DESSIN
DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

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D13.1: Quantified ESS for 3 mature sites including recommendations for application PART 3 - Llobregat case

Lead Author: Cetaqua, April 2016

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Introduction

In WP13, the DESSIN ESS Evaluation Framework, developed in WP11, was applied to the three DESSIN mature cases in order to test its applicability. The aim was to quantify ESS, to assess changes in ESS provision, and to conduct a sustainability assessment in order to validate the ESS Evaluation Framework.

The three mature case studies are:
PART 1 – Aarhus case in Denmark
PART 2 – Emscher case in Germany
PART 3 – Llobregat case in Spain

The mature cases represent case studies where innovative solutions were already realized. Therefore, it is possible to compare the status before and after the solution was implemented. The case studies are distributed throughout Europe in order to cover a broad geographical range with diverse environmental conditions and social dimensions. Furthermore, the case studies offer an illustration of a wide variety of ecosystem service types targeted with restoration projects.

Each case was included for specific reasons and has a specific focus:

The innovative solution in the **Aarhus mature case** study is the real-time control of a full urban water cycle with sewers and wastewater treatment plants as well as recipient waters such as lakes, river, and a harbor. All these elements are combined into one model-based real-time decision support system (DSS). The aim of this real-time DSS system was to adapt Aarhus' water system to climate change related challenges and to raise the recreational potential in the city of Aarhus via an improvement of the water quality. Thus, this case has a special emphasis on water quality issues and recreational values.

The **Emscher site** applies the ESS Evaluation Framework to individual sections of the Emscher river network for the status before and after the large-scale Emscher restoration was realized. Subsequently, the results are transferred across the multi-site case study allowing a prognosis for the whole catchment. Service provision is, in the end, related to the costs of the restoration project for the river network as a whole.

The **Llobregat study** has a focus on the economic valuation of changes in ESS provision resulting from the implementation of infiltration ponds. These ponds were created in order to replenish the groundwater reserves and provide drinking and non-drinking water to the Barcelona area. The current and past status and the resulting benefits are assessed for individual beneficiaries.

The application of the analytical evaluation framework consists of the following steps for each case:

- Selection of key ESS affected by the innovative solutions
- Identification of relevant indicators to measure changes in ecosystem status and service provision
- Quantification of the case-relevant ESS
- Valuation of the final ESS
- Assessment of the innovative solution with regard to sustainability aspects

A reflection of the applicability of the ESS methodology was formulated for each mature site throughout the validation process, going along with the development of the Framework. This provided practical recommendations for the improvement of the methodology during the developmental phase.

The recommendations are reported in the combined **Milestones 21 & 26**.

D13.1: Quantified ESS for 3 mature sites including recommendations for application
PART 3 – Llobregat case

SUMMARY	
This Deliverable reports the results of the application of the ESS Evaluation Framework (D11.2) for the 3 mature cases: PART 1 – Aarhus case PART 2 – Emscher case PART 3 – Llobregat case	
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List of Acronyms and Abbreviations

AB	Aigües de Barcelona Drinking Water Supply company
ACA	Catalan Water Agency
AMB	Àrea Metropolitana de Barcelona public administration
ASR	Aquifer Storage and Recovery
ASTR	Aquifer Storage Transfer and Recovery
CICES	Common International Classification of Ecosystem Services
CUADLL	Association of groundwater users in the Llobregat aquifer
DPSIR	Drivers, Pressures, State, Impacts and Response scheme
DWTP	Drinking Water Treatment Plant
ESS	Ecosystem Services
FESS	Final Ecosystem Services
GDP	Gross Domestic Product
ICTM	Individual Travel Cost Method
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
MAR	Managed Aquifer Recharge
MPN	Most Probable Number (unit of microbiological concentration)
MTTF	Mean Time To Failure
MTBF	Mean Time Between Failures
SA	Sustainability Assessment
SCC	Santa Coloma de Cervelló
SJD	Sant Joan Despí facility of Drinking Water Treatment Plant (Barcelona)
SVH	Sant Vicenç dels Horts
WHO	World Health Organisation
WTP	Willingness To Pay

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Executive summary

This report is included in task T13.1 of the DESSSIN project, aiming at applying the DESSIN ESS assessment methodology to existing data from measures already implemented in the water basins. Three European sites have been selected: Emshcher river restoration (Germany), rehabilitation of a coastal area including the river as part of the city in Aarhus (Denmark) and the construction of large infiltration ponds for aquifer replenishment in Baix Llobregat area (Barcelona). The methodology for ESS evaluation developed within the DESSIN project is based on DPSIR scheme (drivers, pressures, state, impact and response). The cookbook describes the method to be applied, and contains standard lists for classification of drivers, pressures, beneficiaries and type of services (intermediate or final), for instance. To know more about the methodology developed in the cookbook, it is hardly recommended to consult it (Anzaldúa *et al.* 2016).

Specifically, this report evaluates the ESS linked to the infiltration system planned in Santa Coloma de Cervelló (SCC). SCC infiltration system is designed to occupy 13 ha of surface placed and an infiltration capacity of 10 Mm^3/year. This is one of the top priorities for the future investments 2015 – 2020 of the Catalan Water Agency (ACA). The investment for its construction is 8 M€. For the biophysical approach and the evaluation of expected impacts in hydrogeology and biophysical indicators, the system of SVH has been taken as a reference, with an annual infiltrated volume of 1 Mm^3/year in average. SVH represents a 10% of the amount of water that could be recharged in SCC, but can illustrate perfectly the changes in native groundwater quality and the changes along soil-aquifer interface in terms of pollutants removal. SCC has been selected as mature site in the Llobregat area due to the high impact in groundwater resources and the previous experience gathered in Sant Vicenç dels Horts (SVH) system. Results obtained will be directly applied by ACA to the cost-benefit analysis in their starting plan of investments in hydraulic infrastructures linked to the water cycle.

The first part of the document explains the **drivers and pressures** which contextualize the construction of the infiltration ponds. Industry and urban development have been the two drivers identified, causing a list of inter-connected pressures in groundwater: local industrial pollution as solvents or PAHs, municipal and industrial waste water treatment discharges, increase of extraction rates for industry and drinking water production and hydrological alteration caused by the urbanization of areas in the river basin.

The complexity of the ESS assessment of SCC is due to: (1) assumption of the similar effectiveness of SCC system to SVH system in terms of water quality and operational regime; (2) evaluation of research opportunities and cultural services of a very specific nature-based infrastructure, (3) uncertainty of the effects of piezometric level rise and salinity decrease for the groundwater users and (4) determination of added value of groundwater for the users in the aquifer. To deal with these uncertainties, the work started with a series of interviews with hydrogeologists and water managers of the area in order to identify the main beneficiaries of groundwater and the area of influence of SCC system. Once identified drinking water operators and industries as the main groundwater end-users, Aigües de Barcelona (AB) and DAMM Company were selected as the most representative beneficiaries due to their large volume of pumped groundwater compared to other drinking water operators (e.g. Aigües del Prat) and industries, respectively. Moreover, the numerical model developed by CUADLL simulating the groundwater level rise in the aquifer after the implementation of SCC system has been used to determine the groundwater level expected in the pumping wells evaluated.

Four ecosystem services linked to the infiltration ponds have been identified and assessed: (1) water for drinking purposes (selected beneficiary: Aigües de Barcelona); (2) water for non-drinking purposes (selected beneficiary: DAMM); (3) research opportunities (selected beneficiary: scientific community); (4) cultural services (selected beneficiary: population living in the surroundings and Barcelona Metropolitan Area).

There has been defined a **list of biophysical indicators of state** whose value change before and after the implementation of the SCC system. There have been classified in: physical parameters related to water quantity (e.g. groundwater level), quality parameters in native groundwater (e.g. salinity); quality parameters in recharge water that will improve during SAT (i.e. micropollutants), other parameters naturally occurring in groundwater (e.g. constant temperature) and biological aspects related to ponds implementation (e.g. number of bird species watched).

Authors realized that despite the large number of indicators of state that can be quantified, few of them are **key indicators for end-users** of groundwater interviewed (Aigües de Barcelona and DAMM). Specifically, DAMM restricts the parameters to the salinity reduction (linked to the membranes for water pre-treatment) and groundwater level (linked to the wells power consumption). Aigües de Barcelona agrees with the importance of groundwater level rise and specific physico-chemical parameters affecting the water production (turbidity, temperature, ammonium) and the relevance of having additional groundwater to use as input water instead of river water (savings in the conventional treatment). Then, the biophysical impacts indicators that are related to changes in state and cause the economic impacts are assessed using the key indicators for the end-users.

Finally, the impacts on the ESS are assessed. First the **biophysical impact**, impact I, and later the **economic impact**, impact II. Due to data and time constraints different valuation methods are applied; avoided costs, travel cost and revealed preferences. These valuation methods were applied in the assessment of four different ESS (1) water for drinking purposes, (2) water for non-drinking purposes, (3) educational and (4) experiential use of landscapes in different environmental settings. The benefits and the respective beneficiaries resulting of the assessment are AB with 220k€, Damm Company with 217k€, researchers with 484k€ and, finally, experiencers and viewers with 20k€. These figures derived from different kinds of benefits per each beneficiary, a more detailed explanation is done in step 8 of this document and the information is summarized in Table 33.

The aggregation of the different figures resulting from the assessment is not technically recommended due to the use of different valuation methods, recommendations on how to carry on the economic assessment are done in the cookbook and the companion document (Anzaldúa *et al*. 2016). However, while the implementation of the measure, 8M€ projected, is not economically profitable for Agència Catalana de l'Aigua (ACA), the entity responsible of the response construction; it seems that from a wider perspective, taking into account all the beneficiaries, the response will be economically and environmentally positive. To ensure the economic viability, a Cost Benefit Analysis is highly recommended in order to facilitate the aggregation of all the benefits, and accounting the whole costs.

Last but not least, a **sustainability assessment (SA)** is done. Different indicators are selected in four dimensions: social, environmental, financial and assets. While the DESSIN assessment is about the impacts on the changes of ESS, the sustainability assessment is aimed to assess the sustainability of the solution or technology. Thus, the SA is a complementary tool for decision makers that allow comparing alternative technologies. Results of the SA highlight the benefit of auto-depuration of the infiltrated water along the soil-aquifer interface (reduction of 10^6 microbial pathogens from the river to the extraction wells) and show the economic effort of the investment and the operational expenditure.

In general, this report illustrates the application of the valuation methods of ecosystem services using a common methodology developed in DESSIN project, while it is a valuable document at regional scale to open the discussion about the implementation of MAR systems to increase water resources availability in a water-stressed region.

PART I – STUDY DESCRIPTION

Step 0: Setting the scene

Llobregat River basin

Llobregat River is located in the North-East of Spain and has typical Mediterranean climate regime. The total length of the river is 170 Km, and the surface of the river basin is 4,948 km^2. Administratively, it is located in Catalonia region, and the management is carried out by the Water Catalan Agency (ACA by its Catalan name). The river basin is characterised by irregular and heavy rain periods, followed by periods of severe droughts which occur in an interval of 8 – 10 years. Different pressures appear along the course of the river. While in the upper course it is characterised by the high quality of water and biodiversity, this worsens gradually due to anthropic activities.

Llobregat river course has been historically modified. There are 3 reservoirs (dams) named "*La Llosa del Cavall*" (80 hm^3 of capacity), "*Sant Ponç*" (24 hm^3 of capacity) and "*La Baells*" (109 hm^3 of capacity), with a total storage capacity of 213 hm^3. They regulate artificially the flow according to (1) water needs in the lower valley area where the drinking water treatment plants (DWTP) are located and (2) meteorological alerts which indicate a need of extra storage capacity (this is called preventive discharge). As an orientation data, in Martorell, near Abrera DWTP, Llobregat River has an average flow of 20.7 m^3/s.

Figure 1: Fresh water management infrastructures in the Llobregat river basin
Source: https://hacdoso.wordpress.com/

Several valuation studies have been conducted in the river basin. Most of them are based in the following ecosystem services provided by the Llobregat River:

- **Drinking water provision:** including the metropolitan area of Barcelona.
- **Sediment retention:** reduction of costs in sediments removal in the dams, and enlargement of their expected lifetime.
- **Energy production:** using hydropower generation.
- **Water purification:** avoiding costs of treatment in drinking water treatment plants downstream.

Table 37 summarises main scientific papers already published about valuation of ecosystem services in the Llobregat River basin. Recent studies carried out by ICRA (Catalan Water Research Institute) revealed a total of 1,000 M€ per year of ecosystem services provided by the Llobregat river basin[1].

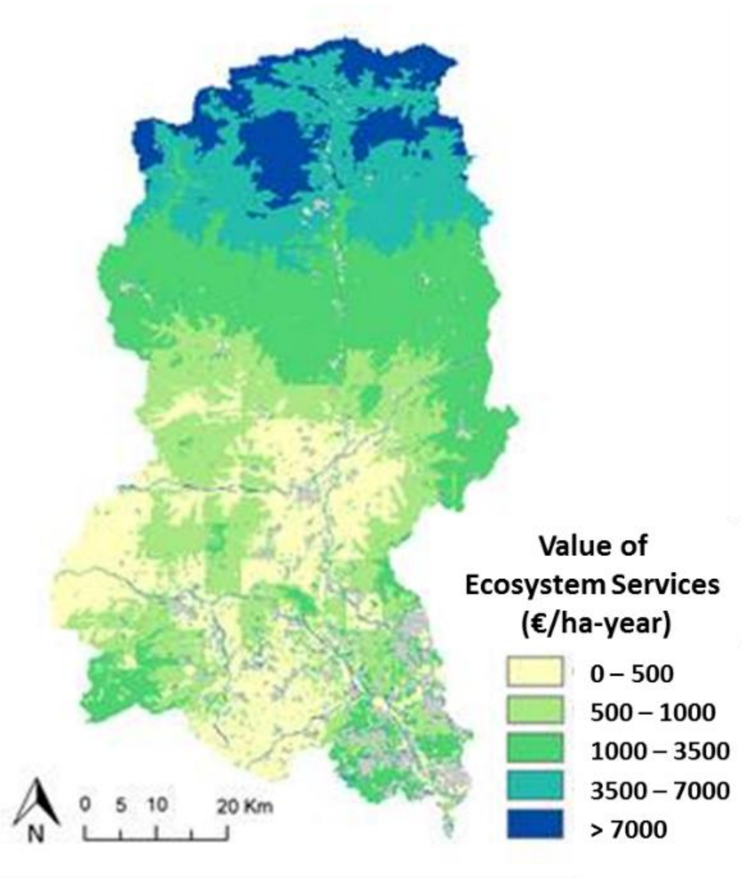

Figure 2: Valuation of ESS in the Llobregat river basin
Source: http://www.clipmedia.net/galera/ICRA/Dossiers_premsa/2011/091311_memoria10/Cast/Llobregat.html

Given the practical approach of the selected mature sites of DESSIN project, the theoretical estimations of the ecosystem services provided in the Llobregat basin do not fit exactly with the aim of the mature sites exercise itself. As a result, a project carried out in the Llobregat lower valley has been selected as demonstration site. The project that application of EES methodologies is going to be carried out is about Managed Aquifer Recharge (MAR) techniques.

[1] http://www.clipmedia.net/galera/ICRA/Dossiers_premsa/2011/091311_memoria10/Llobregat.html

Infiltration ponds in the lower valley of Llobregat River

The economic development of the Barcelona metropolitan area caused several pressures in the the lower course of the Llobregat River and the delta of the Llobregat River. Some factors that will be exposed in this report (construction of transport infrastructures, industry, urbanisation…) caused increasing loss of permeable soil due to the growing of the urban area, causing a hydrogeological direct impact on the aquifers. The available soil surface for natural infiltration has been reduced notably. This fact, joined with the continuous growth of groundwater extractions along time, caused a decrease in the groundwater availability. At this context, the electrical conductivity of groundwater increased, affecting urban and industrial wells inland.

The solution to these problems was no simple, and consisted in a package of measures to assure the sustainability of the area in terms of hydraulic resources. In this context, Catalan Water Agency (ACA) projected two artificial recharge systems located in two municipalities: Sant Vicenç dels Horts and Santa Coloma de Cervelló. Sant Vicenç dels Horts was constructed in 2007 and has been operated for more than 6 years, with an annual capacity of injection of 1 Mm^3. Santa Coloma de Cervelló system is projected (not yet constructed), and the annual capacity is expected to be 10 Mm^3. In this context, Sant Vicenç dels Horts system will be used as training area to test the effectiveness and positive effects on the aquifer of this technique. Results will encourage ACA to construct the new system at bigger scale, learning also from failures in Sant Vicenç dels Horts.

A combination of **both systems will be used as "mature site"** in the DESSIN project. Data available of Sant Vicenç dels Horts will allow the quantification of the impacts obtained in groundwater quality, while the bigger dimensions of Santa Coloma de Cervelló will allow the quantification of the impacts in the population visiting the site, as well as an increase in groundwater resources for end users in the aquifer.

Table 1: Summary of main properties of the infiltration ponds in the Lower Valley of Llobregat

	Sant Vicenç dels Horts	Santa Coloma de Cervelló
Infiltration volume	1 Mm^3/year	10 Mm^3/year
Occupied surface (water)	1 ha	13 ha
Year of construction	2007	Not constructed
Type of infiltration water	River / Reclaimed	River / Reclaimed
Data of water quality	Yes	No (similar to Sant Vicenç)
Expected visitors / cultural services	No – closed to the public	Yes – open to the public
Expected habitats creation	Limited (small surface)	High (large surface)
Expected impact in groundwater users (drinking water operators & industries)	Limited (small surface)	High (large surface)

Sant Vicenç dels Horts infiltration system

The infiltration system of Sant Vicenç dels Horts consists of an infiltration ponds system in the right margin of Llobregat River. It was finished in 2007. This infrastructure was projected as a compensation measure for the construction of the railway in the area. The infiltration system was built by the high speed train public company ADIF (national), and its property was transfer to the Catalan water agency ACA (regional).

The system consists mainly in two ponds: settling pond of 6,000 m^2 (reduction of sediments) and infiltration pond of 5,600 m^2 (percolation in the aquifer). From 2008 the system has infiltrated 4 Mm^3 in the aquifer, with maximum volume infiltrated of 1.16 Mm^3 in 2011. The main objective of the system is to introduce additional freshwater into the aquifer to gain an average extra volume of 1 Mm^3/year. The operation consists in a direct intake of Llobregat river water 2 km upstream of the ponds. The catchment area is an intake channel that has to be reconstructed from time to time according to rainy periods that can destroy totally or partially the intake channel. Collected water circulates downstream by a concrete pipe of an inner diameter of 1,000 mm. All the system is controlled manually by CUADLL (Association of Users of the aquifer) according to quality alerts and meteorological forecast.

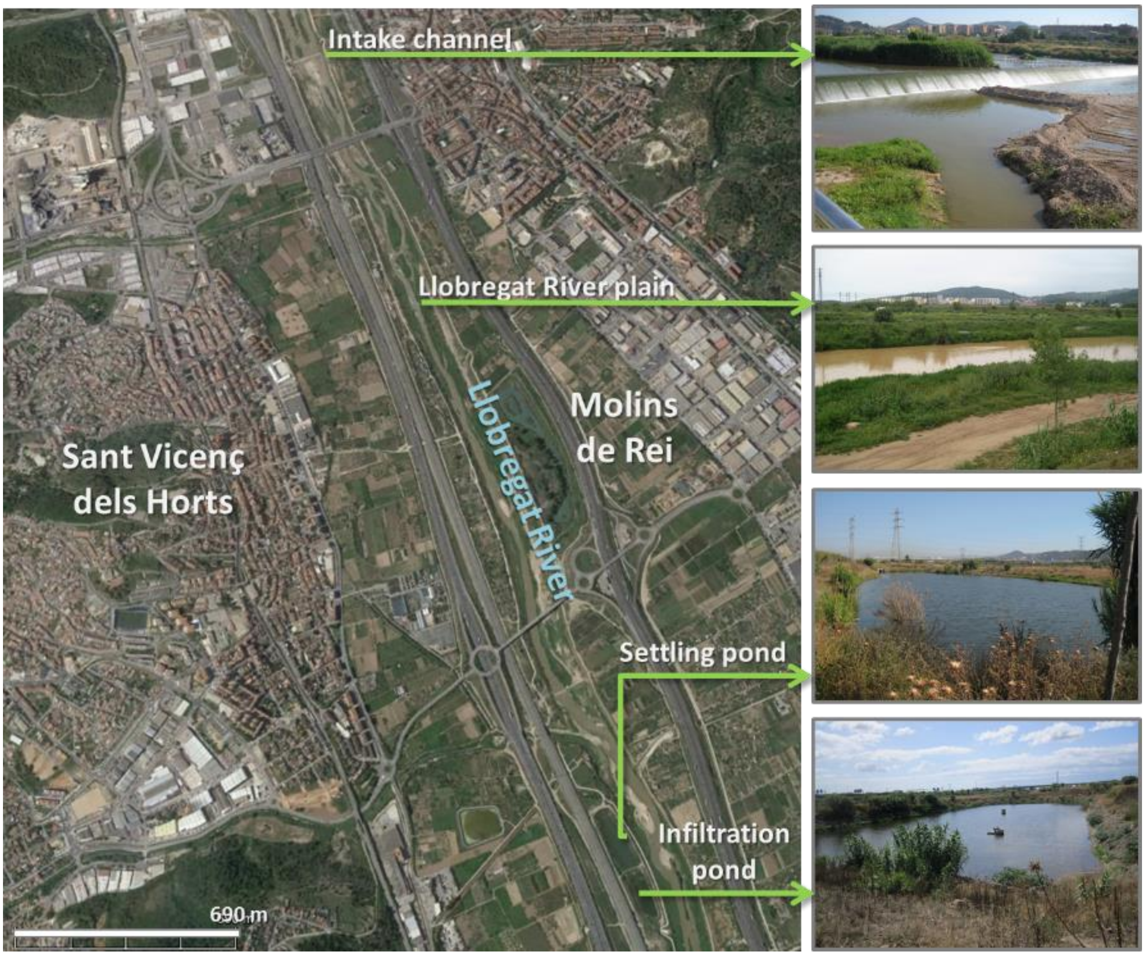

Figure 3: Location of Sant Vicenç dels Horts infiltration ponds

Previous R+D projects and PhD thesis have studied the site. The most important are listed below:

- **GABARDINE**: FP6 project which proposed Sant Vicenç dels Horts as a demonstrative site. The GABARDINE project (Groundwater Artificial recharge Based on Alternative sources of wateR: aDvanced INtegrated technologies and managEment) is a Specific Targeted Research Project, which develops innovative technologies for alternative water sources. It is undertaken in the FP6 priority "Global Change and Ecosystems ". The project implementation is being developed by a consortium of 14 partners. The consortium is co-ordinated by the University of Göttingen in Germany. Final reports and publications related to Sant Vicenç dels Horts are not published on the website:

  http://cordis.europa.eu/publication/rcn/13034_en.html

- **ENSAT**: Life+ Project whose main objective was to assess the improvement of retention of emerging pollutants in the MAR system using a reactive organic layer made with vegetal compost. It has been the most complete project in improving the knowledge of the hydrogeological and hydrochemical aspects of the aquifer recharge system. Cost-effectiveness analysis of the reactive layer implementation was carried out. http://www.life-ensat.eu/

- **PREPARED:** FP7 project aiming at evaluating the preparedness of urban water facilities to deal with climate change impacts. Sant Vicenç dels Horts was proposed as a demonstrative site to evaluate the impact of high turbidity values in recharge water, and improve maintenance techniques. LCA – LCC analysis of the system and measures carried out was done. http://www.prepared-fp7.eu/

- **DEMEAU**: FP7 project that aims at assessing innovative technologies in water and wastewater sector to deal with emerging pollutants. Sant Vicenç dels Horts is one of the demonstrative sites of the project, as it was included in the LCA – LCC analysis of MAR sites. Pharmaceuticals concentrations have been also assessed, as a continuation of the results of ENSAT. The effectiveness of the reactive layer has been assessed by conducting leaching tests. http://demeau-fp7.eu/

- **MARSOL**: Water Inno-Demo project based on Managed Aquifer Recharge Techniques. Sant Vicenç dels Horts has been proposed as a test site to evaluate the importance of microorganisms in degradation of organic pollutants and biofilm formation. http://www.marsol.eu/

Most of research done have been focused on contaminant attenuation capacity of the aquifer to improve water quality by using soil-aquifer treatment approach. Nonetheless, the positive impact of the existence of this infiltration system in the area goes beyond. The ecosystem services impacted positively by the construction and operation of this MAR facility are:

- Increase of groundwater resources in the aquifer.
- Improve water quality along soil-aquifer interface.
- Reduction of anthropic pollutants in the aquifer (organic contaminants).
- Creation of a bird and micro fauna habitat.
- Increase of interest of local people in water resources in the Llobregat (noticeboard for runners, bikers and trekkers in the pathways). Identification of the place as "interesting point" in the area[2].
- Technical visits to the facility (study tours, project visits in workshops…).

Santa Coloma de Cervelló infiltration system

The selected location of this large infiltration system was the municipality of Santa Coloma de Cervelló (Baix Llobregat region, Barcelona), in a 13 ha of surface area placed on the right margin of Llobregat River between the river bed and the high speed train (AVE) platform, owned by ADIF (public Spanish rail company). This is an ambitious project with a total estimated cost of 8.0 million euros that will provide an extra infiltrated volume of 10 Mm^3 to the Llobregat aquifer. The construction project was presented in 2008, but it is still not constructed due to financial constraints in ACA. Nevertheless, this is one of the top priorities for the future investments 2015 – 2020.

This system has been selected as mature site in the Llobregat area due to the high impact in groundwater resources and the previous experience gathered in Sant Vicenç dels Horts (SVH) system. The SVH infiltration system works at smaller scale, infiltrating 1Mm^3/year. It has been considered that the working scale to evaluate the ecosystem services will be Santa Coloma de Cervelló and results obtained will be directly applied by ACA to the cost-benefit analysis in their starting plan of investments in hydraulic infrastructures linked to the water cycle.

