible to monitor the operation and manage the system, which is very important for knowing the mechanisms and processes of natural underground accumulation.

5.2.2. Analysis of the water supply

We can define the supply in the context of water supply with multiple perspectives. Namely, as a supply, we can consider the entire amount of water on the island. However, this category is neither known nor means much in terms of the quantities available. We could also define the water supply using a parameter derived from the hydrological balance. However, this is a potential quantity that we can only theoretically consider as a supply. The third option is to define a supply within the limits of the current sustainable abstracted amount of water. However, again, we only have approximate data that probably amounts to about 350,000 to 500,000 m^3 per year. The fourth option to define supply, which is the option that we are interested in in this study, is the amount of water available to the MAR scheme when it is put into operation. To define (estimate) the supply in these frames, a hydrological balance has been elaborated.

In the final report of D.T3.6.2 “Report on the field work of the pilot feasibility study for mar deployment in Split-Dalmatia County semiarid karst region” (see Annex 3), prepared in the DEEPWATER-CE project, the following parameters have been observed as key parameters defining the potential water supply:

- air temperature (determined by latitude, altitude, and other factors such as place exposure, cloudiness, vegetation, etc.),
- precipitation (defined by latitude, sea vicinity, field configuration, etc.)
- evaporation and runoff.

These parameters have been analyzed in the abovementioned report. Based on them, parameters for estimating the effective precipitation, i.e. runoff for the analyzed pilot areas on the island of Vis, have been calculated. The report analyzed the pilot area “Korita” and the pilot area “Pizdica”. This feasibility study is being prepared for the pilot area “Korita”.

In Table 5 the summary of the calculated parameters is shown:

Table 5. Input parameters for the assessment of runoff for the pilot area "Korita" on the island of Vis (1961-1990)

Basin	Unit of measurement	Value
Basin surface	(km^2)	18.45
Average altitude	(mm)	255
Average annual precipitation quantity	(mm)	951
Mean annual air temperature	(°C)	14.1
Average annual runoff - Turc	(m^3s^{-1})	0.193

Average annual runoff - Langbein	(m^3s^{-1})	0.120
Annual runoff coefficient - Turc	/	0.35
Annual runoff coefficient - Langbein	/	0.22
Regional annual runoff coefficient for Hellenic karst – according to (Žugaj, 1995)	/	0.34

The D.T3.6.2 report concludes that there are relatively small quantities of average annual discharges (runoff) as well as average annual runoff coefficients. The reason for this lies in the island's natural specific characteristics with a relatively small amount of annual precipitation but with relatively high air temperatures. Values obtained according to Turc method (0.35) practically match regional runoff coefficient values for Hellenic karst (Žugaj, 1995) (0.34), thus when implementing the assessment of the impact of climate changes on runoff, evapotranspiration assessment results according to Turc (1954) are used (i.e. 65%).

The current maximum capacity of the Korita pumping site pumping area (about 40 l/s or 0.04 m^3s^{-1}) has a water intake of about 20% of the average annual runoff from the catchment. The realistic value is significantly lower because maximum pumping capacity occurs only during the summer months when pumps are operating throughout the day and night.

5.2.3. Projection of future trends in the water supply on the island of Vis

The report D.T3.6.2 (see Annex 3) presents the generated climate time series up to 2100 and the generated time series of average annual runoffs up to 2100. In the simulation of average annual temperatures and annual precipitation up to 2100, three climate models were used: Aladin, RegCM, and Promes. The Promes model enables forecasts to 2050 only.

The generated time series of average annual temperatures across all three models show a rise in temperatures to the middle (Promes), i.e. to the end (Aladin and RegCM) of the 21st century, while precipitation shows a generally slight decrease. According to the Aladin model, a further increase in the average annual air temperature of 2.1 °C by the end of the century, i.e. 2.9 °C according to the RegCM, can be expected. By the middle of the 21st century, the Promes model showed an average temperature increase of 1.2 °C compared to the current (1991-2020). As for precipitation, the Aladin model shows reduced precipitation in Komiža by about 14 % by the end of the 21st century, while the RegCM model shows a slight increase in annual precipitation of about 2 %. By mid-century, the Promes model indicates a 7 % decrease in annual precipitation.

The averaged annual runoffs generated until 2100 by both the Aladin and RegCM models show a continuous decrease in average annual runoffs for the Korita area. The Aladin decrease has the highest trend, ranging from 4.7 % in the more recent period 1991-2020 to 39.1 % for 2071-2100. According to the RegCM model, the runoff reduction ranges from 4.2 % (1991-2020) to 21.3 % (2071-2100) compared to the reference period (1961-1990). The Promes model shows a slight increase in runoffs for 1991-2020, followed by a decrease in the mid-century (2021-2050) by 13.5 % compared to the reference period.

Using these trends, we may expect a decrease in the annual minimum runoff at the Korita site to approximately 16 l/s (or 0.016 m^3s^{-1}) by the end of the 21st century (according to Aladin model projections).

According to the report, even though all presumptions are hypothetical, it depends on many factors how reliable model predictions will be by the end of the century, primarily regarding greenhouse gas emissions. Still, despite such great uncertainty, the given assumptions help monitor changes over time and prepare ourselves for appropriate managing responses. All potential scenarios certainly involve a further increase of average annual temperatures but not significant changes in annual precipitation, so we expect a substantial decrease of average yearly discharges in the analyzed area and, subsequently, the reduction of available water supplies from the existing water system resources. It is evident only a minor part of its water balance is being used nowadays. Thus, there are possibilities to increase the resilience of the source and the island's water supply system to climate changes. For instance, their exploitation may be optimized by changing the type of water intake structure / by increasing the usage of static water reserves, by multiple water usage, or by applying an approach neglected so far in domestic practice such as managed aquifer recharge of the island's aquifers.

5.2.4. Analysis of the water demand

Current demand has been analyzed by the actual data on water consumption on the island of Vis. The source of data collected is a water supply company on the island of Vis, i.e. the company Vodovod i odvodnja otoka Visa d.o.o. (VOOV in further text)

Figure 18. shows the annual water consumption on the island of Vis in the period 2014-2020. Losses in the distribution water system amount to around 25 %.

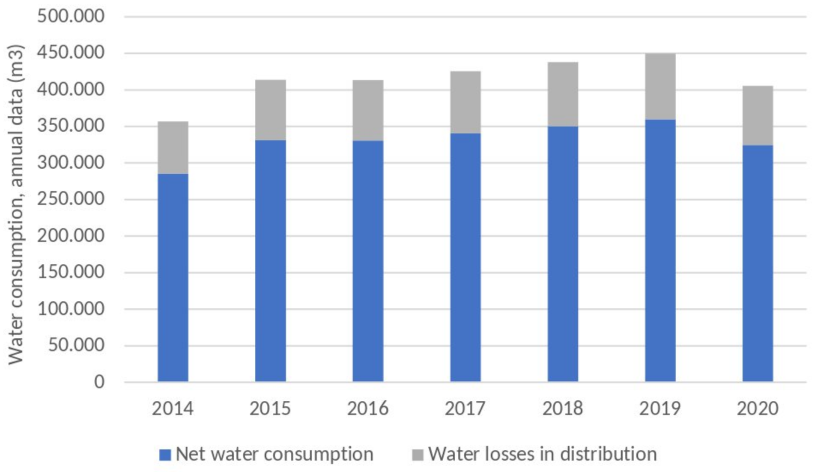

Figure 18. Annual water consumption from the water distribution system on the island of Vis (2014-2020)(source: VOOV)

There are two larger water consumers on the island: Hotel "Biševo" in Komiža (accommodation capacity of about 250 beds) and Hotel "Issa" in Vis (accommodation capacity of about 250 beds). Both hotels have only seasonal water consumption, i.e. during the summer tourist season. There are no other major water consumers on the island.

The current annual water consumption in households is about 255,000 m3, in public institutions (schools, schools, etc.) about 6,700 $m^{3,}$ and by the remaining consumers about 90,000 m^3 water per year (Figure 19).

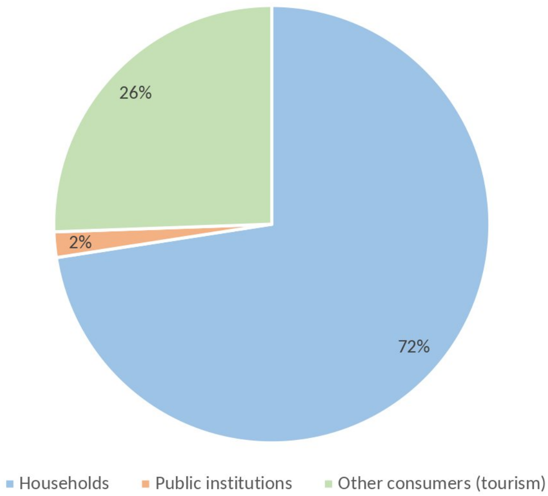

Figure 19. Water consumption structure on the island of Vis by the type of consumer

Water consumption on the island of Vis is increasing. The most significant influence on the increasing trends can be attributed to the increase in tourist arrivals and overnight stays on the island over the years and partly to a slight increase in consumption among the local population. The number of inhabitants on the island of Vis is slightly increasing, and in addition, consumer habits and needs are changing, resulting in a slightly higher average annual water consumption.

Figure 20. shows monthly water consumption on the island of Vis in 2014-2020. The chart shows net water consumption by consumers.

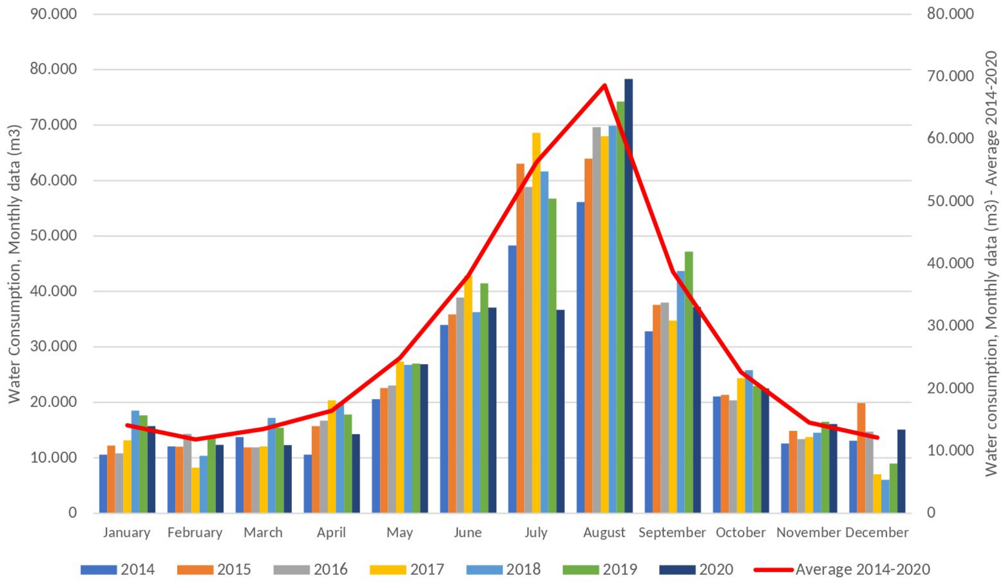

Figure 20. Monthly consumption of water from the water supply system on the island of Vis by final consumers (2014-2020)

The chart clearly shows a distinct increase in water consumption during the summer months when the island is full of tourists. In August, for example, the water consumption on the island of Vis increases by almost six times compared to February, which is the month with the lowest average water consumption on the island. We have to highlight the year 2020, which is, due to the impact of the Covid-19 pandemic situation, a non-specific year in terms of water consumption. In August 2020, the water consumption was very high compared to the remaining summer season 2020 due to the arrival of many domestic guests. Namely, the epidemiological situation on the island of Vis was very favorable during the summer, which attracted many domestic guests. The water consumption data in 2020 can well show the significance of tourism in terms of water consumption on the island.

The MAR methodology highlights five key factors that could theoretically influence water consumption:

- The economic criteria: regarding economic variables, factors affecting water demand could be the price and the income. However, the water demand is price-inelastic, which means that a change in the price of 1 % is expected to cause a change in demand for less than 1 %.
- The socio-demographic criteria: a factor that could affect water demand is, for example, the age of the population. The results of the studies are conflicting. For example, the presence of children in the household very likely leads to higher water consumption. In the elderly population, the results of the studies are most conflicting; on the one hand, older people could consume more water because they are mostly at home. On the other hand, most of them have a water-saving attitude, so it could be expected from them to have lower water consumption.
- Physical characteristics: factors that could affect water demand are, for example, the size of the house, the garden and outdoor size, the presence of a swimming pool. Research has shown no clear correlations between the physical size of the house or garden and other outdoor areas. On the other hand, the presence of a swimming pool was always found to be significant and positively related to water consumption.
- Climate characteristics: the most influential variables are the amount of rainfall and air temperature (increased use of water to fill the pools in hot periods of the year, watering gardens, etc.).
- Other criteria: for example, regulations and non-pricing policy measures, which are mainly established during droughts to reduce water consumption. The effectiveness of these measures depends primarily on their timing, the number of different water consumption reduction programmes introduced, and the level of information by the consumer and enforcement efforts of the programme.

The EU CBA methodology additionally highlights the following relevant factors influencing water demand:

- Demographic dynamics: the total water demand is directly related to the size of the population. The project should take into account the demographic forecasts, and the migration flows for an estimate of the users.
- Economic trend: a fast-growing economy generally demands a higher quantity of water. Tourism is highlighted as one of the essential factors in forecasting water demand.

The island of Vis is a very evident example of how strong the summer tourist season affects the water consumption on the island. In August, for example, the water consumption on the island increases by a factor of 5-6 compared to February, which is the month in the year with the lowest average water consumption on the island.

Based on the analysis of the current situation and trends in previous years, we can conclude that water consumption among the local population does not change significantly over the years, which is also the result of awareness of the inhabitants about the need for continuous water saving. The most significant impact on water consumption on the island is tourism.

On the island of Vis, various campaigns and projects are continuously held to make water consumers aware of relatively simple measures to reduce water consumption. For example, the water-saving campaign SUNCE, project "Water-saving challenge", and the promotion of water consumption reduction on the island of Vis as part of the #EuBeachCleanup campaign.

According to MAR methodology (D.T3.2.5 Common methodological guidance for DEEPWATER-CE MAR pilot feasibility studies), different approaches to estimating **future water demand** are possible. We have applied a method based on historical water consumption data to estimate a future water demand on the island of Vis. Given the relatively simple structure of water consumption on the island and the fact that the island is a closed-up community, this method seems appropriate for projecting future water consumption on the island of Vis. There are no industrial water consumers on the island; in addition to the Hotel "Biševo" in Komiža and Hotel "Issa" in Vis, all remaining consumers can be classified as small consumers. The whole island is supplied from one water distribution system. Therefore, the total water consumption on the island is relevant to the pilot project.

Given the specific dynamics of water consumption during the year, the following factors have been taken into account in the projection of future water demand on the island of Vis:

- historical data on the water consumption,
- data on water consumption during the wet and dry periods of the year,
- data on water consumption during the summer tourists season and the other periods of the year,
- adopted plans for residential construction and construction of tourism capacities,
- future development plans in tourism on the island.

The projection of future water demand on the island of Vis was made under the assumption of further development of tourism on the island that can be reasonably expected given the strategic development plans of the city of Vis and the city of Komiža, and the actual (growing) attractiveness of the island as a tourist destination.

Table 6. summarises the assumptions used to estimate future water demand on the island of Vis by 2030.

Table 6. Assumptions for the projection of future water demand on the island of Vis

Consumer group	Assumptions used
Households	The city of Vis and the city of Komiža are continuously implementing a pro-natal policy that shows promising results. The the island's population is slowly increasing. This can be realistically expected in the future, especially with the improvement of living conditions on the island, to which this project will contribute. Various activities and campaigns are continuously carried out among the inhabitants to raise awareness of the importance of water consumption reduction. At the same time, habits and needs are changing, as well as the age structure of the inhabitants. The final assumption used is continuously increasing future water demand by the local population by 0.5 % per year.
Tourism - capacities	Following the strategic development plans, the city of Vis and the city of Komiža will support investors in constructing new tourist accommodation

	capacities (hotel and apartment accommodation). The assumption used is that the newly built capacities will affect the increase in tourists arrivals in the pre-season (May) and the increase in tourist traffic during the 2025 season and beyond. It is assumed that the newly built capacities will impact the water consumption in May by 5 %, in June and September by 7 %, and during the summer months in the range of 10 % compared to current consumption in these months. This assumes an overall increase in water consumption in tourism by 20 % by 2028.
Agriculture	Agriculture will not be a beneficiary of the MAR water system.
Economy	Also in the future, the resource (including water) intensive Economy will not be present on the island. On the other hand, the island is increasingly turning towards smart growth and development. The island is becoming a comfortable place to live and work, attracting new investments in modern technologies and activities that accompany sustainable development. Even though the island's economy is developing, the island is not affected by the intensive extraction of natural resources.
Losses in the distribution system	It is assumed that continuous investment in the renovation, development, and improvements of the water distribution system will reduce water losses from the current 25% to 18% by 2029.

By applying the above-listed assumptions, we got the following projection of water demand on the island of Vis by 2030 (Figure 21).

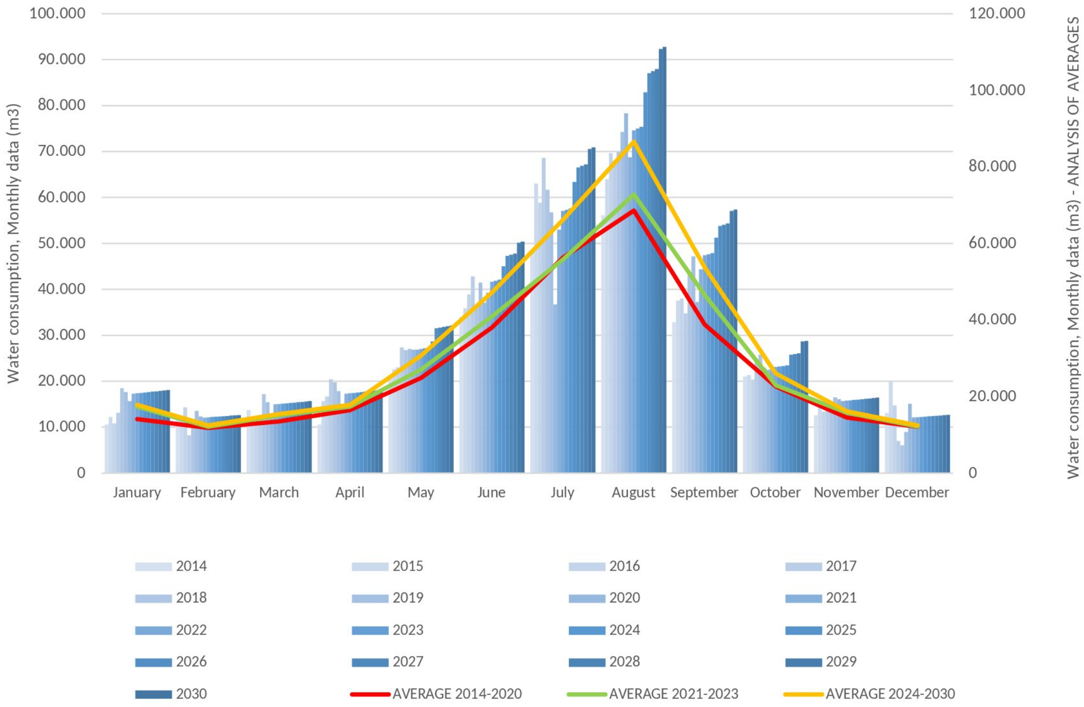

Figure 21. Water consumption (monthly, 2014-2020) and future water demand (monthly, 2021-2030) on the island of Vis

The total yearly quantities of future water demand (i.e. gross quantities including water losses in the distribution system) are presented in Figure 22.

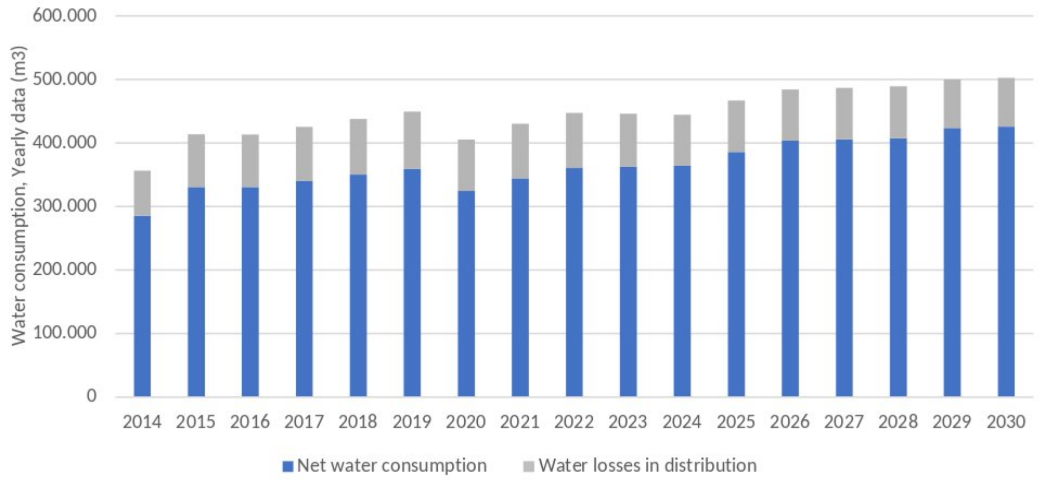

Figure 22. The annual water consumption on the island of Vis in 2014-2020 and the projection of annual water demand in 2021-2030

The annual incremental (additional) net water demand by 2030 is as presented in Figure 23.

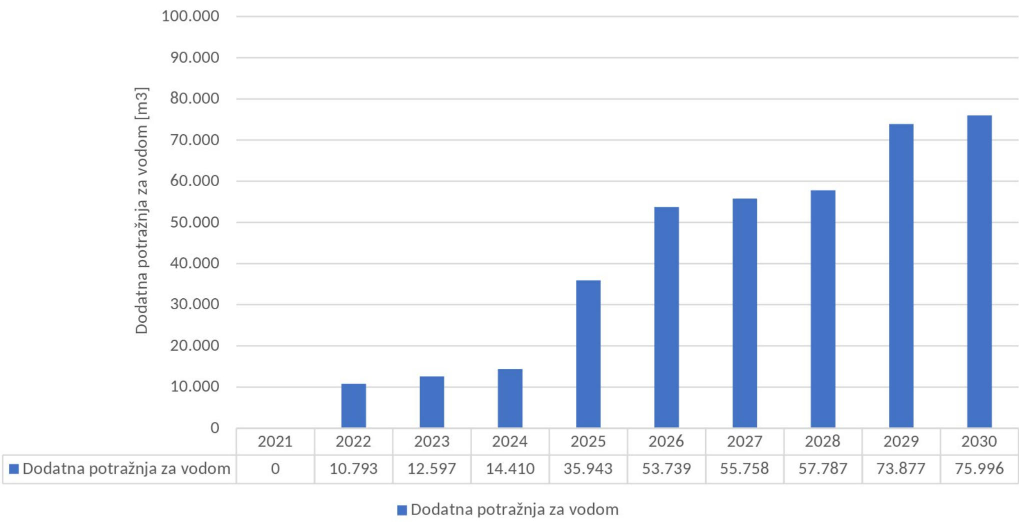

Figure 23. Projection of annual incremental net water demand on the island of Vis in 2021-2030

The year 2019 was taken as the base year since the pandemic year 2020 is not representative.

The projections until 2030 have been made on a monthly basis. They are based on the future development plans of the island, which are foreseen in the strategic development documents of the cities of Vis and Komiža.

With the time lag, it is more difficult to define the assumptions that will eventually determine the future water demand on the island. Therefore, the projection after 2031 is annually based and predicts a linear growth in total water demand of 0.5 % per year. In addition, the assumption is that the losses in the distribution system will further decrease to the final 15 % in 2031.

The chart in Figure 24 presents the long-term projection of water demand on the island of Vis:

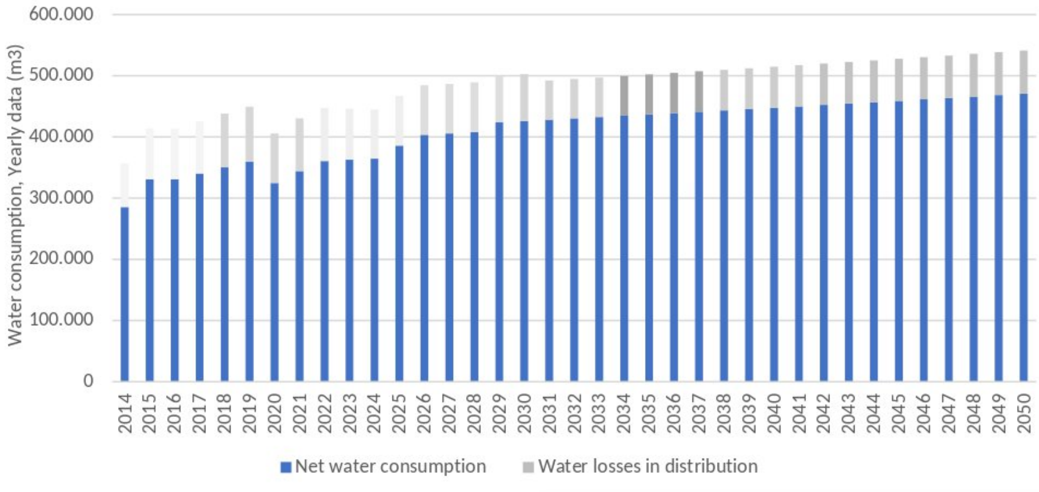

Figure 24. The annual water demand projection on the island of Vis by 2050

It is an essential fact that the further development of the island of Vis depends on the ability and success of providing additional quantities of drinking water. Currently available quantities meet current consumption, with risks, reductions, and difficulties during summers. Without providing additional water quantities, further development of the island of Vis in any direction is not possible. The strategic development plans of the city of Vis and the city of Komiža include several activities and projects that are directly linked to the additional demand for water on the island.

