D.4.2.1 Report on case studies: management, administration and exploitationon best practices

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1. INTRODUCTION

According to a 2009 report by European Commission, approximately 3.8 million ha of European Union land is at risk from salinization, most of which affects the Mediterranean basin. The Mediterranean basin is characterized by a large number of smaller coastal river basins which differ in the geological structure of the aquifers. The most common are sedimentary, alluvial and karstic carbonate aquifers, which are closely connected and often hydraulically connected to the sea. Extensive seawater intrusions in karst and alluvial coastal aquifers within the Mediterranean basin induce an increasing risk for water and soil salinization in coastal river valleys. Moreover, it is expected that more frequent and severe droughts, irregular precipitations and changes in sea level will aggravate the salinization processes, which in turn might lead to desertification of many agricultural areas of the Mediterranean basin. The intrusion of the sea, as a hydrological phenomenon, is a consequence of the difference in viscosity and density between freshwater and the marine aquatic ecosystem. In coastal areas, the sea penetrates below the surface in the form of a wedge, the width of which is greatest at the very bottom of the aquifer. In general, the intrusion of the saltwater wedge depends on the tidal intensity, the permeability of the aquifer and the freshwater inflow from the basin. The higher the permeability of the aquifers, the more pronounced is the influence of the sea. For example, in the microtidal area of the east coast of the Adriatic Sea, marine intrusion into carbonate aquifers is pronounced and can extend up to 25 km upstream. Sea intrusion into estuaries leads to salinization not only of surface water, groundwater, but also of soil. As these are mostly water supply systems, salinization is not only the result of the natural "wedge" of sea intrusion into the interior, but also of the conical uplift caused by extensive water pumping. The natural equilibrium among the different geological and geomorphological processes on the coastal environment is strongly affected by the human impact.

Since such scenarios are usually unavoidable, there are various approaches that can reduce the consequences of degradation processes. Rational management of water and soil salinization requires an understanding of how water and soil salt concentrations vary across the land. Surveys and maps illustrating the geografic distribution of salinity can contribute to the improvement and sustainability of natural ecosystems as well as agriculture. An intermediate or large scale may be useful in delineating specific areas where salinity may be problematic for agriculture, wetland habitats and other natural or near-natural habitats in the valley.

2. NATIONAL POLICIES AND STRATEGIES

2.1. Italy: national policies and strategies

There are numerous international, national, and regional laws that regulate the Water subject. However, some of these have to be considered as fundamental keys in the framework of water resource management and administration (table 1). The first to be cited is the Presidential Decree n.236 of 24/05/1988, which establishes the quality requirements of the water intended for human consumption, for the protection of public health and the improvement of living conditions. It gave rise to rules to ensure the protection of water resources. After that, the Law Decree (D.Lgs) n.152 of the 11/05/1999 defines the general discipline for the protection of superficial, marine and subsurface water, with the aim of

1. preventing and contrasting the contamination, with the subsequent remediation of the contaminated water bodies;

2. pursuing the improvement of the water quality, defining adequate protection to those intended for special uses;
3. pursuing durable and sustainable uses of the water resource, with priority for that intended for human consumption;
4. maintaining the natural self-purification capacity of the water bodies and their capacity to sustain the animal and vegetal communities biodiversity.

An important step forward was made with the European Directive 2000/60/EC “Water Framework Directive”, that the Italian legislation implemented through the D.Lgs n.152 of the 03/04/2006, and with the “European Directive 2006/118/EC “on the protection of groundwater against pollution and deterioration” that the Italian legislation implemented through the D.Lgs n.30 of the 16/03/2009, which establish a framework for Community action in the field of water and have determined an innovative approach into European water legislation, both from an environmental and administrative-management point of view. Both EU and Italian legislators had ambitious objectives such as those to prevent qualitative and quantitative deterioration, to improve the state of water and to ensure sustainable use, based on the long-term protection of available water resources. Water is not considered as a commercial product, rather as a heritage that must be protected and defended. Directive 2000/60/EC aimed to achieve the following key objectives:

1. extend the protection of both ground and surface waters;
2. reach the status of "good" for all waters by December 31, 2015 (art. 4);
3. management of the water resources based on river basins regardless of the administrative structures (art. 3);
4. proceed through action that combines the monitoring of concentration limits, quality standards and quantities of the water resource (art. 8);
5. recognize all water services at the right price that takes into account their real economic cost (arts. 5 and 9);
6. involve citizens in the choices made in this sector (art. 14).

The Directive requires individual Member States to address water protection at the level of the "catchment area" and the territorial reference unit for the management of the basin is identified in the "river basin district", i.e., land and sea areas consisting of one or more neighboring river basins and their groundwater and coastal waters. In each hydrographic district, Member States have to ensure i) an analysis of the characteristics of the district ii) an examination of the impact of human activities on the state of surface and groundwater and iii) an economic analysis of water use must be carried out. Planning must be prepared in each district, taking into account the analyses carried out and the environmental objectives set by the legislator, with the ultimate aim of achieving "good status" of all waters by 2015 (except in special cases determined by the law). These programs are set out in the Management Plans to be prepared by the Member States for each catchment area and which is, therefore, the programming/implementation instrument for achieving the objectives set out in the Directive. As already mentioned, the D.Lgs 152/2006 has implemented, besides the Directive 2000/60/EC, other European legislative frameworks such as the 2004/35/EC. The D. Lgs 152/2006, successively modified and integrated by the D.Lgs. 30/2009, that represents the fundamental laws in the Italian legislation which governs the Environmental Subject and the individuation and characterization of the water bodies. In particular, the third part of the D. Lgs 152/2006 contains the majority of the norms and laws for the preservation, regulation, management and remediation of the natural waters.

A pivotal role to reach the objectives of the Italian and EU law is played by the Regions, to which is assigned the qualitative and quantitative monitoring of the waters, and the writing of the regional “Water Protection Plans (PTA)”. The PTA, defined in the Art. 121 of the D. Lgs 152/06, are the planning tool that contains those interventions necessary to protect the waters and to reach or maintain their quality. These plans must be approved by the Italian Ministry for the Environment, Land and Sea and by the specific River Basin Authority.

The PTA must:

1. contain the identification of environmental quality objectives subdivided per specific destination;
2. contain the list of specific-purpose water bodies and areas requiring specific pollution prevention and remediation actions;
3. integrate and coordinate qualitative and quantitative protection plans by catchment area;
4. contain an indication of the time scale of the interventions and their priorities;
5. define the programs to verify the effectiveness of the actions planned;
6. define the remediation of water bodies;
7. contain the data held by the competent authorities and agencies concerning the monitoring of groundwater in the affected areas and drinking water of the municipalities concerned, collected and periodically updated with the existing monitoring network, to be published to make them available to citizens;
8. contain economic analysis and the plans envisaged to implement the provisions concerning the recovery of the costs of water services. To summarize, the main aim is to achieve the quality objectives of the water bodies and the qualitative and quantitative protection of the water resource, guaranteeing a sustainable water supply in the long term. The PTA objectives are pursued through measures and interventions adopted and planned for each planning cycle (six years).

Another important issue related to the quality of the water resource is related to nitrate concentrations. The topic is dealt by the Council Directive 91/676/EEC of 12 December 1991 (reiterated by the 2006/118/EC) concerning the protection of waters against pollution caused by nitrates, which has the aims of reducing water pollution caused or induced by NO_3 derived from agricultural sources and prevent further pollution.

Table 1 European and national Institutional entities in charge of the groundwater management

Institutional Entity	Legislation		Issue
	Regulation	Type	
The European Parliament and the Council of the European Union	98/83/CE of 03/11/1998	Council Directive	Quality of water intended for human consumption
	2000/60/CE of 23/10/2000	Water Framework Directive	Establishing a framework for Community action in the field of water policy
	2006/118/CE del 12/12/2006	Water Framework Directive	Establishing a framework for Community action in the field of water policy
Italian Government	Constitution of the Italian Republic	Italian Republic	Restrictions of the land use and resources
	D.Lgs. 31/2001 of 02/02/2001	Legislative decree	Implementation of the Directive 98/83/CE about the water for civil use
	D.Lgs. 152/2006 of 03/04/2006	Legislative decree	Implementation of the WFD 2000/60/CE “Code of environment” – art.1 and 144
	D.Lgs. 30/2009 of 16/03/2009	Legislative decree	Implementation of the WFD 2006/118/CE
	D.Lgs. 219/2010 of 10/12/2010	Legislative decree	Implementation of the Directive 2008/105/CE
	D.M. 131/2008 of 16/06/2008	Ministerial Decree	Technical criteria for the water body characterization
	D.M. 56/2009 of 14/04/2009	Ministerial Decree	Technical criteria for the water body monitoring
	D.M. 260/2010 of 08/11/2010	Ministerial Decree	Technical criteria for the shallow water body classification
	D. M. 31/07/2015	Ministerial Decree MiPaaF	Technical review for measuring of water use in agriculture

In the Italian context and especially in the Po River Basin, which is the largest plain in Italy and represents the most important economic area for the country, the Water Framework Directive (WFD) was first transposed in 2006 with the legislative decree n° 152. The D.Lgs 152/2006, modified and integrated by several subsequent decrees/law (L. 221/2015), represents the fundamental law in the Italian legislation which governs the Environmental related subject including the individuation, characterization and preservation of the water bodies. This legislative decree unified previous regulations concerning the environment including water use and protection to reduce the fragmentation of competencies, which is still the major problem of the country. The fundamental modification of this law is the definition of 7 water districts (Fig. 1), in which all minor basins are merged. District Authorities replace the previous Basin

Fig. 1 Water districts in Italy

Authorities and are responsible for the application of the principles of the WFD within each district. This reorganization is aimed at establishing a governing Institution of equal relevance for each district, characterized by a similar managing structure, applying similar procedures to approve and adopt planning actions.