[2] http://www.parcriullobregat.cat/puntsdinteres.php

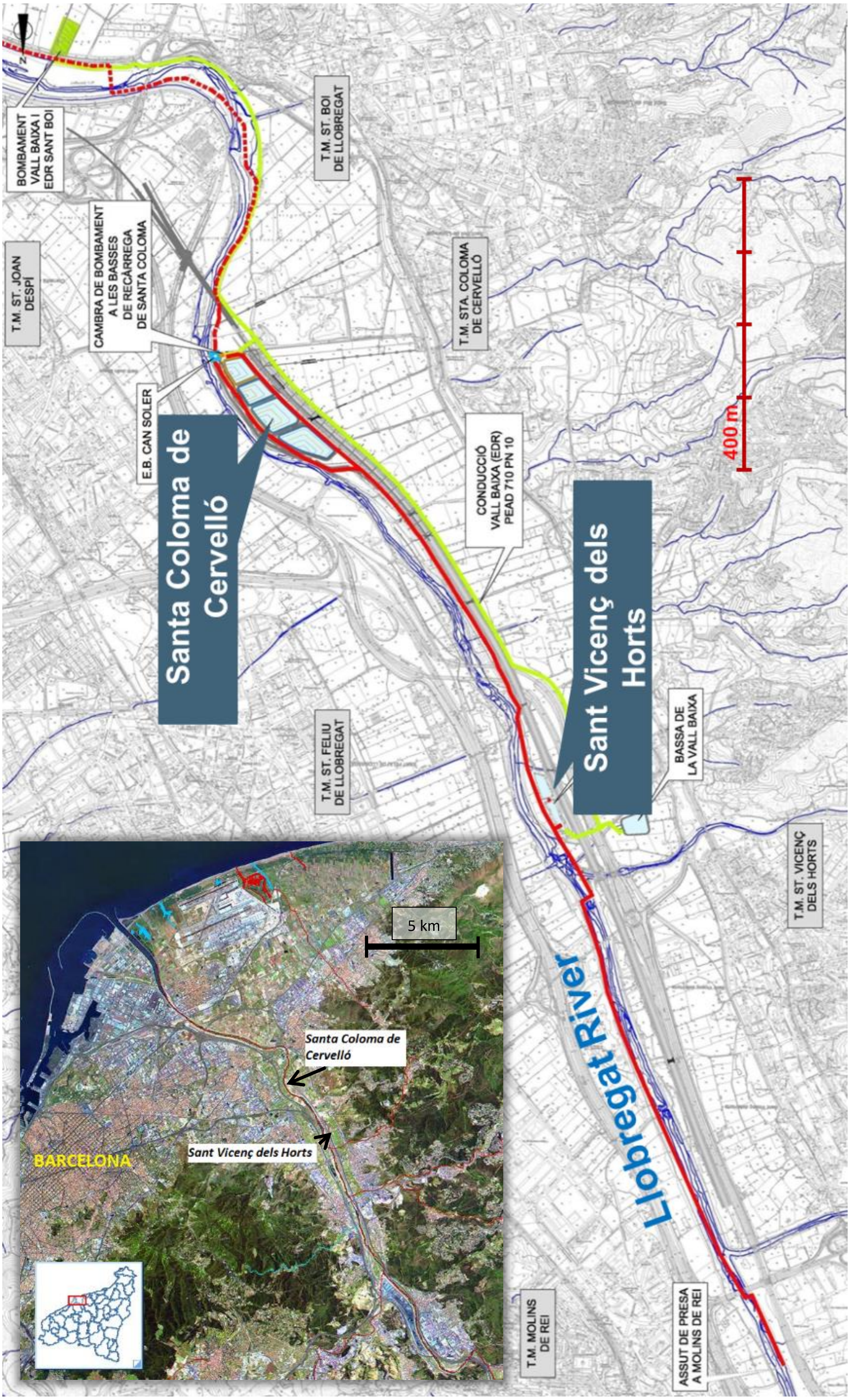

Figure 4: Location of Santa Coloma de Cervelló infiltration ponds

Step 1: Description of drivers

One of the difficulties to present the context of the infiltration ponds and the drivers and pressures which justified their construction is the geographical definition of the impacted area. The infiltration ponds (Sant Vicenç and Santa Coloma) are placed in the lower valley of the river, in the south of the Metropolitan Area of Barcelona (36 municipalities). The administrative division corresponds to The Baix Llobregat region (30 municipalities).

Metropolitan Area of Barcelona: The Metropolitan Area of Barcelona (AMB) is the public administration of the metropolitan area of Barcelona, which occupies 636 km² and is made up by 36 municipalities with more than 3.2 million inhabitants with a mean density of 5,093 inhabitants per km^2. The metropolitan area is also the nucleus of the economic activity in Catalonia, its gross domestic product (GDP) was 99,174 M€ in 2012, that is about 51% of the Catalan GDP.

Baix Llobregat region: The administrative division in Catalonia comprises 41 regions. Baix Llobregat region is constituted by 30 municipalities around the Llobregat River. Some of them are included in the Metropolitan area of Barcelona (see Figure 5):

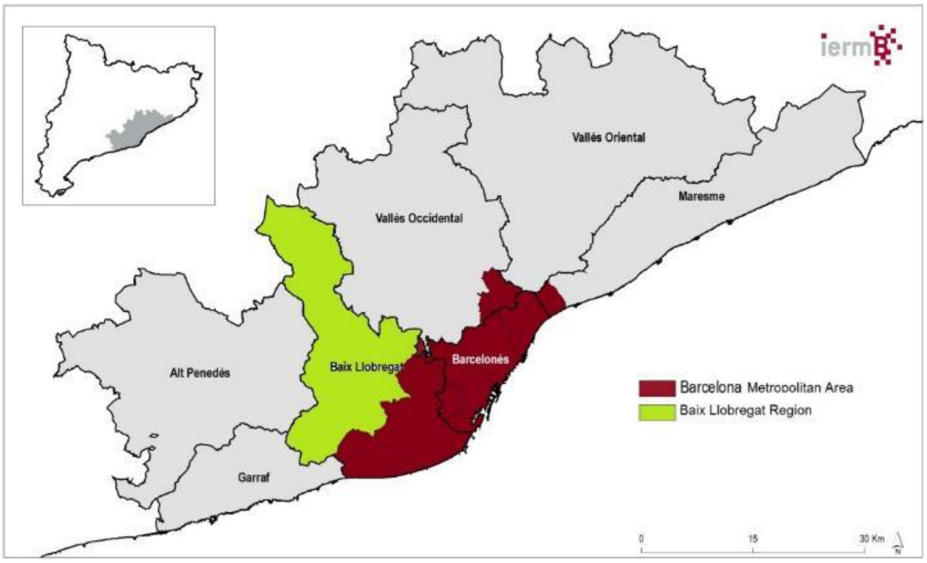

Figure 5: Administrative borders of AMB and Baix Llobregat region
Source: https://iermb.uab.cat/es/

Within DESSIN project, a driver is defined as a human activity that may produce an environmental effect on the ecosystem. Examples for drivers are agriculture or industry (MARS Project Terminology, 2014)[3]. In the study area of the Llobregat River two drivers were identified: industry and urban development.

DRIVER Industry: Industrial bad practices in the past: solvents and PAHs in groundwater and river. Industries increase in the metropolitan area: WWTP discharges

During the last quarter of the XIXst century the industry in Catalonia switched their location from the coastline near ports to the river courses. The aim was to find cheaper sources of energy; changing the British coal that powered the steam boilers, for the water that powered the waterwheels. The Llobregat river course, as one of the main rivers in the area, attracted numbers of industries. This fact carried a growing urban development, which pushed the creation of cities and infrastructures along the river course. But the river was not only used as a resource; it also became the way to get rid of the waste. An authorization for discharging into the river was not mandatory since 1985, when the national government enacted the 29/1985 Law about water. So, the industries were discharging pollutants without

[3] Source: http://www.freshwaterplatform.eu/index.php/glossary.html

control. Furthermore, a unique salt mine in Europe was placed near the river course. The intensive mining activities lasted from 1920 to 1990.

In recent decades, the industry weight in the economy of Baix Llobregat is decreasing. In 2004, the industry represented a 34.3% of the GDP against the 47.6% of 1991. Even though, the 34.3% is higher than the average weight of the industry in Catalonia region, which was about 27% in 2004. As it is shown in the Table 2 below, the main industries in the Baix Llobregat region are transport equipment, chemical and metallurgy. The impact of the discharges and pollutants of these industries are quantified in the following pressures section.

Table 2: Industrial sector GDP structure, year 2004, in percentage
Source: Caixa Catalunya, adapted from Pons i Novell (2005)

	Baix Llobregat	Catalunya
Energy, water and mining	2.2	12.9
Food, drinks and tobacco	9.1	11.0
Textile, leather and footwear	3.9	7.0
Wood and cork	0.9	1.4
Paper and graphic arts	9.9	8.9
Chemical	12.9	13.8
Rubber and plastics	6.3	4.9
Other minerals non metals	5.9	4.8
Metallurgy and metallic products	11.6	9.5
Machinery and mechanical equipment	7.5	6.3
Electric, electronic and optical equipment	8.4	8.5
Transport equipment	19.0	7.8
Other manufacturing industries	2.5	3.2
Industry	**100.0**	**100.0**

DRIVER Urban development: (Intensive use of land in new urbanised areas). Inhabitants increase in the metropolitan area: WWTP discharge, intensive use of the river

Along the lower course of the river, Baix Llobregat region is a fast growing area in terms of population since XIX[st] century. As it is explained in the section before, the industrialization along the river created some population nucleus that were further developed as the cities that are near the river nowadays. In recent decades, the proximity with Barcelona and the impossibility of the capital to grow caused continuously increasing population in the region. Actually, from 1975 to 2014 the population has increased more than 50%. It causes lots of consequences in the water cycle. For first, the drinking water demand has increased as drinking water is directly related to number of inhabitants. It also means that waste water production has increased in this period, following the same relation as for drinking water; the more population, the more production. During this period, the land uses within the area has changed a lot. There is a substitution from the agricultural uses to urban ones, the agricultural surface has decreased in more than 3,000ha, becoming urban in most cases.

All in all, the result of the urbanization of the area is stressing at maximum the water availability. The water demand is increasing; the permeable area of the aquifer is decreasing; so the groundwater resources is under more pressures than ever.

Table 3: Population, from 1981 to 2004, number of inhabitants
Source: Idescat, adapted from Pons i Novell (2005)

	Baix Llobregat	Catalunya	Baix Llobregat/Cat.%
1981	573,461	5,956,414	9.6
1986	583,354	5,978,638	9.8
1991	610,192	6,059,494	10.1
1996	643,419	6,090,040	10.6
2001	692,892	6,343,110	10.9
2004	741,024	6,813,319	10.9
Growth 1986/1981	1.7	0.4	
Growth 1991/1986	4.6	1.4	
Growth 1996/1991	5.4	0.5	
Growth 2001/1996	7.7	4.2	
Growth 2004/2001	6.9	7.4	
Growth 2004/1981	29.2	14.4	

Step 2: Description of pressures

This section explains the pressures identified as a result as applying the DPSIR scheme proposed by the DESSIN framework. The pressures are directly related with the drivers identified in the previous step. This relationship is shown in the Table 4. Following, an explanation per each pressure is done, as well as an identification of at least one indicator to monitor the evolution of the pressures in time, and how they are impacting in the system. In the DESSIN project is considered a pressure the direct environmental effect of the driver, such as an effect that causes a change in water flow or a change in the water chemistry (MARS project terminology, 2014)[4]. Examples are the abstraction of water for industrial processes or an increased nutrient load caused by agricultural use of fertilizers.

Table 4: Drivers and pressures relationship.

Drivers	Pressures
Industry	• Diffuse source: Contaminated sites/abandoned industrial sites. Groundwater pollution (solvents, PAHs, industrial pollutants).
	• Point source: Industrial waste water.
	• Abstraction: Abstraction from industry.
Urban development	• Diffuse source: Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).
	• Point source: Urban waste water.
	• Abstraction: Abstraction urban development
Other	• Hydrological alteration: Reduction of permeable surface for precipitation infiltration.

[4] Source: http://www.freshwaterplatform.eu/index.php/glossary.html

PRESSURE: Contaminated sites/abandoned industrial sites. Groundwater pollution (solvents, PAHs, industrial pollutants) (Diffuse source)

Lot of industries settled in Baix Llobregat region because the strategic location of the area in terms of communication network and the access of River water. The Llobregat Basin, specifically the sub-basin of the Anoia River overpasses the quality objectives of the Water Framework Directive in the following parameters: Chromium, trichloroethylene, perchloroethylene and mercury. Map in Figure 6 illustrates how the Baix Llobregat region has been found as one of the most polluted sites in Catalonia, especially by the episodes of pollution caused by heavy metals and volatile compounds.

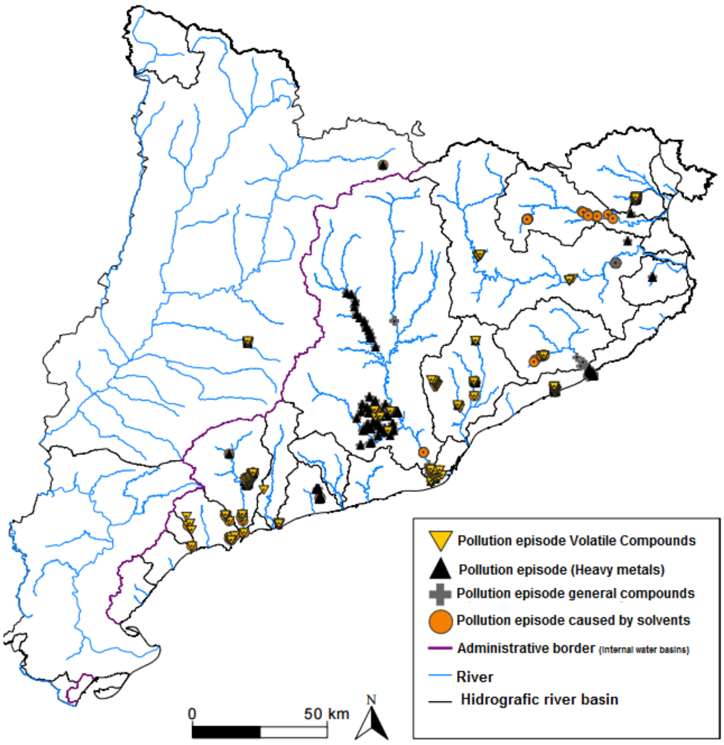

Figure 6: Location of pollution episodes in Catalonia internal water basins

Source: ACA (2005)

INDICATOR: Organic volatile compounds found in the aquifer. Selected indicator compound: Trichloroethane (chlorinated compound largely used as solvent removing grease from machined metal products, in textile processing and dyeing and in aerosols).

Indicator units: µg/L of trichloroethane
Indicator value before the implementation of infiltration ponds: 500 µg/L of trichloroethane
Expected trend once implemented the infiltration pond: reduction

PRESSURE: Industrial waste water (Point source)

River courses have historically attracted industrial activity in their surroundings. This trend can be easily viewed in Figure 7, in which the discharge points of biodegradable industrial effluents (top) and non-biodegradable (bottom) are shown. There is a high concentration of discharge points around Barcelona area. Final disposal of treated wastewater or industrial wastewater below threshold values are streams and rivers near the factories. In this sense, there were lot of industrial settlements whose final disposals of waste water were located near the Llobregat River and its tributaries.

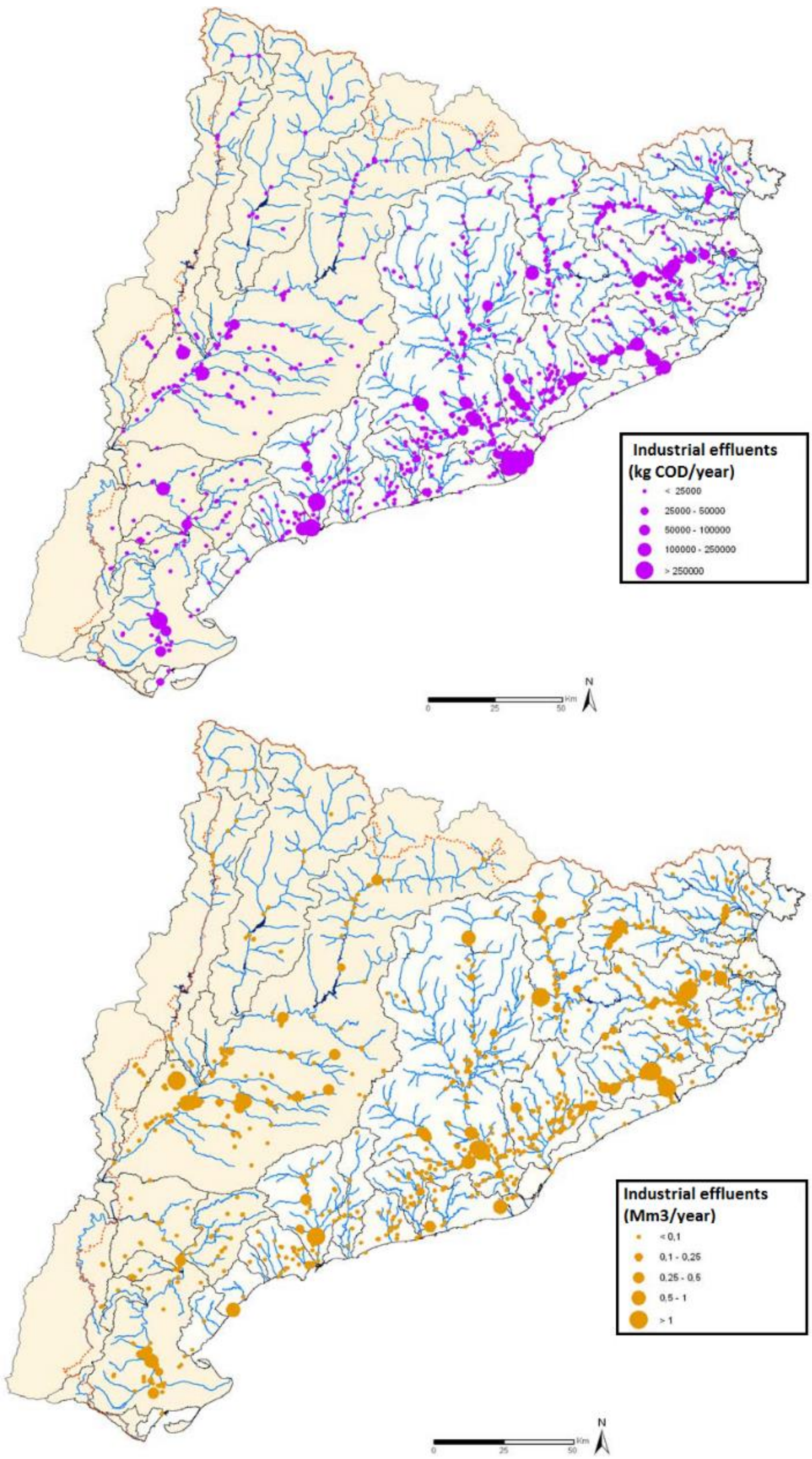

Figure 7: Spot map of industrial effluents in Catalonia

(Top) Biodegradable Industrial effluents of waste water to the environment in kg of COD per year and (Bottom) Non-Biodegradable Industrial effluents of waste water to the environment in volume per year.

Source: ACA (2005)

Lower Llobregat river area and Delta of Llobregat have been classified as high pressured zones by industrial effluents. ACA establishes both Llobregat aquifer (38) and Delta aquifer (39) as groundwater bodies in high risk by the presence of industrial effluents. Figure 8 illustrates this classification.

INDICATOR: Amount of effluents from industries with final disposal in the Llobregat river course.

Indicator units: m^3 of industrial waste water
Indicator value before the implementation of infiltration ponds: 873,176 m^3/year
Expected trend once implemented the infiltration pond: indicator value will be not directly affected by the construction of infiltration ponds.

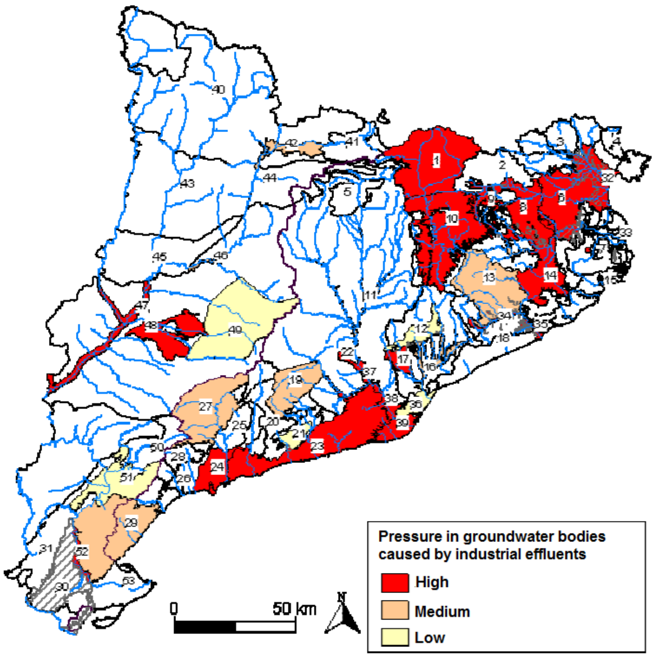

Figure 8: Map of areas with pressure in groundwater bodies caused by industrial effluents
Source: ACA (2005)

PRESSURE: Abstraction from industry (Abstraction)

The attraction of industries in the surroundings of the river course causes not only an increasing pressure in industrial waste water but an increase in water demand as an input. Moreover, water availability is one of the reasons that make river course surroundings attractive.

In Figure 9, a record of total abstractions as well as disaggregation per types of users is shown. Concretely, looking at the industrial users, it can be seen a decrease on water extractions between 1970 and 2010. Similarly, the total amount of abstractions has gone down from 1970 to nowadays. As it is going to be explained in next sections, the permeable area of the aquifer has been reduced during these years, carrying depletion in groundwater level since 1970 to nowadays, due to the amount of abstractions (with the information presented in figures 9 and 10 is really difficult to come to that conclusion)

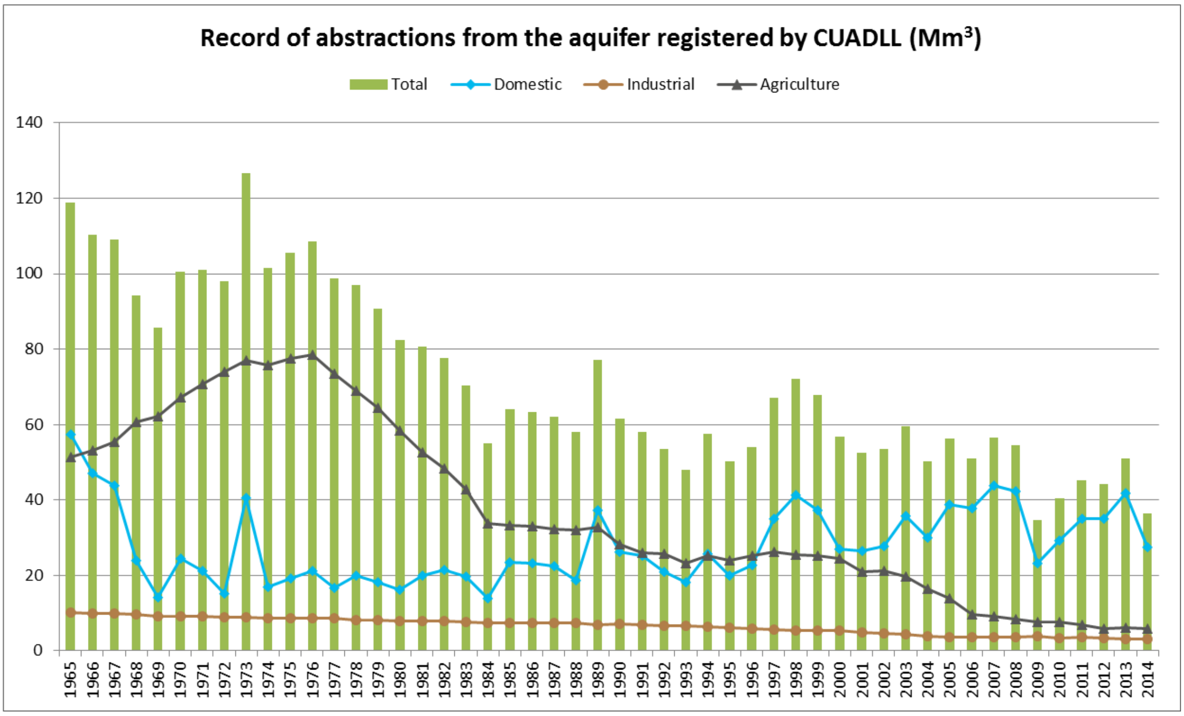

Figure 9: Record of abstractions from the aquifer registered by CUADLL
Source: CUADLL

In the end, the total annual volume extracted from industries in the aquifer is the selected indicator to track the groundwater level in a sustainable way.

INDICATOR: Total annual volume of groundwater extractions from industries.

Indicator units: hm^3 of - groundwater extracted for industrial purposes
Indicator value before the implementation of infiltration ponds (2006): 3.66 Mm^3/year
Expected trend once implemented the infiltration pond: indicator value will be not directly affected by the construction of infiltration ponds.

This effect (decreasing trend) has a direct relation with groundwater level for industrial users and drinking water operators. Figure 10 illustrates this pressure in El Prat del Llobregat, an area representative of the effect of aquifer overexploitation in the Delta area. The minimum groundwater levels were recorded in 1975. In that year, differences between minimum level and maximum level were more than 7 meters, according to the extraction needs of the factories and drinking water production operators. From 2005, the aquifer management has suffered a change of paradigm, obtaining an average difference of about 3.6 meters (see annual values in Table 5).

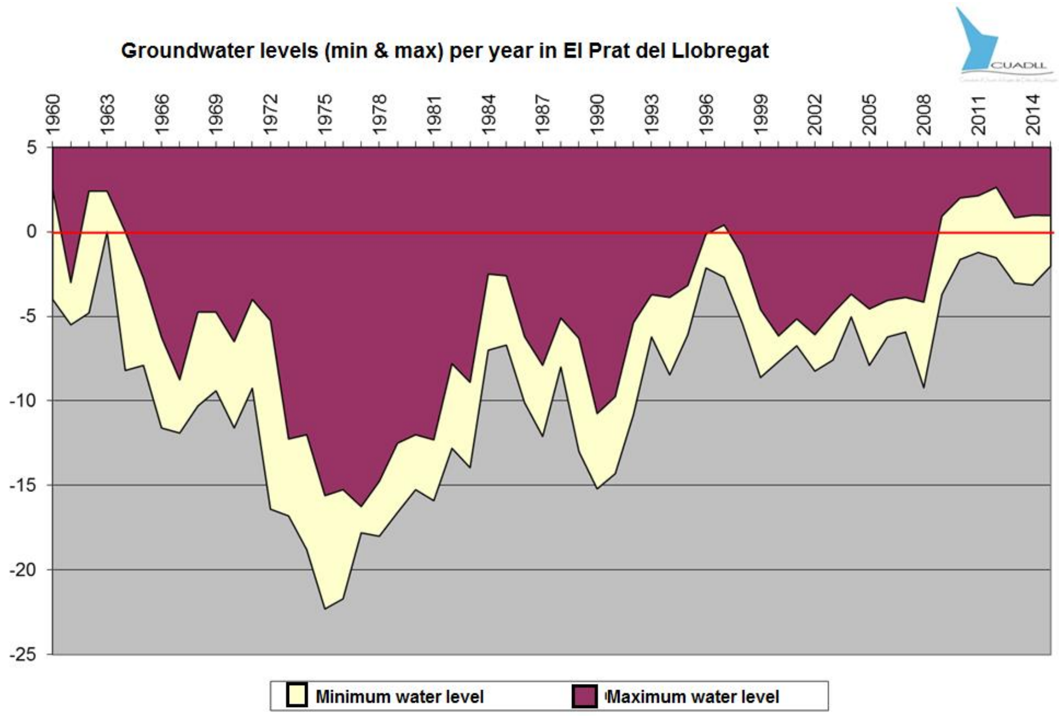

Figure 10: Groundwater levels (min& max) per year in El Prat del Llobregat

Table 5: Maximum differences in groundwater level per year

Year	Difference of level (min – max) [m]	Year	Difference of level (min – max) [m]
2005	3.34	2011	3.35
2006	2.16	2012	4.17
2007	2.05	2013	3.86
2008	5.06	2014	4.13
2009	4.62	2015	2.98
2010	3.64		

In the coastline, the evolution of groundwater level is directly related to salinity. Water extraction drops the level of fresh groundwater, reducing its water pressure and allowing saltwater to flow further inland. In that sense, electrical conductivity measured in production wells can be an additional indicator of this pressure in coastal zones (Delta of Llobregat, for example). Figure 11 shows the increase of chloride concentration in mg/L in four industrial wells in the Delta aquifer of Llobregat, with a peak value in 2009, corresponding to the drought period in Barcelona. As groundwater alteration it is one of the most relevant and direct pressures affecting the Llobregat mature site, two indicators have been designed to control them.