Analysis of the gap between future demand and supply of water

Based on the hydrological balance for the Korita pilot area, available data, and the assumptions presented below, we have estimated the incremental water quantities that will be secured with the MAR scheme at the 'Korita' pilot site.

Input data/assumptions used:

- Dimensions of the infiltration pond: 9,272 m^2, 2.5 m depth, which gives the total capacity of the infiltration pond of 23,180 m^3.
- The infiltration pond will be filled with different dynamics at different periods of the year. The most rainfall on the island is expected in winter, early spring, and late autumn months, and it is assumed that most of the water will be secured in these periods of the year.
- The total annual amount of water secured in the infiltration pond corresponds to the 3.5 full capacity of the lake, i.e. a total of 81,130 m^3 water per year (gross quantity).
- Two types of losses have been applied in the net water quantity calculation:
  - ☒ loss due to evaporation and
  - ☒ loss of water in the distribution system to final consumers.
- According to the hydrological balance, the evapotranspiration coefficient on the 'Korita' area is 0.65. Evapotranspiration consists of evaporation (i.e. evaporation from land) and transpiration (i.e., transpiration of plants). To calculate the loss from the lake, only the part relating to evaporation is relevant. Furthermore, evapotranspiration is much higher in the summer than during winter. Most of the activities related to aquifer recovery will take place

during the winters when the precipitation on the island is the highest. Therefore, it is concluded that the actual evaporation loss coefficient will be significantly lower than 65 %.

- An evaporation coefficient of 35 % is applied in the calculation.
- Applied loss in the water distribution system: 25 % in the project's first year, which will be reduced to the final 15 % in the 11th year of the project (as a result of continuous implementation of measures to reduce water losses in water distribution).

In addition to the above data and assumptions, the **annual net quantity** of water provided by MAR (compared to the current status) has been calculated to be **40,565 m^3**. According to the projection of future water demand on the island, MAR capacity will exceed the incremental water consumption in the first years of operating. In subsequent years, cumulative annual water residues from MAR will be consumed (water remains available in the aquifer for later periods).

Let's now look back at the projections of future water demand on the island of Vis. We can see that MAR, with the assumptions applied, will cover the entire additional water demand on the island in the first six years of operation, later around half and in the long term, with the increasing trend of water demand on the island, about a third of all additional needs.

A comparison of supply (i.e. secured volumes of water from MAR) and demand (incremental volumes of water demand on the island, above current consumption) is shown in Figure 25.

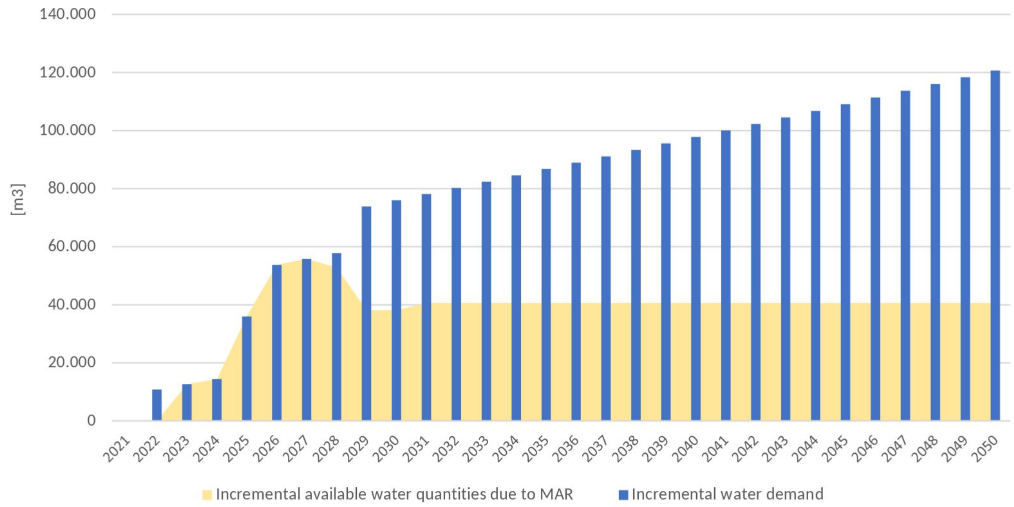

Figure 25. Long-term comparison of incremental supply (secured volumes of water by MAR) and incremental water demand (above current consumption) from 2021-2050

The demand for the results of this pilot project is not questionable. Namely, the projection of future water demand on the island indicates the projected growth of future water demand on the island of Vis, which exceeds the capacity of this pilot project. Nevertheless, this pilot project significantly solves the problem faced by the island of Vis in terms of ensuring drinking water supply.

5.3. Hydrogeology, aquifer characteristics, and water quality

The island of Vis is part of the Outer Dinaric range, an area characterized by very deep and irregular karstification, and is mostly composed of Mesozoic carbonate rocks that are intensely fractured and karstified. Topographically, the relief consists of three hilly chains separated by two valleys. The geological structures and relief strike in a predominantly W-E direction (the so-called Hvar strike), which differs from that of the majority of the Dinaric karst as these usually strike in NW-SE direction (Dinaric strike) (Figure 26).

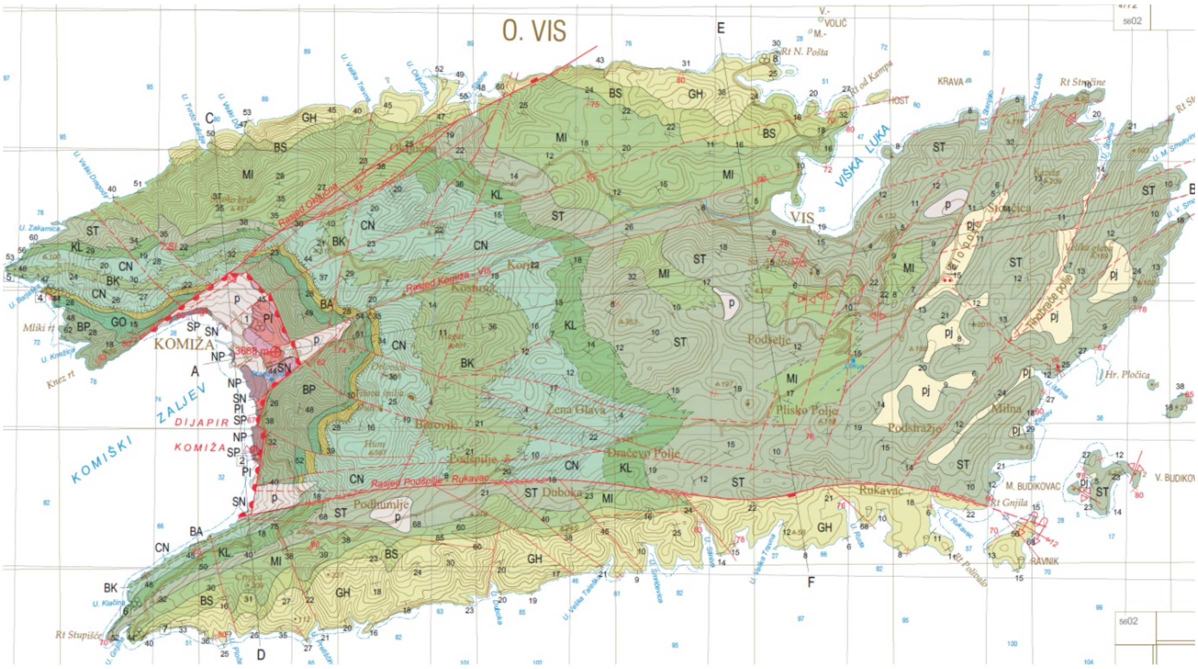

Figure 26. Basic geological map of the Republic of Croatia 1:50.000, Vis sheet (Korbar et al., 2012)

Vis has favorable geological and hydrogeological conditions that have enabled the formation of high-quality karst aquifers from which the fresh water is abstracted. Hence, the island is not connected to the mainland by pipeline and has an autonomous water supply. The greatest pressures on the island's aquifers are represented by climate change and extreme seasonality due to tourism (during the summer, the demand increases fivefold). The water supply system consists of six drilled wells in Korita in the central part of the island, the K1 well in the hinterland of Komiža, and the coastal spring Pizdica in the western part of the island (Figure 27). The maximum pumping yield at Korita is currently 42 l/s, and the groundwater is pumped from a depth of over 120 m. The average seasonal variation of groundwater levels in Korita wells is approximately 4 m. Groundwater quality is excellent and the aquifer is protected from seawater intrusions from the western side by the impermeable volcanic-sedimentary-evaporite complex (Komiža diapir), and the southern side by karst poljes due to the infilling of karstic and tectonic voids with sandy–fine-grained material from the weathering of dolomite. Furthermore, terra rossa provides additional fine-grained material for infilling.

Pizdica, a small coastal spring formed at a fault contact of permeable carbonates and impermeable VSE complex of Komiža bay, has an average yield of 3.3 l/s, and due to its position, it exhibits increased chlorides.

K1 well has a maximum pumping yield of 1.5 l/s and it is protected from seawater intrusions by the VSE complex.

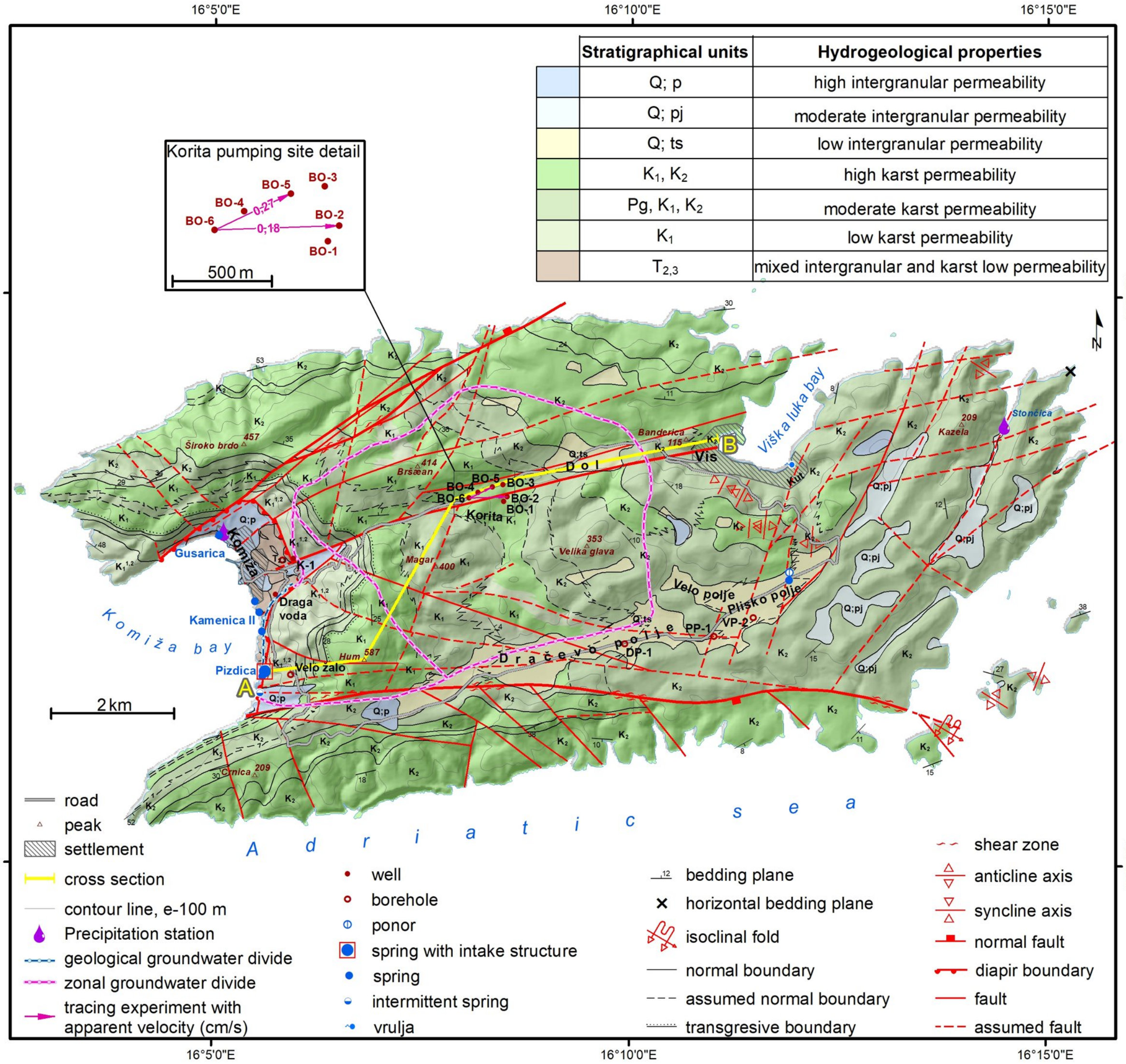

Figure 27. Hydrogeological map of Vis Island (Terzić et al., 2022; based on the geological map by Korbar et al., 2012)

Lithologies on the island have been grouped into five hydrogeological members (Terzić, 2004):

- Almost impervious rocks are those of the volcanic–sedimentary–evaporitic (VSE) complex of Komiža Bay (known as Komiža diapir). The lithological compositions of single formations within this complex vary and contain andesites, siltites, tuffites, marls, dolomites, gypsum, dolomitic-gypsum breccia, and volcanic agglomerates. Collectively, they function as a hydrogeological barrier.
- Low permeability carbonate rocks are mostly well-bedded dolomites. These rocks are spatially connected to the VSE complex as a narrow zone and mostly reinforce their barrier function. Still, these dolomites are fractured and even karstified to a certain extent, and groundwater can flow through significant fracture and fault zones, for example, the Pizdica spring occurs at one of these.
- Moderate permeability carbonate rocks are the most important hydrogeological unit as they are permeable enough to allow groundwater infiltration, accumulation, and flow, but are not too permeable to allow excessive penetration of seawater into the island's aquifer. Due to the presence of dolomitic and dolomitized rock mass and its characteristic weathering into

sand-like sediment, this material fills in most of the karst and fracture voids within this rock mass, thereby reducing its permeability.

- High permeability carbonate rocks are highly karstified Cretaceous limestones situated in two coastal belts: one in the north and one in the south of the island. The high permeability and wide spatial distribution of the coastal belts make them completely worthless from the perspective of fresh groundwater. Their position next to the sea results in the over-salinization of groundwater that either flows from the central part of the island or infiltrates directly into them.
- Quaternary deposits encompass several types of rocks and soils that have variable hydrogeological roles. Terra rossa (ts) is spread all over the island as a thin and discontinuous cover, and as a thicker layer mixed with rock fragments in karst *poljes*. These deposits decrease infiltration, and in the thickest parts in the poljes, they act as a local hydrogeological barrier.

The fieldwork for the pilot feasibility study for MAR deployment in Split-Dalmatia county was conducted by PP8 Croatian Geological Survey, supported by PP7 ViK Split and AP Croatian Waters. The fieldwork was done in the semi-arid karst region of Dalmatia, on the remote island of Vis and it included hydrogeological, hydrological, geophysical, hydrochemical, and structural-geological investigations. Periodical monthly field and laboratory investigations began in September 2019 and lasted until September 2021.

Hydrogeochemical and hydrogeological investigations

Field investigation included in-situ monitoring of pH, temperature (T), O_2 content, and electrical conductivity (EC) by WTW multi-parameter probe. Furthermore, alkalinity, i.e., the concentration of bicarbonate ions, was determined by volumetric titration with 1.6N H_2SO_4 to pH 4.5. Laboratory investigations were performed in the hydrochemical laboratory of the Department of Hydrogeology and Engineering Geology at the Croatian Geological Survey. Principal ion composition (HCO^{3}-, Cl^{-}, SO_4^{2}, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NO_3^{-}) was analyzed by ion chromatography on DIONEX ICS-6000 DP (Thermo Fischer Scientific Inc., Waltham, Massachusetts, USA). Also, analyses of stable water isotopes (^{16}O, ^{18}O, and ^{2}H) were carried out as a part of laboratory investigations (Picarro Isotope and Gas Concentration Analyzer). External experts were hired for the determination of the provenance of sulfate isotope. Furthermore, the laboratory for low-level radioactivities of Ruđer Bošković Institute conducted the determination of tritium activity concentration by the method of electrolytic enrichment using the liquid scintillation counter Quantulus 1220. Additionally, hydrogeological investigations included monthly measurements of groundwater levels at wells and measurements of spring discharge (whenever possible). A high-resolution monitoring network was established at the most important objects (springs, wells) of the water supply system. In particular, we installed automatic groundwater loggers – CTD Diver (Eijkelkamp ltd.), that measure groundwater level (as a function of hydrostatic pressure), electrical conductivity, and temperature. The resolution was set to 1 hour. Additionally, one baro logger was set up to subtract the atmospheric pressure from the hydrostatic pressure.

Geophysical investigations

Geophysical investigations conducted on the island of Vis include Electrical Resistivity Tomography (ERT) and the Magnetotelluric method. The ERT method is based on the application of electric current into analyzed bedrock and measurement of the intensity of electric resistivity to its conduit. Essentially, it gives us information on the electric resistivity properties of analyzed material towards passing electrical current (Lazzari et al. 2006, Sass et al. 2008). ERT uses measurements of the potential field, created by injecting current into the ground, to determine the spatial variability of electrical resistivity. To acquire 2D electrical resistivity tomography data in the field, a four-electrode array can be used. Two of these electrodes are used to inject electrical current into the ground and are referred to as current electrodes. The other two electrodes are connected to a voltmeter and are used to measure the potential difference between electrodes. These are called potential electrodes. The magnetotelluric method is an electromagnetic method of surface geophysical research and it is used to determine the electrical properties of the underground (distribution of electrical conductivity/resistivity by depth). It is a method that registers existing (natural) fields of external origin. The basis of the magnetotelluric method is the simultaneous measurement of the total EM field, that is, the change of the magnetic field and the induced electric field over time. The electrical properties of geological formations can then be determined from the interrelationships of the components of the measured electric and magnetic fields. In accordance with the properties of all electromagnetic waves, the depth of penetration depends on the frequency of the wave.

Structural geological investigations

Structural geological investigations focused on structural mapping and the acquisition of structural measurements, including orientation, spacing, length, aperture, and topology of fractures. Orientation data were acquired in structural sites and structural transects. At sites, linear scanlines were performed on vertical exposures to analyze spacing, aperture, and length distributions. Moreover, 20 scan areas were selected for studying fracture topology. Orientations were plotted in stereonets (Wulff lower net). The acquired dataset was tested against different statistical distributions following the workflow of Bistacchi et al., 2020.

Results

Hydrogeochemical analyses were used to establish long-term trends and dynamics for the karstic aquifer on the island of Vis, which is characterized by extremely high heterogeneity. The chemical composition of the groundwater on the island of Vis is graphically represented on a Piper diagram (Figure 29) and sampling locations in Figure 28.

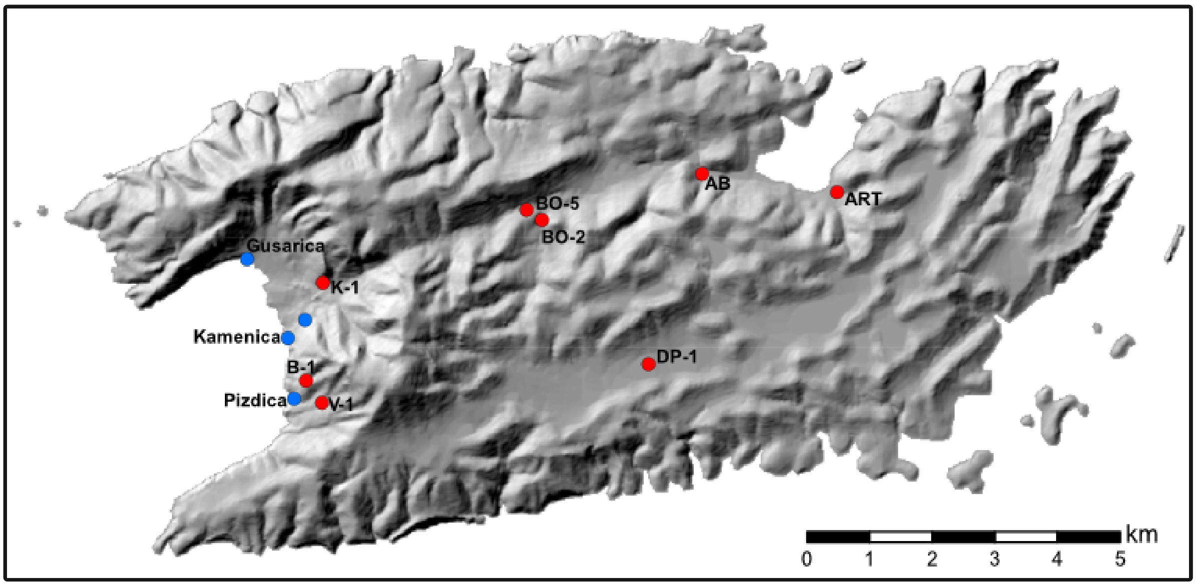

Figure 28. Sampling locations on the island of Vis. Red color represents boreholes and wells, and blue color represents natural springs

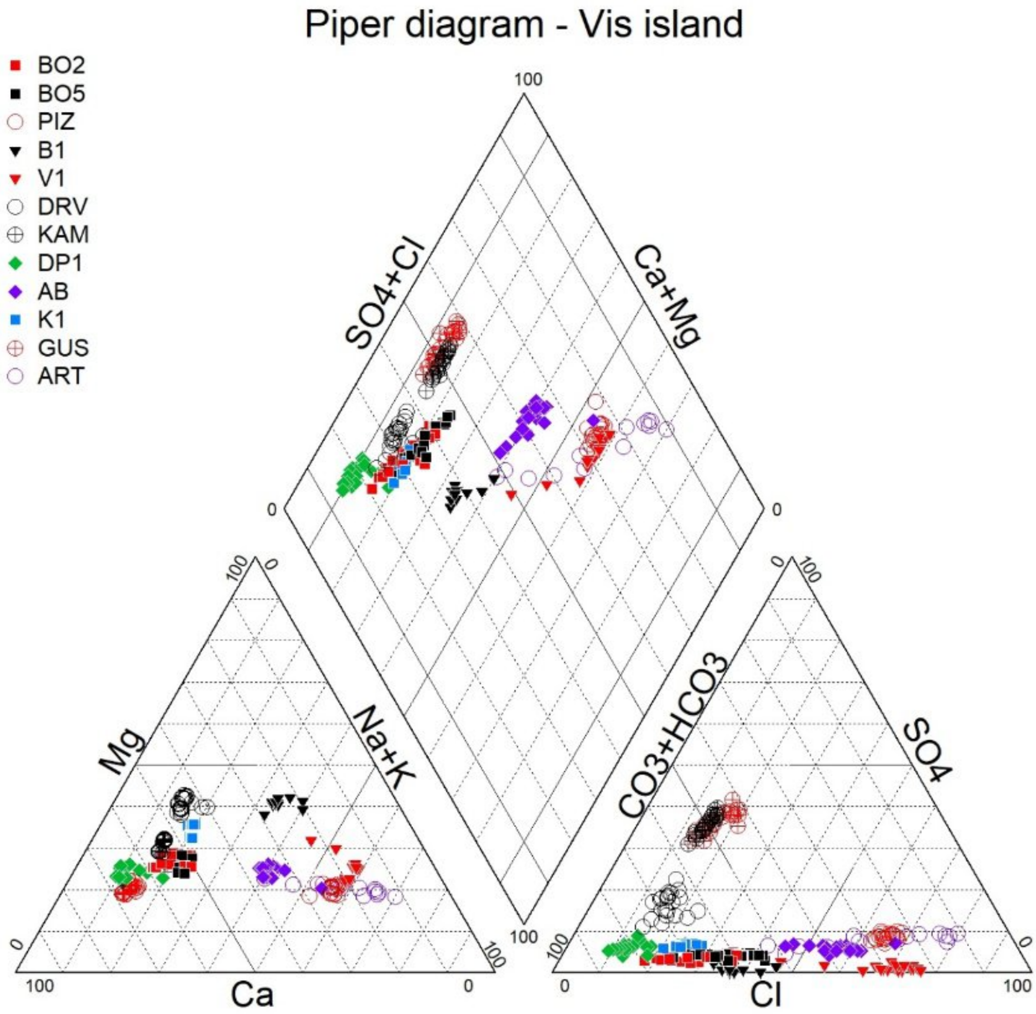

Figure 29. Piper diagram of groundwater samples from the island of Vis (from September 2019 to September 2021)

By conducting monthly sampling, almost all potential hydrological scenarios were covered (e.g. high and low groundwater levels, corresponding to wet and dry season; extreme droughts; floods). The main aquifer on the island (Korita aquifer, where a pumping site is present) displayed long-term stability despite record-low precipitation in 2020 and 2021, with a slight increase in chloride and EC concentration which indicated relatively high groundwater reserves that have shown resilience towards over-pumping and are protected from seawater intrusion (Figure 29), making the Korita aquifer an ideal candidate for implementation of IP and/or ASR. Additionally, the site is known for excellent groundwater quality, however, with the utilization of MAR, even more security in case of extreme hydrological events (prolonged droughts) could be achieved. Tritium activity evidenced a mixture of sub-modern and modern waters in the Korita aquifer, therefore, one could conclude that the recharged water will not quickly discharge through a highly karstified fracture network (e.g. discharge into the sea).