These District Authorities are supervised at the national level by the Minister for the Environment, Land and Sea (Civita et al., 2017). Furthermore, institutional cooperation is established among Regions belonging to each district and the State, through a central body: the Committee of Ministers. Two Sectoral Plans for each basin belonging to the district are carried on:

1. Hydrogeological Plan, concerning soil protection and hydrogeological risk;
2. Management Plan, concerning environmental protection of water bodies and rational exploitation of water resources.

These Regional Authorities are involved in the quality of the water bodies by implementing a set of measures adopted through Environmental Plans to be issued every 6 years. These plans must conform to the general directives of the District Authority contained in a Master Plan and must be approved by the District Authority (Civita et al. 2017).

2.2. Croatia: national policies and strategies

Similar to the legal situation in Italy, the National Water Act (OG 66/19) and Directive 2000/60/ EC of European Parliament (Water Framework Directive) are the basic documents for establishing a framework for action in the field of water policy and they define groundwater as all water below the soil surface in the saturation zone and in direct contact with the soil surface or underground layer.

Groundwater in Croatia is grouped into the so-called groundwater bodies. The first characterization of groundwater bodies was carried out in 2005 for the basin Black Sea (continental part) (Brkić et al., 2005) and in 2006 for the Mediterranean part (Brkić et al., 2006). The basis for delineation of groundwater units, in accordance with the requirements of Water Framework Directive, was the analysis of: geological terrain, porosity, geochemical composition, hydrogeological characteristics, geomorphological phenomena, directions and velocities of groundwater flow, yield of springs and wells, groundwater supply, relationships with surface flows and the position of groundwater units within river basins, as well as the requirement of the Water Framework Directive (2000/60/ EC) to identify all groundwater bodies that are or may be used for public water supply and provide more than 10 m3/day on average (Brkić et al., 2006).

Applying these criteria in the Mediterranean, a total of 98 groundwater bodies (BGBs) were identified, of which 86 belong to the mainland part of the basin and another 12 to the larger islands (Krk, Cres, Rab, Pag, Dugi otok, Čiovo, Šolta, Brač, Hvar, Vis, Korčula, Lastovo) (Brkić et al., 2006). A large number of BGBs, many of which occupy a small area, prevent optimal management. Therefore, for the purposes of monitoring, assessment and management of groundwater, the grouping of the original BGBs was carried out. According to the River Basin Management Plan 2016-2021, 13 grouped groundwater bodies (GWBs) with a total area of 26 685 km2 have been identified in the Mediterranean basin. Most of the GWBs cover the neighboring countries Slovenia and Bosnia and Herzegovina, so the transboundary part of the grouped groundwater bodies is 15 757 km2 and the national part is 10 928 km2. Towards the south, the share of transboundary ARCs increases. In the Dubrovnik area, only the sources of the Neretva GWB are located in Croatia, while most of the GWB is located in Bosnia and Herzegovina.

According to the Law on Water (OG 66/19), water use is considered to be: abstraction, extraction and use of surface and groundwater for various purposes, where the supply of drinking water to the population is in the public interest and has priority over the use of water for other purposes. To ensure priority of water use for water supply, Croatian Waters will separately designate in each water district:

(1) all waters for human consumption that provide more than 10 cubic meters of water per day on average or serve more than 50 persons; and (2) all waters reserved for these purposes in the future.

The area where the spring or other water reservoir (used or reserved for public water supply) is located must be protected not only from contamination (intentional and accidental), but also from other influences that may affect the safety or abundance of the water. For this reason, zones of sanitary protection of springs are established (Fig. 2). In the Republic of Croatia, 16 protected areas for surface water and 320 protected areas for groundwater have been established, which are used for public water supply or are reserved for this purpose in the future.

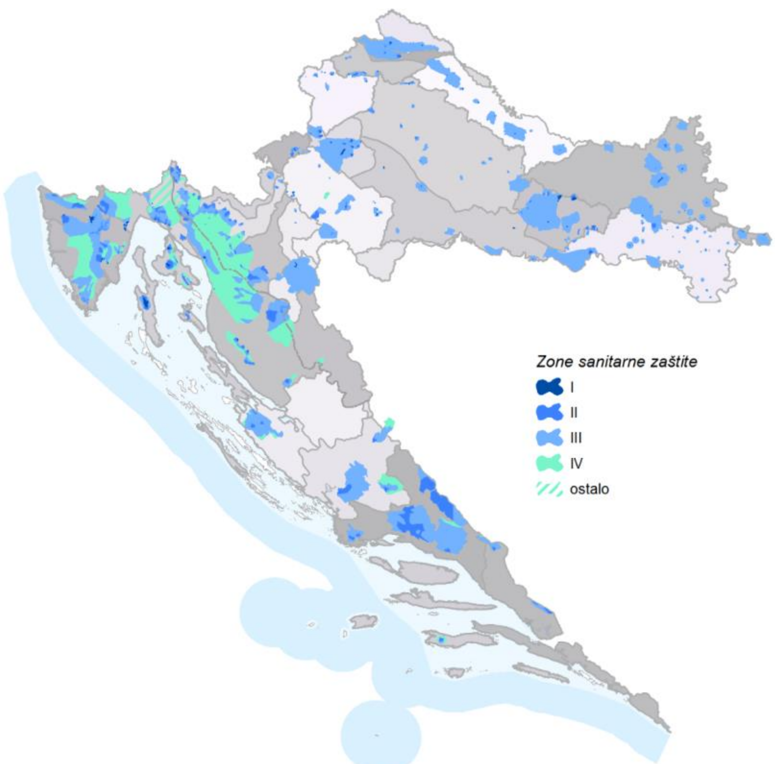

Fig. 2. Sanitary protection zones

Source: Vlada RH (2016) Plan upravljanja vodnim područjima 2016.-2021.

No additional water quality standards are defined for protected areas, as the same criteria generally apply to surface water and groundwater. Higher concentrations of certain substances in groundwater are only permitted if they are of natural origin and if they cannot be eliminated by preparatory water protection measures, but only by adequate water purification before distribution to end users.

Another important issue related to water quality is nitrate concentrations in both surface and groundwater. This issue is addressed by the Council Directive 91/676/EEC of 12 December 1991 (reaffirmed by the 2006/118/ EC) and implemented in the Croatian legislation and concerns the protection of waters from pollution by nitrates from agricultural sources and the prevention of further pollution.

According to the Water Act (OG 66/19), water services are activities of general interest and are provided as a public service in service areas established in one or more existing water supply areas and agglomerations. Water services are services of public water supply and public water drainage and are provided in the service area by a public utility whose sole founder is the local self-government unit.

3. INSTITUTIONS INVOLVED IN GROUNDWATER MANAGEMENT

3.1. Italy: institutions involved in groundwater management

3.1.1 Marche region and coastal area of Fano

A pivotal role to reach the objectives of the D.Lgs 152/2006 is played by the Regions with the writing of the regional PTA which defines the main criteria adopted to maintain the quality and

quantity standards of the water resource. In the case study of Fano, the role of the Marche Region
(to which the Municipality pertains) and of the local entities in terms of discipline and administration of the water resources are governed by the Regional Law n.18 of the 22/06/1998 and the Regional Law n.10 of the 17/05/1999, respectively. In the Marche Region, the PTA has been delivered with the Regional act n.145 of the 26/01/2010.