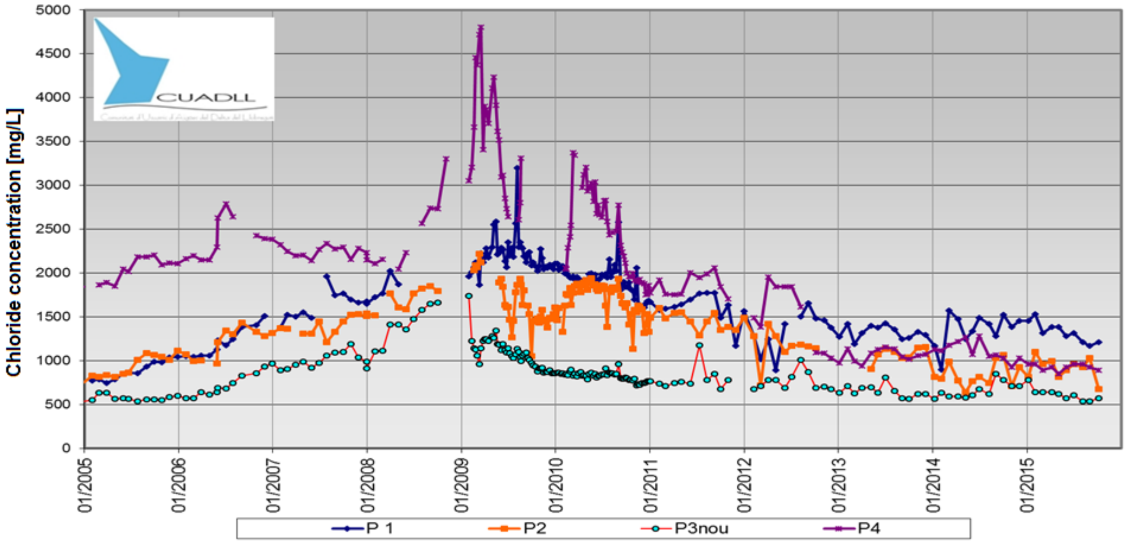

Figure 11: Chloride concentration in industrial wells
Source: CUADLL

PRESSURE: Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium) (Diffuse source)

The large amount of waste water produced in heavy rain episodes affects the treatment capacity of waste water treatment plants. Sewerage networks receive large volume of waste water in a short space of time. If the rain event is long enough, waste water is directly bypassed to the Llobregat River. This discharge has high concentrations of ammonia and low concentration of dissolved oxygen, causing a strong impact on the fauna of the river. Fortunately, the biggest WWTPs in the Barcelona Metropolitan area (El Prat de Llobregat) are discharging to the sea, avoiding the impact on river ecosystems. Nonetheless, in Baix Llobregat region, there are some WWTPs discharging directly to the Llobregat River or to one of its tributaries (streams and creeks). Table 6 lists the WWTPs in the Baix Llobregat region. Regarding the problem of the bypass of not completely treated waste water, Abrera, Martorell and Sant Feliu del Llobregat are the WWTPs which could cause higher impact on the river water quality. As an example, Table 7 presents typical values of input water in Sant Feliu.

Table 6: WWTPs in Baix Llobregat region and fate of effluent discharge

WWTP	Design Flow [m^3/day]	Equivalent inhabitants	Effluent discharge
ABRERA	34,500	115,000	Llobregat River
BEGUES	1,200	7,000	Stream
CASTELLVÍ DE RONSANES	400	1,667	Stream
GAVÀ-VILADECANS	64,000	384,000	Mediterranean sea
LLEDONER	472	3,149	Stream
MARTORELL	10,500	61,250	Stream
OASIS-AMETLLER	9	56	Stream
OASIS-CAN MIQUEL AMAT	60	400	Stream
OASIS-JAUME	42	280	Stream
EL PRAT LLOBREGAT	420,000	2,275,000	Mediterranean Sea
SANT FELIU DE LLOBREGAT	64,000	673,333	Llobregat River

Table 7: Waste Water characterisation in the inflow of WWTP Sant Feliu del Llobregat
Source: Alcobé (2009)

Parameter	Concentration [mg/L]	Parameter	Concentration [mg/L]
Total Solids	308.1	Ammonium	36.9
BOD_5	325.5	Orthophosphate Phosphorus	5.2
Nitrate	3.7	Organic Phosphorus	1.3
Organic nitrogen	3.3	Phytoplankton Phosphorus	0
Phytoplankton nitrogen	0		

INDICATOR: Discharges of waste water not completely treated in WWTP in Baix Llobregat region.

Indicator units: number of episodes per year
Indicator value before the implementation of infiltration ponds (2006): not available information. This information is currently being required by a new Spanish regulation RD 1290/2012 for the accomplishment of the Water Framework Directive 2000/60/CE.
Expected trend once implemented the infiltration pond: indicator value will be not directly affected by the construction of infiltration ponds.

PRESSURE: Urban waste water (Point source)

As it is pointed out before, river courses have historically attracted industrial activity in their surroundings. And it carries urban growing and urban development. Due to the increase in population, an increase of waste water production also occurred. This is shown/may be observed in the construction of new WWTP in the area in recent years. A list of the six plants operating in the area is shown in Table 8 as well as the treatment capacity and equivalent population. In this sense, the total waste produced in Catalonian WWTP is shown (Figure 12). The Baix Llobregat region is one of the top waste producers in Catalonia with more than 50 thousand tons per year.

Table 8: Capacity of Waste Water treatment plants in El Baix Llobregat region
Source: ACA website

Municipality	Year of implementation	Treatment capacity [m3/day]	Equivalent population
Abrera	1994	34,500	115,000
Begues	2004	1,200	7,000
Gavà-Viladecans	1986	64,000	384,000
Martorell	1984	10,500	61,250
El Prat del Llobregat(*)	2002	420,000	2,275,000
Sant Feliu del Llobregat (*)	1989	64,000	373,333

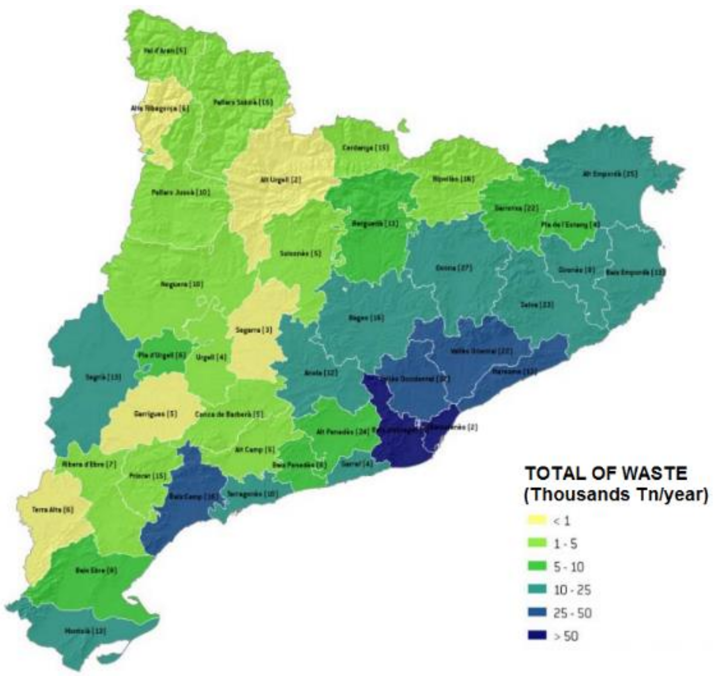

Figure 12: Total of waste produced in Waste Water Treatment Plants in Catalan regions
Source: ARC (2013)

Furthermore, the production of urban waste water is directly related with the population in the surrounding area (Mateo-Sagasta *et al*. 2015). Due to this strong relationship between urban waste water production and population, the number of inhabitants in the Baix Llobregat region is chosen as the indicator for this pressure. As it is shown in Figure 13; the increase in population in the last 40 years is about 57.5%. It is the same amount of increase of the density, due to the surface is always the same, but it is also shown in the figure to understand the level in which density is. All the data is shown in Table 36 in the Annex.

INDICATOR: Number of inhabitants in the Baix Llobregat region.

Indicator units: inhabitants (inh.)
Indicator value before the implementation of infiltration ponds: 771,516 inh.
Expected trend once implemented the infiltration pond: indicator value will be not directly affected by the construction of infiltration ponds

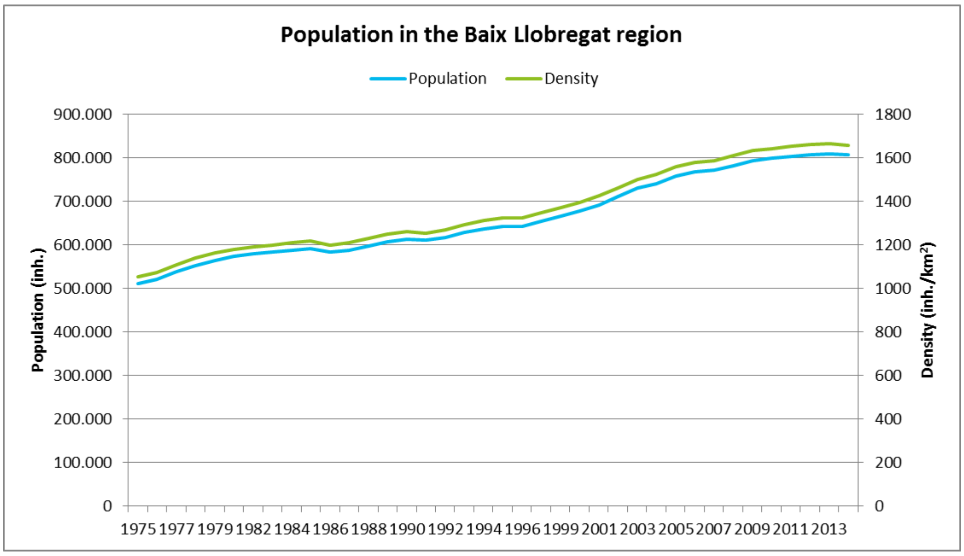

Figure 13: Population in the Baix Llobregat region
Source: Idescat

PRESSURE: Abstraction urban development (Abstraction)

Following the same scheme as for industrial water uses, the urban growing along the river course not only causes an increase in the waste water production but an increase in the drinking water demand. And, in a region such as Catalonia where the stress in potable water is high, it becomes crucial to have different sources of pre-potable water to ensure the supply of drinking water.

As it is explained in the previous section, the population has grown over 50% in the last 40 years. It carries an increase in the drinking water demand that is reflected in the abstractions for supply in Figure 9. The groundwater abstractions for drinking water supply are highly variable between years because they depend- on different factors, such as river water quality (the other source available), river water availability and precipitations. However, it is clear that the trend is growing along time.

Moreover, the substitution from industrial water uses to drinking water uses means that the quality of the aquifer water becomes more important. Also the quantity, as the continuity of water supplies becomes crucial.

Likewise the volume of extractions from industries, the total annual volume of extractions in the aquifer for drinking water supply as an indicator is necessary to track the groundwater level in a sustainable way.

INDICATOR: Total annual volume of groundwater extractions for drinking water supply.

Indicator units: hm^3 of aquifer water
Indicator value before the implementation of infiltration ponds (2006): 37.68 hm^3/year
Expected trend once implemented the infiltration pond: indicator value will be not directly affected by the construction of infiltration ponds

PRESSURE: Hydrological alteration: Reduction of permeable surface for precipitation infiltration

As a result of the increasing population, and as another indicator of the urban development, the change in land uses in the Baix Llobregat region is shown in Table 9. It can be seen in the figures that a substitution from agriculture soil to urbanized soil is happening. The reduction in the agricultural surface was 35% from 1993 to 2013. In the same period, the forestry surface is almost the same. It means that what is growing is the urbanized surface.

The substitution from agriculture to urbanized surface carries less permeability in the region due to tarmac is not as permeable as agriculture surface, causing less recharged volume of water in the aquifer. Adding the increasing demand of groundwater level, the result is a high stress in the aquifer.

Table 9: Change in land uses in the Baix Llobregat region (ha).
Source: Idescat

	Forestry surface		Agriculture surface		Urbanized surface	
1993	24,187	49.86%	10,121	20.86%	14,200	29.27%
2013	24,868	51.19%	6,541	13.46%	17,172	35.35%
Difference	3%	-	-35%	-	21%	-

INDICATOR: Weight of urbanized land use in the Baix Llobregat region

Indicator units: hectares (ha)
Indicator value before the implementation of infiltration ponds (1993): 14,200 ha
Expected trend once implemented the infiltration pond: indicator value will be not directly affected by the construction of infiltration ponds

PART III: RESPONSE CAPABILITIES AND POTENTIAL BENEFICIARIES

Step 3: Description of proposed measure and its capabilities

Description of the proposed measure: construction of infiltration ponds Santa Coloma

As stated in initial chapters of this document, one of the responses to deal with such complex pressures was the design and execution of infiltration ponds in the surrounding areas of the Llobregat River. Santa Coloma de Cervelló is the biggest system designed, and it is designed to allow the infiltration of three types of waters with different origins:

- Llobregat River water (surface water) (upstream)
- Desalinated water treated in the electrodialysis treatment in Sant Boi (downstream)
- Reclaimed water treated in the regeneration plant of El Prat (downstream)

Table 10 summarises main characteristics of Santa Coloma de Cervelló MAR system:

Table 10: Design parameters of infiltration system in Santa Coloma de Cervelló

Parameter	unit	Estimation
Occupied area	ha	13
Settling surface	m^2	88,600
Infiltration surface	m^2	56,300
Total infiltrated volume	Mm^3/year	10
Operation	Percentage of time (%)	75
Design flow	m^3/s	0.5
Infiltration rate	m/d or m^3/ m^2/day	1.0
Electrical Conductivity of Infiltration water	µS/cm	Surface water (Llobregat River) = variable Desalinated water (Sant Boi) = 1,200 (20ºC) Reclaimed Water (El Prat) = 3,000 20ºC
Estimated settling time	days	Surface water (Llobregat River) = 6 days Desalinated water (Sant Boi) = 0 days Reclaimed Water (El Prat) = 0 days

Capabilities and expected impact description

Main capabilities are listed below:

- Enhancing water infiltration by additional permeable surface
- Increasing groundwater resources in the aquifer
- Improving water quality via soil-aquifer treatment
- Reducing pollutants in the aquifer
- Creation of a new surface water body (aquatic ecosystem)

ANNEX of Part III of this document summarises expected impacts in drivers and pressures after its implementation. The impact evaluation of the measure will be evaluated in the following section of the document (Part IV) in detail.

Step 4: Identification of expected beneficiaries of the changes introduced by the proposed measure

The construction, maintenance and operation of the infiltration ponds will benefit multiple actors in the Llobregat area. Table 11 matches the capabilities listed with the potential beneficiaries. This matching will be very useful in Step 7 of the methodology, for the calculation of the human wellbeing indicators, as they have to be related to a final beneficiary. This table has been completed after the interviews with the most relevant stakeholders in the case study.

Table 11: Identification of beneficiaries linked to system capabilities

	Industries using groundwater	Drinking water operators	Students and Researchers	General population
Enhancing water infiltration by additional permeable surface	X	X		X
Increasing groundwater resources in the aquifer	X	X		
Improving water quality via soil-aquifer treatment		X	X	
Reducing pollutants in the aquifer	X	X		
Creation of a new surface water body (aquatic ecosystem)			X	X

PART IV: RESPONSE EVALUATION

The response evaluation is done through the quantification of impacts generated due to the response application. Impacts are the effects on ecosystem services (Impact I) and on human wellbeing (Impact II) resulting from changes in ecosystem state due to response application. In this section each ecosystem service is described, followed by the corresponding assessment of impact I and II. In addition, the state of the ecosystem is the baseline that generates the impacts either to ecosystem or the population. A further explanation of the state before and after the implementation is done in step 5 and 8a and impacts are assessed in steps 6, 7 and 8b.

Regarding the results of the quantitative IMPACT II assessments it shall be noted, that no aggregation of the different calculated economic figures was pursued. This is due to the fact that the results partly do express figures with different “economic meanings”, since different economic evaluation methods have been used for each calculation. The aggregation would need a careful interpretation and adjustment process which was out of scope of this mature case study. For additional information on this topic it shall be referred to the explanations in Step 7 of the DESSIN Cookbook and in chapter 5 of the Companion Document (Anzaldúa *et al.* 2016).

Step 5: Identification of parameters establishing the “state”

Taking into account the proposed measure of the construction and equipment of an infiltration pond system, there are a list of indicators that can define the state before and after its implementation. The parameters listed below are all the indicators that can be applied to assess the changes occurring at ecosystem level by the implementation of the infiltration ponds system. Most of them have already been characterised in the infiltration system of Sant Vicenç dels Horts and the results are going to be presented in Step 8 of this section:

Table 12: State parameters identified in the infiltration ponds

Parameter	State parameters
Physical parameters related to water quantity (before / after the implementation of the system)	Infiltration area
	Infiltration capacity – permeability of the soil
	Groundwater level NOTE: it can be measured in several observation points of the aquifer, including the saturated zone under infiltration system itself. For the evaluation of the impact of the measure, it will be especially important to evaluate it in the location of pumping wells of groundwater users.
	Volume of groundwater replenishment by surface infiltration NOTE: this parameter can be globally considered by the local managers of groundwater resources.
Quality parameters in native groundwater (before / after the implementation of the system)	Natural attenuation: the presence of an additional source of water in the water balance will imply mixing processes between recharge water and groundwater. This effect will be applied to salinity and chlorinated compounds to determine the state before and after the implementation of the system.
	Electrical conductivity / Salinity NOTE: it can be measured in several observation points of the aquifer, including the saturated zone under infiltration system itself. For the evaluation of the impact of the measure, it will be especially important to evaluate it in the location of pumping wells of groundwater users.
	Chlorinated compounds in the aquifer
Quality parameters in recharge water that improve during Soil-Aquifer-Treatment	Nitrate concentration
	Organic content (Dissolved organic carbon)
	Micropollutants (pharmaceuticals, pesticides…)

Other parameters naturally occurring in groundwater	Ammonium concentration	
	Temperature	
	Turbidity	
Biological aspects related to ponds implementation	Number of bird species watched in the area	
	Volume of surface water available for amphibians and aquatic species	

Step 6: Selection of biophysical indicators (defined as impact I)

Impact I measures the change of biophysical indicators. These indicators are part of the list of the parameters defining state in the previous Step 5. In fact, Table 13 describes the relation between state parameters and impact I indicators.

Table 13: Link between state parameters and impact I

Parameter	State parameters	Impact I indicator
Physical parameters related to water quantity (before / after the implementation of the system)	Infiltration area	Area available able to be actively infiltrating water during managed aquifer recharge [m^2]
	Infiltration capacity – permeability of the soil	Infiltration rate [$m^3/m^2/d$]
	Groundwater level	Increase of groundwater level in the extraction area of the groundwater user (for drinking and non-drinking purposes) [m]
	Volume of groundwater replenishment by surface infiltration	Additional amount per year in groundwater reservoir provided by the infiltration system [Mm^3/year]
Quality parameters in native groundwater (before / after the implementation of the system)	Natural attenuation	Percentage of mixing ratio in certain observation Wells according to distance and travel time
	Electrical conductivity / Salinity	Reduction in groundwater salinity in the extraction area of the groundwater user (for drinking and non-drinking purposes) [µS/cm]
	Chlorinated compounds in the aquifer	Reduction of selected chlorinated compounds of concern for drinking water [µg/L]
Quality parameters in recharge water that improve during Soil-Aquifer-Treatment	Nitrate concentration	Reduction of nitrate concentration through the unsaturated zone [mg/L]
	Organic content (Dissolved organic carbon)	Reduction of dissolved organic carbon through the unsaturated zone [mg/L]
	Micropollutants (Pharmaceuticals, pesticides…)	Percentage of reduction of micropollutants in infiltration process (average value according to their type) [% elimination]
Other parameters naturally occurring in groundwater	Ammonium concentration	Difference between ammonium concentration in groundwater and ammonium concentration in river water taking into account seasonal variations in the river [µg/L]
	Temperature	Difference between temperature in groundwater and temperature river water taking into account seasonal variations in the river [°C]]

	Turbidity	Difference between turbidity values in river water and groundwater (extreme values and average values) [NTU]
Biological aspects related to ponds implementation	Number of bird species watched in the area	Number of species watched related to wetlands and surface water [list]
	Volume of surface water available for amphibians and aquatic species	Additional volume of surface water considering the construction of the infiltration system in Santa Coloma [m^3]

Step 7: Selection of human wellbeing indicators (defined as impact II)

Impact II measures the change of human wellbeing after the implementation of the proposed measure. To this end, end users have been identified the following ESS described in Table 14. As shown in the table below, there are two type of uses, new uses due to the creation of ponds infiltration system and improved uses. Adding both, the impact II is obtained per each beneficiary.

Table 14: Definition of beneficiaries and associated Impact II

Beneficiaries	Impact II	
Drinking Water Treatment Plant Operators. AB example.	Improved ESS.	Energy cost for pumping.
		Energy cost for membranes system.
	Created ESS.	Breakdowns cost.
		Energy cost for pumping.
		Water treatment.
		Maintenance.
Industrial Processors. DAMM example.	Improved ESS.	Energy cost for pumping.
		Energy cost for membranes system.
		Membranes purchasing cost.
Researchers.	Created ESS.	Research studies value.
		PhDs conducted at the ponds value.
		Technical visits value.
Experiencers and viewers.	Created ESS	Visitors' value.

Step 8(a): Quantification of state level before and after the implementation of infiltration ponds system

Infiltration area (before/after)

The total surface occupied by Santa Coloma de Cervelló recharge system is around 13 ha. The surface includes settling ponds, infiltration ponds, paths and auxiliary zones (services, etc…). This indicator is quantified in 56,300 m^2 of infiltration surface available.

Santa Coloma de Cervelló infiltration system provides **56,300 m^2** of new infiltration area.

Infiltration capacity – permeability of the soil (before/after)

The implementation of Santa Coloma de Cervelló system will allow the maximisation of infiltration rate, as the place has been selected according to preliminary studies (boreholes and numerical modelling) to determine the optimum infiltration rate. Taking into account the experience gained in the system located in Sant Vicenç dels Horts, an average infiltration rate of $1m^3/m^2$/day is expected.

Santa Coloma de Cervelló infiltration system provides an infiltration capacity of **$1m^3/m^2$/day**.

Groundwater level (before/after)

One of the direct effects of the implementation of the infiltration ponds in Santa Coloma de Cervelló is the increase of groundwater level in the surroundings of the infiltration system. The quantification of the state before and after the implementation of the ponds is not easy, as the reference values vary according to irregular regime of precipitation. For the standardisation of the calculations of the effect of the aquifer replenishment, CUADLL developed a scenario using the numerical model for the lower Valley and Delta of Llobregat aquifer. The scenario modelled consisted in a constant recharge of surface water in the aquifer, having an annual volume of 10 Mm^3. Figure 14 shows the estimated increase of groundwater level.

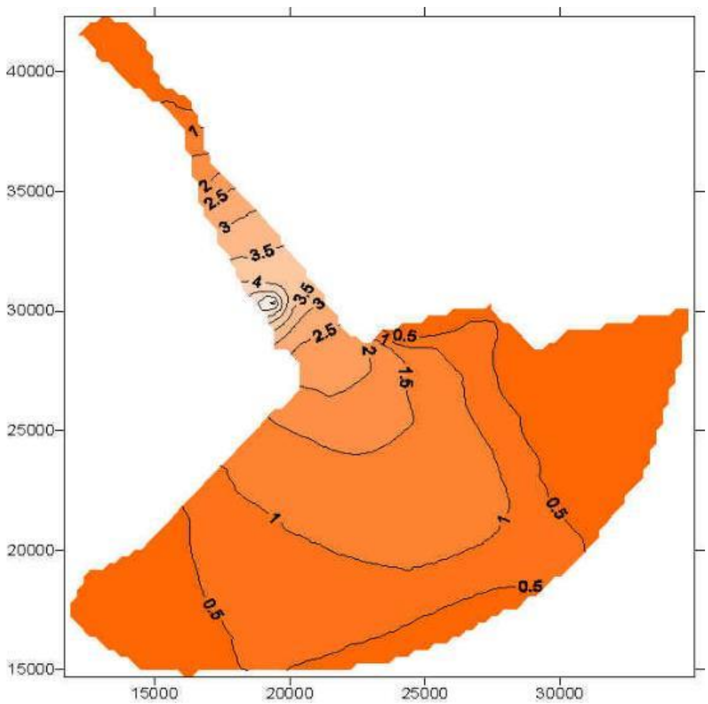

Figure 14: Increase in groundwater level (modelled) after the implementation of SCC system

NOTE: lines represent the relative increase in groundwater level (in meters) caused by infiltration of additional 10 Mm^3/year in Santa Coloma de Cervelló. Source: CUADLL

Santa Coloma de Cervelló infiltration system generates an increase in groundwater level that varies depending on (i) the distance (ii) the direction of flow and (iii) hydrogeological parameters of the aquifer, but in general the model predicts a **maximum increase of 4-5 meters** in the surroundings and a **measurable effect up to 0.5 meters** in the major part of the Lower Valley aquifer and Llobregat Delta aquifer.

Volume of groundwater replenishment by surface infiltration (before/after)

Volume of groundwater replenishment has been established in 10 Mm^3, which will be added as input in the groundwater balance in the aquifer. This volume could vary depending on the operational regime of the system.