Geophysical investigations focused on the southern side of the island, where little hydrogeological data exists due to the absence of boreholes and wells and the main goals were to investigate the Quaternary deposits and their thickness. Generally, rock mass and aquifers below these karst *poljes* showed very low productivity and low transmissivity, because the rock mass and fractures are infilled by the products of dolomite weathering (sand-like material) and clayey Terra rossa particles. Hence, karst *poljes* on the southern side of the island provide an excellent barrier for seawater intrusion into the central Korita aquifer (Figure 30).

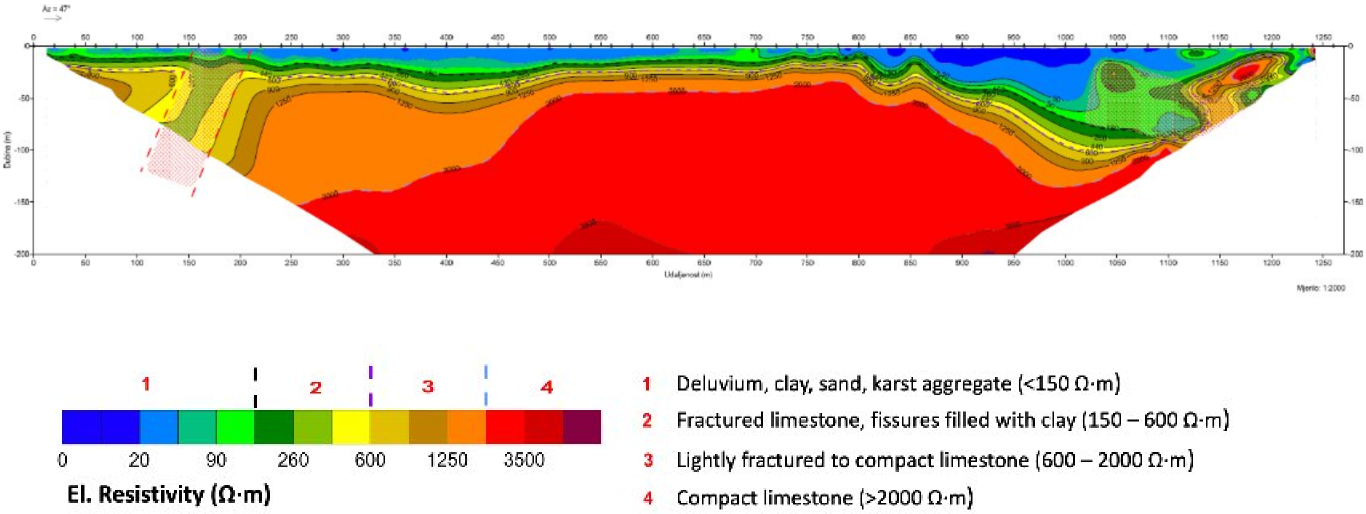

Figure 30. ERT profile Airport 3 and the legend

By conducting structural investigations, it was determined that the structural fabric of the island is dominated by the influence of the underlying diapir. Overlying Cretaceous limestones and dolostones present a half-dome structure with strata dipping mostly to the E, but also towards N along the northern shoreline and S along the southern one. Accordingly, the diapir and Cretaceous deeper units outcrop on the W side of Vis only. Main fault zones depart from the top of the diapir with radial geometry. Three main fault zones, crossing all the island, were identified: Komiža-Oključna with N60° strike, Komiža-Vis with N75° strike, and Komiža-Rukavac with N90° strike.

Groundwater quality on the island of Vis is very high. It is probably one of the highest quality waters originating from an island aquifer in Croatia. As a result, water is only chlorinated before the distribution to end-users to reduce microbiological (bacterial) activity. There is no need for filtration, UV treatment, and reverse osmosis, as the water is of exceptional quality (except the presence of bacteria, which is characteristic of groundwater from deep karstic aquifers). The main groundwater abstraction site Korita is not polluted by nitrates, sulfates, or phosphates as the agricultural activity in the adjacent areas is generally very low. Furthermore, due to favorable geological and hydrogeological conditions, Korita is protected from seawater intrusion, which would cause a high concentration of chlorides in groundwater, rendering it unusable for water supply.

6. Risk management

The main aim of the report D.T3.6.3 was to provide an overview of risk assessment methodologies used to identify, describe, and provide potential mitigation techniques for the Croatian pilot site – Korita water abstraction site on the remote island of Vis. The two most prospective methods for MAR implementation were infiltration pond (IP) and aquifer storage and recovery (ASR), and here was provided an assessment of risks related to the implementation of these two MAR schemes.

Generally, risk assessment methods can be divided into two main groups (Krogulec et al., 2018):

- Quantitative methods are based on measurable quantitative data. These methods lead to the determination of a specific numerical dependence of risk and are related to the methods of statistics.
- Qualitative methods do not include the numerical creation of risk values. The use of qualitative methods in risk analysis does not require, for example, the installation of sensors to read data or conducting constant control of changes in values of different parameters. These methods are based on expert knowledge, the experience of people conducting the analysis, and the relation of described risks to similar objects. These methods are prepared as risks lists along with an appropriate risks ranking.

For the Croatian pilot site – Korita on the island of Vis, a quantitative risk analysis matrix was proposed by Swierc et al., (2005) and a qualitative probabilistic approach by Rodríguez-Escales et al., (2018) were conducted.

6.1. Selected risk assessment methods

The risk assessment for the Korita pilot site was primarily based on the methodology of the Qualitative Risk Analysis Matrix (Swierc et al., 2005). The risk analysis matrix is used to assess the risk level from high to low for each identified hazard or hazardous event. By classifying risks in this way it is possible to establish a hierarchy of risks, which is essential to determine priorities for risk management. The level of risk is estimated by determining the likelihood of occurrence and identifying the severity of the consequence/impact of each hazard or hazardous event. The risk analysis matrix usually distinguishes five degrees of the consequence of a given risk (insignificant, minor, moderate, major, catastrophic) and five degrees of the likelihood of a given risk (rare, unlikely, possible, likely, almost certain). However, the proposed 5 step scales should be treated as general guidelines and always be adapted to the specific case study for which the risk analysis is being performed.

The risk factor matrix after Swierc et al., 2005, is shown in Figure 31.

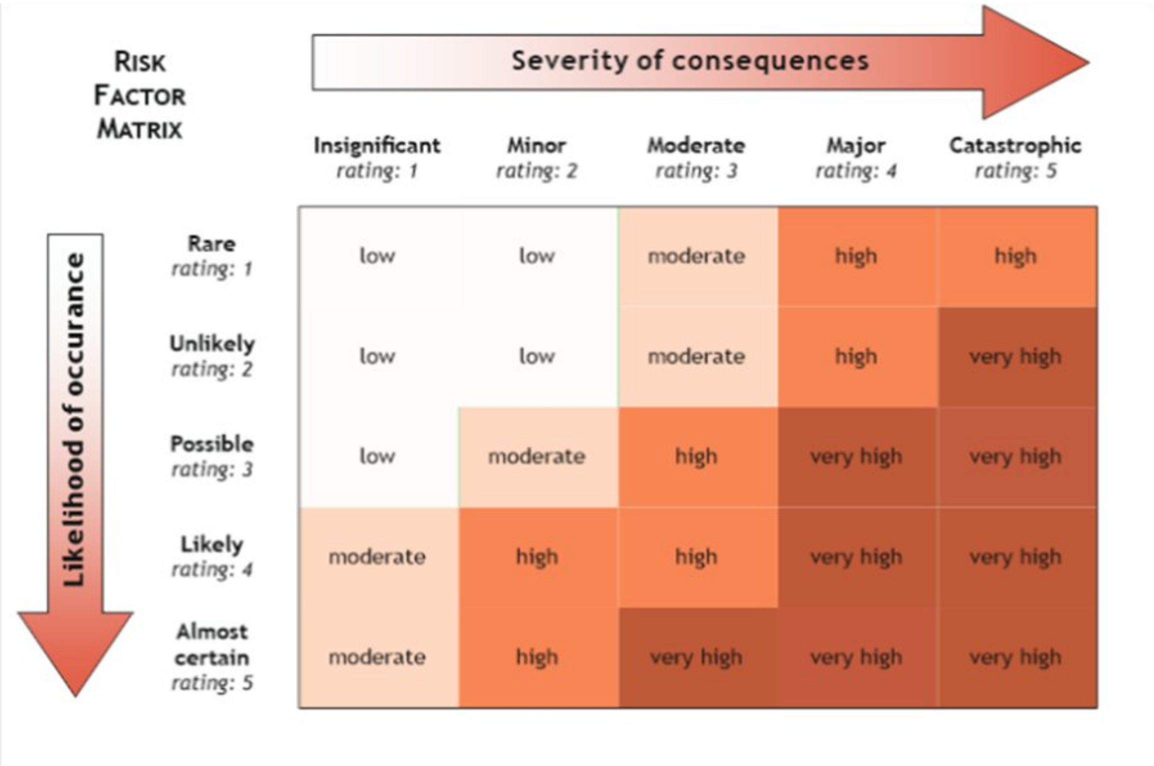

Figure 31. Risk factor score matrix for qualitative risk assessment (adapted from Swierc et al, (2005))

The principle of operation of the risk factor matrix is simple, as a risk factor for a particular risk is obtained by multiplying its severity of consequence (rating 1-5) with its likelihood of occurrence (rating 1-5).

In addition to the Qualitative Risk Analyses Matrix, a second method, a probabilistic risk assessment based on fault trees was utilized (Rodrigues-Escales et al., 2018). The developed methodology evaluates the risk of MAR failure, taking into account various risks (technical and non-technical) at two stages: design/construction and operation. This methodology was successfully applied in the EU FP7 project MARSOL (http://www.marsol.eu/6-0-Home.html) at six different MAR facilities in Europe and Israel. The first step of implementing this method is to define the concept of a system failure and identify events that may affect the correct operation of the MAR facility. The second step is the creation of an appropriate fault tree to avoid the situation that the events affecting MAR will be dependent on each other (all events should be as independent of each other if possible). The third step is a mathematical fault tree expression described in detail by Tartakovsky (2007), based on Boolean algebra. The last step is to determine the probability of individual events affecting the system based on fault tree results.

Because the Croatian pilot area is still in the conceptual phase, we decided to use a simplified approach where risks were identified using the MARSOL RISKAPP, however, fault tree analyses were skipped due to possible errors in interpretation and many special considerations that need to be taken into account when implementing MAR in karstic aquifers. Identified risks contained in the MARSOL RISKAPP were evaluated based on professional experience and analogous case studies, and risk factor score was assigned to all recognized risks based on Swierc et al. (2005) (as seen in Figure 31).

6.2. Risk identification and treatment

Qualitative Risk Analysis Matrix

Detailed elaboration of the methodology of the Qualitative Risk Analysis Matrix is presented in the report D.T3.6.3: "Compiled checklist for the application of Risk Management Protocol during the FIELD WORKS for MAR" (Annex 3).

According to the methodology, risks are analyzed through the two major groups:

- risks during the design and construction of a MAR facility,
- risks during the MAR operational process.

The major groups of risks expected at the pilot site on the island of Vis and suggested treatments are listed in the Table 7.

Table 7. Non-technical risks during (i) design and construction phase, and (ii) operational phase

POTENTIAL RISKS DURING DESIGN AND CONSTRUCTION OF A MAR FACILITY						
NON-TECHNICAL RISKS	**Constraint description**	**Likelihood**	**Severity of consequences**	**Risk score**	**Risk rating**	**Suggested risk treatment**
Legislation risks						
European territorial constraints	Changes in European legislation	2	1	2	low	Transpose the EU legislation related to MAR into national legislation to ensure the proper operation of MAR systems. Cooperation of national and local decision-makers, water legislative experts, health legislative experts, and other stakeholders. Development of national guidelines for MAR implementation and MAR health-related standards. Integration of MAR into existing drinking water protection zones and related legislation.
National territorial constraints	Changes in national legislation	3	4	12	high	
Regional/Local territorial constraints	Changes in regional legislation	2	2	4	low	
Health legislation	Amendments to regulations related to water intended for human consumption	3	3	9	high	
Others	Other changes in legislation affecting MAR facilities in the design phase	2	1	2	low	
Governance risks						
Lack of coordination	Mismanagement of MAR facility by its operators	2	3	6	moderate	Expert supervision of the MAR facility during design and construction
Commitment of stakeholders	Joint interest and commitment for a joint MAR project	4	3	12	high	The motivation of key stakeholders by dissemination of MAR benefits, knowledge sharing, and promotion. Popularise and spread MAR benefits (financial, environmental, etc.) to support the operation of MAR systems among investors and users.

Insufficient technical knowledge	Lack of technical knowledge on the side of staff responsible for the design of the MAR facility	4	4	16	very high	Well-trained researchers, operators, and technical staff responsible for the design and construction of the MAR systems. Potential involvement of external professionals with MAR experience, particularly in karstic terrains.
Economic risks						
Low price of water	The low price of accessible water from other sources makes the proposed MAR facility potentially unviable.	3	3	9	high	Additional support for the use of MAR facilities (preferably supported by state financial mechanism) in order to promote its financial viability. The best practice is to avoid an increase in the price of water for end-users
High installation cost	High cost of construction related to material prices, workmanship, and services.	5	3	15	high	Targeted support from the state budget, EU financial mechanisms, or other sources. Consider proper and optimal MAR system design, evaluate its capacity, size, feasibility, and effectiveness to attract more users/investors.
High maintenance cost/maintenance requirements	Increase in maintenance requirements of MAR facility resulting in increased costs	3	3	9	high	Maintenance costs should be projected accurately and included in cost-benefit analyses. Financial safety margin should be defined. Best practices should be fostered to reduce operating and maintenance costs
Lack of private /public funding	Underestimation of the project costs, lack of funds at a certain stage of the planned implementation	4	4	16	very high	Disseminate and promote MAR schemes to decision-makers, policy makers and planners, water suppliers, and end-users. Investigate funding schemes from existing sites.
Social risks						
Health risk perception by society	Health concern due to MAR technology implementation	4	2	8	high	Foster two-way communication with the general public. Promote sustainable and efficient MAR

						schemes. Integrate strict guidelines regarding water quality and detailed monitoring
High-cost perception by society	Concern about the increase in water prices due to MAR design.	3	2	6	moderate	Provide information on MAR benefits, especially considering climate change impacts. Emphasize the enhanced water availability in dry seasons.
Fair distribution of treated water	The possibility is that farmers who are closer to water withdrawal points would be gaining more water than the ones further from them.	1	1	1	low	A water distribution system should be designed to supply the users properly, without any preferences due to distance from a water source. The water distribution plan must be approved by all users.
Perception of effectiveness by society	Public understanding and awareness of the benefits of MAR solutions.	3	2	6	moderate	Knowledge sharing and promotion of MAR systems by emphasizing the environmental benefits (sufficient water availability in dry seasons for agriculture and ecosystems, water retention as an adaptation measure to climate change, etc.).
POTENTIAL RISKS DURING OPERATIONAL PHASE OF MAR						
NON-TECHNICAL RISKS	**Constraint description**	**Likelihood**	**Severity of consequences**	**Risk score**	**Risk rating**	**Suggested risk treatment**
Legislation risks						
European territorial constraints	Changes in European legislation	2	1	2	low	Transpose the EU legislation related to MAR into national legislation to ensure the proper operation of MAR systems. Cooperation of national and local decision-makers, water legislative experts, health legislative experts,
National territorial constraints	Changes in national legislation	2	2	4	low	
Regional/Local territorial constraints	Changes in regional legislation	2	2	4	low	
Health legislation	Amendments to regulations related to water	3	3	9	high	

	intended for human consumption					and other stakeholders. Development of national guidelines for MAR implementation and MAR health-related standards. Integration of MAR into existing drinking water protection zones and related legislation.
Others	Other changes in legislation affecting MAR facilities in operation	2	1	2	low	
Governance risks						
Lack of coordination	Mismanagement of MAR facility by owners of waterworks	3	4	12	high	Expert supervision and high-resolution monitoring of the performance of the MAR facility during the operational phase
Insufficient technical knowledge	Lack of technical knowledge on the side of staff responsible for the operation of the MAR facility	2	2	4	low	Well-trained researchers, operators, and technical staff responsible for the operation of the MAR systems. Potential involvement of external professionals with MAR experience, particularly in karstic terrains.
Economic risks						
Macroeconomic constraints	Global factors that can affect entire economies, e.g. the variation in interest rates, inflation rates, and unemployment rates	2	2	4	low	Preparation of alternative and backup financial scenarios during cost-benefit analysis
Low price of water	The low price of accessible water from other sources makes the proposed MAR facility potentially unviable. Though this risk will be lower in the operation phase (since by this time the MAR system has already been completed, so the high construction costs have already been spent) but still	3	3	9	high	Additional support for the use of MAR facilities (preferably supported by state financial mechanism) in order to promote its financial viability.

	has to be considered as high risk as it might menace the effectiveness of the MAR system.					
High maintenance cost/ maintenance requirements	Increase in maintenance requirements of MAR facility resulting in increased costs	2	3	6	moderate	To incorporate the budget for maintenance costs of the MAR system in designing MAR financing.
Social risks (unacceptance)						
Health risk perception by society	Health concern due to the MAR technology implementation	2	2	4	low	Share information on water quality of infiltrated/pumped water (e.g. design of proper monitoring system). Ensure proper operation of the facility and minimize associated risks
High-cost perception by society	Concern about the increase in water prices due to MAR	3	3	9	high	Provide information on MAR benefits, especially considering climate change impacts. Emphasize the enhanced water availability in dry seasons. Avoid increase in water costs for end-users
Behavioural requirements	Fear that MAR will affect people's daily lives (e.g. longer road to work, due to existence of new infiltration channels, prohibitions, and restrictions near MAR site)	1	1	1	low	Due to the “off-road” position, the MAR facility will not affect transport or the daily lives of the local community.
Fair distribution of treated water	The possibility is that farmers who are closer to water withdrawal points would be gaining more water than the ones further from them.	1	1	1	low	A water distribution system should be designed to supply the users properly, without any preferences due to distance from a water source. The water distribution plan must be approved by all users. In Croatia, most of the concerns related to these risks are solved through the Water Act and other relevant laws.
Perception of effectiveness by society	Public understanding and awareness of	3	2	6	moderat e	Knowledge sharing and promotion of MAR systems by

	the benefits of MAR solutions.					emphasizing the environmental benefits (sufficient water availability in dry seasons for agriculture and ecosystems, water retention as an adaptation measure to climate change, etc.).

Table 8. Technical risks during (i) design and construction phase, and (ii) operational phase

POTENTIAL RISKS DURING DESIGN AND CONSTRUCTION OF A MAR FACILITY						
TECHNICAL CONSTRAINTS	**Constraint description**	**Likelihood**	**Severity of consequences**	**Risk score**	**Risk rating**	**Suggested risk treatment**
Sanitary / biological restrictions (e.g. due to the pathogens)	Recharge water entering the MAR system is contaminated with pathogens or other toxic substances of biological or sanitary origin leading to concentrations in the water exceeding national and WHO standards	4	2	8	high	During the design and construction phase, proper monitoring and purification systems must be envisaged to ensure the highest quality of source water.
Turbidity /particles	Turbidity of the water entering the MAR system leads to a reduction in the efficiency of the MAR system due to excessive suspended solids. Material that causes water to be turbid include clay, silt, very tiny inorganic and organic matter, algae, dissolved coloured organic compounds, plankton, and other microscopic organisms	4	3	12	very high	The accumulation structure is located in old river beds that evacuate flood and storm waters towards the sea. The site is adjacent to hilly terrain, therefore, high turbidity of the source water must be anticipated and proper solutions (e.g. settling tanks, filtration) must be considered.
Metals	MAR's recharge water contains too high concentrations of substances which, despite its purification potential, it is unable to reduce	1	3	3	low	Monitor the MAR system´s water quality regularly in order to detect metals, salts, nutrients, and organic chemicals in time. Since the dominant land use in the vicinity of the MAR site is
Salinity and sodicity		1	3	3	low	
Nutrients (nitrogen, phosphorous)		1	3	3	low	

Organic chemicals (pollutants, EOCs)	to a level consistent with water quality standards public water supply	1	3	3	low	natural forests and shrublands, no significant pollution problems are expected (e.g. runoff, leaching).
Water scarcity risks						
Droughts and rainfall event periodicity (Influence of climate change on water supply)	Not sufficient water available to meet water demand due to periodic droughts/rainfall event	4	4	16	very high	Extreme climate events (floods and droughts) can negatively influence the water quantity in the accumulation structure. High waters and potential floods should be regulated by the dam, and since the precipitation is the only water source considered, droughts will cause cessation of water accumulation and artificial recharge.
Changes in water demand and supply	Increased demand and overuses deplete the system or production with higher capacity cannot fulfil requirements	2	2	4	low	Increased demand (e.g. during the summer due to tourism and irrigation) will not affect the MAR site since the majority of the recharge will be conducted in autumn and winter time (i.e. during the wet season).
Hydraulic and hydrogeological assessment of risks						
Risk of clogging	The presence of at least one type of clogging (physical, chemical, biological) in any part of the MAR system (water-transporting ditches) reduces the effectiveness of the MAR or leads to the need for renovation work at the MAR facility.	4	4	16	very high	Clogging can be caused by fine sediments, so the regulated turbidity should be applied to clean up the channels from fine sediments. Furthermore, filtration systems must be designed before recharging the water via the ASR method.
Risk of low water storage	Unfavourable aquifer parameters for water storage (e.g. low thickness or extension of aquifer, low	4	4	16	very high	Proper and detailed geological and hydrogeological investigation (desktop study and field measurements) to define precisely the hydraulic

	values of effective porosity, water storativity, etc., or marine discharge)					characteristics, the storage capacity of the aquifers, supported by hydraulic tests and modelling.
High thickness and not shallow aquifer	Aquifers with significant depth to the water table (high thickness of the unsaturated zone) may not be suitable for some MAR methods	4	4	16	very high	
Hydrogeological setting	Determining whether the proposed MAR facility has the significant potential to impact adjacent groundwater abstraction sites, modify flow directions, water table depths, etc. in terms of local hydrogeology or hydrochemistry	4	3	12	high	
Lack of infrastructure risks						
Lack of potentially available land	Lack of infrastructure is understood as making the designed MAR investment more expensive due to the problem of land availability or high land purchase or lease prices, lack of technical facilities/solutions to provide water of adequate quantity and quality to the MAR	1	1	1	low	The potential MAR site is located on state-owned land and managed by the local water supply company, who would be the MAR operator in this case.
Lack of water pre-treatment infrastructures		4	4	16	very high	At the proposed location, no pre-treatment facility exists. The construction and design of such a facility present a major economical constraint and funding (national, local, or EU) must be ensured.