Another fundamental Regional Law is the n.30 of the 28/12/2011 with the object *"Provisions on water resources and integrated water service"* that, besides recognizing the water as a heritage of humanity to be protected, states that the Region defends and guarantees the supply and the right of potable water to everyone. Moreover, it identifies the tools through which guarantee the satisfaction of the water resource need by *i) its rational use, ii) the improvement of water quality, also from a sanitary point of view, through the pollution prevention and reduction; iii) the protection and improvement of aquatic ecosystems,* and *iv) the protection of socially and economically disadvantaged subjects or those residing in areas territorially disadvantaged*. Another important issue deriving from this law is the organization in the regional territory of the Integrated Hydric Service (*SII*), articulated in the Optimal Territorial Ambit (ATO), as defined by the Art. 148 of the D.Lgs 152/2006, in order to guarantee the water management following efficiency, effectiveness, and cost-effectiveness criteria. The ATO has the role to develop the Ambit Plan, which is an administrative document constituted by the following parts:

1. *reconnaissance of infrastructures*
   i.e., recognizing the state of the infrastructures to be entrusted to the integrated water service manager, specifying the state of operation;
2. *program of interventions*

i.e., identifying the extraordinary maintenance works and the new works to be carried out, necessary to achieve at least the minimum service levels, as well as to satisfy the overall user demand; the program of interventions commensurate with the entire management, specifies the objectives to be achieved, indicating the infrastructures planned for this purpose and the implementation times;

3. *management and organizational model*

   i.e., defining the operational structure through which the manager ensures the service to users and the implementation of the intervention program;

4. *economic and financial plan*

   i.e., providing the trend of management and investment costs net of any non-repayable public funding; it is supplemented by the annual forecast of tariff income, extended to the entire credit line period. The plan, as drawn up, must guarantee the achievement of economic and financial equilibrium and, in any case, compliance with the principles of effectiveness, efficiency and cost-effectiveness of management, also concerning planned investments.

In the case study, Fano is comprised within the Metauro River system that pertain to the "*ATO1 - northern Marche, Pesaro-Urbino Province"*, politically constituted by the Mayors (or by their delegates) of the municipalities that fall inside the territory, and by the President of the Province. The ATO is the public authority that entrusts the hydric service in conformity with the national legislation "*on the organization of local public services with an economic relevance"*. In fact, at the local scale (i.e., the municipality), the groundwater can be managed by public or private companies, as stated by the D.Lgs n.133 of the 06/08/2008 (which modified the D.Lgs n.112 of the 25/06/2008), where the *Art. 23bis* reports the arrangement for the entrustment and the management of the economically relevant public services, including the water supply issue, affirming the procedures to obtain the management of the water resource. Although this latter can be managed by public or private agencies, the distribution network remains of public property, as also stated by the Marche Regional Law n.5 of the 09/06/2006 that disciplines the derivations of public water and the occupations of the water state property. Accordingly, in the case study of Fano, the local water supply is managed by ASET S.p.A., a public multi-utility group that regulates the water exploitation and the aqueduct, sewerage, and purification systems for the whole municipality. The *SII regulation* drawn up by ATO1 for the territorial entities disciplines all the services delivered by the hydric resource manager and integrates rules of the laws actually in force on the protection of water from pollution, public hygiene and health. *Art. 4* of the SII regulation defines the activities of the manager, which in the case of Fano is ASET S.p.A., consist of:

1) the management of the integrated water service;
2) the implementation of the program of interventions approved during the assignment of the service and its possible and subsequent updates;
3) the evaluation of plans and projects relating to water and sewerage networks of new urbanizations;
4) the connection to the aqueduct and sewerage network of the users of the service;
5) the exercise of expropriation powers and the conduct of the relevant procedures, according to Art. 158a of D.Lgs 152/2006 (and successive modifications), within the limits of the delegation referred to in the Convention for the Management of the SII of ATO 1;
6) the performing of the necessary controls on connection to public networks;
7) any technical inspections of the pipes and private systems connecting to the works of the integrated water service, as well as the related sampling to check compliance with the provisions of the *SII regulation*.

3.1.2. Emilia-Romagna region and coastal area of Ravenna

The Emilia Romagna region is part of the Po water district (highlighted by the magenta color in Fig. 1). Several Authorities are involved in the groundwater governance of the coastal area of Ravenna depending on the different uses of water, such as supply to the population, wastewater treatment, farmland irrigation and drainage, wildlife management and biodiversity protection (Table 2).

Table 2 Local Institutional entities in charge of the groundwater management in Italy

Institutional Entity	Legislation		Issue
	Regulation	Type	
Po River Basin Authority (ADBPO)	Decree 1/2016 of 03/03/2016 D.P.C.M. 27/10/16	DPCM	Water Plan of Po basin
Interregional agency for the PO River (AIPO) (ex- Magistrato per il Po)	Regional laws of Po regions (Piemonte, Lombardia, Emilia Romagna e Veneto)		Hydraulic safety, water domain and river navigation
Land Reclamation Authorities	R.D. 13/02/1933 n.215		Management of the water for the irrigation and drainage. Land reclamation authorities for management drainage areas (of first and second degree) (C.E.R.)
Regional Government - Emilia Romagna	Resolution N. 40 of 21/12/2005 - Regional Legislative Assembly		Tool for the sustainable water supply
Agenzia Territoriale Emilia-Romagna (A.Ter.Sir)	L. R. n. 23/2011		Water Integrated Service (S.I.I.). Urban waste Integrated Service (S.G.R.U.)
ARPA ER - Regional Prevention and Environment Agency of Emilia Romagna	L.R. 32/1988 L.R. 9/1999 R.D. 1443/1927 D.P.R. 128/1959 L.R. 13/2015		Environmental certificate Analysis and monitoring of the air and water quality Well licensing and registering

As shown in Table 2, ADBPO and ARPAE are identified as the main competent actors in the local (regional) management of groundwater and surface water. In Resolution No. 3/2017 of the "permanent institutional conference" of the Po River District Basin Authority

(ADBPO), the Directives for the assessment of environmental risk related to water withdrawals, or water abstraction (surface and groundwater) are modified and integrated. The purpose of the "Withdrawals Directive" is to assess the compatibility of water abstractions with the environmental quality objectives defined in the management plan of the Po River Hydrographic District ("Withdrawals Directive") and to verify their maintenance in the affected water bodies for the hydrographic district of the Po river.

The competencies related to the administrative management of the concessions inherent to the subjects of the water resources and the use/occupation of state water areas are of competence of the "Structures Authorizations and Concessions (SAC)" of ARPAE.

The use and withdrawal of public waters are regulated by the laws of the State (*"Testo unico delle disposizioni di legge sulle acque pubbliche e impianti elettrici e successive"* R.D. n.1775 del 11/12/1933 e s.m.i.) and of the Emilia-Romagna Region (Regional regulation n.41 del 20/11/2001, for the regulation of the procedure of concession of public water). Specific aspects of the discipline are contained in other state or regional laws, regulations or resolutions of the Emilia-Romagna Regional Council as described above.

The Region, after consultation with the Po District Basin Authorities, regulate the groundwater withdrawals for domestic uses, as defined by Article 93 of Royal Decree 11 December 1933, n. 1775, where it is necessary to ensure the balance of the water resource (Article 96, paragraph 11, D.Lgs.152/2006).

For groundwater (e.g. wells), the key criteria that help determine which is the procedure to apply when granting a permit are:

1. "Ordinary procedure": well depth larger than 30 meters and/or annual consumption greater than 3,000 cubic meters.
2. "Simplified procedure": well depth within 30 meters and annual consumption equal to or less than 3,000 cubic meters.

For drilling operations that exceed 30 m in depth, it is necessary to communicate the start of drilling operations to ISPRA - *Istituto Superiore per la Protezione e la Ricerca Ambientale* (Law 04/08/1984 n. 464).

For surface waters (including sub-watersheds) there are two options:

1. "Ordinary procedure": all withdrawals not included in the next type;
2. “Simplified procedure":
   a. Withdrawals of surface water having a provisional character, consequent to water needs related to contingent situations, for a limited and defined temporal duration, with a maximum flow rate not exceeding 5 l/s, exercised by mobile withdrawal works and infrastructure;
   b. Withdrawal of surface water for domestic or irrigation use, if the operation of the withdrawal is carried out with mobile works and that the maximum flow is not greater than 2 l/s.

3.2. Croatia: Institutions involved in groundwater management

Both surface and groundwater management and administration at the national level are carried out in the following order (Fig. 3).

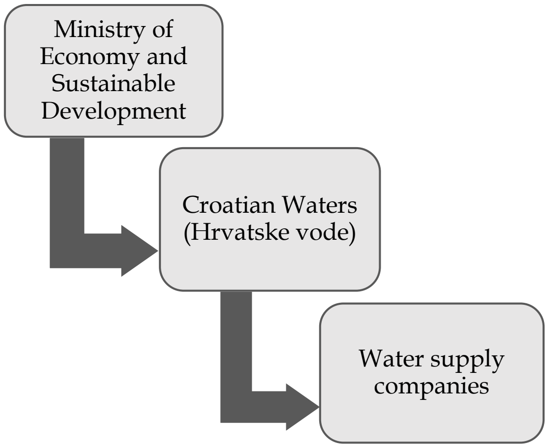

Fig. 3 Institutions involved in water management

The Ministry of Economy and Sustainable Development proposes laws and regulations, i.e. issues regulations in the field of water management, carries out administrative and inspection supervision and provides international cooperation. The Ministry is responsible for the transposition of the acquis communautaire into Croatian water legislation and for all issues related to the establishment of a system for monitoring and control of the application of water legislation in practice.