Santa Coloma de Cervelló infiltration system provides additional groundwater input of **10 Mm^3/year**.

Natural attenuation (before/after)

Infiltration water will act as an additional volume of water that will be naturally mixed with native groundwater circulating in the aquifer (Figure 15 represents the concept of natural attenuation). As most of the parameters of state in the aquifer, the degree of natural attenuation achieved will depend on the location of the observation well (distance, travel time, hydrogeological properties, and preferential paths among others). A rough estimation of the natural attenuation in Santa Coloma can be given (see Table 15). This information is key to quantify the local benefits of natural attenuation of hazardous pollutants (chlorinated solvents, for instance) in abstraction wells located near the infiltration facility.

Table 15: Natural attenuation depending on observation wells

Observation well	Total depth [m]	Filter screen depth [m below surface]	Distance to infiltration pond [m]	Approximate travel time of recharge water [days]	Proportion of infiltrated water (conservative tracer test)*
BSV-8.1	16.0	13-15	0*	N.A.	57%
BSV-8.3	10.0	7 - 9	0*	4	88%
BSV-5	21.5	5-23	10	6	98%
BSV-9	26.6	9.5 – 24.4	100	13	96%
BSV-10	22.5	6-20	200	17	98%

(*) zero distance means that observation well BSV-8.1 and BSV-8.3 are located inside the infiltration pond.
Conservative tracer test is referred to ENSAT project (http://www.life-ensat.eu/?page_id=620)

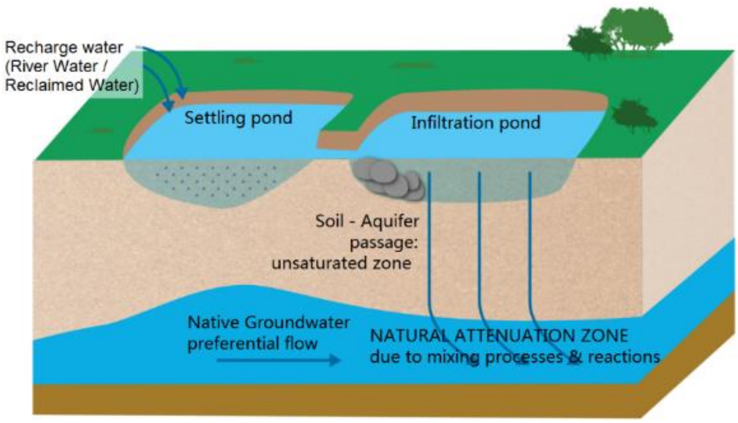

Figure 15: Hydrogeological scheme of infiltration ponds.

Natural attenuation depends on the location of the observation well, but in general, attenuations **between 90% and 98%** are expected in the surroundings downstream of the infiltration system (distance of about 200 meters). In deeper wells, the **natural attenuation can be limited to 60% below the pond**. Long distances attenuations have not been assessed[5].

Electrical conductivity / Salinity (before / after)

Salinity in the Llobregat aquifer is very variable depending on the distance to the sea and the extraction regime. In fact, in 2008 the hydraulic barrier against sea water intrusion was started, and the operation continued until 2011, when the hydraulic barrier injection was stopped due to financial restrictions. Moreover, more frequent and severe drought periods make the aquifer more vulnerable to saline intrusion. Natural recharge decreases, while extraction regime continues with constant or at least independent regimes of operation. These regimes generate cones of depression, inducing changes in natural direction of groundwater flow and causing local seawater intrusion. To calculate salinity reduction caused by increase of groundwater replenishment by using managed aquifer recharge, we can do the comparison between native groundwater before and after implementation of infiltration ponds, as electrical conductivity is a conservative parameter.

Locally, as native groundwater has less salinity than Llobregat river water, there is an increase in salinity. There are 2 parameters that provide similar information:

- Electrical conductivity: measured in microSiemens/cm =[µS/cm]
- Chloride concentration: measured in milligrams of chloride per litre = [mg Cl^-/L]
-

Table 16: Salinity values of native groundwater and influenced water by managed aquifer recharge

	Electrical Conductivity	Chloride concentration
Average salinity in the Llobregat river	1,136 µS/cm (SVH) 1,260 µS/cm (ETAP SJD)	230 -270 mg/L (SVH) 230 v (ETAP SJD)
Average salinity in reclaimed water (Tertiary treatment)	2,140 µS/cm	-
Average salinity in native groundwater in Santa Coloma de Cervelló *(same values than in Sant Vicenç dels Horts)*	1,330 µS/cm	200 mg/L
Average salinity in native groundwater AB extraction wells *(constant value not affected by sea water intrusion – located inland)*	1,850 µS/cm	270 mg/L
Average salinity in native groundwater DAMM extraction wells *SCENARIO 1: drought period – extreme values*	10,000 µS/cm	-
Average salinity in native groundwater DAMM extraction wells *SCENARIO 1: wet period – extreme values (similar to MAR in operation)*	6,500 µS/cm	-

Salinity of native groundwater and recharge water is very similar, around **1,100 – 1,300 µS/cm**. The impact of the implementation of Santa Coloma de Cervelló infiltration system will have low impact in **Aigües de Barcelona extraction wells (potential reduction from 1,850 µS/cm to 1,300 µS/cm)**. Other groundwater users located downstream and affected by seawater intrusion (as the DAMM factory with peaks of 10,000 µS/cm) will find a high impact in their salinity levels, reaching **values around 6,000 – 7,000 µS/cm**. These users will experience the reduction of salinity in their extraction wells due to (i) natural attenuation (not very relevant) and (ii) an increase of piezometric level and displacement of seawater intrusion.

[5] CUADLL developed the numerical model for the assessment of groundwater level increase (http://h2ogeo.upc.edu/en/investigation-hydrogeology/software/152-visual-transin-en). Using conservative transport, a simulation of natural attenuation could be provided if needed.

Chlorinated compounds in the aquifer (before / after)

This document described the presence of organic solvents in groundwater due to industry bad practices. Figure 6 establishes the locations where pollution episodes have been detected, most of them located in the Llobregat lower valley. Trichloroethane has been found as a good indicator (see this compound in tables as 1.1.2 Trichloroethane). The quantification of this pressure has been characterised around 500 µg/L of Trichloroethane, but locally it may reach peaks of 700 – 900 µg/L. Specifically, experience obtained from Sant Vicenç dels Horts recharge system, demonstrated that the infiltration plume has an attenuation factor of almost 100% during a continuous recharge period.

Taking into account the flow model and the natural attenuation in Sant Vicenç dels Horts, Figure 16 and Figure 17 represents 1.1.2 Trichloroethane obtained over the same period of time (and same sampling campaign from C1 to C19) along 2011 and 2012. While BSV-1 (located upstream) maintain 1.1.2 Trichloroethane concentrations between 200 and 700 µg/L before and after the recharge period, BSV-8.1 (located inside the infiltration pond) shows a rapid decrease in the concentration of this compound due to the natural attenuation. Obviously, the 1.1.2 Trichloroethane is not naturally found neither in river water nor reclaimed water. The evidence of reduction can be seen in the following figures when comparing groundwater influenced and not influenced by recharge.

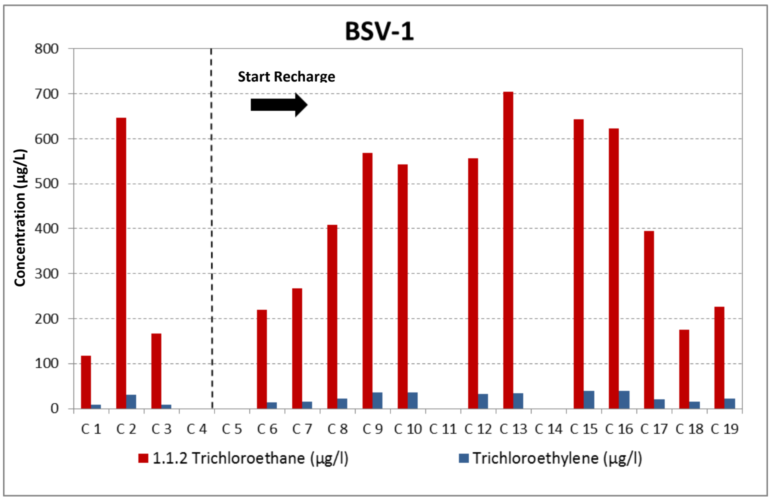

Figure 16: 1.1.2 Trichloroethane in groundwater not influenced by recharge (before and after)
NOTE: BSV-1 is an observation well located upstream the infiltration system of SVH and used as control point of native groundwater conditions during recharge periods.

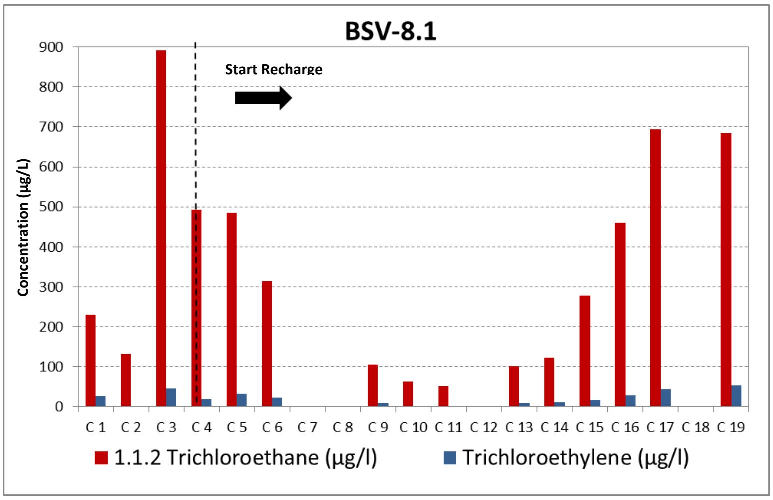

Figure 17: 1.1.2 Trichloroethane in groundwater influenced by recharge (before and after)
NOTE: BSV-8.1 is an observation well located in the infiltration pond of SVH.

Chlorinated compounds in the aquifer are related to buried waste from bad practices in the past. Chlorinated solvents are not naturally present in recharge water (river water or reclaimed water). The promotion of aquifer replenishment using infiltration ponds could reduce the concentration around the system from peaks of **700 – 900 µg/L to below the detection limit**.

Nitrate concentration (before / after)

Nitrate concentration in the aquifer is not a pollutant of concern. Average concentration in recharge water is around 6 mg/L, with peaks of 10-12 mg/L of nitrate, while nitrate concentration in the aquifer varies enormously depending on the zone. In the observation network of Sant Vicenç dels Horts, nitrate concentration varies from 5 to 17 mg/L, with an average concentration around 8 mg/L.

Baix Llobregat region is not classified as vulnerable area of nitrates (up to 50 mg/L). The vulnerable areas in Catalonia are located mainly in the North, and directly related to farming. Nitrate concentration evolution in the aquifer is unknown. There are no vulnerable zones identified (> 50 mg/L). As nitrate is not a conservative compound, it is difficult to predict the evolution. There are not simulations about that. The reduction of nitrate concentration in groundwater is not a key issue in the area for any of the groundwater users that have been surveyed.

In the surroundings of the infiltration pond, nitrate concentration (8mg/L) is almost the same than in recharge water (12 mg/L), so a priori **no changes in nitrate concentration are expected**.

Organic content (Dissolved Organic carbon) (before / after)

Organic content in recharge water is around 3 – 4 mg/L of dissolved organic carbon, corresponding to the same concentration of the raw Llobregat river water in the water intake for the wastewater treatment plant. Settling ponds have not any effect in the concentration of DOC before infiltration. Due to soil-aquifer processes, organic carbon is being degraded by adsorption and biodegradation processes. Thus, despite river water has an average concentration of 3-4 mg/L, groundwater is characterised by DOC values between 1.0 and 1.5 mg/L. The effect of having the infiltration ponds in operation leads to faster this process, changing recharge water composition from 3-4 mg/L to 1-1.5 mg/L.

With the infiltration ponds in operation, recharge water will reduce the organic content, passing **from 3-4 mg/L to 1-1.5 mg/L.**

Micropollutants (pharmaceuticals, pesticides…) (before / after)

Micropollutants include a broad list of substances almost infinite. There are evidences of the potential removal of emerging pollutants as pharmaceuticals, pesticides and personal care products along the infiltration process, including unsaturated zone and saturated zone. The effectiveness of the removal rates depends on multiple factors: initial concentration, DOC content in water, temperature, and redox conditions and of course, travel time. Studying the same system with identical conditions, the removal rates of emerging pollutants have been quantified from 0% to 100% depending on their molecular weight, polar behaviour, specific chemical groups, etc., although this is a field under exploration. In the case of Sant Vicenç dels Horts, there are insights based on several experiments about the removal of some pharmaceuticals, pesticides and hormones along soil-aquifer interface. Moreover, the infiltration pond of Sant Vicenç dels Horts demonstrated the feasibility of increase micropollutants removal using an organic layer of vegetal compost installed in the bottom of the infiltration pond. Figure 18 and Figure 19 illustrates differences in eliminating micropollutants along the infiltration system of Sant Vicenç dels Horts (at laboratory and field scale).

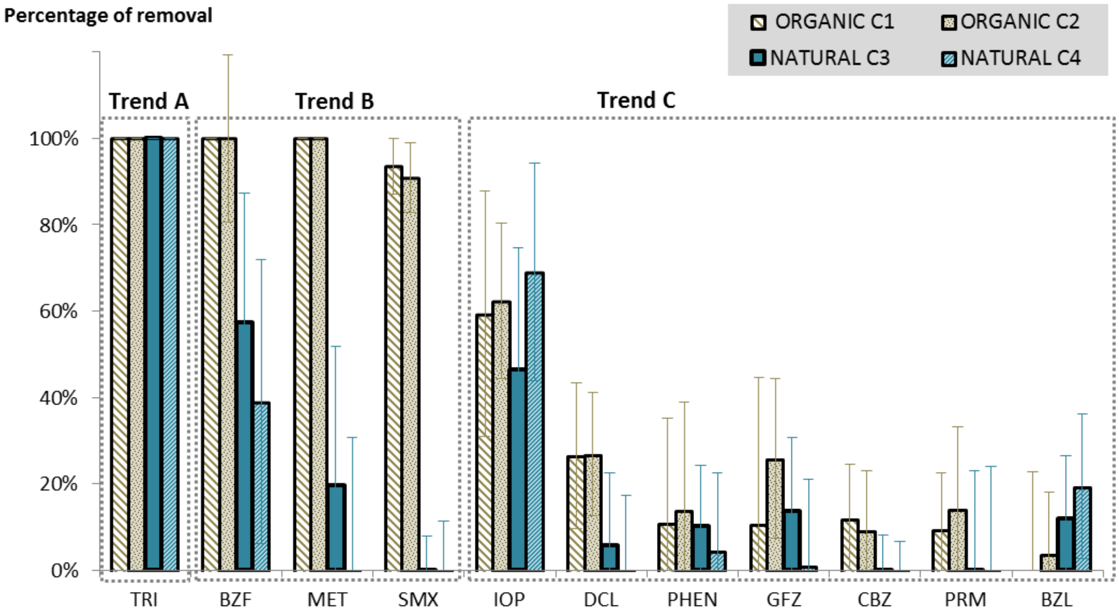

Figure 18: Trends of micropollutants removal in Llobregat infiltration system (laboratory results)

NOTE: TRI = Trimethoprim; BZF = Bezafibrate; MET = Metoprolol; SMX = Sulfamethoxazole; IOP = Iopromide; DCL = Diclofenac; PHEN = Phenazole; GFZ = Gemfibrozil; CABZ = Carbamazepine; PRM = Primidone; BZL = 1-H Benzotriazole. Trend A, Trend B and Trend C correspond to the classification of different behaviours found in emerging pollutants according DEMEAU project classification Source: D12.3 (b) Application of the guidelining soil-column protocol (http://demeau-fp7.eu/toolbox/assessment-and-feasibility-mar-sites/field-and-laboratory-tests/application-guiding-soil)

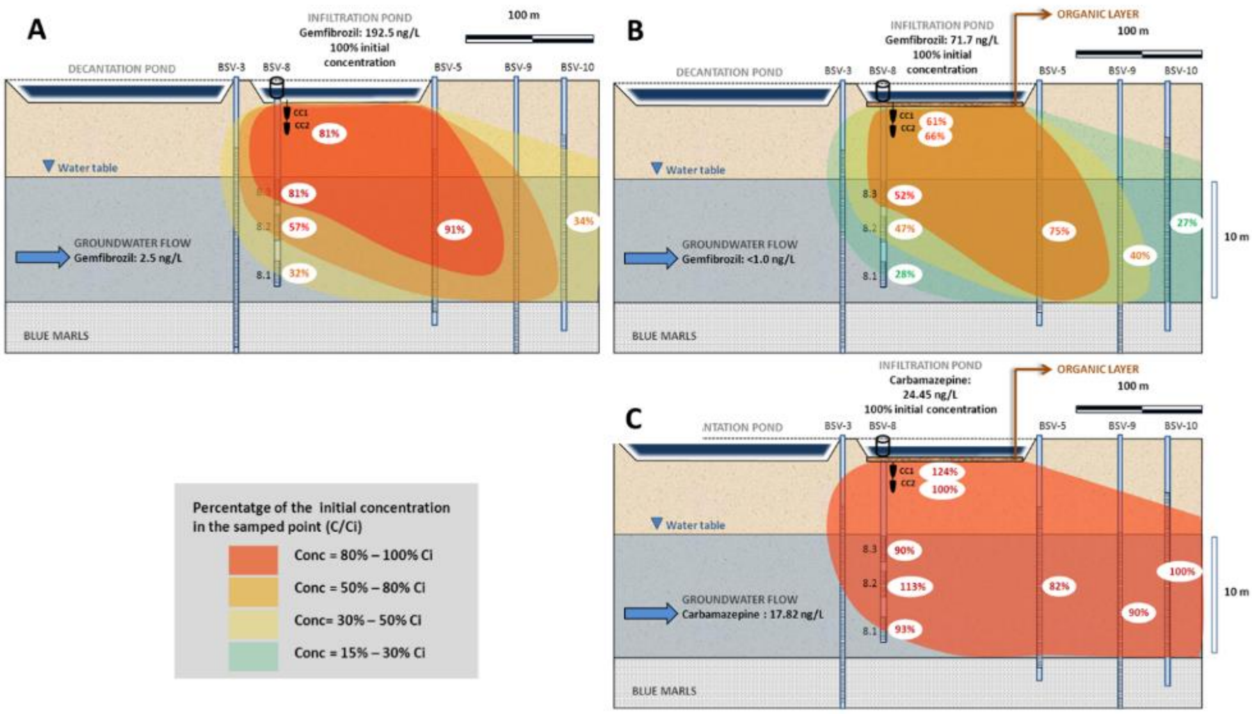

Figure 19: Trends of micropollutants removal in Llobregat infiltration system (field results)

Micropollutants are commonly present in Llobregat river water and reclaimed water at very low concentrations (ng/L to µg/L). The infiltration process through the unsaturated and saturated zones has been proved to be an **effective technique for the removal of some micropollutants**. These substances are not naturally present in the aquifer.

Ammonium concentration (before / after)

Normally, ammonium concentration in the aquifer is below detection limit. River water can present peaks of ammonium, especially in winter, when the performance of WWTP is not totally completed. Ammonium is not a conservative compound, which means than additional inputs of ammonium via infiltration could react depending on the redox conditions, presence of organic matter and total nitrogen in the aquifer.

Regarding the comparison between ammonium concentration in river water and groundwater as fresh water resource for drinking water production, low ammonium concentration in groundwater is one of the most valuable parameters of this input water. It is going to be taken into consideration in the impact I and impact II evaluation for drinking water operators.

Ammonium is not present in groundwater. River water can have peaks of ammonium, but this will be a control parameter to stop their operation. The implementation of the infiltration ponds is not expected to increase ammonium concentration in the aquifer, as it is transformed.

Temperature (before / after)

Groundwater in Llobregat aquifer is around 18ºC all the year (winter and summer). The infiltration of river water with a higher or lower temperature in the infiltration system of Sant Vicenç dels Horts is not going to affect aquifer temperature in general (only at local scale). Infiltration water temperature will evolve to groundwater temperature according heat transfer laws.

Regarding the comparison between temperature in river water and groundwater as fresh water resource for drinking water production, constant temperature of groundwater is one of the most valuable parameters of this input water. It is going to be taken into consideration in the impact I and impact II evaluation for drinking water operators.

Temperature of groundwater is constant along the year **(18ºC). Temperature will remain constant** after the implementation of infiltration system.

Turbidity (before / after)

Turbidity of groundwater is normally below 5 NTU. Infiltration water is higher (5 to 50 NTU have been the range of values of turbidity of recharge water in Sant Vicenç dels Horts. Fine particles are retained in a thin surface layer that will be periodically cleaned. It is not expected to have an increase in groundwater turbidity as a result of the operation of infiltration ponds.

Regarding the comparison between turbidity in river water and groundwater as fresh water resource for drinking water production, low turbidity of groundwater is one of the most valuable parameters of this input water. It is going to be taken into consideration in the impact I and impact II evaluation for drinking water operators.

Turbidity in groundwater is very low (less than 5 NTU). The implementation and operation of infiltration ponds will not bring additional turbidity to groundwater, as the settling pond will eliminate most of turbidity and top layer of the pond will act as a filter.

Number of bird species watched in the area (before / after)

The construction of the large system in Santa Coloma de Cervelló will attract numerous bird species that have been already identified in smaller systems (Sant Vicenç dels Horts system and Castellbisbal system). The amount of species is very difficult to be estimated, so a list of the bird species identified in the infiltration ponds upstream is provided in Annex IV: List of bird species identified in SVH infiltration system, of this document. There is more information available, as the birds in the natural wetlands of the Delta del Llobregat, but this comparison would overestimate the attraction effect of Santa Coloma de Cervelló ponds.

52 bird species already identified in Sant Vicenç and Castellbisbal infiltration system could be watched in the infiltration system of Santa Coloma de Cervelló.

Volume of surface water available for amphibians and aquatic species (before / after)

With the implementation and normal activity of the settling and infiltration ponds, there will be a new surface water area near the river able to be colonized by amphibians and aquatic species. The settling surface is about 86,600 m^2, while infiltration surface is 56,300 m^2. Taking into account an average of 75 cm of water column, the new volume of water available will be 107,000 m^3.

Total new volume available of surface water is estimated in **107,000 m^3**, corresponding to water in the settling ponds and infiltration ponds.

Percentage of days with surface water available (before / after)

Infiltration system is a nature-based solution using groundwater replenishment as an alternative water source to increase water availability. The system operation will depend on climatic conditions (flooding episodes can damage partially the facilities), and maintenance tasks. Based on previous experiences in Sant Vicenç dels Horts, is feasible to establish and operation percentage of 75% of days, when settling and infiltration ponds having surface water inside. It is expected than in this situation, infiltration system will be more attractive to visitors and population in the surroundings.

The percentage of days with surface water available in the settling ponds and/or infiltration ponds is estimated around **75%.**

Step 8(b): Quantification of changes impact I and impact II

Impact I and Impact II have been evaluated from the perspective of the end users. To this end, following information in this section is going to be presented in sub-sections, taking into account an example of beneficiary.

Assessment of impact I & II for drinking water operators: Aigües de Barcelona

Two main operators are extracting groundwater for drinking water supply from the aquifer: Aigües de Barcelona and Aigües del Prat. The former uses the aquifer as a complementary source of the river water. The latter one only relies on groundwater to supply potable water to the whole city of el Prat, of about 60,000 inhabitants. For the assessment of impact I & II, Aigües de Barcelona has been selected due to more data is available.

Since 2009, Aigües de Barcelona (AB) has extracted 114 Mm^3, but the annual values are very variable. They depend on the river water quality, the water level in the aquifer, and it is limited by a total annual amount imposed by ACA (Catalan water public agency). Due to this variability, the average from 2009 to 2015, which is 16.3 Mm^3, is going to be considered as the annual extraction volume. This number is taken as the annual extraction volume in order to do the calculations shown below.

Impact I

Impact I has been assessed as the changes in state (before / after the infiltration ponds implementation) that alter the ecosystem services of provision or regulation and impacts in one or several beneficiaries.

1. **Increase of groundwater level nearby pumping wells:** according to numerical modelling carried out by CUADLL, groundwater level is expected to increase around 3 metres in the pumping wells located in Estrella area and 2 metres in the pumping wells located in Cornellà area. There are well fields for drinking water purposes in both locations. Impact II will quantify the economic benefits of this additional increase of groundwater level.

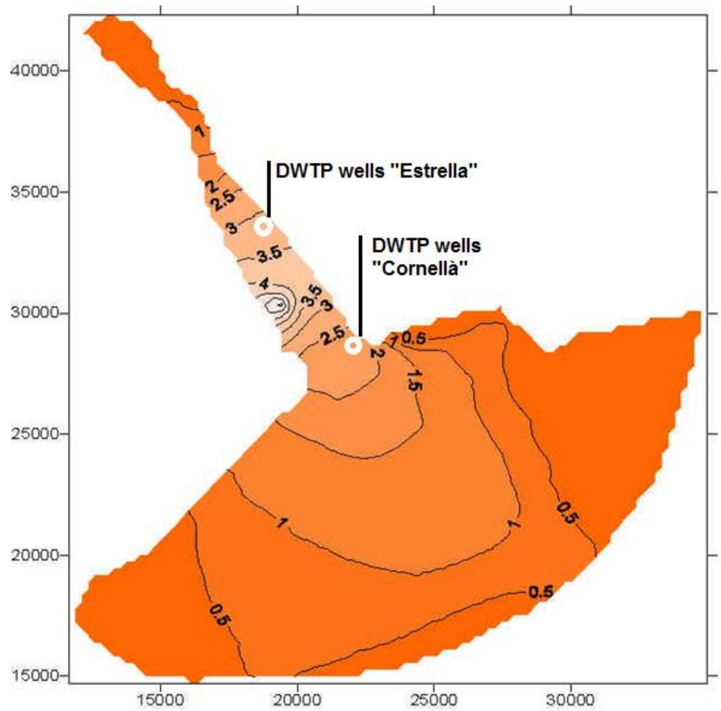

Figure 20: Modelling of groundwater level increase after the implementation of SCC in AB wells

NOTE: black lines represent the relative increase in groundwater level (in meters) caused by infiltration of additional 10 Mm^3/year in Santa Coloma de Cervelló and AB wells location.
Source: CUADLL

2. **Ammonium elimination:** in winter, WWTP performance upstream the DWTP can be limited due to temperature. Main secondary treatment of WWTP is activated sludge. If ammonium concentration in river is above 2.5 mg/L, intake of water is stopped (with concentration up to 1.8 mg/L there is an alert situation). In this case, the use of groundwater becomes critical, as this is the only available resource to maintain the full production of the plant. Ammonium is not present in groundwater (in general), so the increase of groundwater availability due to the infiltration in Santa Coloma de Cervelló will allow having an additional volume of groundwater to deal with ammonium peaks in the river catchment.