Lack of wells	The possibility is that farmers who are closer to water withdrawal points would be gaining more water than the ones further from them.	1	1	1	low	5 active wells already exist at the proposed site, as well as 1 inactive well (potential target for ASR well recharge)
POTENTIAL RISKS DURING OPERATIONAL PHASE OF MAR						
TECHNICAL CONSTRAINTS	**Constraint description**	**Likelihood**	**Severity of consequences**	**Risk score**	**Risk rating**	**Suggested risk treatment**
Structural damages due to environmental events or human activity (civil work failures)						
Flooding	Destruction of infrastructure, interruption of the well field operation, pollution of the aquifer, sudden changes in recharged water quality.	2	2	4	low	Dam regulation of water level in the accumulation
Natural hazards (e.g. earthquake)	Destruction or serious damage to the MAR facility, interruption in MAR operation due to a natural disaster	3	3	9	high	The island of Vis is seismically active, however, the earthquakes are not very strong. Still, the accumulation and the dam structure must be constructed to withstand earthquakes with a significant safety margin
Terrorism activities or vandalism	Destruction of the well casing, deliberate contamination of the infiltration ditch or well, destruction of the monitoring network, etc	1	1	1	low	The proposed MAR site is fenced off, guarded, and under video surveillance
Equipment breakage	Breakdown of any instrument (water-collecting pipe, valves, pre-treatment facility, etc.) in the MAR system may cause the MAR to stop operating	2	2	4	low	Ensure regular maintenance of all equipment. Monitoring by automated systems
Aquifer dissolution (e.g. in karstic aquifer)	Considerable deterioration of the aquifer	4	4	16	very high	Detailed hydrochemical analyses of ambient

	properties and MAR surface facilities e.g. due to the dissolution of calcium minerals in the karst aquifer					groundwater. Adjustment of infiltration volumes. Mineralisation of source water before the recharge
Others	Any other risks associated with civil work-related breakdowns, but usually quickly fixable and does not endanger the MAR operation	3	1	3	low	Inform nearby population on MAR system, conclude insurance to MAR system, keep financial reserves for covering unforeseen costs
Risks of a decreased amount of water supplies due to inadequate water quality						
Sanitary/biological restrictions (e.g. due to the pathogens)	Recharge water entering the MAR system is contaminated with pathogens or other toxic substances of biological or sanitary origin leading to concentrations in the water exceeding national and WHO standards.	2	3	6	moderate	High-resolution monitoring and pre-treatment of the source water.
Turbidity/particles	Turbidity of the water entering the MAR system leads to a reduction in the efficiency of the MAR system due to excessive suspended solids. Material that causes water to be turbid includes clay, silt, very tiny inorganic and organic matter, algae, dissolved coloured organic compounds, plankton, and other microscopic organisms.	4	3	12	high	The accumulation structure is located in old river beds that evacuate flood and storm waters towards the sea. The site is adjacent to hilly terrain, therefore, high turbidity of the source water must be anticipated and proper solutions (e.g. settling tanks, filtration) must be considered.
Metals (e.g. arsenic, manganese)	MAR's recharge water contains too high concentrations of substances which, despite its purification potential, it is unable to reduce	1	3	3	low	Monitor the MAR system´s water quality regularly in order to detect metals, salts, nutrients, and organic chemicals in time. Since the dominant land use in
Salinity and sodicity		1	3	3	low	
Nutrients (nitrogen, phosphorous)		1	3	3	low	

Organic chemicals (pollutants, EOCs)	to a level consistent with drinking water standards. Contamination may originate from agricultural production, industry (e.g. nutrients, organic pollution, pesticides, metals, etc.) or its sources may be geogenic (e.g. aquifer dissolution, changes in chemical composition due to water table fluctuation, redox conditions, etc.)	1	3	3	low	the vicinity of the MAR site is natural forests and shrublands, no significant pollution problems are expected (e.g. runoff, leaching).
Radionuclides (regarding input water)		Not relevant				
Water scarcity risks						
Droughts and rainfall event periodicity	Not sufficient water is available to meet water demand due to periodic droughts/rainfall events.	4	4	16	very high	Extreme climate events (floods and droughts) can negatively influence the water quantity in the accumulation structure. High waters and potential floods should be regulated by the dam, and since the precipitation is the only water source considered, droughts will cause cessation of water accumulation and artificial recharge.
Changes in water demand and supply	Increased demand and overuses deplete the system or production with higher capacity cannot fulfil requirements.	2	3	6	moderate	Increased demand (e.g. during the summer due to tourism and irrigation) will not affect the MAR site since the majority of the recharge will be conducted in autumn and winter time (i.e. during the wet season).
Clogging risks						
Pipe filter failure	Malfunctioning of filter resulting in an inadequate amount of water supplied and/or insufficient	1	4	4	low	Pipe filter failure would cause temporary cessation of MAR operation, however, such an event is unlikely if a

	removal of particles and potential deterioration of water quality					filter is properly maintained and inspected regularly
Residence time	Water stays in underground drainpipes for too long (mineral precipitations, pathogens) or too short (too much suspended solids in water), which worsens its quality	2	2	4	low	This risk only applies to ASR technology. However, the existing wells are properly lined and they tap into an unconfined aquifer. Source water must be purified and pre-treated prior to recharge
Source of fine particles (generation inside MAR facility)	Particles generated directly at MAR facility (pipes, old aging wells, etc.)	1	2	2	low	Regular inspection and maintenance of wells
Deposition (transport sedimentation in water-distributing ditches)	The deposition of organic and inorganic solids at the bottom of a water-distributing structure with non-cemented bottom leads to a "clogging mat" (outer blockage)	2	2	4	low	The bottom of the accumulation structure must be a clean and paved surface, with no sediments.
Erosion (transport sedimentation in water-distributing ditches)	Submergence of soil may give rise to the disintegration of aggregate structures, which may lead to erosion. As a result of this process soils from the slope can settle on a permeable sand/gravel bottom, thus reducing infiltration	1	2	2	low	Floods and extreme rainfalls usually cause erosion of structure that should be avoided by consolidated banks of accumulation structure.
Bioclogging	Microorganism growth can create microbial biomass which restricts the volume of water that can infiltrate the pore space.	1	1	1	low	Prioritize artificial in the wet season (autumn-winter), when the air temperature is lower, thus reducing algal blooms and eutrophication
Evaporation (chemical clogging)	Excessive evaporation increases the mineralisation of water, precipitates minerals, and reduces the availability of water for MAR.	1	2	2	low	To ensure constant flow (accumulation and infiltration) to avoid increasing of water temperature and consequently evaporation.

Water mixtures (chemical clogging)	Recharge of water not in equilibrium with the groundwater or aquifer sediments can cause chemical reactions. These lead to the production of insoluble precipitates that alter the permeability of the aquifer	3	4	12	very high	Geochemical and hydrochemical monitoring. Adjustment of recharge volume. Pre-treatment of source water (i.e. mineralization).
Risks connected to the unacceptable quality of water at a sensitive location						
Organic matter (as the result of inefficient natural attenuation)	Risks associated with the insufficient potential of the MAR system to natural attenuation of organic matter	2	2	4	low	The listed pollutants are not characteristic of the proposed area (karstic terrain with low population density, no industry, or any major pollutants, including agriculture). However, regular monitoring and sampling of the water to detect the presence of organic matter, excess nutrients, N-compounds, emerging substances, and metals to allow the highest quality of water for public water supply is required.
Emerging organic compounds (as the result of inefficient natural attenuation)	Risks associated with the insufficient potential of the MAR system to natural attenuation of emerging organic compounds	1	2	2	low	
Nutrients (as the result of inefficient natural attenuation)	Risks associated with the insufficient potential of the MAR system to natural attenuation of nutrients	2	2	4	low	
Nitrogen cycle (NO_2^-, N_2O as a product of metabolite generation)	Risks associated with the insufficient potential of the MAR system to reducing products of nitrogen cycle compounds	1	2	2	low	
Emerging organic compounds (as a product of metabolite generation)		2	2	4	low	
Other nutrient cycles (e.g. H_2S)	Risks associated with the insufficient potential of the MAR system to reduce products of other than nitrogen cycle compounds e.g.	1	2	2	low	

	phosphorus, H_2S, etc.)					
Metals mobilization	Risk of metal mobilisation in water at a MAR facility	1	2	2	low	
Specific targets risks						
Seawater barrier risk	Risk related to the failure of fulfilling the protective role of MAR against seawater intrusion	Not relevant since the goal of MAR is not to prevent seawater intrusion, but rather to provide an augmented quantity for water supply				
Water level - groundwater	The risk of any MAR operation can lead to negative changes in the position of the groundwater table. Recharge of unconfined aquifers increases storage and may protect groundwater-dependent ecosystems in stressed aquifers. However, if the water table is raised too high, recharge of unconfined aquifers may also have adverse impacts. For example local flooding, effects of anoxia on vegetation, or mobilisation of pollutants from a nearby contaminated site. On recovery of stored water, lowering of the water table may increase pumping costs for other groundwater users and reduce yields of shallow wells. It may also mobilise metals and reduce groundwater discharge to	4	4	16	very high	Detailed monitoring of groundwater level through piezometers. Monitoring of aquifer response time in relation to recharge rate. Investigation of new potential outflow zones (marine discharge). Detailed monitoring of temperature, electrical conductivity, and pH in groundwater to detect possible changes in freshwater/seawater relation.

	dependent ecosystems at times when this is most needed.					

6.3. Sensitivity of MAR to climate-induced extreme situations

The methodology for assessing the sensitivity of the MAR scheme to climate-induced events was described in deliverable O.T2.1 Transnational decision-support toolbox for designating potential MAR locations in Central Europe (DEEPWATER-CE, 2020a). In this scope of this chapter, the sensitivity of the conceptual MAR scheme on the island of Vis to particular events related to climate extremes is assessed. Notable consideration is given to the combination of the two proposed methods (due to the depth of the aquifer of approximately 120 meters), and the sensitivity addresses the combination of methods (Table 9).

Table 9. Checklist on sensitivity analysis of MAR site to extreme climate events

<table>
<tr><th colspan="7">Checklist on sensitivity analysis of MAR site (island of Vis, Korita pumping site) to extreme climate events</th></tr>
<tr><td rowspan="2">Trigger / Stimulus</td><td colspan="2" rowspan="2">Climate extremes</td><th>Dry period</th><th>Risk assessment</th><th>Wet period</th><th>Risk assessment</th></tr>
<tr><td>• Extremely low amounts of precipitation
• Extremely high temperature/ evapotranspiration
• Extremely low temperature</td><td rowspan="3">The most significant impact of the drought will be the lack of source water for IP and ASR. Most commonly droughts occur during summer periods (Mediterranean climate), however, in 2020 and 2021, winter droughts occurred on the island of Vis. As a consequence, only 300 mm of cumulative annual precipitation was measured in 2020 (average annual precipitation is 800 mm for Vis in the long term). Additionally, high evapotranspiration (up to 60%) decreases even further the potential source water availability. Due to the small size of the island (90 km^2) and its remote position in the open sea, droughts are impossible to predict or to model. Climate models for the Mediterranean region show neither increasing nor decreasing trends, however, seasonal redistribution is likely to occur, reducing winter precipitation and enhancing summer storms and extreme summer precipitation.</td><td>• The short period of extremely high amounts of precipitation
• An extremely long period of precipitation
• A long period of extremely high amounts of precipitation</td><td rowspan="3">The three most significant risks associated with wet periods are the potential overflow of the accumulation structure, the high potential for contamination of the karstic aquifer, and the increased turbidity due to total suspended solids. The overflow can be easily solved by regulation of the accumulation lake dam, allowing excess floodwater to naturally flow towards the sea. During wet periods, water quality should be monitored with increased frequency to detect possible contamination and eventually, cessation of artificial recharge in case of contamination of surface water. This is further aggravated by the low filtration capability of karstic rocks. Furthermore, enhanced pre-treatment may be needed during this period. As for turbidity, it is an inherent condition of karstic systems during extreme rainfall, and it is hard to overcome. The main problem is the increased turbidity of potable water distributed to end-users, who often have to boil it before use.</td></tr>
<tr><td rowspan="3">Hazardous events</td><td rowspan="2">Natural hazards</td><td>Hazard groups</td><td>• GW drought
• Hydrological drought</td><td>• Flood</td></tr>
<tr><td>Hazard types</td><td>• Drought (lack of physical precipitation)
• GW table depression</td><td>• Extreme surface runoff;
• Flood (high precipitation)
• Increased turbidity
• Potential contamination of the karstic aquifer</td></tr>
<tr><td colspan="2">Anthropogenic impacts</td><td>• Water overexploitation for various uses (dominantly for tourism in summer months)</td><td>The water demand increases fivefold in the summer months due to intensive tourism. This is synchronous with the increased need for irrigation. The highest stress on the island's aquifer occurs during the summer, and periodically, reductions for end-users are necessary. In extreme cases of overexploitation, groundwater levels drop so significantly that this condition would enable seawater intrusion and total contamination of aquifer with chlorides.</td><td>• Diffuse and point pollution originating from specific land use
• Surface discharge over artificial surfaces</td><td>This risk is relatively low since the dominant land use in the vicinity of the proposed MAR site is forest and shrubland. Although there are small agricultural patches, it is located mainly downstream from the proposed MAR location. Furthermore, the agricultural production is not massive and is mostly organized as a family business, therefore there is not a significant risk of pollution from overuse of plant protection products. The background values of nitrates, nitrates, and phosphates in groundwater from the Korita site exhibit very minor concentrations of these compounds. Furthermore, there are not many artificial surfaces at the Korita location, thus the majority of surface overflow related to flood occurs in the cities of Vis and Komiža.</td></tr>
</table>

	Surface & hydrogeological environment	• GW table depression • Deteriorati on of GW quality • Lack of soil moisture	During dry periods, GW levels in the Korita aquifer tend to significantly decrease, if overexploited. The main risk is associated with an increased chance of seawater intrusion, however, significant implications on GW chemistry could occur. Here, the main concern is the increase in electrical conductivity, chloride, and bicarbonate content. The lack of soil moisture is an additional problem that has a significant influence on infiltration through the soil and shallow subsurface. If soil moisture decreases, more and more precipitation is required to satisfy the equilibrium condition, before the infiltration to the deeper parts (i.e. aquifer) can occur. As a result, small or even moderate precipitation (considering quantity and duration) after a long and dry period has practically no influence on groundwater recharge.	• Clogging of the infiltration pond • Aquifer characteristics (e.g. porosity, transmissivity, properties related to pollutant transport & fate, GW chemistry)	Eventual overflows in the accumulation structure will be solved with a regulation dam. Heavy rains and floods are usually associated with higher turbidity which can have a negative effect on infiltration structure. Additionally, higher pre-treatment costs could be derived in order to ensure the proper quality of water for direct infiltration (ASR). Due to the very deep aquifer (approximately 120 m below the surface), the risk of groundwater flood is negligible.

6.4. Risk monitoring milestones and determination of responsible entities for risk assessment and mitigation

Water supply systems that utilize groundwater resources from karstic aquifers, with or without MAR systems, are generally considered highly sensitive and vulnerable to pollution. During standard abstraction of karstic aquifers, detailed chemical and microbiological analyses (as defined by the Decree on Water for Human Consumption of the Republic of Croatia) should be conducted on daily basis. Monitoring of other physicochemical parameters (e.g. EC, pH, O_2, T) should be conducted at all times during pumping and distribution. Furthermore, groundwater levels should be monitored constantly (in real-time), to allow the cessation of pumping in case the levels significantly drop (e.g. drop of groundwater below the pump level). The responsible entity for conducting quality control, as well as the risk mitigation, is the operator, i.e. the water supply company.

One of the most significant risk groups recognized in the risk assessment was the one connected with source water quality and groundwater quality. During the operational phase of the MAR facility, the source water is the most critical variable that is prone to reduced quality. It should be monitored continuously (i.e. loggers for continuous measurements of pH, turbidity, EC, and other parameters if possible) and exhaustive hydrochemical and chemical analyses should be conducted before its infiltration (i.e. daily, weekly, or at other time increments). Groundwater should also be monitored as frequently as possible, by loggers for continuous measurements and by sampling and performing a standard array of (geo)chemical investigations. Water intended for human consumption should undergo daily analyses, as proscribed by the law. To achieve a well-structured and functional system of detailed monitoring of all types of water, it is necessary to establish close cooperation between the potential operator (Vis water supply company), accredited laboratory for water testing (Croatian Public Health Institute and/or Croatian Waters), and a research institution (Department of Hydrogeology and Engineering Geology of the Croatian Geological Survey). The monitoring scheme should be evaluated and changes (e.g. increased frequency or expansion of parameter list) should be made accordingly.

Groundwater levels should also be closely monitored during MAR operation. Response of groundwater levels with respect to infiltrated quantities is the main indicator to see whether MAR operation is successful or not, particularly in karstic aquifers. Due to the high heterogeneity of karstic aquifers and relatively unknown geometry of the aquifers, the level of response could be instant or significantly delayed, while the ratio of infiltrated and reclaimed water could be hard to interpret. Besides existing wells in the Korita well field where monitoring of level is taking place, it would be necessary to monitor groundwater levels in piezometers which would be drilled upstream and downstream from the water abstraction site, to obtain information in more remote parts of the aquifer. The recommendation is to use groundwater loggers for monitoring of level (in hourly resolution) in piezometers, and real-time level indicators in active wells. With this, it would theoretically be possible to detect eventually increased discharge (marine discharge) in response to recharged water, and eventually, aquifer dissolution and appearance of new flowpaths (channels, conduits, fracture zones). Since the Korita catchment is an isolated catchment, it is presumable that an artificial recharge in this area will not affect coastal springs and levels in other wells, particularly those in the western part of the island, around the city of Komiža. However, during the early stages of the operational phase, it would be necessary to organize a simple monitoring campaign to confirm this hypothesis.

Clogging and related risks should be solved by proper construction of the accumulation structure (paved clean surfaces), proper pre-treatment (to reduce turbidity), monitoring of recharge rate and hydraulic head loss, regular cleaning of the infiltration pond, and removal of mud layer from the bottom. To prevent chemical clogging, the analyses of the source water should be done before the recharge. Engineering aspects of the accumulation and infiltration structure (either pond or injection well), as well as a treatment facility, and pumping facility, should be regularly maintained and repaired by trained and authorized staff of the operators to avoid critical failure and potential environmental harm.

6.5. Qualitative risk analyses in project implementation

The Table 10 shows the qualitative risk assessment of the pilot project in the implementation phase.

Table 10. Qualitative risk analysis in project implementation

Element	Risk	P	S	X	Risk prevention and mitigation measures
Project management and administration	[1] Inadequate project management	1	3	3	Prevention measures: Delegate project management to a permanent team of highly motivated people with project management knowledge (professional project manager). Regularly monitor the progress of the project and coordinate with partners and suppliers. Mitigation measures: Where appropriate, involve additional members in the project management team. Re-examine the project management activity plan and correct it if necessary.
	[2] A change in leadership happens (by the investor, in the city administration), and the new leadership does not support the	1	3	3	Prevention measures: Commit the leadership with the contracts, no matter who represents it. Mitigation measures: In the case of a leadership change, the transfer of information about the project and the obligation for its further implementation needs

	project				to be ensured. The public must be regularly informed about the project and its progress to create a feeling of ownership of the commitment among citizens, thus influencing the responsibility of city authorities and/or investor leadership to its execution and completion.
Public procurement procedures	[3] Delay in contracting of works	1	3	3	Prevention measures: Prepare unambiguous and precise procurement documents according to professional rules. Start contracting immediately at the beginning of the project and plan enough time for potential appeals and negotiations. Include sufficient personnel capacity in the procurement team. Mitigation measures: Include additional professional staff capacities to speed up procedures and the procurement process can be completed as soon as possible.
	[4] Received offers are not of high quality	2	3	6	Prevention measures: All public procurement procedures in the project should be prepared with the continuous cooperation of the project manager and the certified public procurement expert. The first will contribute to the expertise, while the second to the proper procurement procedures. The eligibility criteria of tenderers should be clearly defined and carefully selected, and weighted according to their relevance to the specific procurement. Provide interested tenderers with access to existing documentation. Mitigation measures: If there is a need to cancel a certain public procurement procedure, technical and professional requirements and selection criteria for the tenderers should be re-examined. After that, repeat the procurement procedure and give a more extended deadline for submitting tenders.
	[5] No offers received	2	3	6	Prevention measures: Before collecting offers, explore the market in detail, and make a list of potential contractors. Put realistic criteria in the conditions for tenderers. Mitigation measures: Re-explore the market, consult potential offerers, repeat the invitation and leave it open for a longer time so that potential bidders can better prepare their offers. Re-check the eligibility criteria of tenderers.
Project preparation	[6] The project	2	3	6	Prevention measures:

	documentation does not correspond to the actual situation.				As a pilot project, there is a risk of errors in preparing the project documentation and preparing the project for implementation. The project is being prepared as part of the INTERREG project DEEPWATER-CE in with partners, and therefore the risk is reduced but still exists. There is a need for great flexibility in the preparation and continuous change of project assumptions following the results and conclusions at a particular project preparation stage. At drafting the project documentation, active participation with the design engineers and the remaining expert team is required to prepare the project. Mitigation measures: Continued preparedness for modifications and provision of additional financial resources if necessary.
Implementation of works and equipping	[7] Delay in the execution of works	3	2	6	Prevention measures: Include financial penalties in case of delays in the contracts. Selected contractors should be obliged to provide a bank guarantee for the contract's proper (also in the meaning of time) performance. Constant monitoring of the fulfillment of the time plan by the project manager and the coordinator of the works, constantly communicating with the contractors. Require tenderers to submit a list of their suppliers already in the tender, which the project manager verifies before signing the contract. In the time plan, a reserve period should be planned in case of delays in the main works (e.g. 2 months period). Mitigation measures: Activation of contractual financial penalties in the case of delays in the completion of works.
	[8] Poor weather conditions during the execution of works	1	2	2	Prevention measures: The implementation of practically all the activities of this project can depend on suitable weather conditions. As the entire project is located in the sub-mediterranean climate zone, it is very unlikely that bad weather conditions will last for an extended period. In the contract for works, a longer period can be opened, in which the provider must finish all works, with a further definition that the works must start as soon as the weather conditions allow this. Mitigation measures: Activation of contractual financial penalties in case of delays in the completion of works.
	[9] The project assumptions have	1	3	3	Prevention measures:

	changed				After the completion of all technical project documentation and before opening public procurement procedures for works, it is necessary to re-check the consistency of the documentation, clarify possible ambiguities and require further clarifications from the technic designers if required. Mitigation measures: In case of occurrence (realisation) of this risk, other possible options and sources of additional funding should be analysed and the best option chosen to continue the project.
	[10] During construction, archaeological findings which need to be investigated have been encountered, causing delays in the works	2	3	6	Prevention measures: This risk always exists at every excavation and should be taken into account. The risk can be prevented by previous protective archaeological research into critical parts of the site that is foreseen for implementing the project. Mitigation measures: If archaeological remains are found during earthworks, further works will have to be stopped until archaeological research is carried out. The investor should then undertake all steps needed to carry out such research as soon as possible so that the construction can continue and provide financial resources for potential adaptation and modification of the existing technical project documentation.
Supervision of works and financial audit of the project	[11] Supervision and audit activities have not been carried out in good quality	1	3	3	Prevention measures: External experts for implementing supervisory and audit activities must be selected according to strict professional criteria of quality and competence according to the size and complexity of this project. The required qualifications should be defined in detail in the procurement documents, and adequate financial resources should be planned. The offer should be selected by economic criteria where the price does not have the highest weighting but quality and references. Quality assurance with bank guarantees and/or financial penalties should be included in contracts. In contracts, the scope of the work and methods of work should be defined precisely. Mitigation measures: Activation of bank guarantee and/or financial penalties.
Promotion and visibility, communication, stakeholder education	[12] Project promotion and visibility do not sufficiently contribute to the	2	1	2	Prevention measures: Adhere to any activities envisaged. Quality external experts for the implementation of project visibility and publicity activities should

	actual visibility of the project				be selected. Visibility and publicity activities should be carried out for the entire duration of the project and not only in the last months. Mitigation measures: Boost activities using simple promotion channels immediately after the first signs that the project is not sufficiently visible occur. A wider audience should be targeted, and activities should be carried out continuously. Involve a project communication expert if needed.
	[13] Stakeholders are not interested in their education about the project	2	1	2	Prevention measures: Early involvement of stakeholders in outreach and education activities, preparation of tailor-made education programmes to different target groups of stakeholders. Mitigation measures: Adapt better activities to specific target groups, verify the adequacy and effectiveness of promotion and visibility activities, enhance the involvement of associations and other organisations active in environmental protection.

P=probability (likelihood)
1=low probability, 2=medium probability, 3=high probability
S=severity (impact - consequences)
1=low severity, 2=medium severity, 3=high severity
X=risk power
1=low risk, 2=medium risk, 3=high risk

6.6. Quantitative risk analysis in project implementation

Quantitative risk analysis is already partly covered in the table above, where we analyzed individual risks in implementing the project. We have attributed two dimensions of the problem to each risk:

- likelihood (frequency): the probability of something happening and
- impact (significance): how strong will the effect of an unwanted event impact successful project implementation.

For each dimension, we have defined a list of possible values:

Probability (likelihood):

- very unlikely to unlikely (low probability): 0 % to 33 %;
- about as likely as not (medium probability): 34 % to 67 %;
- likely to very likely (high likelihood): 68 % to 100 %.

Severity:

- non-material impact (low severity): level 1 - negligibly small to minor severity of consequences;
- medium impact (medium severity): level 2 - medium severity of consequences;

> complete disaster (extremely high severity): level 3 – high to extremely high severity of consequences.

We can calculate the risk level with the multiplication of probability and severity. The following risk matrix presents qualitative risk analysis.SEVERITY (IMPACT)→ PROBABILITY ↓	1 – Negligibly small to minor severity of consequences	2 – Medium severity of consequences	3 – High to extremely high severity of consequences
3 – Likely to very likely			
2 – About as likely as not	[12], [13]		[4], [5], [6], [7], [10]
1 - Very unlikely to unlikely		[8]	[1], [2], [3], [9], [11]

Figure 32. The risk matrix in project implementation

Legend:

LOW RISK	MEDIUM RISK	HIGH RISK	EXTREMELY HIGH RISK

From the risk matrix, we can see that most of the risks fall under the "high risk" category, and some are under the "medium risk" category (Figure 32).

Risk prevention and mitigation measures are listed in Table 11. Qualitative risk analysis in project implementation.

7. Cost-benefit analysis

7.1. Financial analysis

With the financial analysis, we verify the project's financial viability from the position of the entity responsible for project construction and operation (investor). To perform a financial analysis, first, we have to calculate the annual cash flow at constant prices during the reference project period. A cash flow has been calculated into present value by discounting using a financial discount rate. The following financial indicators are calculated as a financial analysis output: Net Present Value (NPV) and Internal Rate of Return (IRR).

Future costs and revenue flows have been calculated to present value so that the financial discount rate reflects the opportunity cost of capital. On their basis, a Net Present Value, which determines whether the revenues can cover the investment cost and other project costs (operational costs), has been calculated.

The Net Present Value (NPV) shows the present value of the difference between costs and benefits of the project (net cash flow) calculated using the financial discount rate.

The positive net present value shows that the project is profitable and should therefore be accepted on a financial basis.

If the NPV of the project is negative, the project entails a loss and should, therefore, purely commercially, be rejected. On the other hand, from the point of view of EU funding, this is a necessary condition in assessing the project's eligibility.

The Internal Rate of Return (IRR) shows the discount rate at which the difference between costs and benefits (net cash flow) has a net present value of zero. The IRR higher than the financial discount rate shows that the project brings a profit and should therefore be accepted on a financial basis.