The remit of the Ministry of Economy and Sustainable Development includes, inter alia, activities related to the protection and preservation of the environment and nature in accordance with the policy of sustainable development of the Republic of Croatia; activities related to waste management and environmental impact assessment; work related to climate change mitigation and adaptation; tasks related to water management; and administrative and other tasks in the field of energy.

Croatian Waters (Hrvatske vode) is a legal entity that carries out activities related to water management. The governing body of Hrvatske vode is the Management Board with seven members, six of whom are appointed and dismissed by the Government of the Republic of Croatia. The Director General of Hrvatske vode, who is also appointed and recalled by the Government, is responsible for managing the business. Hrvatske vode are organized with a central office in Zagreb and six territorial units (water management departments or WMDs) with a total of 33 branches.

The activity of Hrvatske vode is water management within the scope of the following tasks:

a) **Preparation of planning documents for water management**

Preparation of drafts Water Management Strategy, preparation of drafts River Basin Management Plan, preparation of drafts of long-term construction programs, adoption of detailed plans and programs accompanying River Basin Management Plan, preparation of draft financial plan and adoption of Water Management Plan; studies and analytical tasks - preparation of terms of reference, conceptual solutions, studies and investment programs and review of planning documents, with the exception of control of final drafts in terms of regulations on physical planning and construction;

b) Water regulation and protection from adverse effects of water

Monitoring and establishing hydrological conditions, assessing flood risks, monitoring the condition of watercourses and water regulation structures; investment tasks in the construction and maintenance of water regulation and water protection facilities; supervising the construction and maintenance of water regulation and water protection facilities; managing flood risks; directing, monitoring and implementing preventive, regular and emergency flood protection;

c) Amelioration drainage

Investment and project management for construction and maintenance of basic melioration drainage facilities, supervision of construction and maintenance of basic melioration drainage facilities;

d) Water use

Identification of water reserves, maintenance of strategic water reserves, water research work, issuing opinions on implementing regulations issued by local and/or regional self-government units in accordance with the Water Law; taking other measures for the appropriate and rational use of water; co-financing the construction of public water supply facilities and monitoring the appropriate use of funds during construction;

e) Water protection

Management of water quality, application and monitoring of the application of other obligated parties of the application of measures from the National Plan of measures for sudden and Accidental Pollution, issuing opinions and exceptionally approving implementing regulations issued by local and/or regional self-government units on the basis of the Water Act, co-financing the construction of public wastewater collection facilities and monitoring the expedient use of funds during construction;

f) Irrigation

Managing projects for the construction of irrigation facilities owned by regional self-government units in accordance with national programs and projects, co-financing the construction of irrigation facilities owned by regional self-government units;

g) Management of public water resources

Water utilities shall be responsible for water supply, wastewater collection, treatment and discharge in their territories;

h) Technical matters

Management of water documentation and water information system, issuance of water rights acts, activities related to issuance of concessions for economic water use, supervision of implementation of conditions from water rights acts and concession conditions, calculation and collection of fees for concessions for industrial water use and other fees in accordance with the law regulating financing of water management.

The investigated area of the Neretva river valley is located in the southernmost county, Dubrovnik-Neretva, which is territorially organized into 22 local government units, which includes 5 cities (Dubrovnik, Korčula, Ploče, Metković and Opuzen) and 17 municipalities (Blato, Dubrovnik coast, Janjina , Konavle, Kula Norinska, Lastovo, Lumbarda, Mljet, Orebić, Pojezerje, Slivno, Smokvica, Ston Trpanj, Vela Luka, Zažablje and Župa dubrovačka).The area of the County can be divided into three basic functional and geographical units: Dubrovnik coast, Lower Neretva valley and the Pelješac peninsula and the islands of Korčula, Mljet and Lastovo.

The Lower Neretva Valley, which consists of the area of the lower Neretva and the coast, has an area of 414.35 km^2 and includes the towns of Metković, Opuzen and Ploče, and the municipalities of Kula Norinska, Pojezerje, Slivno and Zažablje. The water supply of the entire County is characterized by a large number of water supply systems, 13 of them, which are of regional to local importance. The regional system Neretva-Pelješac-Korčula-Lastovo-Mljet (NPKLM) is divided into:

- Basic supply system Neretva-Pelješac-Korčula
- Subsystems Vid and Prud

- Subsystems Kula Norinska and Slivno
- Opuzen subsystem
- Janjina subsystem
- Orebić Subsystem
- Trpanj subsystem
- Korčula-Lumbarda subsystem

In addition to the regional water supply system, there is also:

- Ploče water supply system (divided into the Klokun subsystem and the Modro Oko subsystem),
- Metković water supply system,
- Blato water supply system,
- Lastovo water supply system,
- Mljet water supply system,
- Žuljana water supply system,
- Ston water supply system, and
- Slano water supply system
- Zaton-Orašac-Elafiti water supply system,
- Dubrovnik water supply system,
- Župa dubrovačka water supply system and
- Konavle water supply system (Konavle-West subsystem and Konavle-East subsystem).

It is important to mention two systems that are not located in the Dubrovnik-Neretva County, but they supply certain areas within the county, namely: water supply system Vrgorac that supplies water to the subsystem Kobiljača-Staševica and water supply system Neum that supplies water to the subsystem Moševiči-Visočani.

The water supply systems located within the study area, the control body, the catchment and the supply area are shown in Table 3.

Table 3 Water supply systems in the research area

Water supply system	Control body	Catchment	Supply area
The regional system NPKLM - Basic supply system Neretva-Pelješac-Korčula	„NPKLM vodovod“ d.o.o., Korčula	Spring Prud	Whole area
The regional system NPKLM - Subsystems Vid and Prud	„Metković“ d.o.o., Metković	Local reservoir „Prud“ – catchment Prud Local reservoir „Vid“ – catchment Prud	Prud and Vid (town Metković)
The regional system NPKLM - Subsystems Kula Norinska and Slivno	„NPKLM vodovod“ d.o.o., Korčula	Local reservoir „Kula Norinska“ – catchment Prud Local reservoir „Blace“ - catchment Prud Local reservoir „Kremena“ and „Komarna“ - cachment Prud	West part of municipality Kula Norinska and municipality Slivno
The regional system NPKLM - Opuzen subsystem	„Vodovod Opuzen“ d.o.o., Opuzen	Local reservoir - catchment Prud	Town Opuzen
Ploče water supply system – Klokun subsystem	JU „Izvor“, Ploče	Spring Klokun	Town Ploče, east part of municipality Gradac in Split-Dalmatia County
Ploče water supply system – Modro Oko subsystem	JU „Izvor“, Ploče	Spring Modro Oko	Part of municipality Kula Norinska (Desne)
Metković water supply system	„Metković“ d.o.o., Metković	Spring Doljani (BiH)	Town Metković, municipality Zažablje and Doljani (BiH)
Kobiljača-Staševica subsystem	„Komunalno“ d.o.o., Vrgorac	Spring Butina	Municipality Pojezerje and north part of town Ploče – Otrići, Kobiljača i Staševica

Source: Jakelić et al. (2009) Vodoopskrbni plan Dubrovačko-neretvanske županije

The structure of water supply companies and their activity within the region are shown in Table 4.

Table 4 Ownership structure and activity of water supply companies in the research area

Company	Ownership	Share (%)	Activity
NPKLM VODOVOD d.o.o.	Town Korčula Town Metković Municipality Blato Municipality Kula Norinska Municipality Lastovo Municipality Mljet Town Opuzen Municipality Orebić Municipality Slivno Municipality Smokvica Municipality Ston Municipality Vela Luka	2 2 21 12 11 2 8 3 4 14 9 12	- Drinking water supply - Drainage and wastewater treatment - Design, construction and supervision
JU Izvor Ploče	Town Ploče (Municipality Gradac)	100	- Drinking water supply - Drainage and wastewater treatment
Metković d.o.o.	Town Metković	100	- Drinking water supply - Drainage and wastewater treatment - Utility management, municipal waste management,cemetary management and funeral services, retail market
Vodovod Opuzen d.o.o.	Town Opuzen	100	- Drinking water supply - Maintenance of water supply systems
Komunalno d.o.o. Vrgorac	Town Vrgorac	100	- Resource user of a neighboring, supplies water to Dubrovnik-Neretva County - Utility management, municipal waste management,cemetary management and funeral services, retail market, public lighting service

Source: Jakelić et al. (2009) Vodoopskrbi plan Dubrovačko-neretvanske županije

3.2.1 Neretva river valley

The studied area of the Neretva Valley is located in the southernmost county Dubrovnik-Neretva, which is territorially organized into 22 municipalities, including 5 cities (Dubrovnik, Korčula, Ploče, Metković and Opuzen) and 17 municipalities (Blato, Dubrovnik Coast, Janjina, Konavle, Kula Norinska, Lastovo, Lumbarda, Mljet, Orebić, Pojezerje, Slivno, Smokvica, Ston Trpanj, Vela Luka, Zažablje and Župa dubrovačka). The area of the County can be divided into three basic functional and geographical units: The Dubrovnik Coast, the Lower Neretva Valley and the Pelješac Peninsula, as well as the islands of Korčula, Mljet and Lastovo.