3. **Turbidity reduction:** Groundwater presents naturally low turbidity. This is a warranty to use groundwater in case Llobregat river water presents turbidity values above 500 NTU. An increase in groundwater resources due to the additional 10 Mm^3 in the aquifer, will allow Aigües de Barcelona to rely on groundwater resources to deal with turbidity peaks.

4. **Temperature regulation:** as stated, DWTP in Sant Joan Despí can switch from surface water to groundwater. Water input can be mixed (after the primary/conventional treatment) or can be one of the two options (100% river water or 100% groundwater). In winter, with low temperatures in river water (5ºC to 10 ºC), damages in the piping system have been identified. The distribution network engineers detected more pipe breakages in winter due to this effect. Aigües de Barcelona studied this effect and calculated the number of breakages due to temperature contrast, and since then they uses groundwater to prevent this effect. Warm temperature of groundwater in winter has another positive effect in the drinking water treatment. When water temperature is higher, membrane porous dilates, which allow working with smaller pressure than in cold water conditions. This effect can be also measured economically.

Impact II of infiltration ponds in AB abstraction wells: economic assessment

The monetisation of impact II in water for drinking purposes is done in five axes. First, the avoided costs in energy for pumping; then, avoided costs in pipes network breakdowns reparation; and, third, the substitution from surface water to groundwater, that includes increased costs in energy for pumping, avoided costs in water treatment and change in maintenance costs. The first two are changes in the actual use of groundwater due to the change in quality and quantity, while the lasts are due to the substitution of 8Mm^3 from surface water to groundwater. This substitution is due to the more water available in the aquifer. All the values are assessed using avoided costs valuation method (Zografos, 2010). Note that the pipes network is made of the transportation network and the distribution network. The former are the network from the treatment plants to the cities, high volume pipes; while the latter is the network within the cities, small and medium pipes. The avoided costs are assessed for the distribution network only since no data is found for the assessment of the avoided breakdowns in transportation network. However, it is known by the operator that using more groundwater will reduce breakdowns in the transportation network that are more expensive to maintain than the distribution breakdowns.

Regarding the avoided costs in energy for pumping, due to the additional recharge from infiltration ponds, the groundwater levels will increase up to 2-2.5 metres (Figure 20)... A difference of 4-5 kWh per well is assumed. The working time is equivalent to three wells working full time, every day of the year. Thus, a difference in consumption of 12 kWh per hour has been calculated. This difference in energy consumption is converted in avoided costs in Table 17. The annual avoided costs in energy for pumping for AB beneficiary is 9,586.80€/year.

Table 17 Avoided costs in energy for pumping in AB

Avoided costs in energy for pumping	unit	
Difference in energy consumption by the pump at x+2 metres.	kWh/hour	12
Number of hours of use in the whole year.	hour/year	8,760
Energy cost.	€/kWh	0.091
Annual avoided costs in energy for pumping.	€/year	9,586.80

Regarding the avoided costs in pipes network breakdowns reparation, the indicators needed are the total number of breakdowns, the average cost per breakdown and the percentage attributable to the use of groundwater. In case of the number of breakdowns, it is taken from the DSO (2014) report. The average cost per breakdown is the result of dividing the total cost of breakdowns by the total amount of breakdowns. And, finally, it is assumed that 10% of the reduction in breakdowns is due to the use of groundwater. It is a conservative assumption taking DSO (2014) report as reference. The annual avoided costs in pipes network breakdowns reparation is 64,400€/year, as it is shown in Table 18.

Table 18: Avoided costs in pipes network breakdowns reparation in AB

Avoided costs in pipes network breakdowns reparation	unit	
Difference in the number of breakdowns.	units/year	230
Average cost per breakdown.	€/unit	2,800
Percentage attributable to the use of groundwater.	%	10%
Annual avoided costs in pipes network breakdowns reparation.	€/year	64,400

Due to the substitution from surface water to groundwater as input to DWTP, three different changes are taken into account. The first is the increase in costs due to the energy needed for groundwater pumping. The energy consumption is 0.11 kWh/m^3, with an increase in water pumped of 8 Mm^3/year and an energy cost of 0.091 €/kWh. These figures result in increased cost of 82,954.97€/year, summarized in Table 19.

Secondly, there are the avoided costs in water pre-treatment. Due to the aquifer-soil interface eliminates some pollutants; the pre-treatment is not needed in case of groundwater. These treatment cost is 0.034 €/m^3 that with the substitution of 8 Mm^3/year, means an annual avoided costs of 296,600€/year (Table 20).

Finally, a change in the maintenance costs is expected. This change is supposed to affect the corrective costs rather than the preventive ones. In fact, a ratio €/Mm^3 is calculated for the corrective maintenance. Thus, the change in corrective maintenance supposes an increase of 63,803.68 €/year in the pumping wells and a decrease in pre-treatment corrective maintenance of 22,857.14 €/year. The difference between them, represents an increase of costs of about 40,946.54 €/year (Table 21).

All in all, the net result of the substitution from surface water to groundwater is 145,698.49 €/year.

Table 19: Increased costs in energy for pumping in AB

Substitution from surface water to groundwater:	unit	
Increased costs in energy for pumping		
Difference in energy consumption between groundwater and surface water	kWh/m^3	0.113701
Water quantity.	Mm^3/year	8
Energy cost.	€/kWh	0.091199
Annual increased costs in energy for pumping (catchment)	€/year	82,954.97

Table 20: Avoided costs in water treatment in AB

Avoided costs in water treatment		
Total amount of water treated substituted by groundwater.	Mm^3/year	8
Treatment cost.	€/m^3	0.034
Annual avoided costs in water treatment	€/year	269,600

Table 21: Change in costs in maintenance in AB

Change in costs in maintenance	unit	
Corrective maintenance costs in pumping wells	€/year	130,000
Corrective maintenance costs in pre-treatment	€/year	280,000
Total amount of groundwater abstracted before measure implementation.	Mm^3/year	16.3
Total amount of groundwater pre-treated before measure implementation.	Mm^3/year	98
Corrective maintenance costs in pumping wells per Mm^3	€/Mm^3	7,975.46
Corrective maintenance costs in pre-treatment per Mm^3	€/Mm^3	2,857.14
Water pre-treated substituted per groundwater	Mm^3/year	8
Increased costs in corrective maintenance in pumping wells	€/year	63,803.68

Avoided costs in corrective maintenance in pre-treatment	€/year	22,857.14

Change in costs in maintenance	€/year	40,946.54

The total annual benefits for AB are 219,685.29 € per year, which is the sum of all the values reported above.

Assessment of impact I & II for industrial users of groundwater: DAMM factory

DAMM is the main industrial user of groundwater in terms of extracted water. DAMM factory is located in the municipality of El Prat Del Llobregat. The strategic location of the factory responds to the need of fresh water available as a raw material for the production of beer. The factory has a quite constant production, around 435,000 m^3/year (period 2010-2014). DAMM gets all the water needed for the industrial processes from the aquifer. Four wells provide enough groundwater for direct and indirect water uses. Total consumption of DAMM is around 2.3 Mm^3/year, which represents a half of total industrial consumption in the aquifer.

Because it has a considerable influence on the organoleptic characteristics of the beer, the water used must be pure, sterilised and devoid of extraneous tastes or smells. Therefore, the factory installed a purification system consisting in reverse osmosis. Between 2005 and 2008 the factory faced a critical situation, due to groundwater salinization (Figure 21). The company installed a new reverse osmosis scheme, to deal with high levels of electrical conductivity, having a high investment in equipment and additional costs related to electrical consumption. Moreover, groundwater level decreased in that period giving rise to higher costs in energy for pumping.

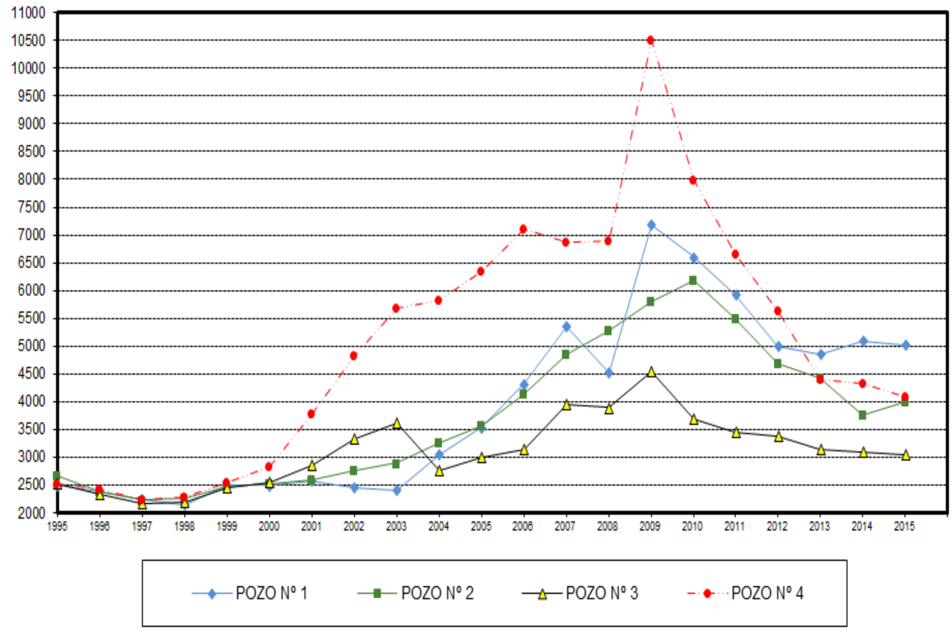

Figure 21: Electrical conductivity in the extraction wells (unit µS/cm)
Source: DAMM

DAMM factory has been selected as an example of the industrial end user that will be directly favoured by the increase of groundwater resources with the implementation of the infiltration system in Santa Coloma the Cervelló, In fact, despite the distance between the ponds and the factory (Figure 22), a raise of 1.5 meters in phreatic level has been predicted by the simulations. Regarding quality parameters, as water for industry needs a very exhaustive quality control; most of factories have their own purification system. In the case of DAMM, only electrical conductivity is a parameter of concern that can affect its production costs.

Using data from 2014, results obtained in this case study would represent approximately 65% of the industrial users consuming groundwater for their production and auxiliary processes. There is, of course, the uncertainty of the values of the indicators used for the calculations, which are based on DAMM data.

Impact I

1. **Increase of groundwater level nearby pumping wells**

According to the model developed by CUADLL, a relative increase of 1.5 meters of groundwater is expected nearby the location of the 4 pumping wells of DAMM factory in the municipality of El Prat de Llobregat. Figure 22 illustrates the location of SCC infiltration system, with maximum groundwater level rise of 5 meters around the infiltration ponds, and the isopiezometric values caused by infiltration. The 4 pumping wells of DAMM (named P1, P2, P3 and P4) will be impacted similarly due the proximity between them.

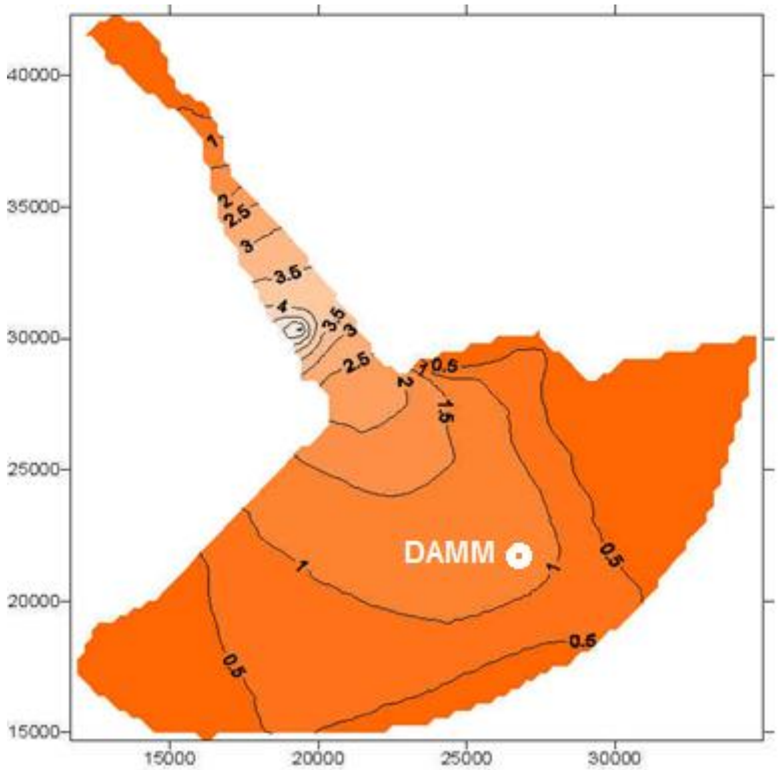

Figure 22: Modelling of groundwater level increase after the implementation of SCC in DAMM wells

NOTE: Black line represent the relative increase in groundwater level (in meters) caused by infiltration of additional 10 Mm^3/year in Santa Coloma de Cervelló and DAMM location
Source: CUADLL

2. **Salinity decrease in groundwater for brewery**

Groundwater salinity has been considered the key indicator of groundwater quality. High conductivity values (around 10,000 µS/cm) are the maximum electrical conductivity registered in the area, which conditioned the factory to the installation of a more robust reverse osmosis scheme. A scenario of a half of this value (5,600 µS/cm) is considered as optimal situation to change the reverse osmosis scheme, having less power consumption. This value will be reached with the infiltration ponds of Santa Coloma de Cervelló in operation.

Impact II of infiltration ponds in DAMM abstraction wells: economic assessment

As it is explained above the three avoided costs to be monetised are the difference in energy costs for pumping, in energy costs for running the membranes systems, and the difference in the price of purchasing and installing the membranes system itself.

Firstly, for the monetisation of the avoided costs in energy for pumping two scenarios are taken, the current scenario that is the actual groundwater level, and a future scenario where the groundwater level will raise 1 meter. This future scenario is consistent with the results of the CUADLL model of groundwater level (Figure 22).

For the future scenario, a less powerful pump is needed and the energy consumption is lower than for the actual scenario. The calculation is shown in the following table:

Table 22 Avoided costs in energy for pumping in DAMM

Avoided costs in energy for pumping	unit	
Energy consumption for the pump at "x" metres	kWh/m³	0.26
Energy consumption for the pump at "x + 1" metres	kWh/m³	0.17
Energy cost	€/kWh	0.1
Water flow	m³/h	250
Hours of use per year	h/year	8,454
Avoided cost per hour	€/h	2
Avoided cost per year	€/year	17,753

As it is shown in the table, the total avoided cost per year in energy for pumping will be 17,753€ per year. Considering that the annual cost of pumping is 54,951€, it means a 32% reduction in costs annually.

Secondly, for the monetisation of the avoided costs in energy for running the membranes system two different scenarios are taken. Scenario 1 corresponds to the actual salinity level, and scenario 2 considers a decrease in the salinity of about 39.3%. In scenario 1 there is a system with membranes from Koch. In this case the membranes used are DESAL-CE8040-F. These membranes need a pressure of 21 bars to be efficient. On the other hand, the system of scenario 2 is built from Dow BW30HR-440i membranes; and the pressure needed to run the system is 11 bars. The difference between the pressures needed in the first and the second causes the avoided costs in energy. In the following table the calculation is shown:

Table 23: Avoided costs in energy for membranes system in DAMM

Avoided costs in energy for membranes system	unit	
Membranes consumption scenario 1	kWh/m³	1.10
Membranes consumption scenario 2	kWh/m³	0.57
Energy cost	€/kWh	0.1
Water flow	m³/h	250
Hours of use per year	h	8,454
Avoided cost per hour	€/h	13
Avoided cost per year	€/year	112,016

As it is shown in the table, the total avoided cost per year in energy for membranes system will be 112,016€ per year. Considering that the annual cost of pumping is 232,485€, it means a 48% reduction in costs annually.

Finally, for the monetisation of the membrane systems avoided costs the two salinity scenarios above are taken into account. There are 696 membranes per each system and the lifetime expected is 5 years. As an annual discount rate we consider 3%. The calculation is shown in the table below:

Table 24: Avoided costs in membranes system purchasing in DAMM

Avoided costs in membranes system purchasing	unit	
Membrane unitary cost scenario 1	€	1,100
Membrane unitary cost scenario 2	€	525
Total number of membranes	units	696
Lifetime of the membranes	years	5

Lifetime avoided cost	€/5 years	400,200
Annual avoided cost	€/year	87,385
Discount rate	%	3%

As it can be seen in the table, the total avoided cost is 400,200€, that is 87,385€ per year with a discount rate of 3%. This 3% is taken from the Cookbook step 8 recommendations. It is a decrease of 52% of the annual cost with respect to the scenario 1.

All in all, the sum of all the avoided costs due to the improve either in quality and in quantity is 217,154€ per year, which is a depletion in costs of 47.71%.

Table 25: Total annual avoided cost in DAMM in euros per year

Total annual avoided cost	217,154
Avoided costs in energy for pumping	17,753
Avoided costs in energy for membranes system	112,016
Avoided costs in membranes system purchasing	87,385

A recommendation on the Cookbook part IV step 7 (Anzaldúa *et al.* 2016) regarding the addition of different figures is done. The recommendation is not to sum results of different valuations. However, as the valuation method, the data sources and the beneficiary is the same the addition of this figures is found appropriate.

Additionally, a benefit transfer is done to assess the avoided costs for the other industrial users. Damm is chosen as the example because is the main industrial user but there are other industrial users in the area. Due to the lack of data, a benefit transfer using DAMM figures is proposed. The only avoided cost that is assessed is the energy for pumping. The whole industrial abstractions in the aquifer is 3.17Mm^3 annually[6]. A total of 1.06Mm^3 correspond to the other industrial users. By using the same assumptions than in DAMM case, the avoided costs in energy for pumping will represent 8,864.84€/year. The figures are summarized in the following Table 26.

Table 26: Avoided costs in energy for pumping in other industrial users

Avoided costs in energy for pumping	unit	
Groundwater abstracted by DAMM	Mm^3	2.11
Groundwater abstracted by other industrial users	Mm^3	1.06
Avoided cost per year at DAMM	€/year	17,753
Avoided cost per Mm^3 per year at DAMM	€/Mm^3*year	8,399.77
Avoided cost per year at other industries	€/year	8,864.84

Assessment of impact I & II for researchers & scientists

Sant Vicenç dels Horts infiltration system started its operation in 2008. Since then, several R+D projects have used this facility as demonstration site to evaluate the properties of MAR systems (Managed Aquifer Recharge) and to know more about the capabilities of natural purification, clogging processes and other physico-chemical processes occurring. MAR systems are nature-based solutions increasingly applied.

The case of Sant Vicenç dels Horts, jointly with the facilities located in Segovia (Santiuste and Carracillo ponds[7]) has been included as demonstration site in several European EC funded projects. The construction and start-up of a new and bigger system in the Baix Llobregat region, will lead some research groups to continue exploring these systems in a multidisciplinary approach. Specifically, Catalan research groups and institutes are specialised in MAR systems,

[6] 2014 data, source CUADLL.
[7] http://www.eip-water.eu/sites/default/files/MAR4FARM-workshop-Santiuste-en-v8.pdf

being an international reference, with some scientific publications and continuous participation in public European projects.

Moreover, this kind of facilities attracts the interest of foreigners as students, scientists and water managers. The infiltration system of Sant Vicenç dels Horts has been visited as technical visit of some international conferences as AQUACONSOIL (2013)[8] or EIP Water meeting (2014)[9].

Figure 23: pictures to illustrate the research opportunities of infiltration ponds

Impact I evaluation

The selection of the indicators to calculate the educational services and the research opportunities provided by the infiltration pond is not an easy task. Scientifics are attracted by these nature-based solutions for passive- depuration through soil-aquifer treatment. Regarding educational services, it can be estimated the number of water professionals interested in this kind of systems that would take advantage of the existence of Santa Coloma de Cervelló system. In that sense, Sant Vicenç dels Horts system can serve as an example (with smaller area) about how many researchers, scientists and students have visited and/or studied the managed aquifer recharge system.

Impact II evaluation

There are three impacts in human wellbeing generated because of the infiltration ponds construction in terms of research. These three impacts are the technical visits, the PhDs and the research projects conducted in the ponds. Following, the valuation of these impacts is done.

First, the infiltration ponds are an innovative solution that captures the attention of technicians. Since the infiltration ponds construction several international conferences about water were done in the area of Barcelona. The attendants had the opportunity to visit the infiltration ponds into the conference context. The overall number of technical visitors during the 8 years of life was 232. As the infiltration ponds are out of the city and had not a public transport connection, a private bus was hired to go to the ponds. The cost per visitor to go from Barcelona to the

[8] http://www.aquaconsoil.org/

[9] http://www.eip-water.eu/5th-6th-november-2014-eip-water-conference-barcelona-es

ponds and come back is 13€. This is the result of dividing the total cost of the bus hiring by the amount of visitors per trip. In the following Table 27, the total value of the visits is calculated.

Table 27: Value of the technical visits conducted at the infiltration ponds

Technical visits value		
Average cost from Barcelona to the ponds	€/visitor	13.00
Number of visitants	visitors	232
Total value of the technical visits	€	3,016.00
Lifetime of the ponds	years	8
Discount rate	%	2%
Annual value of the technical visits	€/year	411.71

The total value of the technical value is annualized in order to make able the aggregation of all the quantities per each ESS. The annual value of the technical visits is 411.71€ per year.

Second, the infiltration ponds also give the opportunity to research more in deep in numerous subjects. In the 8 years of ponds life 6 PhDs were been conducted in it. Each PhD will be impossible to be done without the ponds existence, so we valued the whole grant per student as the created value. In the following table, all the calculations are shown.

The total value of the PhDs conducted at the ponds amount to 369,264€. As it is done in all of the valuations, the total amount is annualized in order to permit the aggregation of all the values. The annual value of the PhDs is 50,408.15€ per year.

Table 28: Value of the PhDs conducted at the infiltration ponds

PhD values		
Grant per PhD student	€/PhD	61,544.00
Number of PhD students	students	6
Total value of the PhDs	€	369,264.00
Lifetime of the ponds	years	8
Discount rate	%	2%
Annual value of PhDs conducted at the infiltration ponds	€/any	50,408.15

Last but not least, the assessment of the research projects value is done. A total of 5 different projects, apart from DESSIN, were conducted, almost partially, in the infiltration ponds. Each project budget and the percentage attributable to ponds existence are listed in the Table 29. Regarding ENSAT project, it is fully attributable to the ponds existence. GABARDINE's and MARSOL's percentages are due to the ponds are a case study. In case of GABARDINE is one over four case studies and one over eight case studies in MARSOL. Finally, the percentage in case of DEMEAU and PREPARED is the weight of Cetaqua's budget over the global project budget. Thus, the total value in research projects conducted at the ponds is 3,173,777.06 and the annual value of it is 433,251.67 € per year.[10]

Table 29: Value of the research projects conducted at the infiltration ponds

Research projects value		
ENSAT budget	€	1,240,358
Percentage attributable to ponds existence	%	100%
GABARDINE budget	€	3,286,579
Percentage attributable to ponds existence	%	25%
DEMEAU budget	€	4,618,591.6
Percentage attributable to ponds existence	%	3%
PREPARED budget	€	10,657,756
Percentage attributable to ponds existence	%	3%
MARSOL budget	€	5,200,000
Percentage attributable to ponds existence	%	12,5%
Total value of the research projects conducted at the ponds	€	3,173,777.06
Lifetime of the ponds	years	8
Discount rate	%	2%
Annual value of the research studies conducted at the ponds	€/year	433,251.67

All in all, the total annual value due to research, which is the aggregation of the three values, is 484,071.53.

[10] The values and calculations per these three ESS are done in current euros.

Assessment of impact I & II for experiencers and viewers

Barcelona Metropolitan Area presents a high density of population, and the green space per habitant in the city of Barcelona is around 6 m^2/inh, very distant from the optimum of 15 m^2/inh recommended by WHO. This is a key factor to explain how valuable green areas are in the city and in the surrounding zones. The Llobregat delta wetlands are a natural area protected permanently visited by scholars, families and ornithologists.

Infiltration pond project in SCC includes some paths connecting transversely the settling and infiltration ponds, and will be opened to the public, so runners, bikers and visitors could come near the water. The already constructed infiltration system in SVH has been perimeter fenced to protect the measurement equipment, so people can only get closer to the fence. To imagine how could be the relation of the citizens with an open infiltration system, it is necessary to consider also public health issues, as the prevention of direct contact with reclaimed water, and the protection of the equipment. So in the end, it will be necessary a solution of compromise consisting in having large lagoons that will attract birds, and the prevention measures to maintain the population safe of not disinfected reclaimed water.

Impact I evaluation

To analyse the potential impact in terms of visitors of SCC system and existing water bodies in the surroundings, a selection has been done taking into account some criteria. Finally, Murtra wetland and Maiola pine area have been chosen due to:

- Size of water body: Murtra is a coastal wetland around 22 Ha.
- Accessibility: there are not public announcements nor indications to reach the site. It is only known by local people (from Gavà and Viladecans) and local biologists. In the case of SCC, it is not expected to reach the infiltration system by car.
- Public services: there are no public services as a parking area, bathroom or restaurants.
- Poor biodiversity: la Murtra coastal lagoon is nowadays suffering from eutrophication and salinization, which makes it a water body without a big amount of bird species. Moreover, there are not activities of identification of birds programmed. SCC will attract birds (according to those observed already in Annex IV of the document), but it can be temporally, taking into account the maintenance periods (25% of the days).

Figure 24: Pictures to illustrate the cultural services of infiltration ponds (similar to Murtra system)

Impact II evaluation

The main indicator of the impact II use is the number of visitors, which are estimated through a survey done in the whole Delta area. The result of the survey for Murtra wetland and Maiola pine area, which are chosen due to the similarity to the ponds, are 250 visitors for the Murtra and 5,000 visitors for the Maiola per year. The results are shown in the following table.

Table 30: Estimated visitors in the Murtra and Maiola areas

Estimated visitors			
Visitable places	**Free visitors (not organised)**	**Scholar visitors**	**Total Visitors**
Murtra wetland	250	0	**250**
Maiola pine area	5,000	0	**5,000**
Total			**5,250**

But more indicators are needed in order to make able the monetisation of the visitors. Thus, the indicators needed are the distance to the ponds, the travel time to reach it, the average wage or gain per hour and the fuel cost. The indicators are quantified and explained along the monetisation application.

The monetisation of the impact II is done through the Individual Travel Cost Method (ICTM). ITCM is a standard methodology applied in several projects to determine the monetary surplus value of visitors (Langemeyer, 2015). ITCM includes two values, the cost of the transportation and the time invested in it, as an opportunity cost.