If the project’s internal rate of return is lower than the financial discount rate, the project entails a loss and should, therefore, purely commercially, be rejected. On the other hand, from the point of view of EU funding, this is a necessary condition in assessing the project’s eligibility.

The incremental method has to be used for calculating financial indicators: it considers the difference between inflows and outflows of the scenario “do something else” and scenario without a project, i.e. “no changes”.

7.1.1. Presumptions of financial analysis

Currency - prices used in the analysis

The prices used in the analysis are **constant prices** in Croatian kunas (HRK) from the base year. Prices available on the Croatian market have been used to ensure comparability of costs and benefits.

Financial analysis period

MAR methodology recommends a 30-year reference period.

The EU CBA methodology recommends the length of the reference period by sector in which the specific project is implemented. This pilot project is classified as a water supply project for which a 30-year reference period is foreseen.

In the cost-benefit analysis of this pilot project, we, therefore, apply a **30-year reference period**.

Estimation of revenues

The pilot project **will generate direct revenues in the form of distributed water billing to consumers**.

The primary purpose of this pilot project is to improve the quality of life on the island of Vis, improve the quality of tourism for the visitors, and improve the conditions for the economy, i.e. touristic activity on the island. The pilot project will generate direct revenues through the collection of additional distributed amounts of water.

Other benefits will be indirect and are, as such, presented in the economic analysis of the pilot project.

Estimation of costs

Investment costs are based on the estimations made by technical experts of the company Vodovod i kanalizacija d.o.o. Split, and a received informative offer for the drilling of the well. The bases for assessing the investment costs are described in more detail below. The investor company Vodovod i odvodnja otoka Visa d.o.o. cannot use VAT refunds for works and other costs in the project. Therefore, the total investment costs are shown with VAT since the non-refundable VAT is an eligible cost in accordance with the Ordinance on the eligibility of costs (OG 115/2018).

Operating costs and costs of maintenance over the 30-year project period are based on a cost estimation made by the experienced technical experts of the company Vodovod i kanalizacija Split d.o.o., based on their experience in implementing projects with similar elements of works and equipment. Operating costs include costs for the maintenance of project results, such as maintenance of the built infrastructure. Operating costs do not include VAT.

Discount rate

According to the EU CBA methodology, a 4 % financial discount rate is applied. The EU CBA methodology defines a financial discount rate of 4 % and a social (economic) discount rate of 5 % for EU Members.

7.1.2. Bases for estimating the costs and revenues of the pilot project

Costs assessment basis

The costs estimation was first approached by studying available literature, i.e. studies and expert papers describing experiences in implemented projects around the world and/or theoretical basis in accessing costs estimates. Given that this is a pilot project in Croatia, there is no practice that we could apply directly. Furthermore, technical documentation or costs estimation has not been elaborated for this pilot project. After analyzing the available studies and expert papers, we had to conclude that they are not relevant in terms of assessing the costs of this specific pilot project. Furthermore, there is practically no literature available for karst areas.

The costs in different projects implemented in various locations around the world differ significantly, and a function that adequately describes their interdependence cannot be identified.

Case studies and theoretical bases helped to look at the overall cost picture, i.e. identifying the types of costs to be included in calculating investment and maintenance costs. On these grounds and using the framework cost structure defined by the MAR methodology, we have developed an adequate cost scheme for this pilot project.

The basis for estimating investment costs are shown in Table 11.

Table 11. The basis for estimating investment costs of the MAR pilot project on the island of Vis

Type of cost	Comment
Costs of the pilot project preparation	Costs of geophysical research. Costs of studies and project documentation. Costs of obtaining licences. Acquisition of the necessary data.
Costs of land acquisition	After defining the exact location of this pilot project, it is concluded that the costs of acquiring the land will not occur (the land is in the ownership of local authorities (City of Komiža, City of Vis).
Construction costs	Phase 1: A list of the relevant investment elements for two different technical options of the pilot project has been developed. Phase 2: A cost estimation for each element from Phase 1 has been done, according to the Standard Work Calculation for the projects of the company Vodovod i kanalizacija d.o.o. Split.
Costs of legislative mandatory and operational water quality tests	Water quality tests and analyses cost during construction and before the system is put into operation.
Costs of supervision	Supervision of technical design, supervision of works, financial evaluation of the project.

The basis for estimating operating and maintenance costs are shown in Table 12.

Table 12. The basis for estimating the operating and maintenance costs of the MAR pilot project on the island of Vis

Type of cost	Comment
Operating costs of groundwater use	The defining of all costs according to these categories, with adding categories if appropriate. The costs are estimated based on the experience of the technical experts of the company Vodovod i kanalizacija Split d.o.o. in implementing projects that included similar elements of works and equipment.
Labor costs	
Electricity costs	
Costs of water quality testing	
Infrastructure maintenance costs	
Maintenance costs of installed equipment	
Costs of pre-treatment and after-treatment of water	

According to the data collected from the available literature, the operating costs in the implemented projects were:

- between 0.01 and 0.85 USD/m^3 of water recovered in MAR in ASR technology (the difference between the minimum and maximum is ×85);
- between 0.02 and 0.14 USD/m^3 of the water recovered in MAR in infiltration pond technology (the difference between the minimum and maximum is ×7).

These values can be helpful as an indicative orientation, but we cannot apply them directly as representative values.

Revenues assessment basis

Price:

To estimate the direct revenues of the pilot project, we have applied the current price of water paid by the users of the water supply system on the island of Vis. The project will generate revenues from additional quantities of water distributed to the final beneficiaries. Only the additional (incremental) water quantities resulting from the implementation of this pilot project and the associated additional revenues are included in the CBA.

Applied water prices are shown in Table 13.

Table 13. Applied water prices in revenue projection

	Item	Price	Social tariff	Assumptions
1.	Water supply service (HRK/m^3)			
	Households, farming	7.97 HRK/m^3	4.78 HRK/m^3	70 % of Incremental Water Consumption
	Economy	10,65 HRK/m^3		30 % of Incremental Water Consumption
	Schools, kindergartens, other public institutions	6.83 HRK/m^3		
2.	Monthly fixed fee (HRK/month)			
	Households (25 mm: 30 new beneficiaries until the 16th year of the project)	36.00 HRK/month	21.60 HRK/month	The diameter of the pipe determines the price of the monthly fixed fee. Assumptions, as indicated in the column 'Item', have been used.
	Hotel (125 mm: 2 new beneficiaries by the 6th year of the project)	888.00 HRK/month		
	Smaller medium tourist accommodation facility (30 mm: 4 new beneficiaries until the 8th year of the project)	56.00 HRK/month		
	Larger medium tourist accommodation facility (40 mm: 4 new beneficiaries by the 8th year of the project)	80.00 HRK/month		

Source: Vodovod i odvodnja otoka Visa d.o.o., valid pricelist of services for 2021 and the study's assumptions.

The remaining items of the total price of the water supply service are of a transitory character, and therefore, they are not applied in the calculation of revenues:

- a development fee (2.50 HRK/m^3),
- a water-use fee (2.85 HRK/m^3),
- a waters protection fee (1.35 HRK/m^3), and
- a drainage fee (1.00 HRK/m^3 for households and 1.63 HRK/m^3 for the economy).

In the revenue projection, we assume that the water price for the final consumer on the island of Vis remains unchanged throughout the reference period. The inhabitants are heavily burdened by the high water price due to shortage of water and demanding technical supplying conditions, which affect the final water price. The following chart (Figure 33) compares the price of the water supply service on the island of Vis with the price in some other nearby water supply areas.

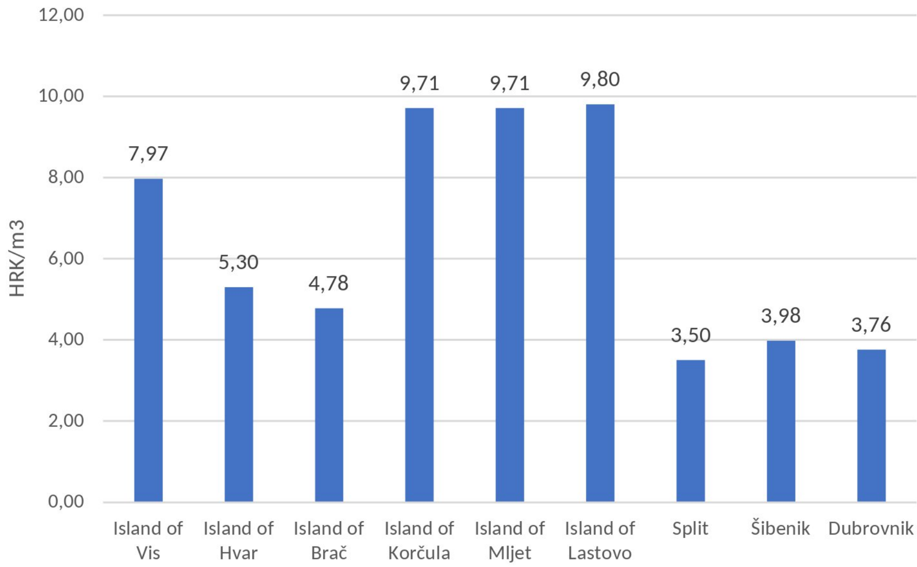

Figure 33. Comparison of the price of the water supply service (Source: Published pricelists of water supply companies)

Out of 157 respondents who participated in the survey, 61.8 % live in financially disadvantaged households with a total annual household income below 155,000 HRK.

The Water Framework Directive (2000/60/EC) requires a water pricing policy to be conducted following the principle of covering the costs from water services; the water price should cover the costs (management, operation, depreciation, and the cost of the water environment and resources). On the other hand, there is a requirement of affordability; the price of water must be affordable to consumers, i.e. the cost of water must not exceed the rate of net disposable income, which is in Croatia 3 %.

If implemented by the infiltration pond method, the financial analysis of the pilot MAR project shows the project's financial feasibility, which means that this pilot project is financially justified without increasing the water price for the final consumers.

Quantities:

The incremental quantities of water that will result from MAR and will be available to be delivered to consumers on the island of Vis are calculated based on:

- projected future water demand on the island of Vis (Chapter 5.2.3 Estimating future water demand on the island of Vis),
- the results of the hydrological balance (Final report: “Hydrological balance and implementation of geophysical researches”, Terra Compacta d.o.o., August 2021),
- accepted assumptions on the capacity of the pilot MAR system, i.e. the quantities of water captured by the pilot MAR system, i.e. the additional water quantity available (Chapter 5.2 Analysis of supply),
- expected losses due to evaporation (i.e. losses from the accumulation lake) (Chapter 5.4 Analysis of the gap between future demand and supply of water),

- expected losses in water distribution to final consumers (Chapter 5.2.4 Analysis of the gap between future demand and supply of water).

Based on all relevant data and the assumptions taken, a projection of the annual revenues of the pilot project was prepared for the duration of the reference period (30 years) - *Chapter 7.1.6 Estimation of project revenues*.

7.1.3. Investment costs estimation

An estimation of the investment costs of the pilot MAR project on the island of Vis has been made following several steps. Finally, an estimation that is presented here has been concluded.

In the first step, the technological frameworks have been defined, i.e. the MAR methods relevant for the application in the pilot area concerned: the infiltration pond method and the ASR method. In the next step, a basic scheme of investment costs for setting up the MAR system MAR methods has been developed for both appropriate MAR methods. After the final definition of the pilot site and the dimension of the pilot project, a detailed estimate of the costs for the pilot site has been made. The following total investment costs have been established:

- Option 1: Implementation of the pilot project according to the infiltration pond method: 3,142,851.20 HRK
- Option 2: Implementation of the pilot project according to the ASR method: 4,689,559.70 HRK

Given the almost 50 % difference in total investment costs and with the same physical outcome (i.e. the same additional quantity of water available for final consumers), the infiltration pond model is selected as a priority option that we analyze in more detail below. Option 2 is presented as an alternative option at the end of the study *(Chapter 8.1.3 Option "do something else" - Alternative option)*.

Infiltration pond method – investment costs estimation

Total investment costs, including VAT, are estimated at **3,142,851.20 HRK** to implement the pilot MAR pilot project on the island of Vis according to the infiltration pond method.

Total investment costs consist of the following items (Figure 34):

- project management and administration;
- preparation of the project;
- implementation of works and equipping,
- project supervision and audit;
- promotion and visibility, communication and education of stakeholders.

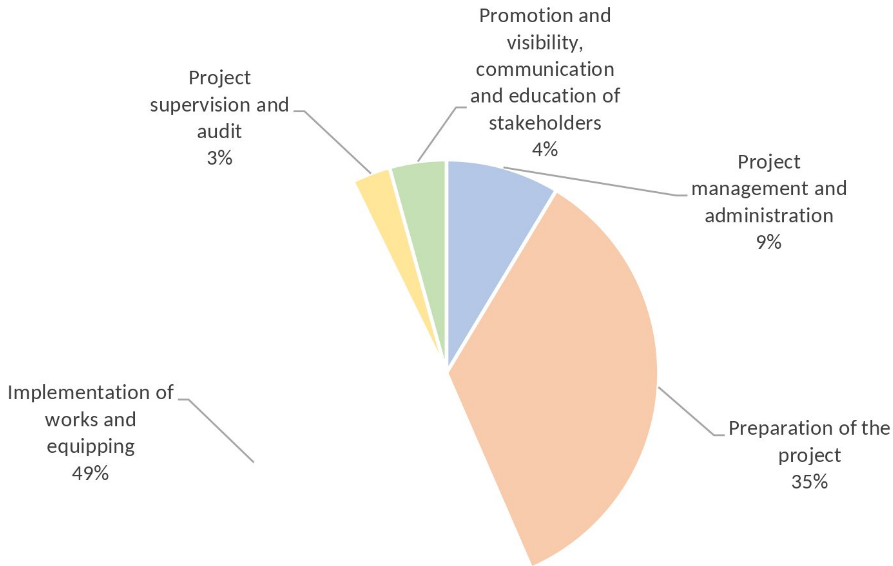

Figure 34. Total investment costs structure – implementation of the pilot MAR project on the island of Vis according to the infiltration pond method

Total investment costs (single budget lines), calculation of depreciation and residual value, and estimation of operating and maintenance costs for infiltration pond are shown in Annex 5 of this report.

7.1.4. Estimation of project revenues

A pilot project will generate direct financial revenues in the form of the charged price of additional quantities of water distributed to final consumers on the island of Vis. The incremental method is applied in calculating project revenue, i.e. additional revenues that would not have been generated without the project.

Table 14 shows the projection of the direct financial revenues of the MAR project according to the infiltration pond method. Direct financial revenues consist of revenues from the drinking water supply and revenues from the monthly fixed fee for the duration of the pilot project (30 years).

The basis for estimating revenue is presented in Chapter 8.1.2.2 Revenues assessment basis.

Table 14. Projection of the revenues – infiltration pond method

	Desaiption	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Revenues from the supply of drinking water	0	0	101.153	115.711	288.630	431.534	447.744	424.185	306.198	306.198	325.742	325.742	325.742	325.742	325.742
2	Revenue from the monthly fixed fee	0	0	0	0	14.448	28.896	31.392	33.888	34.752	35.616	36.480	37.344	38.208	39.072	39.936
	TOTAL INCREMENTAL FINANCIAL REVENUES	0	0	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678

		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Revenues from the supply of drinking water	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742	325.742
2	Revenue from the monthly fixed fee	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800	40.800
	TOTAL INCREMENTAL FINANCIAL REVENUES	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542

7.1.5. Calculation and interpretation of financial indicators

Based on the estimated costs and revenues of the pilot project, we have calculated annual cash flows and financial indicators. Financial indicators show the financial rationality of the project, i.e. the rationale of the project for the investor.

The financial return on investment is calculated based on estimated incremental costs and revenues. The “do something else” scenario, which represents the chosen variant, is analysed, compared to the “business as usual” scenario, which represents a situation without an investment.

The calculation of the financial indicators is based on the estimated costs and revenues of the pilot project in the 30-year reference period, taking into account 4 % of the financial discount rate. The results show that, from a financial point of view, this investment is profitable and brings a minimum positive financial net present value (FNPV > 0) and a positive internal rate of return (FRR > 4 %) (Tables 15 and 16).

Table 15. Financial indicators – infiltration pond method

Financial discount rate	4 %
FNPV	685,970 HRK
FRR	5.74 %
NPV of investments	2,948,692 HRK
NPV of residual value	0 HRK
Net present value of revenues	5,328,381
Net present value of costs	1,693,719 HRK

FNPV - financial Net Present Value

FRR - financial internal rate of return

Table 16. Annual net cash flow – infiltration pond method

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Operating Revenues	0	0	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678
Residual value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POSITIVE CASH FLOWS	0	0	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678
Investment	1.161.351	1.981.500													
Operating Costs	0	0	71.298	72.855	135.283	93.839	95.518	147.278	88.064	88.754	144.811	91.372	92.083	148.584	93.526
NEGATIVE CASH FLOWS	1.161.351	1.981.500	71.298	72.855	135.283	93.839	95.518	147.278	88.064	88.754	144.811	91.372	92.083	148.584	93.526
NET CASH FLOW	-1.161.351	-1.981.500	29.854	42.856	167.794	366.591	383.618	310.795	252.885	253.059	217.411	271.714	271.867	216.230	272.152

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542
94.259	152.472	95.745	96.500	156.478	98.032	98.810	160.604	100.388	101.189	164.856	102.815	103.641	169.237	105.316
94.259	152.472	95.745	96.500	156.478	98.032	98.810	160.604	100.388	101.189	164.856	102.815	103.641	169.237	105.316
272.284	214.070	270.797	270.042	210.065	268.510	267.733	205.938	266.154	265.353	201.686	263.727	262.902	197.305	261.226

Financial sustainability of the investment

The financial sustainability of the investment is one of the essential financial criteria for each project. The project is financially sustainable when there is no risk that it will not have available financial sources during its implementation and operation phase. Thus, the main objective of the financial sustainability analysis is to ensure that the investor does not encounter cash flow constraints, which could lead to the illiquidity of the project.

The financial viability analysis verifies that positive cash flows cover the negative cash flows during the project's lifespan. If the cumulative cash flow in the last year is negative, the project's financial viability may be jeopardized.

We can connect the issue of financial sustainability to the requirement of the Water Framework Directive (2000/60/EC). Following the Directive, all investments in water infrastructure must demonstrate financial sustainability, i.e. the price of water must cover the entire investment costs (management, operation, depreciation, and the cost of the water environment and resources). Given that the current price of water on the island of Vis is already high, we have checked whether this pilot project can be implemented and financially justified without raising the price for the final consumer not to affect their affordability. The financial analysis results show that the project is financially justified with existing water prices, which is evident from the annual positive net financial cash flows and the cumulative net cash flow at the end of the project (in the 30th year of the project).

The project's financial viability is demonstrated by calculating the cumulative cash flow over the entire time horizon considered. The calculation of the financial viability of the pilot MAR project on the island of Vis is presented in table 17.

The investment is financially viable, with no additional contributions required. The cumulative cash flow is positive throughout the entire operation time of the project.

Table 17. Financial sustainability of the pilot project – infiltration pond method

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Operating Revenues	0	0	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678
Sources of financing	1.161.351	1.981.500													
Contribution required (Budget)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POSITIVE CASH FLOWS	1.161.351	1.981.500	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678
Investment	1.161.351	1.981.500													
Operating Costs	0	0	71.298	72.855	135.283	93.839	95.518	147.278	88.064	88.754	144.811	91.372	92.083	148.584	93.526
NEGATIVE CASH FLOWS	1.161.351	1.981.500	71.298	72.855	135.283	93.839	95.518	147.278	88.064	88.754	144.811	91.372	92.083	148.584	93.526
NET CASH FLOW	0,00	0,00	29.854,22	42.856,22	167.794,47	366.590,52	383.617,88	310.794,62	252.885,46	253.059,47	217.411,34	271.714,32	271.867,42	216.230,00	272.152,23
CUMULATIVE CASHFLOW	0,00	0,00	29.854,22	72.710,43	240.504,90	607.095,43	990.713,31	1.301.507,93	1.554.393,39	1.807.452,86	2.024.864,20	2.296.578,51	2.568.445,93	2.784.675,93	3.056.828,16

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542
94.259	152.472	95.745	96.500	156.478	98.032	98.810	160.604	100.388	101.189	164.856	102.815	103.641	169.237	105.316
94.259	152.472	95.745	96.500	156.478	98.032	98.810	160.604	100.388	101.189	164.856	102.815	103.641	169.237	105.316
272.283,80	214.070,32	270.796,88	270.042,25	210.064,85	268.510,27	267.732,78	205.938,00	266.154,38	265.353,33	201.686,11	263.727,11	262.901,78	197.305,38	261.226,28
3.329.111,96	3.543.182,28	3.813.979,16	4.084.021,41	4.294.086,26	4.562.596,53	4.830.329,31	5.036.267,31	5.302.421,69	5.567.775,02	5.769.461,13	6.033.188,24	6.296.090,02	6.493.395,40	6.754.621,68

7.1.6. Sensitivity analysis of financial indicators

Sensitivity analysis enables the investor to identify critical project variables. Critical variables are those whose positive or negative variations significantly impact the project's financial/economic performance. The analysis is done by changing variables one by one and determining the effects of these changes on the financial/economic net present value (FNPV/ENPV).

Those variables whose variation ± 1 % of the value adopted in the baseline case gives rise to a variation of more than 1 % in net present value should be considered critical.

Sensitivity analysis is performed for each of the variables used in the financial analysis of the project:

- operating revenues of the pilot project;
- operating costs of the pilot project;
- investment costs of the pilot project.

Tables 18 and 19 present the results of the performed sensitivity analysis to variations of the financial net present value (FNPV) variables.

Table 18. Results of the sensitivity analysis of the pilot project to variation of variables to financial net present value (FNPV)

Scenario	Variable	Change	FNPV	Change FNPV	Evaluation of the criticality of the variable
Scenario 0 (base scenario)			685.575	0.00 %	
Scenario A	Operating revenues	- 1 %	632.686	-7.71 %	critical
Scenario B	Investment costs	+ 1 %	656.088	-4.30 %	critical
Scenario C	Operating costs	+ 1 %	668.638	-2.47 %	critical

Discount rate: 4 %

Table 19. Analysis of project sensitivity to variations in costs and revenues in the project financial analysis – infiltration pond method

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Operating Revenues	0,00	0,00	101.152,52	115.711,02	303.077,63	460.429,74	479.136,34	458.072,84	340.949,82	341.813,82	362.222,36	363.086,36	363.950,36	364.814,36	365.678,36
SCENARIO A/Revenues -1%	0,00	0,00	100.141,00	114.553,91	300.046,85	455.825,44	474.344,78	453.492,12	337.540,32	338.395,68	358.600,14	359.455,30	360.310,86	361.166,22	362.021,58
Residual value															
POSITIVE CASH FLOWS (base scenario)	0,00	0,00	101.152,52	115.711,02	303.077,63	460.429,74	479.136,34	458.072,84	340.949,82	341.813,82	362.222,36	363.086,36	363.950,36	364.814,36	365.678,36
POSITIVE CASH FLOWS A	0,00	0,00	100.141,00	114.553,91	300.046,85	455.825,44	474.344,78	453.492,12	337.540,32	338.395,68	358.600,14	359.455,30	360.310,86	361.166,22	362.021,58
Investment costs	1.161.351,00	1.981.500,20													
SCENARIO B/Investment costs +1%	1.172.964,51	2.001.315,20													
Operating Costs	0,00	0,00	71.298,31	72.854,80	135.283,16	93.839,21	95.518,26	147.278,22	88.064,36	88.754,35	144.811,02	91.372,04	92.082,94	148.584,36	93.526,13
SCENARIO C/Operating Costs +1%	0,00	0,00	72.011,29	73.583,35	136.635,99	94.777,61	96.473,44	148.751,01	88.945,00	89.641,89	146.259,13	92.285,76	93.003,77	150.070,20	94.461,39
NEGATIVE CASH FLOWS (base scenario)	1.161.351,00	1.981.500,20	71.298,31	72.854,80	135.283,16	93.839,21	95.518,26	147.278,22	88.064,36	88.754,35	144.811,02	91.372,04	92.082,94	148.584,36	93.526,13
NEGATIVE CASH FLOWS B	1.172.965	2.001.315	71.298	72.855	135.283	93.839	95.518	147.278	88.064	88.754	144.811	91.372	92.083	148.584	93.526
NEGATIVE CASH FLOWS C	1.161.351	1.981.500	72.011	73.583	136.636	94.778	96.473	148.751	88.945	89.642	146.259	92.286	93.004	150.070	94.461
Net cash flow (base scenario)	-1.161.351	-1.981.500	29.854	42.856	167.794	366.591	383.618	310.795	252.885	253.059	217.411	271.714	271.867	216.230	272.152
Net cash flow A	-1.161.351	-1.981.500	28.843	41.699	164.764	361.986	378.827	306.214	249.476	249.641	213.789	268.083	268.228	212.582	268.495
Net cash flow B	-1.172.965	-2.001.315	29.854	42.856	167.794	366.591	383.618	310.795	252.885	253.059	217.411	271.714	271.867	216.230	272.152
Net cash flow C	-1.161.351	-1.981.500	29.141	42.128	166.442	365.652	382.663	309.322	252.005	252.172	215.963	270.801	270.947	214.744	271.217

Description	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Operating Revenues	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36
SCENARIO A/Revenues -1%	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94
Residual value															0,00
POSITIVE CASH FLOWS (base scenario)	366.542,36	366.542,36	366.542,36	366.542,36	365.678,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36	366.542,36
POSITIVE CASH FLOWS A	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94	362.876,94
Investment costs															
SCENARIO B/Investment costs +1%															
Operating Costs	94.258,56	152.472,03	95.745,48	96.500,11	156.477,51	98.032,09	98.809,58	160.604,35	100.387,98	101.189,03	164.856,25	102.815,25	103.640,58	169.236,98	105.316,08
SCENARIO C/Operating Costs +1%	95.201,15	153.996,75	96.702,94	97.465,11	158.042,28	99.012,41	99.797,68	162.210,40	101.391,86	102.200,92	166.504,81	103.843,40	104.676,99	170.929,35	106.369,24
NEGATIVE CASH FLOWS (base scenario)	94.258,56	152.472,03	95.745,48	96.500,11	156.477,51	98.032,09	98.809,58	160.604,35	100.387,98	101.189,03	164.856,25	102.815,25	103.640,58	169.236,98	105.316,08
NEGATIVE CASH FLOWS B	94.259	152.472	95.745	96.500	156.478	98.032	98.810	160.604	100.388	101.189	164.856	102.815	103.641	169.237	105.316
NEGATIVE CASH FLOWS C	95.201	153.997	96.703	97.465	158.042	99.012	99.798	162.210	101.392	102.201	166.505	103.843	104.677	170.929	106.369
Net cash flow (base scenario)	272.284	214.070	270.797	270.042	209.201	268.510	267.733	205.938	266.154	265.353	201.686	263.727	262.902	197.305	261.226
Net cash flow A	268.618	210.405	267.131	266.377	206.399	264.845	264.067	202.273	262.489	261.688	198.021	260.062	259.236	193.640	257.561
Net cash flow B	272.284	214.070	270.797	270.042	209.201	268.510	267.733	205.938	266.154	265.353	201.686	263.727	262.902	197.305	261.226
Net cash flow C	271.341	212.546	269.839	269.077	207.636	267.530	266.745	204.332	265.151	264.341	200.038	262.699	261.865	195.613	260.173

In financial analysis, all three variables (operating revenues, investment costs, operating costs) are critical; their changes for 1 % affect the financial NPV (i.e. the financial rationality of the project) by more than 1 %, with the assumption that all other variables remain unchanged ("ceteris paribus" assumption (Figure 35):

- 1 % change in operating revenues affects more than 1 % change in NPV (7.71 %);
- 1 % change in investment costs affects more than 1 % change in NPV (4.30 %);
- 1 % change in operating costs affects more than 1 % change in NPV (2.47 %).