The Lower Neretva Valley, which consists of the area of the Lower Neretva River and the coast, has an area of 414.35 km2 and includes the towns of Metković, Opuzen and Ploče, as well as the municipalities of Kula Norinska, Pojezerje, Slivno and Zažablje. The water supply of the entire county is characterized by a large number of water supply systems, 13 in number, which are of regional to local importance. The regional system Neretva-Pelješac-Korčula- Lastovo-Mljet (NPKLM) is divided into:

- Main supply system Neretva-Pelješac-Korčula-Lastovo-Mljet
- Subsystems Vid and Prud
- Subsystems Kula Norinska and Slivno
- Opuzen subsystem
- Janjina subsystem
- Orebić Subsystem
- Trpanj subsystem

In addition to the regional water supply system, there is also:

- Ploče water supply system (divided into the Klokun subsystem and the Modro Oko subsystem),
- Metković water supply system,
- Blato water supply system,
- Lastovo water supply system,

- Mljet water supply system,
- Žuljana water supply system,
- Ston water supply system, and
- Slano water supply system
- Zaton-Orašac-Elafiti water supply system,
- Dubrovnik water supply system,
- Župa dubrovačka water supply system and
- Konavle water supply system (Konavle-West subsystem and Konavle-East subsystem).

It is important to mention two systems that are not in Dubrovnik-Neretva County but supply certain areas within the county, namely: Vrgorac water supply system, which supplies water to the Kobiljača-Staševica subsystem, and Neum water supply system, which supplies water to the Moševiči-Visočani subsystem.

The water supply systems located within the PILOT AREA, the control point, the catchment area and the supply area are shown in Table 5.

Table 5 Water supply systems in the PILOT AREA

Water supply system	Control body	Catchment	Supply area
The regional system NPKLM - Basic supply system Neretva-Pelješac-Korčula-Lastovo-Mljet	„NPKLM vodovod“ d.o.o., Korčula	Spring Prud	Whole area
The regional system NPKLM - Subsystems Vid and Prud	„Metković“ d.o.o., Metković	Local reservoir „Prud“ – catchment Prud Local reservoir „Vid“ – catchment Prud	Prud and Vid (town Metković)
The regional system NPKLM - Subsystems Kula Norinska and Slivno	„NPKLM vodovod“ d.o.o., Korčula	Local reservoir „Kula Norinska“ – catchment Prud Local reservoir „Blace“ - catchment Prud Local reservoir „Kremena“ and „Komarna“ - cachment Prud	West part of municipality Kula Norinska and municipality Slivno
The regional system NPKLM - Opuzen subsystem	„Vodovod Opuzen“ d.o.o., Opuzen	Local reservoir - catchment Prud	Town Opuzen
Ploče water supply system – Klokun subsystem	JU „Izvor“, Ploče	Spring Klokun	Town Ploče, east part of municipality Gradac in Split-Dalmatia County
Ploče water supply system – Modro Oko subsystem	JU „Izvor“, Ploče	Spring Modro Oko	Part of municipality Kula Norinska (Desne)
Metković water supply system	„Metković“ d.o.o., Metković	Spring Doljani (BiH)	Town Metković, municipality Zažablje and Doljani (BiH)
Kobiljača-Staševica subsystem	„Komunalno“ d.o.o., Vrgorac	Spring Butina	Municipality Pojezerje and north part of town Ploče – Otrići, Kobiljača i Staševica

Source: Jakelić et al. (2009) Vodoopskrbni plan Dubrovačko-neretvanske županije

The structure of water supply companies and their activity within the region are shown in Table 6.

Table 6 Ownership structure and activity of water supply companies in the PILOT AREA

Company	Ownership	Share (%)
NPKLM VODOVOD d.o.o.	Town Korčula	18
	Town Metković	12
	Municipality Blato	11
	Municipality Kula Norinska	-
	Municipality Latovo	8
	Municipality Mljet	3
	Town Opuzen	4
	Municipality Orebić	14
	Municipality Slivno	2
	Municipality Smokvica	2
	Municipality Ston	7
	Municipality Vela Luka	12
	Municipality Lumbarda	3
	Municipality Janjina	2
JU Izvor Ploče	Town Ploče (Municipality Gradac)	100
Metković d.o.o.	Town Metković	100
Vodovod Opuzen d.o.o.	Town Opuzen	100
Komunalno d.o.o. Vrgorac	Town Vrgorac	100

Source: Jakelić et al. (2009) Vodoopskrbi plan Dubrovačko-neretvanske županije

4. COASTAL AQUIFERS MONITORING AND DATA MANAGEMENT

4.1. Costal aquifers monitoring and data management

D.Lgs 30/2009, that implements the Directives 2000/60/EC, 2006/118/EC and integrates and partially modifies D.Lgs 152/2006 about the characterization and identification of groundwater bodies, establishes the threshold values and quality standards to define the good chemical status of groundwater. Moreover, defines the criteria for quantitative monitoring and classification of groundwater bodies or groups of them.

In particular, it defines:

a) criteria for the identification and characterization of groundwater bodies;

b) quality standards for certain parameters and threshold values for other parameters necessary for the assessment of the good chemical status of groundwater;

c) criteria for identifying and reversing significant and lasting trends in the increase in pollution and for determining the starting points for such reversals;

d) criteria for the classification of the quantitative status;

e) arrangements for the definition of qualitative and quantitative monitoring programs.

4.1.1. Marche Region and coastal area

In the Marche Region there are 49 groundwater bodies (CIS) of which 24 are at risk (as identified by Regional Decree n.2224/2009) which are kept under control by a monitoring network consisting of 233 monitoring stations of both quantitative and qualitative status. This monitoring network is managed by the *Regional Environmental Protection Agency of the Marche Region (ARPAM)*. In particular, ARPAM systematically monitors the groundwater (and the surface waters) throughout the Marche Region. Since 2009 the monitoring survey has been gradually adapted to the criteria established following the transposition of the Directive 2000/60/EC.

The following activities are carried out by ARPAM*: i) management of a three-year monitoring plan; ii) measurements and sampling of the groundwater level and flow; iii) chemical and biological analyses; iv) transmission of information and data to the Higher Institute for Environmental Protection and Research* (*ISPRA - which is the institutional entity responsible for all the management at a national level of information on water protection in Italy*) *through the SINTAI* (*Information System for the Protection of Water in Italy*)*; and v) processing of data and production of classification reports of the analyses*.

On a semestral basis, ARPAM performs the monitoring of two wells located within the study area of the Fano municipality (Fig. 4). Thus, two groundwater sampling campaigns per year are carried out usually in spring and late autumn, with analyses of the following parameters: piezometric level, temperature, pH, electrical conductivity, Cl^-, SO_4^{2-}, NO_2^-, NO_3^-, Na^+, NH_4^+, Ca^{2+}, Mg^{2+}. Additionally, ARPAM monitors two points on the Metauro river (Fig. 5), where the following parameters are analyzed: temperature, pH, electrical conductivity, Cl^-, SO_4^{2-}, NO_2^-, NO_3^-, NH_4^+, Ca^{2+}, Mg^{2+}.

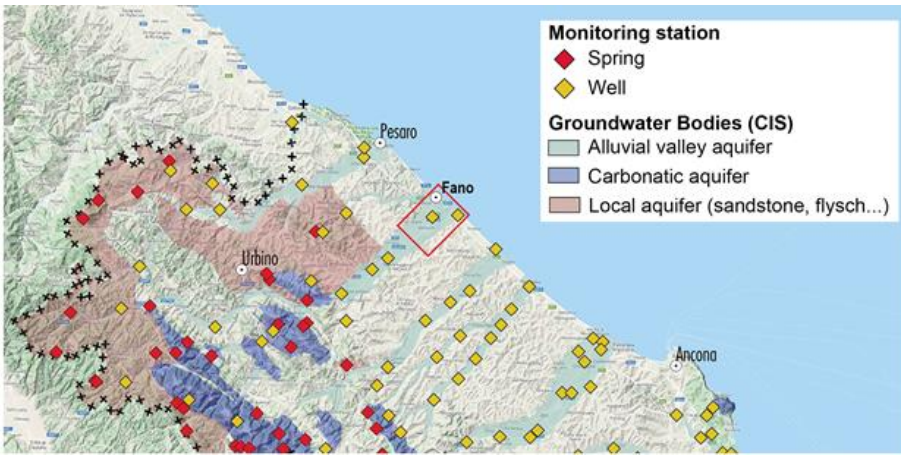

Fig. 4 ARPAM springs and wells monitoring network of the northern part of the Marche Region. The Fano municipality studied area and the groundwater bodies type are also reported.