Transport cost

The transport chosen to do the calculation is the car due to there is no public transport available to reach the ponds area. For the calculation of the cost, an average distance is calculated assuming that the majority of the people come from the surroundings of the ponds. The closer cities are Santa Coloma de Cervelló, Sant Feliu de Llobregat, Sant Joan Despí, Sant Vicenç dels Horts, Sant Boi, Cornellà, Esplugues and Molins de Rei. This assumption is consistent with the results of a survey conducted to the whole area of Delta del Llobregat shown in Table 31. An equal distribution is supposed among the municipalities, thus the average distance to the ponds is 6.0875 km. The fuel consumption is calculated with 7l/100km of fuel consumption with a fuel cost of 1.25€/L.

Table 31: Visitors origin

Coming from survey done to 16337 visitors			
Catalonia region	**Europe**	**rest of Spain**	**Other countries (excluding Europe)**
97%	1.90%	0.90%	0.20%

Travel time

As it is done in Langemeyer (2015), the travel time was determined as hourly wages multiplied by a factor 0.5. Then, hourly wages are taken from the national institute of statistics (Idescat), the national average benefit in €/h is taken, 15.63 €/h. Using the same assumptions as per transport cost, the average travel time resulted in 0.18 hours per journey. Finally, the total travel cost is multiplied by 2, because the return is also included. All the calculations are summarized below in Table 32.

Table 32: Value of the visitors to the infiltration ponds

Visitors value		
Transport cost	€/visitor	0.53 €
Number of visitors	visitor/year	5,250
Travel time	hours	0.18
Time value	€/hour	7.815
Annual value of visitors	€/year	20,477.30 €

The annual value of visitors is 20,477.30€/year.

Summary of Impact II assessments

In conclusion, the whole values assessed due to the creation of the infiltration ponds are summarised in the following Table 33. A wider sort of beneficiaries is found impacted by the measure and in general in a positive way. However, the beneficiaries identified correspond to a specific point of time; it could change along the infiltration ponds lifetime as there are a lot of external conditions affecting each beneficiary. Furthermore, the actual use of ESS per each beneficiary could change during the lifespan of the measure too. As it is expressed before and on step 7 of the Cookbook (Anzaldúa *et al*. 2016) it is not recommended to aggregate the different values. However, as broader analysed in Financial Dimension of the Sustainability Assessment (SA), it seems that the balance between benefits and costs is positive if all the beneficiaries are taken into account. The aim of the methodology application, to assess the wider value created by the measure, is reached. And, finally, as expressed in SA, a cost-benefit analysis is recommended to ensure the financial affordability of the measure.

Table 33: Summary of the values assessed due to the infiltration ponds creation

Final ESS type	Beneficiary	Valuation method	Assumptions/comments/references	Values[11] (€/year)	Uncertainty
FESS1: Water for drinking purposes	AB	Avoided costs	Energy for pumping	9,586.80	🟡
		Avoided costs	Breakdowns reparation	64,400	🟡
		Avoided costs	Energy for pumping. Assumption: water source substitution from surface water to groundwater	-82,954.97	🟡
		Avoided costs	Water treatment. Assumption: water source substitution from surface water to groundwater	269,600	🟡
		Avoided costs	Maintenance costs. Assumption: water source substitution from surface water to groundwater	-40,946.54	🟡
FESS2: Water for non-drinking purposes	DAMM	Avoided costs	Energy for pumping	17,753	🟡
		Avoided costs	Energy for membranes system	112,016	🟡
		Avoided costs	Membranes system purchase	87,385	🟡
	Other industrial users	Avoided costs	Energy for pumping. Assumption: same pumping costs per m^3 as DAMM; benefit transfer for the whole water abstractions	8,864.84	🔴
FESS3: Educational	Researchers	Travel cost	Technical visits value	411.71	🟡
		Revealed preferences	PhDs value	50,408.15	🟡
		Revealed preferences	Research projects value	433,251.67	🟡
FESS4: Experiential use of landscapes in different environmental settings	Experiencers and viewers	Travel cost	Visitors' value	20,477.30	🟡

[11] Positive sign is a gain or a save, in contrast negative sign is a loss or a cost.

PART V: SUSTAINABILITY ASSESSMENT

Step A: Definition of the assessment and decision case

The objective of the sustainability assessment (SA) for the Llobregat case was to test the SA framework developed in DESSIN project. The decision to implement the MAR facility in Santa Coloma de Cervelló has already been made, as discussed above. Therefore, the SA described below is simply an ex-post assessment for the fictive decision case where one has to decide if the MAR facility in Santa Coloma de Cervelló is an appropriate and viable solution to improve water availability in the area without having too many negative "side effects", e.g. on the society and the environment, or not. For this, the DESSIN SA framework proposes to use a set of indicators, enlightening the effects from the social, environmental, governance, assets and financial perspective.

Consequently the task of this mature case test was to identify potentially interesting indicators from the different DESSIN SA dimensions from the decision maker's point of view, quantify them and exemplify how they could have produced valuable decision relevant results for the past decision on implementing the MAR solution. In other words, two scenarios have been compared by using a set of indicators for different assessment criteria: The (fictive) scenario without the existence of the infiltration ponds in Santa Coloma de Cervelló, and the scenario with the existence of the system.

Step B: Selection of indicators

The application of Steps B.1 until B.3 lead to a set of indicators for the social, environmental, financial and assets dimension. Due to a lack of data it was not possible to identify fitting indicators for the governance dimension. Furthermore no additional indicators where identified to be relevant for the decision case. A detailed list of all indicators selected for assessment can be found in the annex to this chapter (see ANNEX-PART V).

Step C: Definition of additional indicators

No further data was found to be available and thus no additional indicators relevant for the decision case were derived.

Step D: Data collection and assessment

The data collection was conducted by Cetaqua using data from Sant Vicenç dels Horts in terms of technical performance and data of the constructive project of the system in Santa Coloma de Cervelló (ACA, 2011).

Moreover, as few indicators from the ESS evaluation could be identified to be useful in the SA, the following table summarises them. How they could be integrated in the SA is discussed in the next section. Details about their calculation are explained above in the chapter named PART IV, the response evaluation. For the assessment, the time series where annualized making possible a life cycle assessment, to cover all effects until the end of the lifetime of the solution, which is after 18 years.

Table 34: SA data for the Llobregat case derived from ESS evaluation

FESS/ IESS ID	DESSIN ESS	unit	before	after	Potential SA metric/indicator
FESS #1	Net Avoided costs for the municipal DWTP from using groundwater instead of surface water (more expensive treatment)	[k€/a]	0	331	→ F113
FESS #2	Avoided costs for industrial producers from using cheaper groundwater from the aquifer instead of drinking water	[k€/a]	0	215	

FESS/ IESS ID	DESSIN ESS	unit	before	after	Potential SA metric/indicator
FESS #3	Economic impact of research opportunities due to the MAR solution	[k€/a]	0	484	→ S152
FESS #4	Economic impact from visiting and experiential / intellectual interactions with MAR solution	[k€/a]	0	20	

Step E: Results and discussion

Social dimension

The social dimension covers effects of the solution on society and how it influences the quality of life. Numerous indicators from the SA framework in this dimension are most meaningful if the decision case is to choose between alternative solutions. But due to positive data availability and for illustrative reasons the indicators S111 and S152 have been assessed for the Llobregat case and are discussed below.

It was found that the infiltration ponds in Santa Coloma de Cervelló lead to a decrease of the presence of microbial pathogens (S111) in the water abstracted from the aquifer compared to the water infiltrated from the river. For instance, the total coliform is reduced from 322,880 MPN (annual average in Llobregat river water in 2014) to 6.8 MPN (annual average of AB abstraction wells in 2015). This is, in turn, an indication for an improvement for the assessment criteria of health and safety, even when the pumped water does not reach drinking water quality standards (threshold value of 0 MPN).

Additionally it was possible to take into account results from the ESS evaluation for the SA, as mentioned above. So from the impact II assessment an annual value for the intellectual and representative interaction (S152) could be derived. The travel cost method was used therefore, as explained above in the response evaluation chapter of the ESS evaluation. The annual value of visitors at the infiltration ponds is calculated to be 20 k€. This result indicates a positive value added for human wellbeing in the area due to the ponds. To estimate the definite economic value added for human wellbeing the transport cost and opportunity cost (lost labour income) of visitors would need to be subtracted from their WTP to enjoy the recreational experience of the visit to the ponds. Still the calculated value can be said to be the lower bound of the WTP of people enjoying the ponds. Furthermore a value from the impact II ESS for research opportunities could be derived also to be accounted for S152. The research opportunities were estimated to account for 484 k€ annually as explained above. This is a rather optimistic estimation, assuming continuing research projects and PhD studies based on the infiltration ponds to take place in the future, as well as a continuous flow of interested visitors from the areas nearby.

Environmental dimension

Regarding the environmental dimension one potentially decision relevant indicator was identified, the water use efficiency (EN111), since the solution deals with water supply. The indicator is headed under the objective Dn1 Efficient use of water, energy and materials. Thus, the indicator should reflect any losses or waste of natural resources within the utilisation of it. For the infiltration pond, data was available for the evapotranspiration loss during the water storage in the pond. Thus, the water use efficiency indicator was calculated in this case as the percentage of water infiltrated, which equals to water in ponds minus net loss from evapotranspiration. By using time series, the estimates of annual water infiltrated varied between 99.63% and 99.78%. In other words the MAR technology has quite a good efficiency in the use of water. Even though if compared to the situation before, where water from the river was directly transmitted to the drinking water treatment system and hence no evapotranspiration losses have happened, a loss of less than one percentage cannot be seen as negligible environmental degradation.

Financial dimension

For the financial dimension the affordability of the infiltration ponds was estimated by calculating the cost coverage from the point of view of the organisation in charge for the investment and the operation, which is the Catalan Water Agency (ACA). Here it turned out, that from the point of view of the ACA the project is not financially sustainable. The results showed that the investment needed 8,000 k€ plus the maintenance costs estimated 103k€ per year will not produce additional incomes for ACA. However, it must be noted, that from a broader point of view, taking into account other stakeholders, there are additional financial benefits resulting from enhanced provisioning ecosystem services to be expected. Those are the water available for processing by the municipal DWTP in the region (AB). It was estimated that AB could benefit with 331 k€ annually from avoided costs - additional costs (compare the evaluation for the Impact II in the ESS evaluation section above). Also the beer factory Damm benefits from improvements on water quantity and quality for cooling of processing industrial products with an expected amount of avoided costs due to groundwater use instead of drinking water purchased from AB as high as 215 k€ annually (compare the ESS evaluation results above). In other words, the infiltration ponds might not be financially sustainable for ACA, but eventually sustainable from an economic point of view, covering all financial implications to (external) stakeholders affected. To answer this question and cover all externalities a cost-benefit analysis could be additionally envisaged, aiming to cover all relevant economic implications of the solution not only relevant for the organisation in charge of the solution but also for the wider society and thus other stakeholders.

Assets dimension

In relation to the assets dimension there has been quite some data available for indicators informing about the solutions reliability, adequacy and resilience. Most of them are proposed to be used for decision cases where the aim is to compare two or more technological alternatives. Nevertheless resulting values for indicators with data available are summarized and interpreted here. For instance, the lifetime of the facility is expected to be 18 years. This means the mean time to failure (A111) is 18 years. Also data for an estimation of the average interval for the top layer removal in the ponds was available, which is done every 2 years. This means a value of 2 for the indicators A112 mean time between failures. Also the Start-up time (A22) was available, which is just one year. This means the indicator “lifetime of solution / start up time” can be calculated as 18. Furthermore, data was available on the turbidity levels of the recharge water from the river. These data can be used as an indicator for the adaptive capacity of the solution to changes (A131). So in the Llobregat case the “percentage of days per year at which the solution is in use” was found to be depending on the turbidity. Due to the regulatory threshold, the water can only be infiltrated if the turbidity is below 50 NTU. According to time series from 2010-2012, this threshold was met in 43% of the time on an average basis. Thus, it can be concluded that only in 43% of a year the solution can operate properly. All of these mentioned indicators are examples of performance indicators to characterise the solution and could be taken into account to compare it with the performance of an alternative technology. The following table summarizes all SA indicators used to complement the ESS Evaluation indicators.

Table 35: Overview of additional SA data complementing ESS Evaluation indicators

SA metric/ indicator	DESSIN ESS	unit	before	after	source
S111	Presence of microbial pathogens	[MPN]	322,000	7	Cetaqua (based on SVH data)
S152	Economic impact from intellectual and representative interactions (Educational)	[k€]	0	20	Cetaqua (DESSIN ESS)
En111	Water use efficiency	[%]	100	99.63-99.78	Cetaqua (based on SVH data)
F111	Investment expenditure	[k€]	-	8,000	ACA
F112	Operational expenditure	[k€]	-	103.05	ACA
F114	Other sources of financing (e. g. subsidies)	[€]	-	0	ACA
A111	MTTF	[a]	-	18	ACA
A112	MTBF	[a]	-	2	ACA
A131	Adaptive capacity	[0-1]	1	0.43	Cetaqua
A221	lifetime of solution/start up time	[-]	-	18	ACA

Concluding from this test of the Llobregat mature case, the SA framework was applicable and offered reasonable and valuable assessment results for decision support. Nevertheless it becomes obvious, that it is sometimes necessary to define the boundaries of an indicator carefully and eventually to expand or redefine them. Here this became obvious in the financial dimension, where the SA framework originally was meant to check the financial sustainability from the perspective of the organisation financially in charge for implementation and operation. But this narrow definition might leave out valuable financially positive implications of a solution to other external stakeholders benefiting from it. Thus, in case there are financially relevant positive effects from a solution, not fitting to the social dimension in terms of economic impact and also not directly relevant for the organisation implementing the solution, it is recommended to expand the SA integrating these additional monetary benefits as indicators in the analysis.

Conclusions

The application of the ESS DESSIN methodology in the case study of the infiltration ponds in Santa Coloma de Cervelló (SCC) has been challenging. Groundwater is an invisible part of the water cycle, despite in some areas, as in Barcelona, it constitutes an alternative water source together with surface water for drinking water production. Specifically, the presence of fresh groundwater availability made the Llobregat Delta area and Lower Valley the selected placement for multiple water-dependent industries. Thus, in some way groundwater allowed the industrial and urban growth of this part of the Barcelona Metropolitan Area.

This report is one of the first documents evaluating the ESS linked to managed aquifer recharge, going deeper to the general groundwater approach for ecosystem valuation (some references can be found in Qureshi *et al*. 2012; EA, 2007; Marsden Jacob Associates, 2012, among others.). In this case, the aquifer recharge through infiltration ponds is the measure that has been evaluated (before and after) using an innovative methodology based in DPSIR analysis, and using standard lists for classification of drivers, pressures, beneficiaries and type of services (intermediate or final). The detailed methodology can be found in Anzaldúa *et al.* (2016).

As a result of the implementation of the DESSIN framework in SCC system some conclusions have arisen:

- The result of the framework application is taking into account certain conditions that could change along time. The assumptions validity as well as the results needs to be revised in case of changes in the beneficiaries' types and the use of ESS.
- The DESSIN framework permits to incorporate wider beneficiaries and types of benefits allowing understanding the whole impact of the measure.
- Due to the limitations of the valuation methods caused by the lack of data, an aggregation of the different beneficiaries is not recommended. However, the balance between impacts and costs seems positive.
- There is a need of a multidisciplinary team and local experts to deal with complex water management systems. In this case, hydrogeologists and economists have worked together to reach a common language able to join a MAR project and the economic impact. In more complex scenarios, biologists, sociologists and other professionals will be hardly recommended to participate.

Specifically, in the case study of SCC, main results have been:

- Four beneficiaries have been identified: industrial users, drinking water operators, researchers and experiencers and viewers. Despite the high importance of agriculture in other schemes, in Llobregat aquifer the irrigation with groundwater is very limited, and located upstream the SCC system.
- Lot of benefits in terms of improvement of native groundwater quality and recharge water quality have been demonstrated and evaluated. In this report, the list of indicators is included in Step 8(a) *Quantification of state level before and after the implementation of infiltration pond system*. Along the interviews with groundwater users (DAMM and AB), authors realized that most of the benefits are not perceived by the beneficiaries, and only a short list of parameters are strategic for their operation (salinity, groundwater level, groundwater temperature and ammonium concentration).
- For groundwater users located near the coast, in the Delta area, salinity is the key factor that compromises their activity. In that sense, the installation of SCC system or other control measure could mean the replacement of current membranes system, as the salinity will decrease and remain more or less constant. SCC system will be as a guarantee against sea water intrusion. In the case of DAMM, the scenarios of salinity reduction from a maximum of 10,000 µS/cm to 6,500 µS/cm and the groundwater level increase of one meter has been quantified with a total annual benefit of 217 k€/year.
- Aigües de Barcelona benefits from the use of groundwater in the drinking water production partially, as the groundwater consumption represents between 10% and 15% of the total supplied water. Despite the increase of an additional amount of 10 Mm3/year in the aquifer (80% of this amount could be pumped by AB wells), there are lots of administrative restrictions and conditions in the current water management. Advantages of use more groundwater have been listed and quantified by the operators: the savings in the

use of the pre-treatment (groundwater is directly introduced in the advanced treatment after sand-filtration), constant groundwater quality (ammonium and turbidity are frequent limiting factors of the river water) and regulation of temperature in the transport and distribution network. As a drawback, the increase of groundwater pumping would suppose an additional cost of wells maintenance. Total annual benefit of the SCC system scenario has been quantified by AB in 220 k€.

- The most theoretical approach has been the quantification of benefits for educational and cultural services. SVH is not close to the public, so it is not possible to estimate the potential number of visitors in SCC system. Comparing with similar systems in the Llobregat Delta Park, it is feasible to estimate 20 k€ due to the application of travel costs methodologies. Moreover, scientific production based in SVH system have been very prolific, so it is expected that SCC will attract the interest of students, public funds and research projects estimated in 484k€.

The challenge of the evaluation of ESS linked to the infiltration ponds in SCC is that the system is not already constructed, so the operation in terms of infiltration rate, dilution capacity and elimination of pollutants through Soil Aquifer Treatment (SAT) has been evaluated considering similar effectiveness than the monitored system in Sant Vicenç dels Horts (SVH). Regarding the impact in terms of groundwater level increase due to the additional 10 Mm^3 infiltrated annually by the SCC MAR system, the groundwater flow and conservative transport modelling developed by CUADLL has been extremely useful to quantify the water table rise in specific pumping wells. This effort on assumptions will be useful for the future execution of the SCC MAR system, budgeted in 8 M€, and pending to be executed by ACA in the near future.

The infiltration system is expected to be constructed and operated by Catalan Water Agency to improve water resources in the Llobregat area. The cost will be included in the public budget as investment in hydraulic infrastructure. Financially, it is not expected any type of in-kind contribution or financing, as there is a public interest. The document shows the existence of potential beneficiaries of the additional replenishment of the aquifer. Despite it is a very theoretical exercise, the applied ESS methodology could be a practical method to identify and quantify end-users of a public good. The resulting analysis is a powerful tool for decision-makers but the alternative solutions need to be evaluated using the same framework if a decision will be taken based on it.

The work done is of interest to the Catalan Water Agency (ACA). This type of study highlights the benefits to the environment and water users and may be used to justify investments in the water sector. Aigües de Barcelona (AB) was especially interested in the fact of increasing water resources, which will result in an increase in the guarantee of water supply as an ecosystem service. This point is coincident with ACA comments. CUADLL is more interested in discussing the issues directly affecting water users. This stakeholder commented that the groundwater flow model is available in case further evaluations were needed. The Public Health Agency (ACSP) found the methodology useful in order to address concerns on water to stakeholders involved in groundwater management.

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ANNEX I - PART I: Reporting tables of Llobregat mature case (infiltration pond)

Element of Part I	Instructions	User entries
Administrative details	1. Provide general information about: - the entity/ies involved in carrying out the assessment - the provider/s of information for the assessment - the provider/s of funding for the assessment	• *Cetaqua* • *Cetaqua, CUADLL, DAMM, ACA* • *EU FP7 project*
Objectives of the assessment	2. Define the intended audience of the results (*Who will be the main recipient of the outcome report?*) Define and explain the specific purpose and the expected outcomes of carrying out the assessment (*What do you want to achieve by assessing changes in ESS in your area?*).	*Intended audience: Researchers* *Objectives: The assessment is conducted with the aim of (i) testing the ESS Evaluation Framework proposed and (ii) identifying the benefit resulting from the ponds construction.*
Overview of the study area	3. Provide a detailed description of the study area considering: • geographical location (e.g. Mediterranean region, Western Europe, Nordic region) • spatial extent • environmental attributes (e.g. climate type) • economic activities taking place in the area (e.g. land use, land use transitions, comparison of activities by share of GDP) • socioeconomic profile (e.g. population density)	• *Mediterranean region* • *Aquifer area (115 km^2)* • *Typical Mediterranean climate regime* • *Agriculture 0.075%, Industry 22.78%, Construction 6.43% and Services 70.72% (2012 data[12]).* • *5,093 inh/km^2*
Stakeholder list	4. Elaborate an exhaustive list of the stakeholders present in the area.	*People living in the area;* *Industry;* *City councils;* *AB (Private company – drinking water supplier)* *Aigües del Prat (Public company – drinking water supplier)* *Aquadom (Private company – consultancy)*

[12] Source: http://www.idescat.cat/emex/?id=11&lang=es#h1fe000000

		Aqualogy (Private company – consultancy) *AQUATEC (Private company – consultancy)* *AGBAR (Private holding)* *ACA(Public entity)* *AMB (Public entity)* *Agència de Salut Pública (Public entity)* *CUADLL (Public entity)* *CDTI (Public research institution – management)* *ACC1Ó (Public research institution – management)* *CSIC (Public research institution – scientific)* *UPC (Public research institution – scientific)*

ANNEX I - PART II: Tables of drivers and pressures

1. Characterisation Table for Drivers

The list of drivers is based on MARS, 2014.

DRIVER	SPECIFICATION (to be input by the user)
Industry	Industrial bad practices in the past: solvents and PAHs in groundwater and river. Industries increase in the metropolitan area: WWTP discharge.
Urban development	Inhabitants increase in the metropolitan area: WWTP discharge, intensive use of the river.

2. Characterisation Table for Pressures

The relation between the pressure categories and the drivers is based on IMPRESS Guidance No. 3 and MARS, 2014

DRIVER IDENTIFIED IN THE STUDY AREA	PRESSURE CATEGORY	SPECIFICATION
Industry	Diffuse source	Contaminated sites/abandoned industrial sites. Groundwater pollution (solvents, PAHs, industrial pollutants).
Industry	Point source	Industrial waste water.
Industry	Abstraction	Abstraction from industry.
Industry	Other anthropogenic	Groundwater alterations of water level or volume.
Urban development	Diffuse source	Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).
Urban development	Point source	Urban waste water.
Urban development	Abstraction	Abstraction urban development
Other	Hydrological alteration	Reduction of permeable surface for precipitation infiltration.

ANNEX I - PART III Tables of the quantification of infiltration system capabilities

Capabilities of the Proposed Measures:

Proposed measure	Claimed / expected capability	Qualitative description	Quantitative description
Construction and equipment of infiltration ponds	Enhancing water infiltration by additional permeable surface	Increase of infiltration surface available for the infiltration processes.	56,300 m^2 1 m^3/m^2/day
	Increasing groundwater resources in the aquifer	River water is disconnected of the aquifer due to fine particles acting as clogging in the river bed. Infiltration ponds will increase groundwater resources by the infiltration of river water and/or reclaimed water. Periodic maintenance will allow maintaining infiltration surface available.	10 Mm^3/year
	Improving water quality via soil-aquifer treatment	It has been proved an effective reduction of turbidity (sediment retention) and a reduction in chemical compounds.	Sediment retention Denitrification Organic matter reduction Micropolluntants degradation (See PART III for specific evaluation of water quality improvement)
	Reducing pollutants in the aquifer	Anthropogenic substances as chlorinated solvents are present in groundwater. By the infiltration of non-polluted water, a plume of clean water is expected to dilute undesirable substances.	(See PART III for specific evaluation of water quality improvement)
	Creation of a new surface water body (aquatic ecosystem)	The implementation of infiltration system (settling ponds and infiltration ponds) in a dry area will generate several impacts in terms of new ecosystem creation.	13 ha

Capabilities of the Proposed Measures and their effects on DRIVERS, PRESSURES:

		Effect on DRIVER (from D catalogue)		Effect on PRESSURE (from P catalogue)							
Proposed measure	Claimed / expected capability	Industrial bad practices in the past & WWTP	Urban development: (Intensive use the land	Groundwater pollution	Industrial waste water (Point source)	Abstraction from industry (Abstraction).	Groundwater alteration of water level	Discharges not connected to WWTPs	Urban waste water	Abstraction for urban uses & development	Reduction of permeable surface
Construction and equipment of infiltration ponds	Enhancing water infiltration by additional permeable surface										X
	Increasing groundwater resources in the aquifer					X	X			X	
	Improving water quality via soil-aquifer treatment	X		X							
	Reducing pollutants in the aquifer	X		X							
	Creation of a new surface water body (aquatic ecosystem)		X								

Capabilities of the Proposed Measures and their effects on STATE:

		Effect on STATE (from S catalogue)														
Proposed measure	**Claimed / expected capability**	Infiltration area	Infiltration capacity (Permeability)	Groundwater level	Volume of groundwater replenishment by surface infiltration	Natural attenuation	Electrical conductivity / Salinity	Chlorinated compounds in the aquifer	Nitrate concentration	Organic content	Ammonium concentration	Temperature	Turbidity	Number of birds species watched in the area	Volume of surface water available for amphibians and aquatic species	Percentage of days with surface water available
Construction and equipment of infiltration ponds	Enhancing water infiltration by additional permeable surface	X	X													
	Increasing groundwater resources in the aquifer			X	X											
	Improving water quality via soil-aquifer treatment					X			X	X	X	X	X			
	Reducing pollutants in the aquifer						X	X	X		X					
	Creation of a new surface water body (aquatic ecosystem)													X	X	X

ESS from the CICES list associated to the affected parameters of STATE:

STATE Parameter influenced by measure	CICES Class *(restricted to ecosystem type)*	CICES Group	CICES Division	CICES Section
Biological	*Maintaining nursery populations and habitats*	*Lifecycle maintenance, habitat and gene pool protection*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
Hydrology	*Hydrological cycle and water flow maintenance*	*Liquid flows*	*Mediation of flows*	*Regulation & Maintenance*
Physiochemical	*Surface water for drinking*	*Water*	*Nutrition*	*Provisioning*
	Surface water for non-drinking purposes	*Water*	*Materials*	*Provisioning*
	Bio-remediation by micro-organisms, algae, plants, and animals	*Mediation by biota*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Filtration/ sequestration/ storage/ accumulation by ecosystems	*Mediation by ecosystems*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Dilution by atmosphere, freshwater and marine ecosystems	*Mediation by ecosystems*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*

List of stakeholders (Part I) merged with list of beneficiaries (US EPA):