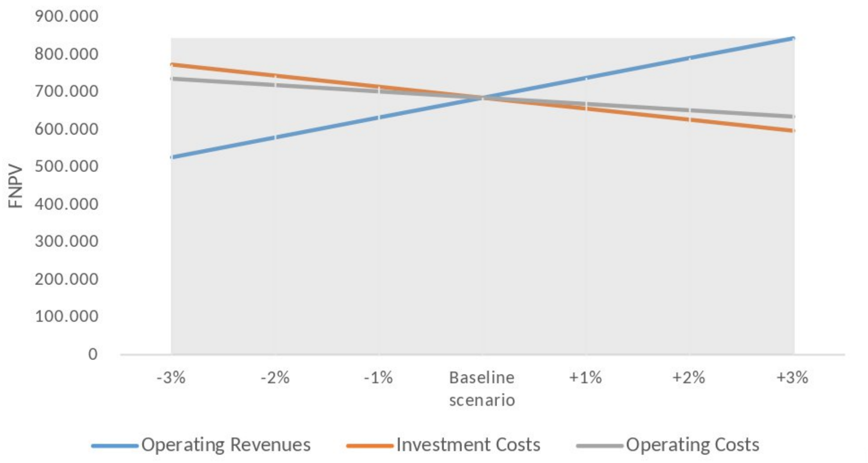

Figure 35. Financial Net Present Value Sensitivity Analysis – infiltration pond method

These results point to the high risk of the project and the need for significant attention in its planning. The financial net present value becomes negative (i.e. the project becomes financially irrational) with the following variation of each variable (with other variables unchanged, i.e. ceteris paribus assumption):

- in case of a 13 % reduction in operating revenues, with the remaining variables unchanged;
- in case of an increase in investment costs by 24 %, with the remaining variables unchanged;
- in case of an increase in operating costs by 41 %, with the remaining variables unchanged.

Public infrastructure projects are rarely financially justified, but this is also not their primary objective. The primary goal of these projects is to create better conditions for the living of the island's inhabitants, further economic (touristic) development of the island, and, with all that, further social development of the island. Whether the project can achieve these goals, we will check in the continuation of the study with an economic (social) analysis, i.e. through the project's total social costs and benefits *(Chapter 7.2 Economic analysis)*.

7.1.7. Simulation of financial indicators and pilot project performance in different scenarios

The financial analysis of the pilot project and the sensitivity analysis highlighted operating revenues as the most sensitive variable. Furthermore, the risk analysis highlighted that risk of insufficient water to recharge aquifers is one of the highest risks, which will directly impact the revenues of the pilot project.

The financial calculations and calculations of the physical impact of the project are made based on assumptions that have been, to a large extent, estimated or assessed approximately. Therefore, before pilot project implementation, more detailed research, measurements, and modeling of the physical impact of the project are recommended. The future water demand on the island is not doubtable, and therefore, the project is not jeopardized in this respect. However, to justify the projected interventions in the natural environment and the financial investment, the pilot MAR project should have guaranteed certain quantities of water for recharge the aquifers. This amount is estimated to be cumulatively 3.5 rechargings of the accumulation lake per year, i.e. a total of 81,130 m^3 water per year. Assuming losses from the lake (35 %) and losses in water distribution to final users (currently 25 %, with the assumed reduction to the final 15 % in the 11th year of the project), a pilot MAR system could reach the annual net water quantity of 40,565 m^3. This net quantity represents 100 % coverage of additional needs of drinking water on the island in the short term, around 50 % in the medium term, and about 30 % in the long term.

In Table 20, different scenarios, concerning the annual number of rechargings of the lake, are presented:

Table 20. The physical and financial impact of the pilot project with varying assumptions of water quantity (annual number of lake rechargings) for aquifer recharge

Scenario	Number of lake rechargings per year	Gross annual water quantity	Net annual water quantity	FNPV	% coverage of additional needs for drinking water on the island		
					Short-term	Medium-term	Long-term
Scenario 0 (base)	3.5	81,130 m^3	40,565 m^3	685,970 HRK	100 %	50 %	33 %
Scenario A	1	23,180 m^3	11,590 m^3	-2,536,192 HRK	100 %	14 %	10 %
Scenario B	2	46,360 m^3	23,180 m^3	-1,232,255 HRK	100 %	30 %	20 %
Scenario C	5	115,900 m^3	57,950 m^3	2,537,494 HRK	100 %	100 %	50 %
Scenario D	10	231,800 m^3	115,900 m^3	4,941,256 HRK	100 %	100 %	100 %

A similar simulation can be performed with the variation of losses due to evaporation, which directly affects the yearly net amount of water available to final users.

The base scenario assumes 35 % of annual losses due to evaporation. Assuming a lower or higher loss percentage, we get new amounts of net available water for final consumption. If we take the base Scenario 0 (3.5 annual lake rechargings), we get the following scenarios (Table 21):

Table 21. The physical and financial impact of the pilot project with varying assumptions of water quantity (evaporation losses) for aquifer recharge

Scenario	Loss due to evaporation	Gross annual water quantity	Net annual water quantity	FNPV	% coverage of additional needs for drinking water on the island		
					Short-term	Medium-term	Long-term
Scenario 0 (base)	35 %	81,130 m^3	40,565 m^3	685,970 HRK	100 %	50 %	33 %
Scenario 1	20 %	81,130 m^3	52,735 m^3	2,048,070 HRK	100 %	100 %	50 %
Scenario 2	50 %	81,130 m^3	28,396 m^3	-438,393 HRK	100 %	35 %	25 %
Scenario 3	65 %	81,130 m^3	16,226 m^3	-1,472,983 HRK	100 %	18 %	15 %

The above examples show the high sensitivity of the project, both physically and financially, when it comes to the amount of water available to aquifer recharge. In addition to the technical risks in the implementation of the project, this is a risk that can significantly affect the success of this pilot project. Therefore, further technological research and testing are recommended before the final decision to implement the project to predict the project's outcome better.

7.2. Economic analysis

7.2.1. Presumptions of economic analysis

The economic analysis of the project needs to be done to assess the project's contribution to overall well-being. This means that the economic analysis is made from the point of view of society, the wider community, rather than from the investors' point of view. The economic rationale of the project can be explained as a synonym for sustainability, cohesion, and growth. An economically justified project creates the goods and services that society needs, contributes to productivity and economic growth, and creates sustainable jobs. Finally, the economic analysis ensures that financial support from national, European, and other international sources is justified.

Economic analysis and evaluation of the project from a social point of view include the analysis of the project's social benefits and social costs. Public infrastructure projects are not intended to generate profits, but their fundamental objective is to create benefits for the wider society (target groups and end-users of the project). Public infrastructure projects aim to influence the community's demographic, social, economic, and environmental development. For these reasons, it is necessary to look at these projects more broadly, evaluate them from a financial point of view and preferably from an economic point of view, and propose their implementation in the case of positive economic indicators.

As the starting point of the economic analysis, cash flows from the financial analysis were considered. Following the international practice, the transformation process from the financial analysis of the project to economic consists of the following adjustments:

- fiscal corrections: exclusion of transfers to the state or local government;
- conversion from market prices to economic prices: where market prices do not show social opportunity costs, a correction (converting) into economic prices is required using appropriate correction factors;
- quantification of social (economic) benefits;
- quantification of non-market effects and corrections regarding externalities: monetize costs and benefits that are not directly reflected in market prices (social, environmental, health, and similar effects);
- inclusion of additional indirect effects (if relevant): indirect social impacts that do not need to be recognized from the investor’s point of view and are socially relevant (effects on other sectors);
- discounting of estimated costs and benefits by selecting the correct social discount rate;
- calculation of economic indicators: economic (social) net present value (ENPV), economic (social) internal rate of return (ERR), benefits/costs ratio indicator (B/C)

We have applied a social discount rate of 5 % in economic analysis, according to the EU CBA methodology.

7.2.2. The transition from financial analysis to economic analysis

Fiscal corrections

Taxes and subsidies are transfer payments that do not represent actual economic costs or benefits to society. Fiscal corrections have to be done to exclude national and/or local government transfers when calculating investment costs. This is how we assure that the outflows towards the market are considered from the public interest point of view and not from the point of view of the public sector.

To correct these distortions, according to the EU CBA methodology, we should make the following **fiscal corrections**:

- all prices are considered excluding indirect taxes (e.g. VAT is an indirect tax and should be excluded in economic analysis);
- input prices are considered excluding direct taxes (e.g. tax on income that is part of gross salaries should be excluded at this stage);
- all prices are considered without subsidies and other transfers provided by the public authority (e.g. grants and government incentives).

Conversion from market prices to economic prices and application of conversion factors to the entry costs of the pilot project

The next step in the economic analysis is the conversion of all inputs from financial (market) prices into so-called shadow prices, i.e., economic prices. The market prices of inputs and outputs used in the financial analysis do not reflect their social value. The reasons for this are, in most cases, in the existence of monopolies and oligopolies in providing services or in the fact that the prices of services are regulated to compensate for market failures. The same situation is with labor costs that do not reflect real social value in most cases. We use conversion factors or correction factors that convert the financial values into economic values, which can be then used in the economic analysis.

Standard conversion factor

First, we apply the Standard Conversion Factor (SCF). It can be calculated based on an estimate of national exports and imports and associated taxes[1], or the competent governmental authority publishes it[2]. If not published or calculated, SCF = 1.

Specific conversion factors applied

The calculation of conversion factors is performed according to the EU CBA methodology, applying national economic individual characteristics. Since Croatia participates in the international market economy principle, the analysis does not have to apply correction factors to eliminate market distortions. Therefore, market prices are considered to be economic prices. The focus is on the conversions of different investment costs; we have to exclude direct taxes from them. The conversion factors applied in the economic analysis of this pilot project are presented below (Table 22).

Table 22. Conversion factors applied in the economic analysis

[1] According to the definition in EC CBA guidelines, the value of the standard conversion factor is: SKF=(M+X)/(M+Tm)+(X-Tx), where M stands for total imports, X for total exports, Tm are taxes on imports and Tx are Export taxes.

[2] In Croatia, the competent authority is the Croatian Bureau of Statistics, but it is currently not publishing the SCF.

Type of cost	Conversion factor	Description
Materials and equipment	1	For materials and equipment, the conversion factor is 1.
Labor costs	0.834	It is estimated that in the construction project, the share of labor and material is equal. The share of skilled workers (SW) is estimated to be 70 % and unskilled (USW) to 30 %. For labor (skilled and unskilled), the conversion factor is calculated as the product of factor 1 minus the share of direct taxes in gross salary (t) and factor 1 minus the unemployment rate for SW and USW in a given county, in our case this is Split-Dalmatia county (u). Conversion factor for labour = (1-t)*(1-u) Conversion factor for the SW group = 0.8011 Conversion factor for the USW group = 0.8217 Calculation of the common conversion factor for labour costs: CF_{labour} = (0.70*0.8011)+(0.30*0.8217)=0.807
Construction costs	0.917	For construction costs, a conversion factor 1 for goods (materials) represents 50 % of the total construction costs, and a conversion factor of 0.807 for labor represents the remaining 50 % of the total construction costs. Calculation of the conversion factor for construction costs: $CF_{construction}$ = (0.5*1)+(0.5*0.807)=0.904
Non-material costs	0.807	Since they consist of labor costs (services), the conversion factor is equal to the conversion factor for the labor costs. $KF_{non\text{-}material\ c..}$ = 0.807
Operating costs	0.900	For operating costs, a conversion factor of 1 for goods (materials), representing 30 % of operating costs, and a factor for the labor of 0.807, representing the remaining 70 % of operating costs, is applied. $KF_{operating\ c.}$ = (0.3*1)+(0.7*0.807)=0.865

Since Croatia has significantly reduced import and export taxes in the process of joining the EU and after it entered into the EU, it is assumed that the **conversion factor of materials and equipment is 1**. **The conversion factor for non-material assets is the same as for labor** since it consists of direct work (services).

Shadow wages

The shadow wages measure the opportunity cost of labor. Current wages may be a distorted social indicator of the opportunity cost of labor because labor markets are imperfect. Therefore, the shadow wage differs from the actual wage on the market.

We calculate shadow wages by using conversion factors. We must correct the market wages with the conversion factors of shadow wages for skilled and unskilled workers. The conversion factor is calculated as the product of factor 1 minus the share of direct taxes in gross salary (t) and factor 1 minus the unemployment rate (u) for skilled workers (SW) and unskilled workers (USW) in a given county where the project is located; in our case, this is Split-Dalmatia county. The conversion factor for each group of workers is calculated by: (1-t)*(1-u).

The calculation of the conversion factor for salaries in the shadow of skilled and unskilled workers is presented in Table 23.

Table 23. Calculation of the conversion factor for shadow wages of skilled and unskilled workers

City of Vis, City of Komiža (calculated averages)	Skilled workers	Unskilled workers
Gross 2 salary	9,203.60 HRK	7,530.22 HRK
Gross 1 salary	7,852.90 HRK	6,425.10 HRK
Pension insurance - 1st pillar (15 %)	1,177.94 HRK	963.77 HRK
Pension insurance - 2nd pillar (5 %)	392.65 HRK	321.26 HRK
Income	6,282.32 HRK	5,140.08 HRK
Personal deduction	4,000.00 HRK	4,000.00 HRK
Tax base	2,282.32 HRK	1,140.08 HRK
Tax (24 %)	547.76 HRK	273.62 HRK
Local tax (4 %) (Vis 3 %, Komiža 5 %)	21.91 HRK	10.94 HRK
Total taxes	569.67 HRK	284.56 HRK
t=taxes in gross 2 salary	6.19 %	3.78 %
Net salary	5,712.65 HRK	4,855.52 HRK
u=unemployment rate	14.60 %	14.60 %
CF=(1-t)+(1-u)	80.11 %	82.17 %
Conversion factor (CF)	0.8011	0.8217

Statistical data from the Croatian Bureau of Statistics have been applied:

- Average monthly net salary in the construction sector (group F) in January-December 2020 in the Republic of Croatia: 5,394.00 HRK. For estimating the ratio between the net salary of the skilled and unskilled workers, older data were applied (last available refer to 2016). According to the available data, a skilled construction worker receives a net salary of 10 % above the average wage in the sector and a non-skilled worker 10 % beneath the average net salary in the sector.
- A valid tax rate was applied for the city of Vis (3 %) and the city of Komiža (5 %).
- Data on the unemployment rate refer to Split-Dalmatia County in 2020.

7.2.3. Quantification of direct social benefits

The direct benefits are the incremental operating revenues, which are taken from the financial analysis (Table 24):

Table 24. Incremental annual operating revenues of the pilot project

Year of project	Revenues (HRK)
Year 1	0
Year 2	0

Year 3	101.153
Year 4	115.711
Year 5	303.078
Year 6	460.430
Year 7	479.136
Year 8	458.073
Year 9	340.950
Year 10	341.814
Year 11	362.222
Year 12	363.086
Year 13	363.950
Year 14	364.814
Year 15	365.678
Years 16-30	366.542

The direct benefit of the MAR system will be the additionally available quantities of drinking water that we can financially value through the additional revenues. Revenues will be generated through the distribution (and sale) of these incremental water quantities to final users. However, this is not the only benefit this project will generate.

7.2.4. Quantification of non-market effects

Defining of non-market effects

The project non-market effects can be defined as effects to the beneficiaries of the project, which are relevant to society but whose market value is not known. We can divide non-market effects into direct and indirect effects. Direct effects affect the same sector but on other stakeholders, while indirect effects affect other sectors. Externalities are also one of the non-market effects are. However, they are most often difficult to assess and are therefore usually given only qualitatively. The "willingness to pay" method is the most commonly used method to quantify non-market effects. With this method, we can estimate the monetary value of a given good or service through known user preferences.

The direct benefits of MAR projects are also not based solely on market revenues, but we should assess the total economic value of the additional water available. The economic value is based on people's willingness to pay (WTP) a certain amount of money to avoid overexploitation of aquifers or groundwater and the consequences of this overexploitation on health, space, economy, pleasant life, etc. The economic value of a good or service for a society is the sum of the WTPs of all individuals. It is evident that the economic value of the water is not fixed; on the contrary, it is affected by circumstances (e.g. scarcity of water resources due to drought or over-exploitation) and individual preferences.

These are some of the most frequently mentioned economic (social) benefits of MAR projects:

- improved access to drinking water in terms of availability, reliability, and quality of service;
- ecosystem conservation - underground aquifer as a renewable water resource;

- additional quantities of drinking water during water scarcity (drought, periods of increased consumption, etc.);
- positive effects on the health of users.

The water market is not a typical competition market and does not function as a competitive market. Also, the price of water paid by the final user does not reflect the water's actual (economic, social) value. For example, water scarcity will increase the value of water in the eyes of the final user. The pilot project on the island of Vis is specific because each final consumer is directly affected by the lack of water. Due to its distance from the mainland, the island is not connected to the water supply on the mainland and depends entirely on its water stocks and the ability to use them. Water reductions in the summer months, which are needed to prevent groundwater from seawater intrusion, directly affect the life comfort of all residents. Furthermore, the island is full of guests during the summer months, and water reductions affect the quality of the overall tourist service provided to them.

MAR projects deliver socio-economic and environmental benefits; however, MAR methodology for feasibility studies focuses on evaluating socio-economic benefits.

In the preliminary environmental impact assessment of the pilot project *(report D.T3.7.1 Preliminary Environmental Impact Assessment)*, the project's potential environmental impacts were analysed. An overall neutral to positive environmental impact is expected, except for the "soil" component, where a long-term direct negative impact is expected. Below is a table (Table 25) summarising the preliminary environmental impact assessment of the pilot project.

Table 25. Preliminary environmental impact assessment of the pilot project

Environmental component	Impact			
	Direct / Indirect	Short-term / Long-term	Positive / Neutral / Negative	Overall score
Climate change	Indirect	Long-term	Neutral	0
Geology	Direct	Long-term	Neutral	0
Soil	Direct	Long-term	Negative	-1
Surface water	Indirect	Short-term	Positive	1
Groundwater	Direct	Long-term	Positive	1
Landscape	Direct	Long-term	Neutral	0
Cultural heritage	Indirect		Neutral	0
Protected areas	Direct	Long-term	Neutral	0
Ecological network		Long-term		0
Population	Indirect	Long-term	Positive	1

Overall rating - legend:

-1 negative impact

0 No impact

1 positive impact

Based on the preliminary environmental impact assessment results of the pilot project, we can conclude that the environmental benefits are far beneath the potential harm (negative impact). This means that with the non-inclusion of environmental impacts, we have not failed the analysis in terms of underestimation of costs. Cumulatively, taking this methodological decision, the social benefits of the project are underestimated, which should be taken into account in the final social evaluation of the project.

There are several methods for estimating the value of water from the point of view of the final user, and the **“willingness to pay” method is used as the most comprehensive method.** We use the “willingness to pay method” also in this feasibility study.

The target beneficiaries of project results should be defined first to define the benefits in the next phase. We have defined key stakeholders of this pilot project in chapter 1.2: “Developing the intervention logic of the project”. We have also descriptively defined the expected benefits for each group of end-users. The method of willingness to pay will help us quantify these described benefits.

We have identified the following main target groups of the pilot project:

- residents of the island of Vis,
- companies, entrepreneurs on the island,
- tourist accommodation providers,
- tourists, visitors to the island,
- company Vodovod i odvodnja otoka Visa d.o.o.,
- City of Vis and City of Komiža.

To observe and quantify the benefits, we have merged all these target groups into two core target groups:

- all inhabitants of the island (improving their living and working conditions with the pilot project);
- tourists, visitors to the island (improving quality of their staying on the island through secured water supply).

The first group is introduced into the benefit analysis through the survey about their willingness to pay. The benefits related to the second group are quantified by assessing the impact of the implemented MAR scheme on the island's attractiveness as a tourist destination and related turnover from tourism and associated activities.

Estimating the actual value of water (i.e. benefits) through the WTP method and calculation of the WTP premium

This pilot project will generate direct revenues. In economic analysis, we need to replace these direct revenues with revenues based on social price, i.e. maximum price, that the beneficiary is willing to pay to obtain desirable economic effects (results). This approach is defined as a “willingness to pay” (WTP) approach. We use the WTP approach to assess the value that users attribute to a particular product or service.

There are several approaches to assess the willingness to pay. The most commonly used method is the method of direct testing of the willingness to pay by the final users (by conducting surveys) or observing consumer habits. In addition to the willingness to pay by users, the variables such as awareness of existing problems, their attitude to the environment, and demographic and socio-status variables are also examined.

As part of this feasibility study, we have assessed the willingness to pay through an online survey. We have decided to perform a survey in an online version. We invited the adult inhabitants of the island of Vis to complete the survey from 11 August 2021 to 31 August 2021. The online survey and the information about the survey were distributed through several local Facebook groups and profiles. We wanted to attract different groups of people with different interests and occupations to ensure that the collected results were representative. The survey was successfully implemented; during the given period, 157 completed surveys were received, representing 5.2 % of all adult inhabitants of Vis island, i.e. 11 % of all households on the island (assuming that one completed survey represents one household).

Demographic sample of respondents

The age structure of the people who submitted the survey is consistent with the overall age structure of the island inhabitants. Even though the survey was distributed and submitted online, 36 % of the responses were received from people over 45 years of age. Only 22 % of responses were received from adults under 30 years of age. According to the Croatian Bureau of Statistics, the average age of the inhabitants of the island of Vis is 46 years (Table 26).

Table 26. Demographic sample of respondents

Variable	Replies	Relative frequency
Gender	Female	36.3 %
	Male	61.8 %
	No answer	1.9 %
Age	16 to 30	22.3 %
	31 to 45	41.4 %
	More than 45	35.7 %
	No answer	0.6 %
The highest level of education achieved	Primary education or below	7.6 %
	Secondary education	35.7 %
	Bachelor's Degree	44.6 %
	Master's Degree	6.4 %
	PhD in Science	3.2 %
	No answer	2.5 %
Annual household income	Less than 155,000 HRK	61.8 %
	From 155,000 HRK to 310,000 HRK	24.8 %
	From 310,000 HRK to 620,000 HRK	3.8 %
	From 620,000 HRK to 1,240,000 HRK	0.6 %
	More than 1,240,000 HRK	1.3 %
	No answer	7.6 %
Employment status	Full-time employment	48.4 %
	Part-time employment	9.6 %
	Looking for a job	16.6 %
	Retired	12.1 %
	No answer	13.4 %
Number of children	0	30.6 %
	1	24.2 %
	2	29.3 %

	3	4.5 %
	More than 3	3.2 %
	No answer	8.3 %

Results — Descriptive statistics

The respondents were first asked about their general knowledge about groundwater issues and their awareness of their influence on the groundwater. Water scarcity is part of the everyday life of the inhabitants of the island of Vis, which they encounter practically every summer. Although most respondents say that they do not have high knowledge about the groundwater, they are very aware of their impact on the quality and quantity of groundwater. On the other hand, a large proportion of the population is unaware of the sources of water they use every day.