Locally, ASET S.p.A. also runs analyses on the physico-chemical characters of the groundwater. In fact, to ensure the correspondence of the water supplied to the current standards imposed by the regulations, the own laboratory of the multi-utility company continuously analyses samples of drinking water taken from the various points located throughout the managed territory. ASET S.p.A. has a monitoring network constituted by 28 water wells localized on the Metauro valley and directly managed by the company itself (Fig. 5) from which, at least once per year, takes samples for the chemical analyses. Besides this fixed network, many other private wells located in the study area are used sporadically for monitoring purposes. The chemical parameters analyzed by ASET S.p.A. varies during the different campaigns, but they generally comprise the following parameters: temperature, pH, electrical conductivity, water hardness, Si, HCO_3^-, NH_4^+, NO_2^-, NO_3^-, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+}, Al, Sb, As, B, Br, Cd, $Cr_{(t)}$, Fe, F, Mn, Hg, Ni, Pb, Cu, Se, V and Naphthalene. Beyond the complete geochemical annual campaigns, ASET S.p.A. performs many different (from 7 up to 14 per year) analyses for the monitoring of the Nitrate concentration in the groundwater, according to the current national and regional legislation.

Concerning the “transmission of information and data to the ISPRA”, ARPAM must communicate the monitoring data through the *SINTAI* designed and implemented by ISPRA. This system is part of those operations and organizational frameworks governed by Ministerial Decree 198/2002 for the standardization of information and the roles of institutional responsibility in the collection, transmission, storage and dissemination of information. SINTAI was created with open-source technologies, available on the Internet, which allows easy access to information and services for the transmission, standardization and certification of information. Information at a national level, in the standard formats established by the standards, is also collected and processed in response to Community obligations.

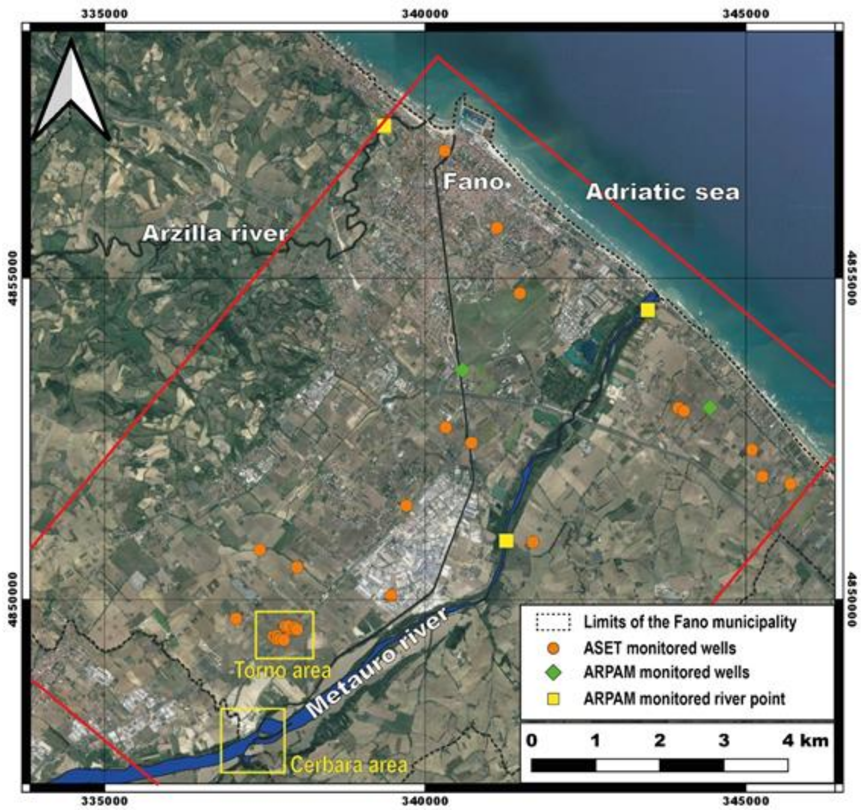

Fig. 5 Monitoring network of wells managed by ASET S.p.A. in the Fano municipality. Two of these wells are also monitored by ARPAM, along with two points on the Metauro river and one in the Arzilla river (in the northern part of the valley). The Torno recharging area and Cerbara catching zone are also reported.

ISPRA joins to the interchange formats established at the European Community level, both in collaboration with the EEA (European Environment Agency) with regard to the Community data flow EIONET, and, above all, as it constitutes, within the national SINTAI, the Italian node of the WISE (*Water Information System for Europe*), the Community reporting system following the Community Directive 2000/60/EC. The SINTAI is implemented and managed by ISPRA's Department for Environmental Monitoring and Conservation and Biodiversity Conservation. Access to the system is free for the Local Authorities that have a reserved area for download and upload operations, through which data transmission standards are implemented. Access to the reserved area of the SINTAI is available also for ISPRA, the *Ministry for the Protection of the Environment, the Territory and the Sea*, the *Regions* and *Autonomous Provinces*, the regional *ARPA* and the *APPA* (*Provincial Environmental Protection Agency*).

At the local scale, the values of the fundamental parameters of distributed water, as established by the *Service Charter*, are communicated in the annex to the consumption invoices and published, at least bi-monthly, on the ASET S.p.A. website (http://www.asetservizi.it/laboratorio-analisi/servizi-allutente/analisi-acque-online/).

4.1.2 Emilia-Romagna region and coastal area of Ravenna

The groundwater bodies identified in the Emilia-Romagna Region Water Protection Plan (2005) have been revised and adapted to the Directive 2000/60/CE. Fig. 6 represents the upper confined portions of floodplain conoids and floodplain water bodies. In Fig. 7 we report the map of the lower confined groundwater body in the Ravenna province.

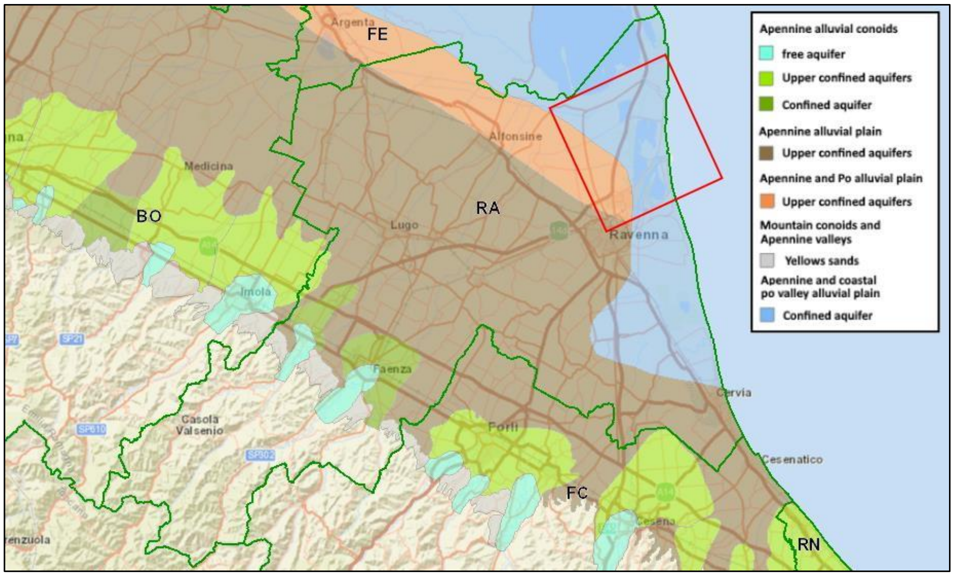

Fig. 6 ARPAE map of free or upper confined groundwater body (https://www.arpae.it/v5_asot.asp?idlivello=247) in the Ravenna province. The red line indicates the Ravenna study area.

Groundwater bodies were identified taking into account the environmental status\conditions defined through groundwater monitoring carried out in Emilia-Romagna since 1976 and then considering existing pressures and impacts.

For each identified groundwater body, a risk analysis was carried out to define the attainment of good status as of 2015, whether chemical or quantitative analysis.