List of stakeholders	List of beneficiaries
People living in the area; *Industry;* *City councils;* *AB (Private company – drinking water supplier)* *Aigües del Prat (Public company – drinking water supplier)* *Aquadom (Private company – consultancy)* *Aqualogy (Private company – consultancy)* *AQUATEC (Private company – consultancy)* *AGBAR (Private holding)* *ACA(Public entity)* *AMB (Public entity)* *Agència de Salut Pública (Public entity)* *CUADLL (Public entity)* *CDTI (Public research institution – management)* *ACC1Ó (Public research institution – management)* *CSIC (Public research institution – scientific)* *UPC (Public research institution – scientific)*	*Municipal Drinking Water Treatment Plant Operators* *Industrial processors* *Researchers* *Experiencers and viewers*

ANNEX I - PART IV: Overview table of ESS classification and list of Fact sheets

Overview table:

Measure	**Capability**	**ESS affected** *(use CICES and US EPA catalogue)*					**Beneficiaries** *(use US EPA categorization)*[1]
		CICES section	**CICES division**	**CICES group**	**CICES class**	**DESSIN ESS** *(use US EPA nomenclature where applicable)*[2]	*(no beneficiary = only intermediate service)*
Construction and equipment of infiltration ponds	- enhancing water infiltration by additional permeable surface - increasing groundwater resources in the aquifer - improving water quality via soil-aquifer treatment - reducing pollutants in the aquifer - aquatic ecosystem creation	Provisioning services	Nutrition	Water	**Groundwater for drinking**	Water suitable for processing by a municipal drinking water treatment plant (DWTP). **FESS** **Fact sheet # 1**	Municipal Drinking Water Treatment Plant Operators
			Materials	Water	**Groundwater for non-drinking purposes**	Water suitable for cooling or processing industrial products. **FESS** **Fact sheet # 2**	Industrial processors
		Cultural services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Intellectual and representative interactions	**Educational**	Research opportunities. **FESS** **Fact sheet # 3**	Researchers
				Physical and experiential interactions	**Experiential use of landscapes in different environmental settings**	(1) Opportunity to view the environment and organisms* within it, and groundwater phenomena. (2) Landscape that provides a sensory experience. (3) Sounds and scents that provide a sensory experience. * Organisms (i.e., flowers, plants, birds, mammals, reptiles, etc.) that can be viewed. **FESS** **Fact sheet # 4**	Experiencers and Viewers

[1]The US EPA categorization of beneficiaries can be found in the appendix (pages 46-70) of:
DH Landers and Nahlik AM. 2013. Final Ecosystem Goods and Services Classification System (FEGS-CS). EPA/600/R-13/ORD-004914. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.
[2]The US EPA nomenclature of ecosystem services can be found in the appendix (pages 46-70) of:
DH Landers and Nahlik AM. 2013. Final Ecosystem Goods and Services Classification System (FEGS-CS). EPA/600/R-13/ORD-004914. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

ANNEX I - PART V: Sustainability assessment table of indicators

Step A:

Proposed measure	Claimed / expected capability	Comparative Technology(ies)
Construction and equipment of infiltration ponds	Enhancing water infiltration by additional permeable surface	n/a
	Increasing groundwater resources in the aquifer	
	Improving water quality via soil-aquifer treatment	
	Reducing pollutants in the aquifer	
	Creation of a new surface water body (aquatic ecosystem)	

Step B: List of selected indicators

ID	Metric	Indicator	Unit	System	Alternative needed?		Data Availability yes	no
S111	Presence of microbial pathogens		[MPN] [MPN] [CFU/100ml] [CFU/ml]	WW/WS	yes		x	
S112	Presence of cyanobacteria and cyanotoxins			WW/WS	no			x
S113	Presence of toxic chemicals			WW/WS	no			x
S121	Economic impact (incl. Indirect and induced impacts) derived from initial spending for the solution itself	(economic impact - initial spending) / economic impact		WW/WS	no			x
S131	Number of jobs, amount of employment created by implementation of technology/solution		[1/a]	WW/WS	yes			x
S132	Number of jobs, amount of employment derived from improved cultural services		[1/a]	WW/WS	yes			x
S141	Number of beneficiaries affected		[-]	WW/WS	yes			x
S142	Categories of beneficiaries affected			WW/WS	yes			x
S151	Experiential and physical use of landscapes in different environmental settings		€/a	WW/WS	yes			x
S152	Intellectual and representative interactions (Educational)		[€]	WW/WS	yes		x	

En111		Water Use Efficiency (WUE)	[%]	WS	no		x	
En112		Water Resources Availability	[%]	WS	no			x
En113	Treated wastewater for reuse	Recycle rate	[m^3] or [%]	WS	no			x
En121		Efficient use of energy	[%]	WW/WS	no			x
En122		Energy recovery rate	[%]	WW/WS	no			x
En123		Green energy usage	[%]	WW/WS	no			x
En124	Energy consumed		[kWh/m^3]	WW/WS	yes			x
En131	Materials, chemicals and other consumables		[kg/m^3] or [kg/a]	WW/WS	yes			x
En132		Recovery of wastes	[%]	WW/WS	no			x
En211	Cumulative energy demand of fossil resources		[MJ]	WW/WS	yes			x
En212	Cumulative energy demand of nuclear resources		[MJ]	WW/WS	yes			x
En213	Global warming potential (100a)		[kg CO_2-eq]	WW/WS	yes			x
En214	Terrestrial acidification potential (100 a)		[kg SO_2-eq]	WW/WS	yes			x
En215	Freshwater eutrophication potential		[kg P-eq]	WW/WS	yes			x
En216	Marine eutrophication potential		[kg N-eq]	WW/WS	yes			x
En217	Particulate matter formation		[kg PM_{10}-eq]	WW/WS	yes			x
En218	Human toxicity (non-cancer)		[CTU_h]	WW/WS	yes			x
En219	Human toxicity (cancer)		[CTU_h]	WW/WS	yes			x
En220	Freshwater ecotoxicity		[CTU_e]	WW/WS	yes			x
F111	Investment expenditure		[€]	WW/WS	no		x	
F112	Annual operational expenditure		[€/year]	WW/WS	no		x	
F113	Avoided costs and/or additional monetary benefits from:		[€/year]	WW/WS	no		x	
F114	Other sources of financing (e. g. subsidies) aligned to the solution		[€]	WW/WS	no			x

G111	Compliance improvement w/ relevant EU standards	water status reached / water status level required		WW/WS	no			x
G112	Compliance with relevant national, local standards			WW/WS	no			x
G121	Number of actors/stakeholders involved in planning, implementation, operations, and monitoring			WW/WS	yes			x
G122	Communicative events			WW/WS	yes			x
G131	Monitoring			WW/WS	yes			x
G132	Information dissemination			WW/WS	yes			x
A111		MTTF	[year/1 failure]	WW/WS	yes		x	
A112		MTBF	[years/1 failure]	WW/WS	yes		x	
A121		Sufficient capacity of the technology/solution to the expected use	[%]	WW/WS	no			x
A131		Adaptive capacity as: The probability that the item is	[0-1]	WW/WS	no		x	
A141		[Hours of exposed or "dirty work"*) on the site/total hours of work per year]*100	[number/reference time]	WW/WS	no			x
A142		Risk episodes, injuries on the site/total hours of work in test period	[number/reference time]	WW/WS	no			x
A151		percentage of load removed	[%]	WW	no			x
A211		Number of complaints about the technology (due to for instance Noise, Dust, Estetics, landscape)/reference time	[number/reference time]	WW/WS	no			x
A221		lifetime of solution/start up time		WW/WS	yes		x	
A231	training hours for staff operating the solution			WW/WS	yes			x

FESS FACTSHEET #1

ESS HEAD	
Measure influencing the ESS	(1) construction and equipment of infiltration ponds
Capability influencing the ESS	(1) enhancing water infiltration by additional permeable surface (2) increasing groundwater resources in the aquifer (3) improving water quality via soil-aquifer treatment (4) reducing pollutants in the aquifer
CICES Section	Provisioning Services
CICES Division	Nutrition
CICES Group	Water
CICES Class	Groundwater for drinking
ESS *(Use US EPA nomenclature)*[2]	**Water suitable for processing by a municipal DWTP.**
Ecosystem *(Use US EPA classification)*[3]	***Class:*** Aquatic. ***Sub-class:*** Groundwater
Temporal scope	Per year
Spatial scope	Local along the aquifer area
FESS or Intermediate Service *(For Intermed. Service stop after Impact I)*	FESS
Intermediary ESS required	(1) Hydrological cycle and water flow maintenance

(Use CICES catalogue)	(2) Filtration/sequestration/storage/ accumulation by ecosystems
Regulatory Threshold	RD1620/2007 (reclaimed water) RD140/2003 (drinking water standards) (Spanish government regulation) ACA threshold (quality of infiltrated water and abstraction permits)
Beneficiary *(From USEPA[3]/NACE)* *(continue after Impact I only if beneficiary is present)*	Municipal Drinking Water Plant Operators E.g. AB

[3]The US EPA classification of ecosystems can be found in the appendix (page 42) of:
DH Landers and Nahlik AM. 2013. Final Ecosystem Goods and Services Classification System (FEGS-CS). EPA/600/R-13/ORD-004914. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality**	**Data quality**
DRIVER *(From IMPRESS/WISE)*	Industry Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)*	Diffuse source: Contaminated sites/abandoned industrial sites. Groundwater pollution (solvents, PAHs, industrial pollutants)	Organic volatile compounds found in the aquifer. Selected indicator compound: Trichloroethane	µg/L	Cetaqua: sampling campaigns in ENSAT project	Direct indicator	Local scale study required by project

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality**	**Data quality**
	Point source: Industrial waste water.	Amount of effluents from industries with final disposal in the Llobregat river course.	m^3	ACA: data pending	Direct indicator	Public data from Catalan Water Agency
	Abstraction: Abstraction from industry.	Total annual volume of extractions from industries in the aquifer.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders
	Diffuse source: Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).	Number of not treated discharges in municipal WWTPs in Llobregat river	Number of episodes	AB: operator of WWTP Sant Feliu	Direct indicator	Public data from operator
	Point source: Urban waste water.	Number of inhabitants in the Baix Llobregat region.	Inhabitants (inh.)	Idescat	Direct indicator	Public data from national statistical institute
	Abstraction: Abstraction urban development.	Total annual volume of extractions in the aquifer for supply drinking water.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders
	Hydrological alteration: Reduction of permeable surface for precipitation infiltration.	Total surface not urbanised nor industrialised (Permeable soils)	Km^2	Idescat	Direct indicator	Public data from national statistical institute
RESPONSE		Area	m^2	ACA		

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality**	**Data quality**
(describe in detail)	Construction and equipment of infiltration ponds.	Infiltrated volume	m^3/year			Local scale study prior to the project.
STATE *(only those relevant for the assessment of Impact I)*	Groundwater available for abstraction.	Groundwater level	m	CUADLL		
	Groundwater capacity of pollution attenuation.	Natural attenuation	%	Cetaqua		
	Salinity of groundwater.	Electrical conductivity/Salinity	µS/cm	CUADLL		
	Anthropogenic pollution.	Chlorinated compounds in the aquifer	µg/L	Cetaqua		
	Organic pollution.	Organic content (Dissolved Organic Carbon)	mg/L	Cetaqua		
	Incomplete waste water treatment (denitrification).	Ammonium concentration	mg/L	Cetaqua		
	Temperature fluctuations summer – winter.	Temperature	ºC	AB		
	Physical particles in dissolution.	Turbidity	NTU	Cetaqua		
IMPACT I - PROVISION	Quality of available water.	Groundwater salinity	µS/cm (electrical conductivity)	CUADLL		

INDICATOR TABLE						
	Case-relevant Element	Indicator	Output unit	Data sources & data availability	Indicator quality	Data quality
(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)	Volume of water available.	Groundwater availability nearby catchment point.	Mm^3	ACA		Local scale study required by project.
IMPACT II - USE	<u>Pump energy consumption:</u>					
	Pump energy consumption.	Difference in energy consumption by the pump at x+1 metre.	kWh/hour			
	Hours of use.	Total amount of hours of use before measure implementation.	Hour/year			
	Energy cost.	Energy cost per kWh.	€/kWh			
	<u>Pipes network breakdowns reparation:</u>			AB		
	Number of breakdowns.	Difference in the number of breakdowns.	units/year			
	Breakdowns avoided due to the use of groundwater.	Percentage attributable to the use of groundwater.	%			
	Cost per breakdown.	Average cost per breakdown.	€/unit			

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality**	**Data quality**
	Substitution from surface water to groundwater: 1) Pump energy consumption					
	Pump energy consumption.	Difference in energy consumption between groundwater and surface water	kWh/m^3			
	Water substituted.	Water quantity.	m^3			
	Energy cost.	Energy cost per kWh.	€/kWh			
	2) Pre-treatment needed in case of surface water:					
	Water treated.	Total amount of water treated substituted by groundwater.	m^3			
	Treatment cost.	Difference in treatment cost for groundwater.	$€/m^3$			
	3) Maintenance:					
	Corrective maintenance costs in pumping wells.	Relative corrective maintenance cost in pumping wells.	$€/m^3$*year			Private data from stakeholders.
	Corrective maintenance costs in pre-treatment.	Relative corrective maintenance cost in pre-treatment.	$€/m^3$*year			

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality**	**Data quality**
	Water substitution.	Surface water substituted by groundwater.	Mm^3/year			

INDICATOR TABLE - Further explanation
A further explanation is done in the respective parts of the text description.

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	Organic volatile compounds found in the aquifer. Selected indicator compound: Trichloroethane.	500	µg/L	
	Amount of effluents from industries with final disposal in the Llobregat river course.	873,176	m^3	
	Total annual volume of extractions from industries in the aquifer.	3.66	Mm^3	
	Number of not treated discharges in municipal WWTPs in Llobregat river.	n/a	Number of episodes.	
	Number of inhabitants in the Baix Llobregat region.	771,516	Inhabitants (inh.).	
	Total annual volume of extractions in the aquifer for supply drinking water.	37.68	Mm^3	
	Total surface not urbanised nor industrialised (Permeable soils).	14,200	ha	
STATE	Groundwater level	3	m	
	Natural attenuation	90%	%	
	Electrical conductivity/Salinity	1,850-1,300 reduction	µS/cm	
	Chlorinated compounds in the aquifer	700-900	µg/L	
	Organic content (Dissolved Organic Carbon)	1-1.5	mg/L	
	Ammonium concentration	1.8	mg/L	

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
	Temperature	18	ºC	
	Turbidity	5	NTU	
IMPACT I / PROVISION	Change in salinity in groundwater.	1,850-1,300 reduction	µS/cm	
	Change in groundwater availability nearby pumping wells.	10	Mm^3	
IMPACT II - USE	Avoided costs in energy for pumping:			
	Difference in energy consumption by the pump at x+3 metres.	12	kWh/hour	
	Number of hours of use in the whole year.	8,760	hour/year	
	Energy cost.	0.091	€/kWh	
	Avoided costs in pipes network breakdowns reparation:			
	Difference in the number of breakdowns.	230	units/year	
	Average cost per breakdown.	2,800	€/unit	
	Percentage attributable to the use of groundwater	10	%	
	Substitution from surface water to groundwater: 1) Increased costs in energy for pumping.			

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
	Difference in energy consumption between groundwater and surface water	0.11	kWh/m³	
	Water quantity.	8	Mm³/year	
	Energy cost.	0.091	€/kWh	
	2) Avoided costs in water treatment.			
	Total amount of water treated substituted by groundwater.	8	Mm³/year	
	Treatment cost.	0.033	€/m³	
	3) Increased costs in maintenance:			
	Corrective maintenance costs in pumping wells per Mm³	7,975.46	€/Mm³	
	Corrective maintenance costs in pre-treatment per Mm³	2,857.14	€/Mm³	
	Total amount of water treated substituted by groundwater.	8	Mm³/year	
IMPACT II - Monetization	Avoided costs in energy for pumping.	9,586.80	€/year	**Valuation method:** Avoided costs
	Avoided costs in pipes network reparation breakdowns.	64,400		
	Substitution from surface water to groundwater: 1) Increased costs in energy for pumping.	-82,954.97		

RESULTS TABLE				
	Case-relevant Element	Output	Output unit	Comments
	2) Avoided costs in water treatment.	269,600		
	3) Increased costs in maintenance.	-40,946.54		

RESULTS TABLE - Description

A further explanation of the results is done in step 8 of the text description.
Negative figures express a loss or an increased cost.

FESS FACTSHEET #2

ESS HEAD	
Measure influencing the ESS	(1) construction and equipment of infiltration ponds
Capability influencing the ESS	(1) enhancing water infiltration by additional permeable surface (2) increasing groundwater resources in the aquifer (3) improving water quality via soil-aquifer treatment (4) reducing pollutants in the aquifer
CICES Section	Provisioning Services
CICES Division	Materials
CICES Group	Water
CICES Class	Groundwater for non-drinking
ESS *(Use US EPA nomenclature)*[2]	**Water suitable for cooling or processing industrial products.**
Ecosystem *(Use US EPA classification)*[3]	***Class:*** Aquatic. ***Sub-class:*** Groundwater
Temporal scope	Per year
Spatial scope	Local along the aquifer area
FESS or Intermediate Service *(For Intermed. Service stop after Impact I)*	FESS
Intermediary ESS required	(1) Hydrological cycle and water flow maintenance

(Use CICES catalogue)	(2) Filtration/sequestration/storage/ accumulation by ecosystems
Regulatory Threshold	RD1620/2007 (reclaimed water) RD140/2003 (drinking water standards) (Spanish government regulation) ACA threshold (quality of infiltrated water and abstraction permits)
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	Industrial Processors E.g. Damm

[3]The US EPA classification of ecosystems can be found in the appendix (page 42) of:
DH Landers and Nahlik AM. 2013. Final Ecosystem Goods and Services Classification System (FEGS-CS). EPA/600/R-13/ORD-004914. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

INDICATOR TABLE

	Case-relevant Element	Indicator	Output unit	Data sources/ Data availability	Indicator quality	Data quality
DRIVER *(From IMPRESS/WISE)*	Industry	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
	Urban development					
PRESSURE *(From IMPRESS/WISE)*	Abstraction: Abstraction from industry.	Total annual volume of extractions from industries in the aquifer.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders
	Abstraction: Urban development	Total annual volume of extractions in the aquifer for supply drinking water.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
	Hydrological alteration: Reduction of permeable surface for precipitation infiltration	Total surface not urbanised nor industrialised (Permeable soils)	Km^2	Idescat	Direct indicator	Public data from national statistical institute
	Diffuse source: Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).	Number of not treated discharges in municipal WWTPs in Llobregat river	Number of episodes	AB: operator of WWTP Sant Feliu	Direct indicator	Public data from operator
	Point source: Urban waste water.	Number of inhabitants in the Baix Llobregat region.	Inhabitants (inh.)	Idescat	Direct indicator	Public data from national statistical institute
	Abstraction: Abstraction urban development.	Total annual volume of extractions in the aquifer for supply drinking water.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders
	Hydrological alteration: Reduction of permeable surface for precipitation infiltration.	Total surface not urbanised nor industrialised (Permeable soils)	Km^2	Idescat	Direct indicator	Public data from national statistical institute
RESPONSE *(describe in detail)*	Construction and equipment of infiltration ponds.	Area	m^2	ACA		Local scale study prior to the project.
		Infiltrated volume	m^3/year			
STATE	Groundwater available for abstraction.	Groundwater level	m	CUADLL		

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
(only those relevant for the assessment of Impact I)	Groundwater capacity of pollution attenuation.	Natural attenuation	%	Cetaqua		
	Salinity of groundwater.	Electrical conductivity/Salinity	µS/cm	CUADLL		
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	Quality of available water.	Groundwater salinity	µS/cm (electrical conductivity)	DAMM		Local scale study prior to the project.
	Volume of water available.	Groundwater availability nearby catchment point.	Mm^3	CUADLL		
IMPACT II - USE	Volume of water abstracted.	Annual groundwater abstracted.	Mm^3	DAMM		
IMPACT II - Monetization	Pump energy consumption:			DAMM		Private data from stakeholders.
	Pump energy consumption.	Difference in energy consumption by the pump at x+1 metre.	kWh/m^3			
	Water flow.	Water flow.	m^3/h			
	Hours of use per year.	Hours of use per year.	h/year			
	Energy cost.	Energy cost per kWh.	€/kWh			
	Membranes system energy consumption:					

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
	Membrane system energy consumption.	Difference in energy consumption by each membrane system.	kWh/m³			
	Water flow.	Water flow.	m³/h			
	Hours of use per year.	Hours of use per year.	h/year			
	Energy cost per kWh.	€/kWh	Energy cost.			
	Membranes system purchasing:					
	Number of membranes.	Number of membranes.	units			
	Lifetime of the membranes.	Lifetime of the membranes.	years			
	Membranes system cost.	Difference in the cost of membranes system.	€/membrane			

INDICATOR TABLE - Further explanation
A further explanation is done in the respective parts of the text description.

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	Organic volatile compounds found in the aquifer. Selected indicator compound: Trichloroethane.	500	µg/L	
	Amount of effluents from industries with final disposal in the Llobregat river course.	873,176	m^3	
	Total annual volume of extractions from industries in the aquifer.	3.66	Mm^3	
	Number of not treated discharges in municipal WWTPs in Llobregat river.	n/a	Number of episodes.	
	Number of inhabitants in the Baix Llobregat region.	771,516	Inhabitants (inh.).	
	Total annual volume of extractions in the aquifer for supply drinking water.	37.68	Mm^3	
	Total surface not urbanised nor industrialised (Permeable soils).	14,200	ha	
STATE	Groundwater level	1	m	
	Natural attenuation	90%	%	
	Electrical conductivity/Salinity	1,300-1,800	µS/cm	
IMPACT I / PROVISION	Change in salinity in groundwater.	3,500	µS/cm (electrical conductivity) (peaks)	
	Change in groundwater availability nearby pumping wells.	10	Mm^3	

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
IMPACT II - USE	Annual groundwater abstracted.	2.113	Mm^3	
IMPACT II - Monetization	Avoided costs in energy for pumping:			
	Difference in energy consumption by the pump at x+1 metre.	0.084	kWh/m^3	
	Water flow.	250	m^3/h	
	Hours of use per year.	8,454	h/year	
	Energy cost	0.1	€/kWh	
	Avoided costs in energy for membranes system:			
	Difference in energy consumption by each membrane system.	0.53	kWh/m^3	
	Water flow.	250	m^3/h	
	Hours of use per year.	8,454	h/year	
	Energy cost.	0.1	€/kWh	
	Avoided cost in membranes system purchasing:			
	Number of membranes.	696	Units	
	Lifetime of the membranes.	5	Years	
	Difference in purchasing cost by each membrane.	575	€	
	Avoided costs in energy for pumping.	17,753	€/year	**Valuation method:**

RESULTS TABLE				
	Case-relevant Element	Output	Output unit	Comments
IMPACT II - Monetization	Avoided costs in energy for membrane system.	112,016		Avoided costs
	Avoided costs in membranes system purchasing.	84,906		
RESULTS TABLE - Description				
A further explanation of the results is done in step 8 of the text description.				

FESS FACTSHEET #3

ESS HEAD	
Measure influencing the ESS	(1) construction and equipment of infiltration ponds
Capability influencing the ESS	(1) enhancing water infiltration by additional permeable surface (2) increasing groundwater resources in the aquifer (3) improving water quality via soil-aquifer treatment (4) reducing pollutants in the aquifer (5) aquatic ecosystem creation
CICES Section	Cultural services
CICES Division	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]
CICES Group	Intellectual and representative interactions
CICES Class	Educational
ESS *(Use US EPA nomenclature)*[2]	**Research opportunities**
Ecosystem *(Use US EPA classification)*[3]	***Class:*** Aquatic. ***Sub-class:*** Lakes and ponds
Temporal scope	per year
Spatial scope	Ponds and surrounding area
FESS or Intermediate Service *(For Intermed. Service stop after Impact I)*	FESS

Intermediary ESS required *(Use CICES catalogue)*	(1) Hydrological cycle and water flow maintenance (2) Filtration/sequestration/storage/ accumulation by ecosystems
Regulatory Threshold	Non applicable
Beneficiary *(From USEPA[3]/NACE)* *(continue after Impact I only if beneficiary is present)*	Researchers

[3]The US EPA classification of ecosystems can be found in the appendix (page 42) of:
DH Landers and Nahlik AM. 2013. Final Ecosystem Goods and Services Classification System (FEGS-CS). EPA/600/R-13/ORD-004914. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
DRIVER *(From IMPRESS/WISE)*	Industry Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)*	Abstraction: Abstraction from industry.	Total annual volume of extractions from industries in the aquifer.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders
	Abstraction: Urban development	Total annual volume of extractions in the aquifer for supply drinking water.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders

INDICATOR TABLE

	Case-relevant Element	Indicator	Output unit	Data sources/ Data availability	Indicator quality	Data quality
	Hydrological alteration: Reduction of permeable surface for precipitation infiltration	Total surface not urbanised nor industrialised (Permeable soils)	Km^2	Idescat	Direct indicator	Public data from national statistical institute
	Diffuse source: Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).	Number of not treated discharges in municipal WWTPs in Llobregat river	Number of episodes	AB: operator of WWTP Sant Feliu	Direct indicator	Public data from operator
	Point source: Urban waste water.	Number of inhabitants in the Baix Llobregat region.	Inhabitants (inh.)	Idescat	Direct indicator	Public data from national statistical institute
	Abstraction: Abstraction urban development.	Total annual volume of extractions in the aquifer for supply drinking water.	Mm^3	CUADLL	Direct indicator	Private data form stakeholders
	Hydrological alteration: Reduction of permeable surface for precipitation infiltration.	Total surface not urbanised nor industrialised (Permeable soils)	Km^2	Idescat	Direct indicator	Public data from national statistical institute
RESPONSE *(describe in detail)*	Construction and equipment of infiltration ponds.	Area	m^2	ACA		Local scale study prior to the project.
		Infiltrated volume	m^3/year			
STATE	Permeable surface available for aquifer replenishment.	Infiltration area	m^2	ACA		

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
(only those relevant for the assessment of Impact I)	Transmissive unsaturated area able to infiltrate water.	Infiltration capacity	$m^3/m^2/day$	ACA		
	Groundwater available for abstraction.	Groundwater level	m	CUADLL		
	Groundwater capacity of pollution attenuation.	Natural attenuation	%	Cetaqua		
	Salinity of groundwater.	Electrical conductivity/Salinity	µS/cm	CUADLL		
	Anthropogenic pollution.	Chlorinated compounds in the aquifer	µg/L	Cetaqua		
	Agricultural pollution.	Nitrate concentration	mg/L	Cetaqua		
	Organic pollution.	Organic content (Dissolved Organic Carbon)	mg/L	Cetaqua		
	Not regulated pollution (emerging contaminants).	Micropollutants (pharmaceuticals, pesticides…)	µg/L	Cetaqua		
	Incomplete waste water treatment (denitrification).	Ammonium concentration	mg/L	Cetaqua		
	Temperature fluctuations summer – winter.	Temperature	ºC	AB		
	Physical particles in dissolution.	Turbidity	NTU	Cetaqua		

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
	Bird's biodiversity.	Number of bird species watched in the area	Bird species	Cetaqua		
	Natural environment enriched for aquatic species.	Volume of water available for amphibians and aquatic species	m^3	ACA		
	Capacity of attraction of visitors by a water system.	Percentage of days with surface water available	days	CUADLL		
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*
IMPACT II - USE	Research studies value:			CETAQUA		Local scale study prior to the project.
	Research studies conducted at the infiltration ponds.	Number of research projects based on infiltration ponds.	Projects			
	PhDs conducted value:					
	PHDs conducted at the infiltration ponds.	Number of PHDs based on infiltration ponds.	PHD students			
	Technical visits value:					

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
	Technical visits conducted at the infiltration ponds.	Number of visitors at the infiltration ponds.	People			
IMPACT II - Monetization	Suitability of an ecosystem or a green infrastructure for acquiring research budget.	Research studies value	€/year	CETAQUA		
	Suitability of an ecosystem or a green infrastructure to be studied in PhDs	PhDs conducted value	€/year	CETAQUA		
	Suitability of an ecosystem or a green infrastructure to receive technical visits	Technical visits value	€/year	CETAQUA		

INDICATOR TABLE - Further explanation
A further explanation is done in the respective parts of the text description.