To the question *"Have you used groundwater in the past or the present?"*, only 60.5 % of respondents answered yes; 25.5 % of respondents replied that they used the groundwater in the past, and 14 % responded they did not use groundwater. We can conclude from the answers received to this question that the inhabitants of the island of Vis are not aware of the water source they consume every day. On the other hand, they are well aware of the problem because it affects them directly. To the question *"Have you heard about any groundwater issues (from any type of media)?"*, 46.5 % of respondents answer "yes, several times" and 38.9 % "yes, very often". Only 14.6 % of respondents have never heard about the groundwater issues. The control question *"Have you heard about problems related to the quality or quantity of groundwater?"* gives a similar result: 55.4 % of respondents replied "yes, several times," and 28.7 % of respondents replied, "yes, very often". 15.9 % of respondents replied that they had never heard about the quality and quantity of groundwater problems.

Respondents' general knowledge about groundwater problems is evaluated from themselves as poor (41.4 % of respondents) or very poor (30.6 % of respondents). Only 23.6 % of respondents assess their general knowledge of groundwater problems as good, and 4.5 % of respondents as excellent.

Regarding groundwater problems, respondents are most concerned about natural pollution (36.3 %) and over-exploitation (31.8 %). To the question *"Please select your main concern regarding groundwater problems"*, respondents selected following (Figure 36):

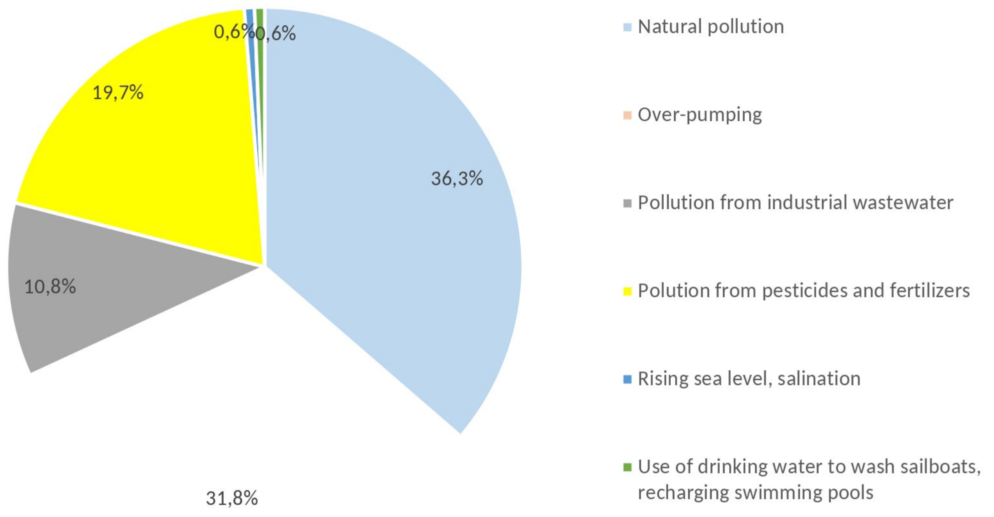

Figure 36. Problems with groundwater most concerned by respondents in the survey

In the respondent's opinion, *the main reason for the groundwater degradation* is the lack of public awareness; the second most significant reason is the poor implementation of existing legislation, and the third, lack of adequate legislation.

In the respondent's opinion, *the prevailing pressures on groundwater are*:

- inappropriate municipal waste management (40.8 %);
- losses from the water supply system (28.7 %);
- municipal wastewater discharge (28.7 %);
- use of fertilizers and pesticides in agriculture (1.8 % of respondents).

75.2 % of respondents believe that it is *very important that the competent authorities (agencies) take care of the protection and conservation of groundwater*; however, even 61.1 % of respondents believe that *the competent authorities do not have the necessary capacity to fulfil this obligation*. 33.1 % of respondents are unsure about this issue, and only 5.7 % believe that authorities have the necessary capacity.

Respondents mostly agree that *it is very important for each individual to take care of the protection and conservation of groundwater* (Figure 37).

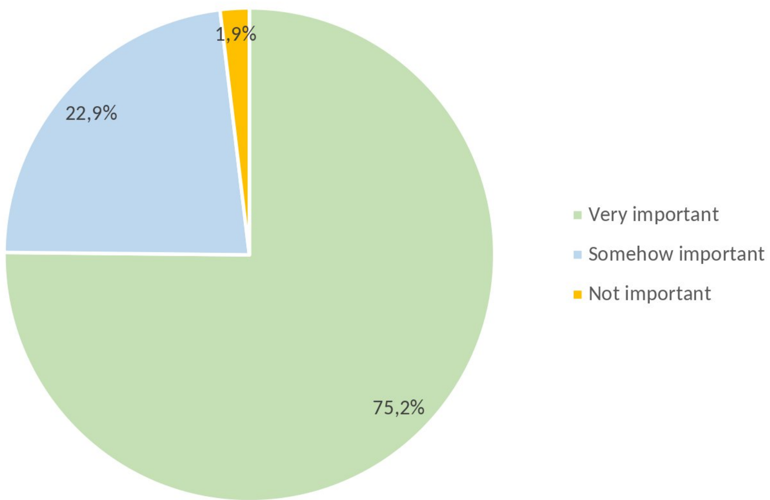

Figure 37. Analysis of the responses to the question: “To what extent is it important for every individual to take care of the protection and conservation of groundwater?”

Interesting are the responses to the next question, which are contradictory with the previous one. Even 34.4 % of respondents believe that their household has no impact on groundwater quality and/or quantity. Let's go back to the previous question. We can see that 75.2 % of respondents believe that it is very important that each individual takes care of the protection and conservation of groundwater. Another 24.2 % of respondents believe it is somewhat important. Only 1.3 % of the population share the view that the behavior of an individual does not matter (Figure 38).

If we look at the question "*Does your household have an impact on groundwater quality and/or quantity?*" we can see that 34.4 % of respondents think that the quality and/or quantity of groundwater is not affected by their household.

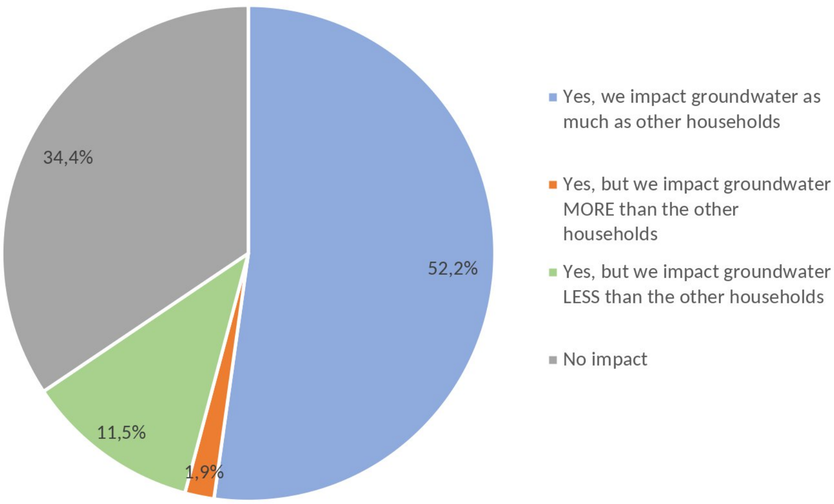

Figure 38. Analysis of the responses to the question: "Does your household have an impact on groundwater quality and/or quantity?"

The respondents' opinion on whether their household impacts the quality and/or quantity of groundwater is statistically not significant to the level of education achieved by the respondents.

Even 94.3 % of respondents believe that there should be a plan for the protection and conservation of groundwater, but only 36.3 % of respondents are ready to participate financially in its implementation.

The survey results showed that the willingness to pay (in terms of yes/no) is higher for people who have achieved a higher level of education (Figure 39). Furthermore, there is a higher overall interest for the topic at people with higher achieved education level. The figure below shows the willingness to pay (in terms of yes/no) in relation to the respondents' level of education. For people with lower-to-middle education, the share of those willing to pay is around 30 %. For graduates with a master's degree, this share is 60 %, and for PhDs, this share is about 80 %.

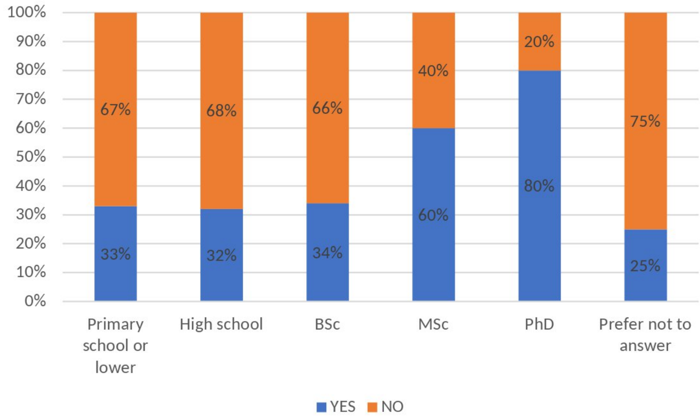

Figure 39. Willingness to pay in relation to the respondents' level of education

When testing a willingness to pay in the correlation with an annual income level of the households, the results are similar: their connection is statistically non-significant, which can also be seen from Figure 40. The annual income level has no relation to the respondents' willingness to pay.

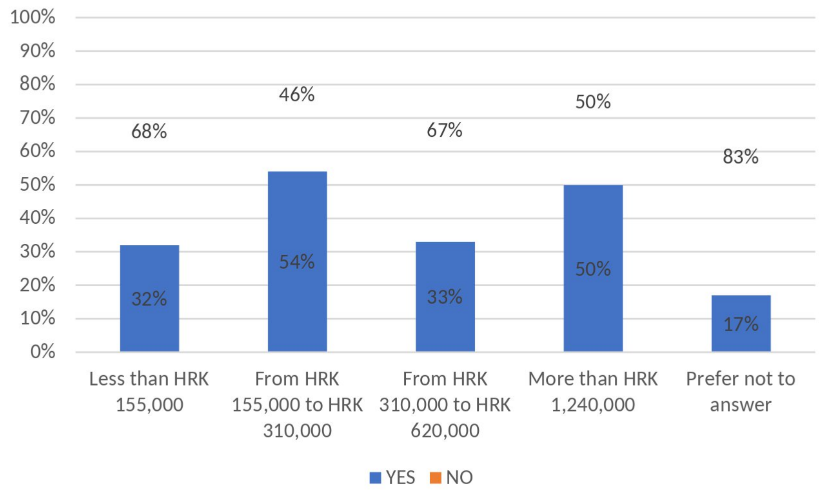

Figure 40. Willingness to pay in relation to the amount of annual income of the respondent's household

Willingness to pay — Results

In the survey, after describing the Groundwater Management Plan scenario and its potential future implementation, respondents were asked if they were willing to pay a monthly contribution to support groundwater conservation and implementation of the plan for the preservation and protection of groundwater. 36.3 % of respondents would financially support such a plan and are willing to participate with their financial contribution in different amounts. For the remaining 63.7 % of respondents, the answer was negative. The most frequently cited reasons for the negative answer are as follows:

(i.) I already pay enough municipal/income taxes: 51 %.

(ii.) I can not afford it: 19 %

(iii.) It is the government's responsibility: 18 %

(iv.) Industries, farmers, etc. should pay: 10 %

(v.) I prefer not to answer: 2 %

The remaining offered answers have not been selected:

(vi.) The proposed plan is not feasible, good enough, convincing, etc. (0 %)

(vii.) I don't care much about protecting and preserving groundwater. (0 %)

Answers (ii.), (vi.) and (vii.) (a total of 19 %) are considered in the literature as "true zero WTP-amounts", meaning, these are indeed negative responses, and responses (i.), (iii.) and (iv.) as "protest zeros", means protest negative responses (79 % in total).

The treatment of protest negative answers is an open question in the literature. While a direct approach to analysis includes only negative responses ("true zeros"), some researchers argue that demonstrators would probably vote against the proposed policies and that it is correct to treat them as "true zero" responses, as selective data removal may affect the validity of assessments (e.g. Halstead et al., 1992; Jorgensen and Syme, 2000; Carson and Hanemann, 2005). Halstead et al. (1992) argue that protest negative responses can be considered legitimate zero values if the purpose of the survey is to measure the value of development (or policy) options rather than a specific good. Thus, since the presented scenario can be understood as a development option, it is assumed that "protest zeros" can be considered legitimate zeros ("true zeros") and, as such represent preferences, which do not support the proposed scenario.

The respondents willing to pay (36.3 % of all respondents) offered between 7 HRK and 350 HRK per month in the first five years to support the proposed scenario. The amount of contributions that individuals are willing to pay is statistically unrelated to the level of the household's annual income in which these individuals live.

According to the results of the survey, two mean premium values were calculated:

- The mean value of the premium for those who are ready to pay is 37.32 HRK per month per household (i.e. maximum premium level);
- The mean value of the premium for all inhabitants of the island of Vis, regardless of their willingness to pay, is 13.55 HRK per month per household (i.e. minimum premium level).

If we take the proportion of positive and negative responses as a weight, we get a weighted average monthly premium of 22.18 HRK per month per household, i.e. 266.16 HRK per year per household for a period of five years. According to the latest statistical data, 1,421 households are on the island of Vis, which turns the total annual average premium from the Willingness to Pay (WTP) 378,211.19 HRK.

The calculated average annual premium is applied in the economic analysis of the project (in item social benefit - willingness to pay - WTP).

Estimation of the social benefits of increased attractiveness of the island as a tourist destination and additional accommodation capacities

In the water demand projection, we assumed that the additionally available quantities of drinking water on the island would encourage investors to build new tourist accommodation capacities. In their strategic development plans, both cities on the island have written to support investors at such programs. Therefore, it can be quite realistically expected that this pilot project would give positive signals for building to interested investors. The current demand for water in the summer season has reached the current maximum sustainability of the existing aquifer. Without additional amounts of drinking water on the island, it is irrealistic to plan further tourist development (in terms of an increasing number of tourist arrivals).

The projected future water demand assumes a 10 % increase in demand in 2025, an additional 5 % in 2026, and another 5 % in 2028, corresponding to the projected increase in tourist arrivals, overnights, and spending. Given that the increase in the number of tourist arrivals will be affected by a whole range of impacts and it is difficult to attribute the effect of this particular project, we assume extremely conservative that only 1 % of all additional tourist arrivals will be a result of the implementation of this pilot project.

We have further assumed that the average duration of the tourist stay will not change. The calculation takes a conservative estimate of 5.5 days (according to the average in 2018-2019, which is one day less than the average in the years before 2018 and also less than the average in 2020).

In estimating tourist spendings, we have applied the value of the average daily consumption of each additional tourist of 519,91 HRK per night. This amount represents a conservative 70 % of the total daily consumption of the average tourist in Split-Dalmatia County in 2019: 99.03 EUR (i.e. 742,72 HRK) (data source: research TOMAS Croatia 2019).

The calculation of the social benefits of the pilot project due to increasing the attractiveness of the island as a tourist destination and additional accommodation capacities is presented in Table 28.

Table 28. Social benefits of the pilot project due to increased tourist attractiveness of the island of Vis as a touristic destination and additionally available accommodation capacities

	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Number of arrivals without project	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
2	Number of night without project	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837
3	Average length of staying on the island	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50
4	Total number of arrivals with project	50.000	50.000	50.000	50.000	55.000	57.750	57.750	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638
5	Total number of nights with project	274.837	274.837	274.837	274.837	302.321	317.437	317.437	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309
6	Additional arrivals (4-1)	0	0	0	0	5.000	7.750	7.750	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638
7	Additional nights motivated with the project (6*3)	0	0	0	0	275	426	426	585	585	585	585	585	585	585	585
8	Daily spending of the tourist with the overnight (u kn)	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91
9	*Additional spending motivated with the project*	*0*	*0*	*0*	*0*	*142 890*	*221479*	*221479*	*303 998*	*303.998*	*303.998*	*303.998*	*303 998*	*303998*	*303998*	*303998*
	TOTAL increase in tourist consumption motivated with the project	*0*	*0*	*0*	*0*	*142.890*	*221.479*	*221.479*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*

	Description	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Number of arrivals without project	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
2	Number of night without project	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837	274.837
3	Average length of staying on the island	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50	5,50
4	Total number of arrivals with project	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638	60.638
5	Total number of nights with project	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309	333.309
6	Additional arrivals (4-1)	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638	10.638
7	Additional nights motivated with the project (6*3)	585	585	585	585	585	585	585	585	585	585	585	585	585	585	585
8	Daily spending of the tourist with the overnight (u kn)	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91	519,91
9	*Additional spending motivated with the project*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*
	TOTAL increase in tourist consumption motivated with the project	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*	*303.998*

7.2.5. Calculation and interpretation of economic indicators

Based on the above assumptions and transformation of financial categories to economic, we have calculated the economic (social) indicators of the pilot project on the island of Vis. The economic analysis encompasses the direct social benefits and costs of the pilot project (i.e. market benefits and costs from financial analysis, which we have transformed into economic categories through adjustments) and its non-market benefits and costs.

The economic analysis of this pilot project shows that the socio-economic impacts of the project significantly exceed its socio-economic costs. Therefore, economic indicators are very favorable, as presented in table 29:

Table 29. Economic indicators of the pilot project

Indicator	Calculated indicator value	Referential values
ENPV	6,037,733 HRK	greater than 0 HRK
ERR	22.59 %	higher than 5 %
B/C	2.84	higher than 1
NPV of economic benefits	9.324.994 HRK	higher than NPV of economic costs
NPV of economic costs	3.287.261 HRK	lower than NPV of economic benefits

Discount rate: 5 %

ENPV - Economic (social) net present value

ERR - Economic (social) internal rate of return

B/C - benefits/costs ratio indicator

The economic net present value of the project at the economic discount rate of 5 % is positive and amounts to 6,037,733 HRK.

The economic internal rate of return of the project exceeds the economic discount rate of 5 % by more than 17 percentage points and is 22.59 %.

The economic benefits of the project are higher than the economic costs, as evidenced by the indicator B/C of 2.84, indicating that 100 HRK of investments returns 284 HRK of economic benefits.

The following table (Table 30) presents the economic analysis of the project, discounting the estimated costs and benefits of the project, using a 5 % economic discount rate.

Table 30. Economic analysis of the pilot project – infiltration pond method

Description	CF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Improved attractiveness of the tourist destination - direct benefits for the tourist sector (increased revenues)		0	0	0	0	142.890	221.479	221.479	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998
Operating Revenues		0	0	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678
Willingness to Pay		0	0	53.687	61.414	153.192	378.211	378.211	378.211	378.211	109.917	0	0	0	0	0
Residual value		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOCIAL BENEFITS		0	0	154.840	177.125	599.160	1.060.120	1.078.827	1.140.282	1.023.159	755.729	666.220	667.084	667.948	668.812	669.676
Labour costs	0,807	38.429	110.497													
Construction costs	0,904	0	1.119.582													
Equipment	1,000	0	0													
Non-material costs (services)	0,807	719.319	191.141													
Total Investment		757.748	1.421.220													
Total Operating Costs	0,865	0	0	61.682	63.028	117.036	81.182	82.635	127.414	76.186	76.783	125.279	79.048	79.663	128.544	80.911
SOCIAL COSTS		757.748	1.421.220	61.682	63.028	117.036	81.182	82.635	127.414	76.186	76.783	125.279	79.048	79.663	128.544	80.911
NET SOCIAL BENEFITS		-757.748	-1.421.220	93.158	114.097	482.123	978.938	996.192	1.012.869	946.973	678.946	540.941	588.037	588.285	540.269	588.765

Description	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Improved attractiveness of the tourist destination - direct benefits for the tourist sector (increased revenues)	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998
Operating Revenues	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542
Willingness to Pay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOCIAL BENEFITS	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.54
Labour costs															
Construction costs															
Equipment															
Non-material costs (services)															
Total Investment															
Total Operating Costs	81.545	131.907	82.832	83.484	135.372	84.810	85.482	138.942	86.848	87.541	142.621	88.948	89.662	146.411	91.111
SOCIAL COSTS	81.545	131.907	82.832	83.484	135.372	84.810	85.482	138.942	86.848	87.541	142.621	88.948	89.662	146.411	91.111
NET SOCIAL BENEFITS	588.995	538.634	587.709	587.056	535.168	585.731	585.058	531.598	583.693	583.000	527.920	581.593	580.879	524.130	579.429

7.2.6. Sensitivity analysis of economic indicators

In economic analysis, sensitivity analysis is performed using the same methodology as in the financial analysis. Sensitivity analysis makes us possible to identify critical project variables. Critical variables are those whose positive or negative variations significantly impact the project's financial/economic performance. The analysis is done by changing variables one by one and determining the effects of these changes on the financial/economic net present value (FNPV/ENPV).

Those variables whose variation ± 1 % of the value adopted in the baseline case gives rise to a variation of more than 1 % in net present value should be considered critical.

Sensitivity analysis was made for each of the variables used in the economic analysis of the project:

- financial revenues of the pilot project;
- the operating costs of the pilot project;
- investment costs of the pilot project,
- the height of the Willingness to Pay premium (WTP),
- the level of additional income in tourism activities.

We have developed and verified the following scenarios of the economic costs and benefits of the project:

- Scenario 1: the level of additional revenues in tourism activities resulting from the implementation of this pilot project is 1 % lower than the baseline scenario.
- Scenario 2: the willingness to pay and the associated premium are 1 % lower than the baseline scenario.
- Scenario 3: the project's financial revenues are 1 % lower than the baseline scenario.
- Scenario 4: investment costs are 1 % higher than the baseline scenario.
- Scenario 5: operating costs are 1 % higher than the baseline scenario.

These are the results of the sensitivity analysis – sensitivity of the projects' ENPV (Economic Net Present Value) to variations of different variables (Tables 31 and 32):

Table 31. Results of the project sensitivity analysis to variations of variables

Scenario	Variable	Change	ENPV	Change in ENPV	Evaluation of the criticality of the variable
Scenario 0 (base scenario)			6,037,733		
Scenario 1	Revenues from tourism	- 1 %	6,004,245	- 0.55 %	not critical
Scenario 2	Willingness to pay	- 1 %	6,024,381	- 0.22 %	not critical
Scenario 3	Financial revenues	- 1 %	5,991,323	- 0.77 %	not critical
Scenario 4	Investment costs	+ 1 %	6,017,625	- 0.33 %	not critical
Scenario 5	Operating costs	+ 1 %	6,024,968	- 0.21 %	not critical

Discount rate: 5 %

Table 32. Analysis of the project sensitivity to variations of variables – sensitivity of Economic Net Present Value (ENPV)

Description	CF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Improved attractiveness of the tourist destination - direct benefits for the tourist sector (increased r		0	0	0	0	142.890	221.479	221.479	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998
SCENARIO 1/lower direct benefits for the tourist sector -1%		0	0	0	0	141.461	219.264	219.264	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958
Willingness to Pay		0	0	53.687	61.414	153.192	378.211	378.211	378.211	378.211	109.917	0	0	0	0	0
SCENARIO 2/lower willingness to pay - 1%		0	0	53.151	60.800	151.660	374.429	374.429	374.429	374.429	108.818	0	0	0	0	0
Operating Revenues		0	0	101.153	115.711	303.078	460.430	479.136	458.073	340.950	341.814	362.222	363.086	363.950	364.814	365.678
SCENARIO 3/lower revenues -1%		0	0	100.141	114.554	300.047	455.825	474.345	453.492	337.540	338.396	358.600	359.455	360.311	361.166	362.022
Residual value		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOCIAL BENEFITS		0	0	154.840	177.125	599.160	1.060.120	1.078.827	1.140.282	1.023.159	755.729	666.220	667.084	667.948	668.812	669.676
SOCIAL BENEFITS - SCENARIO 1		0	0	154.840	177.125	597.731	1.057.905	1.076.612	1.137.242	1.020.119	752.689	663.180	664.044	664.908	665.772	666.636
SOCIAL BENEFITS - SCENARIO 2		0	0	154.303	176.511	597.628	1.056.338	1.075.044	1.136.500	1.019.377	754.630	666.220	667.084	667.948	668.812	669.676
SOCIAL BENEFITS - SCENARIO 3		0	0	153.828	175.968	596.129	1.055.516	1.074.035	1.135.701	1.019.750	752.311	662.598	663.454	664.309	665.164	666.020
Labour costs	0,807	38.429	110.497													
Construction costs	0,904	0	1.119.582													
Equipment	1	0	0													
Non-material costs (services)	0,807	719.319	191.141													
Total Investment		757.748	1.421.220													
SCENARIO 4/investment +1%		765.326	1.435.432													
Total operating costs	0,865	0	0	61.682	63.028	117.036	81.182	82.635	127.414	76.186	76.783	125.279	79.048	79.663	128.544	80.911
SCENARIO 5/operating costs +1%		0	0	62.299	63.659	118.207	81.994	83.461	128.688	76.948	77.551	126.532	79.838	80.460	129.829	81.721
SOCIAL COSTS		757.748	1.421.220	61.682	63.028	117.036	81.182	82.635	127.414	76.186	76.783	125.279	79.048	79.663	128.544	80.911
SOCIAL COSTS - SCENARIO 4		765.326	1.435.432	61.682	63.028	117.036	81.182	82.635	127.414	76.186	76.783	125.279	79.048	79.663	128.544	80.911
SOCIAL COSTS - SCENARIO 5		757.748	1.421.220	62.299	63.659	118.207	81.994	83.461	128.688	76.948	77.551	126.532	79.838	80.460	129.829	81.721
NET SOCIAL BENEFITS		-757.748	-1.421.220	93.158	114.097	482.123	978.938	996.192	1.012.869	946.973	678.946	540.941	588.037	588.285	540.269	588.765
NET SOCIAL BENEFITS - SCENARIO 1		-757.748	-1.421.220	93.158	114.097	480.694	976.723	993.977	1.009.829	943.933	675.906	537.901	584.997	585.246	537.229	585.725
NET SOCIAL BENEFITS - SCENARIO 2		-757.748	-1.421.220	92.621	113.483	480.591	975.156	992.410	1.009.086	943.191	677.846	540.941	588.037	588.285	540.269	588.765
NET SOCIAL BENEFITS - SCENARIO 3		-757.748	-1.421.220	92.147	112.940	479.093	974.334	991.400	1.008.288	943.563	675.528	537.319	584.406	584.646	536.621	585.108
NET SOCIAL BENEFITS - SCENARIO 4		-765.326	-1.435.432	93.158	114.097	482.123	978.938	996.192	1.012.869	946.973	678.946	540.941	588.037	588.285	540.269	588.765
NET SOCIAL BENEFITS - SCENARIO 5		-757.748	-1.421.220	92.541	113.467	480.953	978.126	995.365	1.011.594	946.211	678.178	539.688	587.246	587.489	538.983	587.956