Waterbodies "not at risk" and "at-risk" were identified, indicating in the latter case the chemicals for which the water body is at risk. Based on the results of the risk analysis and taking into account the anthropic pressures, a grouping of water bodies was adopted, aimed to optimizing environmental monitoring, in the period 2010-2015.

Commentato [1]: Chemical components/elements?

The annexes to Emilia-Romagna Regional Council Resolution no. 350 of February 8, 2010 contain the analysis of pressures, the criteria adopted for the identification of new water bodies and their delimitation, the identification of monitoring networks (quantitative, surveillance and operational) and monitoring programs with which analytical protocols and measurement and sampling frequencies have been identified.

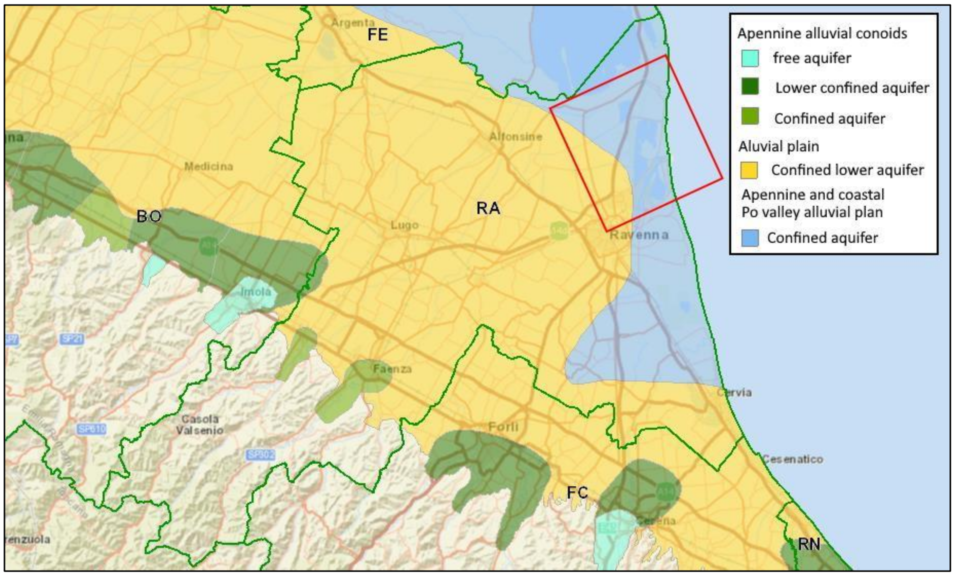

Fig. 7 ARPAE map of lower confined groundwater body (https://www.arpae.it/v5_asot.asp?idlivello=247) in the Ravenna province. The red line indicates the Ravenna study area.

Following the criteria dictated by the D.Lgs. 30/2009 and the information available in the knowledge framework of the Water Protection Plan (PTA) of the Emilia-Romagna Region (2005), it was possible to identify and delimit the new groundwater bodies according to the Directives 2000/60/CE and 2006/118/CE. In particular, new groundwater bodies have been identified and characterized starting from hydrogeological complexes to aquifers, taking into account the homogeneity of chemical and quantitative status as well as impacts caused by anthropogenic pressures.

The lowland aquifers have been distinguished by depth also according to anthropogenic pressures and impacts, while the highland and mountain groundwater bodies are completely new to monitoring (Table 7).

The monitoring network of the Emilia Romagna region is managed by the Regional Environmental Protection Agency of the Emilia Romagna (ARPAE). ARPAE makes available a large set of data and documents in its web portal (https://www.arpae.it/it/temi-ambientali/acqua) through an interactive WebGis based cartography. In this portal, it is possible to visualize the current monitoring network for groundwater and surface water.

Table 7 Number of Water Bodies for each hydrogeological complex in the Emilia Romagna regional area

Quaternary depressions alluvium (DQ)		
Lowland phreatic aquifer	-	2
Apennine alluvial conoids	free aquifer	29
	upper confined aquifers	31
	lower confined aquifers	26
Apennine alluvial plain	upper confined aquifers	1
Apennine and Po Valley alluvial plain	upper confined aquifers	1
Po Valley alluvial plain	upper confined aquifers	1
Apennine and coastal Po Valley alluvial plain	confined aquifers	1
Alluvial plain	lower confined aquifers	1
Plio-Quaternary plateau detrital formations (DET)		
Mountain conoids and Apennine beaches	Yellows sands	2
Valley alluvium (AV)		
Deposits of the Apennine valleys	-	1
Local aquifers (LOC)		
Mountain water body	(LOC1.1)	2
	(LOC1.2)	31
	(LOC3.1)	16

The monitoring of groundwater bodies in Emilia-Romagna, as required by D. Lgs. 30/09, is carried out through 2 monitoring networks (as shortly mentioned above for the "risk" of water bodies):

- Network for the definition of the quantitative status
- Network for the definition of chemical status.

The monitoring of 135 groundwater bodies takes place through 733 stations, 600 of which for the definition of chemical status and 633 for quantitative status. Within the study area (evidenced by a red color in Fig. 8) there are about 8 monitoring network points.

Quantitative monitoring is carried out to provide a reliable estimate of the available water resources and to evaluate the trend over time, and to verify if the variability of the recharge and the withdrawal regime are sustainable over the long term.

Monitoring for chemical status definition is divided into the following programs:

- Surveillance monitoring
- Operational monitoring

Surveillance monitoring shall be carried out on all groundwater bodies and depending on the previous knowledge of the chemical status of each water body, the vulnerability and the rate of groundwater renewal.

There are three different surveillance monitoring schedules:

- surveillance with initial frequency (basic and additional parameter) shall be carried out at monitoring stations of water bodies for which knowledge of the status is inadequate and previous chemical data are not available and in any case only for the initial period of surveillance monitoring;
- long-term frequency surveillance for basic parameters shall be carried out during 6 years in the monitoring stations of water bodies for which the knowledge about the status is good. The analytical profile includes only basic substances;
- long-term frequency surveillance for additional parameters shall be carried out within 6 years at monitoring stations of water bodies with good knowledge of their status. The analytical profile includes additional substances and the frequency is lower than the long-term surveillance monitoring for basic parameters.

For groundwater bodies identified at risk of not achieving good status, it is necessary to program, in addition to the surveillance, also operational monitoring with an at least annual frequency and in any case to be carried out between two monitoring periods of surveillance.

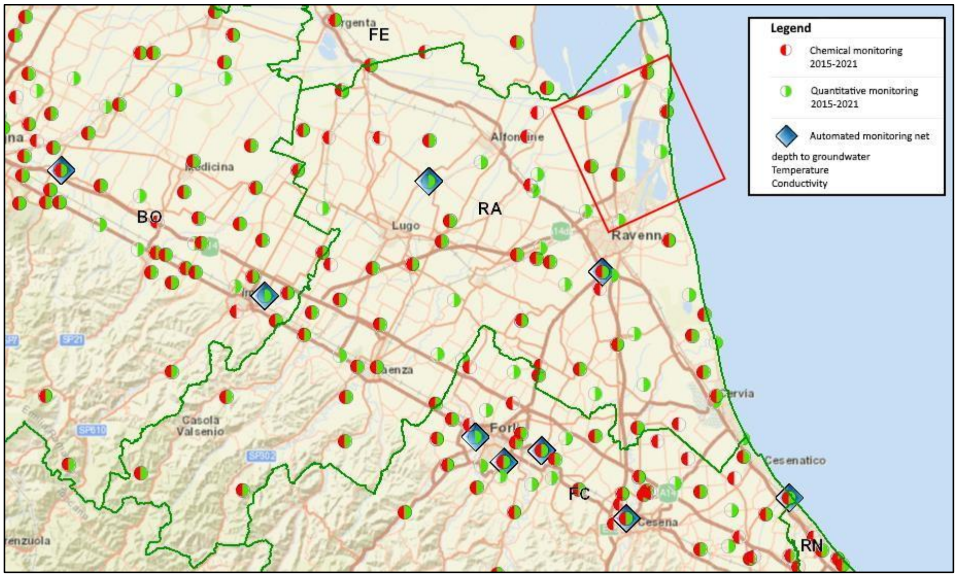

Fig. 8 ARPAE groundwater monitoring network in the Ravenna province. The red line indicates the Ravenna study area.

Considering the complexity of managing the different types of monitoring provided it was decided to identify a different set of analytical profiles. Each analytical profile summarizes the homogeneous characteristic parameters of chemical-physical analysis for each particular environmental requirement.