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	Organic volatile compounds found in the aquifer. Selected indicator compound: Trichloroethane.	500	µg/L	
	Amount of effluents from industries with final disposal in the Llobregat river course.	873,176	m^3	
	Total annual volume of extractions from industries in the aquifer.	3.66	Mm^3	
	Number of not treated discharges in municipal WWTPs in Llobregat river.	n/a	Number of episodes.	
	Number of inhabitants in the Baix Llobregat region.	771,516	Inhabitants (inh.).	
	Total annual volume of extractions in the aquifer for supply drinking water.	37.68	Mm^3	
	Total surface not urbanised nor industrialised (Permeable soils).	14,200	ha	
STATE	Infiltration area	56,300	m2	
	Infiltration capacity	1	m3/m2/day	
	Groundwater level	1-4	m	
	Natural attenuation	90%	%	
	Electrical conductivity/Salinity	1,850-1,300 reduction	µS/cm	
	Chlorinated compounds in the aquifer	700-900	µg/L	

RESULTS TABLE

	Case-relevant Element	Output	Output unit	Comments
	Nitrate concentration	8	mg/L	
	Organic content (Dissolved Organic Carbon)	1-1.5	mg/L	
	Micropollutants (pharmaceuticals, pesticides…)	0	µg/L	
	Ammonium concentration	1.8	mg/L	
	Temperature	18	ºC	
	Turbidity	5	NTU	
	Number of bird species watched in the area	52	Bird species	
	Volume of water available for amphibians and aquatic species	107,000	m3	
	Percentage of days with surface water available	75	%	
IMPACT I / PROVISION	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*
IMPACT II - USE	Value of research studies conducted at the infiltration ponds:			Projects: Gabardine, MARSOL, DEMEAU, PREPARED, and Life + ENSAT.
	Number of research projects based on infiltration ponds.	5	Projects	
	Total research budget attributable to ponds existence.	3,173,777.06	€	
	Lifetime of the ponds.	8	Years	

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
	Value of PhDs conducted at the infiltration ponds:			Students: Manuela Barbieri, Marco Barahona, Danielle Pedretti, Cristina Valhondo, Carme Barba and Albert Carles.
	Number of PhDs based on infiltration ponds.	6	Students	
	Grant per PhD student.	61,544.00	€	
	Lifetime of the ponds.	8	Years	
	Value of technical visits conducted at the infiltration ponds:			
	Number of visitors at the infiltration ponds.	232	Visitors	
	Average travel cost from Cetaqua to the ponds.	13	€	
	Lifetime of the ponds.	8	Years	
IMPACT II - Monetization	Annual value of research studies conducted at the infiltration ponds.	433,251.67	€/year	**Valuation method:** Revealed preferences
	Annual value of PhDs conducted at the infiltration ponds.	50,408.15		
	Annual value of the technical visits conducted at the infiltration ponds.	411.71		**Valuation method:** Travel costs

RESULTS TABLE - Description
A further explanation of the results is done in step 8 of the text description.

FESS FACTSHEET #4

ESS HEAD	
Measure influencing the ESS	(1) construction and equipment of infiltration ponds
Capability influencing the ESS	(5) aquatic ecosystem creation
CICES Section	Cultural services
CICES Division	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]
CICES Group	Physical and experiential interactions
CICES Class	Experiential use of landscapes in different environmental settings
ESS *(Use US EPA nomenclature)*[2]	**(1) Opportunity to view the environment and organisms* within it, and groundwater phenomena.** **(2) Landscape that provides a sensory experience.** **(3) Sounds and scents that provide a sensory experience.** * Organisms (i.e., flowers, plants, birds, mammals, reptiles, etc.) that can be viewed.
Ecosystem *(Use US EPA classification)*[3]	***Class:*** Aquatic. ***Sub-class:*** Lakes and ponds
Temporal scope	per year
Spatial scope	Ponds and surrounding area
FESS or Intermediate Service *(For Intermed. Service stop after Impact I)*	FESS
Intermediary ESS required *(Use CICES catalogue)*	(3) Maintaining nursery populations and habitats

Regulatory Threshold	Non applicable
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	Experiencers and viewers

[3]The US EPA classification of ecosystems can be found in the appendix (page 42) of:
DH Landers and Nahlik AM. 2013. Final Ecosystem Goods and Services Classification System (FEGS-CS). EPA/600/R-13/ORD-004914. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
DRIVER *(From IMPRESS/WISE)*	Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)*	Diffuse source: Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).	Number of not treated discharges in municipal WWTPs in Llobregat river	Number of episodes	AB: operator of WWTP Sant Feliu	Direct indicator	Public data from operator
	Point source: Urban waste water.	Number of inhabitants in the Baix Llobregat region.	Inhabitants (inh.)	Idescat	Direct indicator	Public data from national statistical institute
	Abstraction: Abstraction urban development.	Total annual volume of extractions in the	Mm^3	CUADLL	Direct indicator	Private data form stakeholders

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
		aquifer for supply drinking water.				
	Hydrological alteration: Reduction of permeable surface for precipitation infiltration.	Total surface not urbanised nor industrialised (Permeable soils)	Km^2	Idescat	Direct indicator	Public data from national statistical institute
RESPONSE *(describe in detail)*	Construction and equipment of infiltration ponds.	Area	m^2	ACA		Local scale study prior to the project.
		Infiltrated volume	m^3/year			
STATE *(only those relevant for the assessment of Impact I)*	Permeable surface available for aquifer replenishment.	Infiltration area	m^2	ACA		Qualitative regional study.
	Incomplete waste water treatment (denitrification).	Amonium concentration	mg/L	Cetaqua		
	Bird's biodiversity.	Number of bird species watched in the area	Bird species	Cetaqua		
	Natural environment enriched for aquatic species.	Volume of water available for amphibians and aquatic species	m^3	ACA		
	Capacity of attraction of visitors by a water system.	Percentage of days with surface water available	days	CUADLL		
IMPACT I - PROVISION *(quantify if necessary for the*	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources/ Data availability**	**Indicator quality**	**Data quality**
assessment of Impact II, otherwise describe qualitatively)						
IMPACT II - USE	Infiltration ponds visitors.	Number of visitors	Visitors/year	CUADLL		
	Transport cost	Transport cost	€/visitor	CETAQUA		
	Travel time	Travel time	hours	CETAQUA		
	Time value	Time value	€/hour	Idescat		
IMPACT II - Monetization	Suitability of an ecosystem or a green infrastructure to be visited.	Visitors value	€/year	CETAQUA		

INDICATOR TABLE - Further explanation

A further explanation is done in the respective parts of the text description.

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	Number of not treated discharges in municipal WWTPs in Llobregat river.	n/a	Number of episodes.	
	Number of inhabitants in the Baix Llobregat region.	771,516	Inhabitants (inh.).	
	Total annual volume of extractions in the aquifer for supply drinking water.	37.68	Mm^3	
	Total surface not urbanised or industrialised (Permeable soils).	14,200	ha	
STATE	Infiltration area	56,300	m2	
	Ammonium concentration	1.8	mg/L	
	Number of bird species watched in the area	52	Bird species	
	Volume of water available for amphibians and aquatic species	107,000	m3	
	Percentage of days with surface water available	75	%	
IMPACT I / PROVISION	*Non applicable*	*Non applicable*	*Non applicable*	*Non applicable*
IMPACT II - USE	Number of visitors	5,250	Visitors/year	
	Transport cost	0.53	€/visitor	
	Travel time	0.18	hours	
	Time value	7.815	€/hour	

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
IMPACT II - Monetization	Annual value of visitors	20,477.30	€/year	Valuation method: Travel cost
RESULTS TABLE - Description				
A further explanation of the results is done in step 8 of the text description.				

ANNEX II: Table of population in Baix Llobregat region

Table 36: Population in Baix Llobregat region

Source: Idescat

NOTE: There is a lack of data in 1980 and 1997

Year	Population	Density [inh/Km^2]	Year	Population	Density [inh/Km^2]
1975	511,971	1053.44	2000	678,724	1396.55
1976	521,366	1072.77	2001	692,260	1424.40
1977	538,806	1108.65	2002	710,612	1462.16
1978	553,102	1138.07	2003	730,111	1502.29
1979	564,556	1161.64	2004	741,024	1524.74
1981	573,461	1179.96	2005	757,814	1559.29
1982	579,426	1192.23	2006	767,967	1580.18
1983	583,245	1200.09	2007	771,516	1587.48
1984	587,551	1208.95	2008	781,749	1608.54
1985	591,765	1217.62	2009	793,655	1633.03
1986	583,354	1200.32	2010	798,468	1642.94
1987	587,841	1209.55	2011	803,705	1653.71
1988	596,996	1228.39	2012	806,799	1660.08
1989	606,729	1248.41	2013	808,644	1663.88
1990	613,474	1262.29	2014	806,249	1658.95
1991	610,192	1255.54			
1992	616,595	1268.71			
1993	628,323	1292.85			
1994	637,398	1311.52			
1995	642,889	1322.82			
1996	643,419	1323.91			
1998	654,958	1347.65			
1999	666,173	1370.73			

Annex III: Tables of main publications about ESS valuation in the Llobregat river basin

Table 37: Main publications about ESS valuation in the Llobregat river Basin

River Basin management & water technologies		
Short name	**Full name (citation)**	**Abstract / relevant aspects**
Honey-Rosés, 2012 [1]	Honey-Rosés, J. (2012). Ecosystem Services in planning practice for urban and technologically advanced landscapes. Dissertation submitter in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Regional Planning in the Graduate College of the University of Illinois at Urbana-Champaign, 2012.	Chapter 3: Urban Ecosystem Services and technological change. Case study: the water treatment technologies in Barcelona (p. 94) "By choosing to install new water treatment systems downstream, water managers preference for technological strategies over ecosystems approaches for improving source water quality. And with the new sophisticated treatment system, they attained the capacity to meet output water quality standards across a much wider range of input water qualities. Therefore, according to conventional wisdom the sophisticated new technology further isolated managers from the influence of ecosystem processes. To assess the impact of technological change on the value of ecosystem services I analysed three ecosystem services before and after the adoption of new membrane treatment: - Water quality protection (affecting salinity) - Thermal regulation (affecting temperature) - Nutrient cycling (affecting ammonium)
Honey-Rosés, 2013 [4]	Honey-Rosés, J.; Acuña, V.; Bardina, M.; Brozović, N.; Marcé, R.; Munné, A.; Sabater, S.; Termes, M.; Valero, F.; Vega, A.; Schneider, D.W. (2014) Examining the Demand for Ecosystem Services: The Value of Stream Restoration for Drinking Water Treatment Managers in the Llobregat River, Spain. Ecological Economics 90 (2013) 196–205	Ecosystem services would be incorporated into decision making more often if researchers were to focus more on the demand for these services rather than the supply. This implies examining the economic, decision-making and technological context of the end-user before trying to attribute economic values to well-known biological processes. This paper provides an example of how this research approach for ecosystems services could unfold. In the Llobregat River in north-eastern Spain, higher stream temperatures require water treatment managers to switch on costly water treatment equipment especially during warm months. This creates an opportunity to align the economic interests of downstream water users with the environmental goals of river managers. A restored riparian forest or an increase in stream flow could reduce the need for this expensive equipment by reducing stream temperatures below critical thresholds. We used the Stream Network Temperature Model (SNTEMP) to test the impact of increasing shading and discharge on stream temperature at the intake of the drinking water treatment plant. The value of the stream temperature ecosystem services provided by existing forests is €79,000 per year for the water treatment facility, while additional riparian forest restoration along the Llobregat River could generate economic savings for water treatment managers in the range of €57,000–€156,000 per year. Stream restoration at higher elevations would yield greater benefits than restoration in the lower reaches. Moderate increases in stream discharge (25%) could generate savings of €40,000 per year.

Honey-Rosés, 2014 [5]	Jordi Honey-Rosés, J.; Schneider, D.W.; Brozovic, N. (2014). Changing Ecosystem Service Values Following Technological Change. Environmental Management (2014) 53:1146–1157	Research on ecosystem services has focused mostly on natural areas or remote places, with less attention given to urban ecosystem services and their relationship with technological change. However, recent work by urban ecologists and urban designers has more closely examined and appreciated the opportunities associated with integrating natural and built infrastructures. Nevertheless, a perception remains in the literature on ecosystem services that technology may easily and irreversibly substitute for services previously obtained from ecosystems, especially when the superiority of the engineered system motivated replacement in the first place. We emphasize that the expected trade-off between natural and manufactured capital is false. Rather, as argued in other contexts, the adoption of new technologies is complementary to ecosystem management. The complementarity of ecosystem services and technology is illustrated with a case study in Barcelona, Spain where the installation of sophisticated water treatment technology increased the value of the ecosystem services found there. Interestingly, the complementarity between natural and built infrastructures may remain even for the very ecosystems that are affected by the technological change. This finding suggests that we can expect the value of ecosystem services to co-evolve with new technologies. Technological innovation can generate new opportunities to harness value from ecosystems, and the engineered structures found in cities may generate more reliance on ecosystem processes, not less.
Momblanch et al, 2015 [9]	Momblanch, A.; Paredes-Arquiola, J.; Munné A.; Manzano, A.; Arnau J.; Andreu, J. (2015). Managing water quality under drought conditions in the Llobregat River Basin. Science of the Total Environment 503–504 (2015) 300–318	The primary effects of droughts on river basins include both depleted quantity and quality of the available water resources, which can render water resources useless for human needs and simultaneously damage the environment. Isolated water quality analyses limit the action measures that can be proposed. Thus, an integrated evaluation of water management and quality is warranted. In this study, a methodology consisting of two coordinated models is used to combine aspects of water resource allocation and water quality assessment. Water management addresses water allocation issues by considering the storage, transport and consumption elements. Moreover, the water quality model generates time series of concentrations for several pollutants according to the water quality of the runoff and the demand discharges. These two modules are part of the AQUATOOL decision support system shell for water resource management. This tool facilitates the analysis of the effects of water management and quality alternatives and scenarios on the relevant variables in a river basin. This paper illustrates the development of an integrated model for the Llobregat River Basin. The analysis examines the drought from 2004 to 2008, which is an example of a period when the water system was quantitative and qualitatively stressed. The performed simulations encompass a wide variety of water management and water quality measures; the results provide data for making informed decisions. Moreover, the results demonstrated the importance of combining these measures depending on the evolution of a drought event and the state of the water resources system.

Climate change impact in ESS		
Short name	**Full name (citation)**	**Abstract**
Sabater et al., 2012 [3]	Sabater, S.; Ginebreda, A.; Barceló, D. (2012) The Llobregat. The Story of a polluted mediterranean river. Book. The Handbook of environmental chemistry 21. Springer-Verlag Berlin Heidelberg 2012	**CHAPTER: Ecosystem Services in an impacted watershed. The Relevance of Hydrology, Human Influence, and Global Change (M. Terrado et al.)** Climate change previsions in the Mediterranean regions are associated with more frequent extreme climatic conditions, which could alter water availability and impact the delivery of ecosystem services. In this chapter, the vulnerability of hydrological ecosystem services to recently observed climatic extremes in the Llobregat River basin is assessed. Provisioning (water) and regulating services (erosion control and water purification) were quantified under mean climatic conditions and subsequently compared to their provision under wet and dry conditions. Results stress that in semiarid basins submitted to chronic human pressure, hydrological services are very sensitive to climatic extremes. Provisioning services are important in mean and wet climatic conditions and are the most threatened in dry conditions when their reduction can approach 100%. Conversely, water purification (regulating service) has its largest contribution to human wellbeing in dry conditions. These results constitute a lower boundary of the possible benefits provided by ecosystem services in the basin.
Bangash et al., 2013 [8]	Bangash, R.F.; Passuello, A.; Sanchez-Canales, M.; Terrado, M.; López, A.; Elorza , F.J.; Ziv, G.; Acuña, V.; Schuhmacher, M. (2013). Ecosystem services in Mediterranean river basin: Climate change impact on water provisioning and erosion control. Science of the Total Environment 458–460 (2013) 246–255	The Mediterranean basin is considered one of the most vulnerable regions of the world to climate change and such changes impact the capacity of ecosystems to provide goods and services to human society. The predicted future scenarios for this region present an increased frequency of floods and extended droughts, especially at the Iberian Peninsula. This paper evaluates the impacts of climate change on the water provisioning and erosion control services in the densely populated Mediterranean Llobregat river basin of. The assessment of ecosystem services and their mapping at the basin scale identify the current pressures on the river basin including the source area in the Pyrenees Mountains. Drinking water provisioning is expected to decrease between 3 and 49%, while total hydropower production will decrease between 5 and 43%. Erosion control will be reduced by up to 23%, indicating that costs for dredging the reservoirs as well as for treating drinking water will also increase. Based on these data, the concept for an appropriate quantification and related spatial visualization of ecosystem service is elaborated and discussed.

Risk Assessment / identification of stressors		
Short name	**Full name (citation)**	**Abstract / relevant aspects**
Gottardo et al., 2011 [2]	Gottardo, S.; Semenzin, E.; Giove, S.; Zabeo, A.; Critto, A.; de Zwart, D.; Ginebreda, A.; Marcomini, A. (2011). Integrated risk assessment for WFD ecological status classification applied to Llobregat river basin (Spain). Part I—Fuzzy approach to aggregate biological indicators. Science of the Total Environment 409 (2011) 4701–4712	Water Framework Directive (WFD) requirements and recommendations for Ecological Status (ES) classification of surface water bodies do not address all issues that Member States have to face in the implementation process, such as selection of appropriate stressor-specific environmental indicators, definition of class boundaries, aggregation of heterogeneous data and information and uncertainty evaluation. In this context the "One-Out, All-Out" (OOAO) principle is the suggested approach to lead the entire classification procedure and ensure conservative results. In order to support water managers in achieving a more comprehensive and realistic evaluation of ES, an Integrated Risk Assessment (IRA) methodology was developed. It is based on the Weight of Evidence approach and implements a Fuzzy Inference System in order to hierarchically aggregate a set of environmental indicators, which are grouped into five Lines of Evidence (i.e. Biology, Chemistry, Ecotoxicology, Physico-chemistry and Hydromorphology). The whole IRA methodology has been implemented as an individual module into a freeware GIS (Geographic Information System)-based Decision Support System (DSS), named MODELKEY DSS. The paper focuses on the conceptual and mathematical procedure underlying the evaluation of the most complex Line of Evidence, i.e. Biology, which identifies the biological communities that are potentially at risk and the stressors that are most likely responsible for the observed alterations. The results obtained from testing the procedure through application of the MODELKEY DSS to the Llobregat case study are reported and discussed.

Coastal areas related to river basin		
Short name	**Full name (citation)**	**Abstract / relevant aspects**
Brenner et al., 2010 [10]	Brenner, J.; Jiménez, J.; Sardá, R.; Garola, A. (2010). An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain. Ocean & Coastal Management 53 (2010) 27–38	A spatial value transfer analysis was performed to generate baseline estimates of the value of ecosystem services in the coastal zone of Catalonia, Spain. The study used the best available conceptual frameworks, data sources, and analytical techniques to generate non-market monetary value estimates that can be used to identify scarce ecosystem services among competing coastal uses. The approach focused on natural and seminatural, terrestrial and marine systems, which provide essential services that are not considered in current economic markets. Results show that in 2004 a substantial economic value of $3,195 million USD/yr was delivered to local citizens by surrounding ecosystems. In a spatially explicit manner, the approach illustrates the contribution made by natural environmental systems to the well-being of communities in the coastal zone of Catalonia. It is hoped that this study will highlight the need to consider these coastal systems in future management strategies to ensure their proper maintenance and conservation.

Annex IV: List of bird species identified in SVH infiltration system

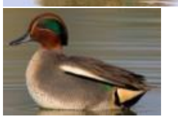
Photo	Species (Scientific name / CAT / ENG)	Photo	Species Scientific name / CAT / ENG)
	***Accipiter gentilis*** CAT: Astor ENG: Northern goshawk NOTE: Condition: near threatened		***Bubulcus ibis*** CAT: Esplugabous ENG: Cattle egret NOTE: 3 times observed in river
	***Actitis hypoleucos*** CAT: Xivitona vulgar ENG: Common sandpiper NOTE: 5 times observed		***Buteo buteo*** CAT: Aligot comú ENG: Buteo NOTE: 1 times observed in wetlands
	***Alauda arvensis*** CAT: Alosa vulgar ENG: Eurasian skylark NOTE: 1 time observed in orchards along the river		***Carduelis cannabina*** CAT: Passerell comú ENG: Common linnet NOTE: 3 times observed in Llobregat river passing through the SVH
 	***Anas crecca*** CAT: Xarxet comú ENG: Eurasian teal NOTE: 4 times observed in river		***Carduelis carduelis*** CAT: Cadernera ENG: European goldfinch
	***Anas platyrhynchos*** CAT: Ànec collverd ENG: Mallard		***Cettia cetti*** CAT: Rossinyol bord ENG: Cetti's warbler NOTE: Condition: least concern
	***Anthus pratensis*** CAT: Titella ENG: Meadow pipit		***Charadrius dubius*** CAT: Corriol petit ENG: Common ringed plover NOTE: 7 times observed in a Sant Vicenç dels Horts
	***Anthus spinoletta*** CAT: Grasset de muntanya ENG: Water pipit NOTE: 1 times observed in river		***Cisticola juncidis*** CAT: Trist ENG: Zitting cisticola

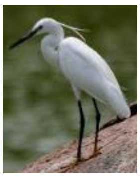
Photo	Species (Scientific name / CAT / ENG)	Photo	Species Scientific name / CAT / ENG)
	***Ardea cinerea*** CAT: Bernat pescaire ENG: Grey heron NOTE: A total of 4 times observed (1 in wetlands and 3 in river)		***Columba livia*** CAT: Colom domestic ENG: Rock dove
	***Columba palumbus*** CAT: Tudó ENG: Common wood pigeon		***Falco tinnunculus*** CAT: Xoriguer comú ENG: Common kestrel NOTE: 2 times observed in river
	***Corvus corax*** CAT: Corb Corvus NOTE: Condition: least concern		***Fringilla coelebs*** CAT: Pinsà comú Common chaffinch
	***Egretta garzetta*** CAT: Martinet blanc ENG: Little egret NOTE: A total of 2 times observed (1 in wetlands and 1 in river)		***Galerida cristata*** CAT: Cogullada vulgar ENG: Crested lark NOTE: Condition: least concern
	***Emberiza cirlus*** CAT: Gratapalles ENG: Ortolan bunting NOTE: 7 times observed in river (as a minimum)		***Gallinago gallinago*** CAT: Becadell comú ENG: Common snipe NOTE: 3 times observed in river
	***Emberiza schoeniclus*** CAT: Repicatalons ENG: Common reed bunting		***Gallinula chloropus*** CAT: Polla d'aigua Common moorhen
	***Erithacus rubecula*** CAT: Pit-roig ENG: European robin		***Himantopus himantopus*** CAT: Camesllargues ENG: Black-winged stilt NOTE: 5 times observed in a Sant Vicenç dels Horts
	***Estrilda astrild*** CAT: Bec de corall senegalès ENG: Common waxbill NOTE: Condition: not applicable		***Larus michahellis*** CAT: Gavià argentat ENG: Yellow-legged gull

Photo	Species (Scientific name / CAT / ENG)	Photo	Species Scientific name / CAT / ENG)
	***Larus ridibundus*** CAT: Gavina vulgar ENG: Black-headed gull		***Phoenicurus ochruros*** CAT: Cotxa fumada ENG: Black redstart
	***Motacilla alba*** CAT: Cuereta blanca vulgar ENG: White wagtail NOTE: Condition: least concern		***Phylloscopus collybita*** CAT: Mosquiter comú ENG: Common chiffchaff
	***Motacilla cinerea*** CAT: Cuereta torrentera ENG: Grey wagtail		***Pica pica*** CAT: Garsa ENG: Eurasian magpie
	***Myiopsitta monachus*** CAT: Cotorreta de pit gris ENG: Monk parakeet		***Picus viridis*** CAT: Picot verd ENG: European green woodpecker NOTE: 1 time observed in wetlands
	***Passer domesticus*** CAT: Pardal comú ENG: House sparrow		***Psittacula krameri*** CAT: Cotorra de Kramer ENG: Rose-ringed parakeet NOTE: 8 times observed in wetlands
	***Passer montanus*** CAT: Pardal xarrec ENG: Eurasian tree sparrow		***Remiz pendulinus*** CAT: Teixidor ENG: Penduline tit
	***Phalacrocorax carbo*** CAT: Corb marí gros ENG: Cormorant NOTE: A total of 9 times observed (2 in wetlands and 7 in river)		***Tachybaptus ruficollis*** CAT: Cabusset ENG: Little grebe NOTE: A total of 3 times observed (1 in wetlands and 2 in river)

Photo	Species (Scientific name / CAT / ENG)	Photo	Species Scientific name / CAT / ENG)
	***Serinus serinus*** CAT: Gafarró ENG: Atlantic canary		***Tringa ochropus*** CAT: Xaivita ENG: Green sandpiper NOTE: 1 time observed in river
	***Streptopelia decaocto*** CAT: Tórtora turca ENG: Eurasian collared dove		***Upupa epops*** CAT: Puput ENG: Hoopoe NOTE: Condition: least concern
	***Streptopelia turtur*** CAT: Tórtora ENG: European turtle dove NOTE: Condition: least concern		***Sylvia atricapilla*** CAT: Tallarol de casquet ENG: Eurasian blackcap
	***Sturnus vulgaris*** CAT: Estornell vulgar ENG: Common starling		***Sylvia melanocephala*** CAT: Tallarol capnegre ENG: Sardinian warbler

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