Description	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Improved attractiveness of the tourist destination - direct benefits for the tourist sector (increased r	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998	303.998
SCENARIO 1/lower direct benefits for the tourist sector -1%	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958	300.958
Willingness to Pay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCENARIO 2/lower willingness to pay - 1%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operating Revenues	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542	366.542
SCENARIO 3/lower revenues -1%	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877	362.877
Residual value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOCIAL BENEFITS	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540
SOCIAL BENEFITS - SCENARIO 1	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500	667.500
SOCIAL BENEFITS - SCENARIO 2	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540	670.540
SOCIAL BENEFITS - SCENARIO 3	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875	666.875
Labour costs															
Construction costs															
Equipment															
Non-material costs (services)															
Total Investment															
SCENARIO 4/investment +1%															
Total operating costs	81.545	131.907	82.832	83.484	135.372	84.810	85.482	138.942	86.848	87.541	142.621	88.948	89.662	146.411	91.111
SCENARIO 5/operating costs +1%	82.361	133.226	83.660	84.319	136.726	85.658	86.337	140.332	87.716	88.416	144.047	89.837	90.558	147.875	92.022
SOCIAL COSTS	81.545	131.907	82.832	83.484	135.372	84.810	85.482	138.942	86.848	87.541	142.621	88.948	89.662	146.411	91.111
SOCIAL COSTS - SCENARIO 4	81.545	131.907	82.832	83.484	135.372	84.810	85.482	138.942	86.848	87.541	142.621	88.948	89.662	146.411	91.111
SOCIAL COSTS - SCENARIO 5	82.361	133.226	83.660	84.319	136.726	85.658	86.337	140.332	87.716	88.416	144.047	89.837	90.558	147.875	92.022
NET SOCIAL BENEFITS	588.995	538.634	587.709	587.056	535.168	585.731	585.058	531.598	583.693	583.000	527.920	581.593	580.879	524.130	579.429
NET SOCIAL BENEFITS - SCENARIO 1	585.955	535.594	584.669	584.016	532.128	582.691	582.018	528.558	580.653	579.960	524.880	578.553	577.839	521.090	576.389
NET SOCIAL BENEFITS - SCENARIO 2	588.995	538.634	587.709	587.056	535.168	585.731	585.058	531.598	583.693	583.000	527.920	581.593	580.879	524.130	579.429
NET SOCIAL BENEFITS - SCENARIO 3	585.330	534.968	584.044	583.391	531.503	582.065	581.393	527.933	580.027	579.334	524.254	577.927	577.213	520.464	575.764
NET SOCIAL BENEFITS - SCENARIO 4	588.995	538.634	587.709	587.056	535.168	585.731	585.058	531.598	583.693	583.000	527.920	581.593	580.879	524.130	579.429
NET SOCIAL BENEFITS - SCENARIO 5	588.180	537.315	586.881	586.221	533.815	584.883	584.203	530.209	582.824	582.124	526.494	580.703	579.982	522.666	578.518

Sensitivity analysis shows that no variable is critical in terms of socio-economic analysis. This means that each variable affects a change in the economic (social) net present value of the project (i.e. the social rationale of the project) by less than 1 % if this variable changes by 1 %, with the remaining variables unchanged (i.e. ceteris paribus assumption).

The sensitivity analysis showed that the project is stable from a socio-economic point of view and is not very sensitive to small changes in the value of the variables tested.

7.2.7. Probabilistic risk analysis

We have finally checked the project's sensitivity with the probabilistic analysis, using the Monte Carlo simulation.

According to the EU CBA methodology, probabilistic risk analysis is necessary when the residual risk exposure is significant or when the subject of the analysis is an investment-intensive project.

This type of analysis assigns the probability distribution to each critical sensitivity analysis variable, defined in the precise range of values around the best estimate, used as a baseline case to recalculate the expected value of the financial and economic indicators of the project.

The simulation returned the results that there is a 100 % probability that the pilot project will result in positive economic net present value, in all cases of changes in the following ranges (Figure 41):

- discounted investment costs from 90 % to 150 % compared to the base case,

- discounted maintenance and operating costs from 90 % to 130 % compared to the base case, and
- the project's discounted net economic revenues from 70 % and 105 % compared to the base case.

Assumptions - Triangular Probability Distributions

Base-case ENPV	HRK	5.691.928,60		
Variables		Investment	O&M	Benefits
Base-case (Present Value)	HRK	2.356.557,83	1.276.507,57	9.324.994,00
Minimum	%	90%	90%	70%
Most Likely (Mode)	%	100%	100%	100%
Maximum	%	150%	130%	105%
Number of iterations	#	10.000		

Run Simulation

Results of Monte Carlo Simulation - ENPV

Aritmetička sredina (Očekivana ENPV)	HRK	4.507.247,40	Minimum	HRK	1.850.950,31
Median	HRK	4.587.980,10	Maximum	HRK	6.253.867,68
Standardna devijacija	HRK	789.802,52	Prob. {ENPV>0}	%	100,0%

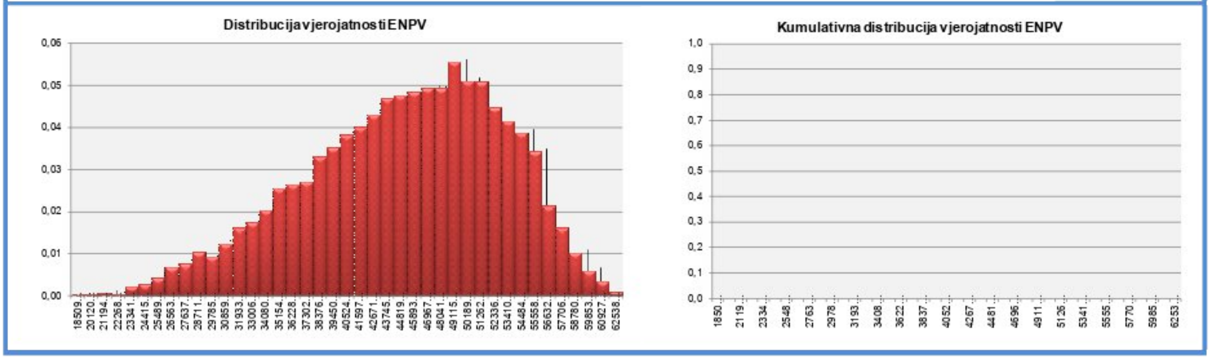

Figure 41. Results of probabilistic risk analysis

8. Comparison of alternative solutions

8.1. Identification and description of options

This chapter analyses options that can ensure the achievement of the set objectives of the pilot project and their feasibility, taking into account the local context, demand, available technology, human resources, and the proposed scope of the project.

The options in the proposed pilot project are considered through a question of their possibility to achieving the specific objectives of the pilot project:

- To increase the available quantities of water on the island of Vis by collecting excess water during periods of higher rainfall and storing it in underground aquifers for dry periods.
- To reduce the risk of ensuring satisfactory water quality on the island of Vis through the artificial recharge of aquifers, thereby preserving them in the long term. Increasing groundwater levels in aquifers will reduce the risk of salination.
- To improve living conditions on the island of Vis and conditions for economic activity, especially for further development of tourism on the island of Vis.

We are also assessing the question, can alternatives contribute to the overall objective of the project: “Develop an example of good practice of maintaining and increasing the quality and quantity of groundwater using sustainable management methods, i.e. MAR systems in aquifers located in semiarid karst areas of Croatia and the wider region”.

Three alternative options will be considered:

- business-as-usual- BAU,
- the “do minimum” option and
- the “do something else” option - the proposed option and alternative option.

The “do something else” option is analysed by this feasibility study as the proposed (chosen) option. In this chapter, as part of the “do something else” option, we will consider another (alternative) option of the MAR system on the island of Vis, i.e. the ASR method, which is a method of aquifer recharging by injection of excess surface water into the aquifer.

8.1.1. Business-as-usual option

The “business-as-usual” or “no change” option is a fundamental option with which we compare the proposed project. What happens if the investor gives up the investment? What are the consequences?

In case of giving up the pilot project, all the social and financial benefits expected by implementing this pilot project will be lost. The highest loss will be the loss of social benefits that have also been recognised through the conducted research on the willingness to pay by users. In addition, social benefits from the sustainable use of aquifers that can be considered renewable water sources will be lost. Since this is also the only water source on the island of Vis, the loss of opportunity benefits is even greater.

The city of Vis and the city of Komiža have developed strategic development plans that include several activities that can hardly be perceived as feasible without secured additional quantities of water on the island. In particular, tourism development plans involving the construction of new tourist accommodation capacities should be highlighted here. In the current water supply situation, the island of Vis, during summers, comes to the upper limit of the maximum possible pumping of water from the aquifer in the Korita well field, which is also the main source of drinking water on the island. The long-term sustainability could become jeopardised at such high water quantities pumped from the aquifer. For the last two years, 2021 and 2020, there has been practically no rainfall on the island in the summer months, making the problem even more significant. Prepared forecasts of climate series and the time series of average annual runoffs at the pilot site (*"Hydrological Balance and Implementation of Geophysical Researches"*, Terra Compacta d.o.o., 2021) have shown that, for the Korita area, we can expect a continuous increase in temperature, a decrease in rainfall and finally a decrease in average annual runoffs. According to the projections, it is very likely that the current minimum overall water yield of all wells in Korita of 27 l/s will decrease to around 16 l/s by 2100. With the assumptions of minimal growth in water consumption in the local population, the island of Vis will no longer be able to maintain current tourist trends. At the same time, tourism is the primary activity of most islanders.

Assuming that this pilot project is not implemented, the project objectives will not be realised, nor will the planned development on the island be possible. In the long term, it will not be possible to maintain the current economic situation of the island. In this case, other options of water supply on the island of Vis should be explored.

8.1.2. Option “do minimum”

Another option is the implementation of minimum measures, i.e., implementing an alternative project with a minimum investment, which could achieve certain results and thereby contribute to meeting the development and project objectives.

In the framework of the option “do minimum”, first should be considered which are those investments in the framework of the envisaged pilot project which we can be classified as “minimum investments”. As such, we can, for example, opt for all promotional, communication, and educational activities, which can achieve a certain increase in general society’s awareness of the need for sustainable management of drinking water as a natural resource.

Also, by educating the population, they would gain greater knowledge of the important facts of water supply on the island of Vis. In the survey carried out, 157 inhabitants have been involved. The survey showed a large part of the population (around 40 %) is not aware of the source of drinking water on the island.

The option “do minimum” can include measures to reduce water losses in the distribution system to final consumers, but this is not part of this project.

A large part of this pilot project includes activities related to the preparation of the project for the implementation: geophysical research, study and project documentation, and acquisition of all necessary permits. These are activities that can also be classified under the “do minimum” option. However, with these activities, none of the objectives of the project will be achieved.

Since this is a fully infrastructural project, all remaining activities within the project represent capital investment and mean high investments to achieve the project’s objectives.

In terms of achieved objectives, the “do minimum” is very similar to the “business-as-usual” option and is therefore not acceptable in this respect.

8.1.3. Option “do something else” – alternative option

As an alternative option in the “do something else” option, we will consider an alternative option of the MAR scheme, i.e. the ASR method, which is a method of the aquifer recharging by injection of water through the well. We will compare this alternative option with the proposed option, i.e. implementing the MAR scheme by the infiltration pond method.

The analysis of the suitability of the pilot site Korita for different MAR schemes resulted in a positive assessment for both methods: the ASR and the infiltration pond method. If we roughly compare both methods in financial terms and in terms of their physical effect, we can conclude that the ASR method is with the same physical effect, financially significantly more demanding.

Aquifer Storage and Recovery method (ASR) – the estimation of investment costs

According to the alternative MAR scheme, i. e. the ASR method, the total investment for implementing the pilot project is 4,689,559.70 HRK, including VAT, which means that the investment is about 50 % higher than the basic (proposed) option.

The table below shows the distribution of costs according to the type of costs (Table 33):

Table 33. Investment costs by the cost types – alternative option: Aquifer Storage and Recovery (ASR)

	Description	Costs (in HRK)	% of total investment costs	Type of cost
1	Project management and administration	401.180,00	8,55%	Non-material
2	Preparation of the project	1.718.750,00	36,65%	Non-material
3	Implementation of works and equipping	2.337.760,00	49,85%	Material
4	Project supervision and audit	115.869,70	2,47%	Non-material
5	Promotion and visibility, communication and education of stakeholders	116.000,00	2,47%	Non-material
	Total investment costs	4.689.559,70	100,00%	
	Ineligible costs		0,00%	
	Total eligible costs	4.689.559,70	100,00%	

At higher investment costs, higher maintenance and operation costs, and with the same physical impact, the pilot project under this alternative option is not financially eligible, while the base option (infiltration pond scheme) is. The financial indicators of the pilot project if implemented according to the ASR method are shown in Table 34. The same assumptions have been used as in the proposed option, except for the difference in investment and operating costs.

Table 34. Financial indicators – alternative option: Aquifer Storage and Recovery method (ASR)

Financial discount rate	4 %
FNPV	-2.848.391 HRK
FRR	-3.62 %
Net present value of investment costs	4.401.846 HRK
Net present value of residual value	0 HRK
Net present value of revenues	5.653.651 HRK
Net present value of costs	4.100.196 HRK

FNP - Financial Net Present Value
FRR - financial internal rate of return

The financial viability of public infrastructure projects is not a fundamental decision-making factor for launching a particular investment. However, the Water Framework Directive (2000/60/EC) requires investment planning in water supply projects in such a way that projects do not generate negative financial results. This means that for an investment that will not cover the costs with the revenues generated, the prices to the final beneficiaries should be corrected in such a way that the projects are financially viable in the long term. Given the already high water prices on the island, this option would be challenging to accept by the inhabitants of the island of Vis.

Aquifer Storage and Recovery method (ASR) - sensitivity analysis of financial indicators

An analysis of the sensitivity of the financial indicators for the alternative variant has been developed. The same assumptions as in the proposed option are used.

The results of the financial sensitivity analysis for the alternative variant are presented in the following table (Table 35).

Table 35. Results of the sensitivity analysis of the pilot project to variation of variables to financial net present value (FNPV) – alternative option: Aquifer Storage and Recovery (ASR) method

Scenario	Variable	Change	FNPV	Change FNPV	Evaluation of the criticality of the variable
Scenario 0 (base scenario)			-848,785	0.00 %	
Scenario A	Revenues	-1 %	-2,904,928	-1.97 %	critical
Scenario B	Investment costs	+1 %	-2,892,804	-1.55 %	critical
Scenario C	Operating costs	+1 %	-2,889,787	-1.44 %	critical

As in the proposed option, all variables are critical. We can see that variations are slightly smaller in the alternative option. However, given that the base scenario is negative, these results mean significant changes are needed for the pilot project under this option to achieve positive financial results.

Aquifer Storage and Recovery (ASR) method - analysis of the social acceptability of the project

Given that financial eligibility for public infrastructure projects is not a fundamental decision-making criterion, we have also analyzed the project's social (economic) eligibility according to the alternative method – the ASR method.

When an alternative project is viewed from the social cost/benefit ratio, the project generates positive results and can be characterized as socially acceptable. The results of the economic analysis are summarised in the table below (Table 36).

Table 36. Economic indicators – alternative option: Aquifer Storage and Recovery (ASR) method

Indicator	Calculated indicator value	Referential values
ENPV	3.674.248 kn	greater than 0 HRK
ERR	13.94 %	higher than 5 %
B/C	1,60	higher than 1
NPV of economic benefits	9.795.928 kn	higher than NPV of economic costs
NPV of economic costs	6.121.681 kn	lower than NPV of economic benefits

Discount rate: 5 %

ENPV...Economic (social) net present value

ERR...Economic (social) internal rate of return

B/C...benefits/costs ratio indicator

The results show that, from the point of view of society, the pilot project is acceptable in the alternative option as well as in the proposed option. Namely, it generates higher social benefits than its social costs are. However, all social acceptability indicators are lower than under the proposed option (infiltration pond method).

Aquifer Storage and Recovery (ASR) method – sensitivity analysis of economic indicators

The sensitivity analysis of the economic (social) indicators for the alternative option has been developed. The same assumptions as those used in the proposed variant are used.

The results of the economic sensitivity analysis for the alternative option are presented in the following table (Table 37).

Table 37. Results of the sensitivity analysis of the pilot project to variation of variables to economic (social) net present value (ENPV) – alternative option: Aquifer Storage and Recovery (ASR) method

Scenario	Variable	Change	ENPV	Change ENPV	Evaluation of the criticality of the variable
Scenario 0 (base scenario)			3,674,248	0.00 %	
Scenario 1	Revenues from tourism	-1 %	3,640,760	-0.91 %	not critical
Scenario 2	Willingness to pay	-1 %	3,659,248	-0.41 %	not critical
Scenario 3	Financial revenues	-1 %	3,624,775	-1.35 %	critical
Scenario 4	Investment costs	+1 %	3,643,959	-0.82 %	not critical
Scenario 5	Operating costs	+1 %	3,643,319	-0.84 %	not critical

Discount rate: 5 %

According to the proposed option, in the sensitivity analysis of the economic indicators, none of the variables was reported as critical. On the contrary, in the alternative option, the revenues are a critical variable. Namely, we can see from the results that if the revenues decrease by 1 %, the economic net present value will decrease by more than 1 %, makings this variable critical.

8.2. Other options

If none of the MAR options under the „do something else“ option is selected, in this case, the island of Vis and the responsible legal and natural persons will need to accept a decision on the implementation of other or more other options in the long term, which will provide additional amounts of water on the island. Different options have been discussed through the strategic development plans in the past but have not been implemented so far.

Water resources exploration activities are continuously ongoing on the island of Vis to provide additional available water. On the other hand, there are ongoing activities to reduce water consumption, from investment measures to improve the efficiency of the distribution system to educational measures aimed at educating the island's residents and guests towards deliberate water consumption. Also, during summers, water reductions are not rare, i.e. physical closure of water distribution at certain times, to prevent water from being salinated due to low water levels in the aquifer. None of these options constitutes a long-term solution to existing (and growing) problems.

A long time ago, there was a plan to establish a reservoir that would allow water collection in periods of heavy rainfall. However, the project has never been realized.

Among other options, most often are under discussion and planning (i.) construction of a desalination plant on the island and (ii.) connecting the island to the mainland. Both options are financially highly demanding and with a huge environmental footprint. The latest updates to the EU CBA methodology (2021) foresee a new evaluation of CO_2 emissions, which will make investments involving fossil-source fuels (at any stage - i.e. in implementation and/or operational period) largely socially unacceptable. For CO^2 emissions, the following shadow prices are recommended (Table 38):

Table 38. Recommended Shadow Prices for CO_2 emissions

Year	EUR/t CO_2e	Year	EUR/t CO_2e
2020.	80	2036.	417
2021.	97	2037.	444
2022.	114	2038.	471
2023.	131	2039.	498
2024.	148	2040.	525
2025.	165	2041.	552
2026.	182	2042.	579
2027.	199	2043.	606
2028.	216	2044.	633
2029.	233	2045.	660
2030.	250	2046.	688
2031.	278	2047.	716
2032.	306	2048.	744
2033.	334	2049.	772
2034.	362	2050.	800
2035.	390		

Source: Economic Appraisal Vademecum 2021-2027, General Principles and Sector Applications (European Commission, DG REGIO, 2021)

Shadow prices are entering into calculations of the project's economic (social) costs, significantly hindering projects involving a large CO_2 footprint. Thus, projects with a lower environmental footprint and closer to sustainable development processes will have an increasing advantage in project planning.

9. Discussion about the chosen option, conclusions, and recommendations for stakeholders or investors

This feasibility study for the pilot project of establishing the MAR scheme in aquifers located in semiarid karst areas of Croatia has been developed under the Interreg project DEEPWATER-CE.

The feasibility analysis is prepared for a proposed and alternative option. The basic (proposed) option represents the implementation of the pilot project according to the infiltration pond method. The alternative option represents implementing a pilot project according to the Aquifer Storage and Recovery method (ASR). Both options are assessed at the same pilot location, i.e. at the area of the Korita aquifer in the central part of the island of Vis. Given the appropriateness of the methods at the selected pilot site, both methods were identified as technically appropriate.

The infiltration pond method compared to the ASR method requires less intervention in the natural environment, is less risky (but still high-risk), is less demanding in terms of capital investment and operating costs, the required infrastructure intervention is smaller, the amount of equipment installed is significantly lower, with the same final effect achieved. Therefore, in terms of elaborating a feasibility study, the infiltration pond method was defined as the primary and the ASR method as an alternative method.

The infiltration pond method proved to be justified in financial and economic (social) terms. On the other hand, the ASR method is not financially justified, whereas, in social terms, it is, but with lower economic NPV than the primary option. Given that investments in public infrastructure must not only be seen in financial terms, but firstly in economic (social), the financial non-acceptability of the pilot project under the ASR method should not be a reason for rejecting the project. However, the Water Framework Directive (2000/60/EC) requires the financial sustainability of all investments into water infrastructure, which entails the necessary price alignment towards final beneficiaries in case of implementing a financially non-feasible project. Given the already high water prices on the island, this option would be challenging to accept by the inhabitants of the island of Vis.

By comparing the options among themselves, the conclusion is that the primary option, i.e. the infiltration pond method, according to all parameters, is better.

The implementation of the proposed pilot project is not investment demanding and is made up of relatively simple operations.

The underlying problem of the project is its high riskiness and high sensitivity to changes in the applied assumptions. Given that this is a pilot project and the lack of implemented MAR systems in the karst area that could be used as a basis and an example of good practice, we were forced to work with many assumptions; some have solid foundations, others are more theoretical.

The high riskiness of the project is demonstrated at different levels of analysis: through risk analysis using the MAR methodology (there are numerous high-risk events), sensitivity analysis (high sensitivity of the project to small changes in input variables), and simulation of the physical and financial effects of the project based on the variation of the amount of water to be infiltrated into the aquifer.

Simulation of the physical and financial effects of the pilot project based on different quantities of infiltrated water has shown that the final net amount of available water can be affected by several factors, where, in practice, more of them can occur at the same time. With a variation of only one factor at a time, we have shown that we quickly come to entirely different financial and physical effects of the project with the application of different assumptions. Even more than financially, the variation of the physical impact of the project is worrying, i.e. how much water will the MAR scheme contribute.

The project is most sensitive to assumptions that define the amount of infiltrated water to the aquifer. On the other hand, these assumptions define the project and are very difficult to predict. In the risk analysis, the quantity of water infiltrated and its quality is one of the highest-ranked risks. As the pilot project is located in the karst area, the risks and unknowns are even more significant and more numerous.

The infiltration pond method is closest to Nature-based Solutions (NBS) conditions, which will become the basis for adaptation to climate change in the medium term, if not in the short time already. The method of the infiltration pond is a simulation of natural processes, and therefore, further study of it is necessary. All fundamental EU and national development strategies are based on conserving the environment, natural (renewable) resources, sustainable development, groundwater conservation. The infiltration lake method encompasses all of the above.

Given the favourable financial and economic indicators of the pilot project and the positive environmental effects, it would be detrimental to reject the project solely because of its high riskiness. To a large extent, risks occur from insufficiently accurate data and the need to use assumptions. They can be reduced by carrying out additional research. Therefore, further research is proposed, particularly at the pilot site on the island of Vis, to anticipate the future outcome of the project better. The island of Vis is an ideal pilot location in all respects. In addition, the further development of the island will be based on ensuring sufficient quantities of water. Priority should be given to solutions with a lower impact on the natural environment, i.e. solutions close to natural processes.

10. Annexes

Annex 1 – Development of intervention logic of the project DEEPWATER-CE

Annex 1 -
Intervention logic of

Annex 2 - D.T3.6.1 *Report on the desk analysis of the pilot feasibility study for mar deployment in fractured and karstified aquifers located in semiarid karst areas*

D.T3.6.1
Croatia.docx

Annex 3 – D.T3.6.2 *Report on the field work of the pilot feasibility study for mar deployment in Split-Dalmatia County*

D.T3.6.2
Croatia.docx

Annex 4 – D.T3.6.3 *Compiled checklist for the application of risk management protocol during the field works for MAR in Split-Dalmatia County*

D.T3.6.3
Croatia.docx

Annex 5 – Total investment costs for IP

Annex 5 - Total
investment costs - br

11. References

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