The Basic profile is always foreseen in any type of monitoring and can be completed and integrated with the other analytical profiles allowing to have in this way a modular analytical screening. Therefore, the applicable analytical profiles in groundwater monitoring are:

- Basic analytical profile (B)
- Additional Analytical Profile of Plant Protection Products (F)
- Additional Analytical Profile of organohalogens (O) and Ethers
- Additional Analytical Profile Other Hazardous (P)

- Additional Analytical Profile Isotopy (OD)
- Additional Microbiological Analytical Profile (M)
- Initial Analytical Profile (I)

Similar to groundwater, the Emilia Romagna region has implemented an efficient monitoring system for surface water (natural river, channels, lake, ponds…). Waters are assessed and classified within the basin and by the hydrographic district to which they belong. For each river basin district, a Management Plan (PdG) has been implemented. The Management Plan is a cognitive, strategic and operational tool through which planning, implementing, and monitoring the measures for the protection, restoration and improvement of surface and groundwater bodies, favoring the achievement of the environmental objectives foreseen by the European Directive. For all water bodies, by 2015, each Member State must achieve "good" status and ensure that "high" status is maintained if already achieved.

The legislation divides surface waters into the following categories: river, lake, transition (inland waters) and marine-coastal. According to the provisions of the Directive, the basic unit of assessment of the state of the water resource is the "water body", i.e. an element of surface water (river stretch, a portion of a lake, a transition zone, a portion of the sea) belonging to a single type with homogeneous characteristics in relation to the state and subject to the same pressures. Each water body must therefore be characterized through an **analysis of the pressures** that insist on it **in addition to the quality status**. The classification of the quality status depends on several technical analyses defined by the implementation decrees of DLgs. 152/06:

- type of surface waters (based on natural, geomorphological, hydrodynamic and chemical-physical characteristics);
- pressure analysis;
- the identification of surface water bodies understood as homogeneous portions of water;

- the attribution to each water body of a class of risk to not achieving the quality objectives provided at European level quality objectives.

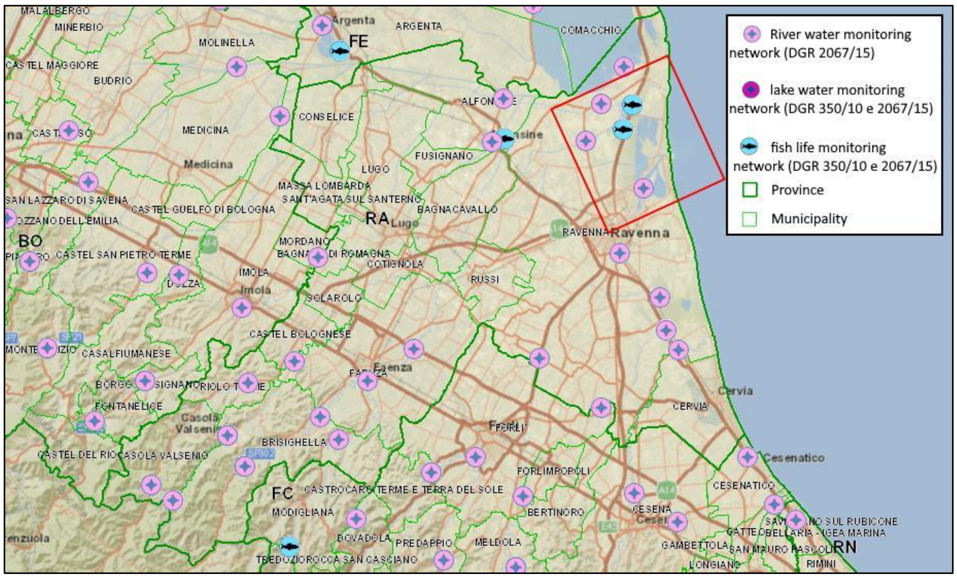

Fig. 9 ARPAE surface monitoring network in the Ravenna province. The red line indicates the Ravenna study area.

With the results of the risk analysis and the indications foreseen by the European Directive, it was possible to redesign the monitoring networks and revise the monitoring programs.

The monitoring strategy is distinguished into:

- surveillance monitoring for water bodies "probably at risk" or "not at risk" of reaching the environmental objectives foreseen by the regulations by 2015;
- operational monitoring for water bodies "at risk of not achieving environmental objectives".

The monitoring network in the Ravenna province is shown in Fig. 9.

For surface water bodies, the "environmental status", an overall expression of the status of the water body, is defined from the assessment of the "ecological status" and "chemical status".

“Ecological status" is an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters. The following elements contribute to its definition a) biological elements (macrobenthos, phytoplankton, macrophytes and fish fauna); b) hydro-morphological elements, supporting the biological elements; c) physical-chemical and chemical elements, supporting the biological elements.

Extensive information and details on the monitoring networks are available on the institutional pages of ARPAE (https://www.arpae.it/index.asp?idlivello=112) and Regione Emilia Romagna https://ambiente.regione.emilia-romagna.it/it/geologia/cartografia/webgis-banchedati/).

It is also possible to download detailed periodic reports on water quality (chemical, physical, quantitative, etc.) for the various surface and deep-water bodies.

4.2. Croatia: Coastal aquifers monitoring and data management

According to Water Framework Directive, it is necessary to distinguish between the terms aquifer and groundwater bodies. An aquifer is an underground layer or layers of rocks or other geological deposits of sufficient porosity and permeability to allow significant groundwater flow or capture of significant amounts of groundwater, while the groundwater body represents a certain volume of groundwater in an aquifer or aquifers.

According to the Regulation on the Standard of Water Quality (OG 96/19), the Regulation on Special Conditions for Conducting Water Sampling and Testing (OG 3/20), the chemical and quantitative status in each individual water body must be monitored and assessed.

The elements necessary for the assessment of the quantitative status of groundwater bodies are:

- groundwater level and
- abundance

The elements necessary for assessing the chemical status of groundwater bodies are:

- general – electrical conductivity, dissolved oxygen and pH
- pollutants – nitrates, pesticides and specific pollutants for which limit values are determined at the GWB level.

Groundwater monitoring is carried out as supervisory and operational monitoring, and if necessary as research monitoring. Supervisory monitoring is carried out in order to achieve the following:

1. supplementing and evaluating the pollution impact procedure
2. obtaining information to assess significant and continuously growing trends resulting from changes in natural conditions and as an impact of human activity.

Operational monitoring is carried out for:

1. determination of the chemical status of all groundwater bodies for which there is a risk for not achieving water protection objectives and on which changes are monitored during the implementation of the program
2. identifying significant continuously growing trends in pollutant concentrations as a result of human activity.

Both supervisory and operational monitoring are carried out every year as a part of River Basin Management Plan according to the dynamics shown in Table 8. The frequency of supervisory and operational monitoring is determined by the Decree on water quality standard. Sampling and storage of samples for chemical analysis are performed according to standards: Water quality — Sampling — Part 11: Guidance on sampling of groundwaters (HRN EN 5667-11) and Water quality — Sampling — Part 3: Preservation and handling of water samples (HRN ISO 5667-3).

Table 8 Groundwater chemical status indicators and annual analysis frequency

Indicator	Analysis frequency in supervisory monitoring	Analysis frequency in operational monitoring
Chemical status elements		
Nitrates	4x	4x-12x
Active substances in pesticides (plan protection products and biocides in accordance with the regulations on permitted active substances in them)		
Organochlorine pesticides (4,4 DDT, 2,4 DDT, 4,4 DDE, 4,4 DDD, α HCH, β HCH, γ HCH, δ HCH, HCB, heptachlor, heptachlorepoxide, heksachlorobutadien, methoxychlor, endosulfan)	4x	4x
Cyclodiene pesticides (aldrine, dieldrine, endrine, isodrine)	4x	4x
Organophosphorus pesticides (dimethoate, pirimiphos-methyl, chlorvenvifos, chlorpyrifos (chlorphyrifos-ethyl), chlorpyrifos-methyl, omethoate, pyrimphos-ethyl, glyphosate)	4x	4x
Triazine pesticides (atrazine, simazine, terbuthylazine)	4x	4x-12x
Chloroacetamides (acetochlor, s-metolachlor)	4x	4x
Specific pollutants		
Arsenic	4x	4x-12x
Cadmium	4x	4x-12x
Lead	4x	4x-12x
Mercury	4x	4x-12x
Ammonium	4x	4x-12x
Chlorides	4x	4x-12x
Sulfates	4x	4x-12x
Orthophosphates	4x	4x-12x

Nitrites	4x	4x-12x
Total phosphorus	4x	4x-12x
Trichlorethylene	4x	4x-12x
Tetrachlorethylene	4x	4x-12x
Conductivity	4x	4x-12x

In addition to the above mentioned indicators, some additional indicators listed in the Decree on water quality standard, for which standards and limit values are not defined, are also monitored within the supervisory and operational monitoring (Table 9).

Table 9 Additional indicators in groundwater and annual analysis frequency

Indicator	**Analysis frequency in supervisory monitoring**	**Analysis frequency in operational monitoring**
Basic physico-chemical indicators		
Temperature	4x-12x	4x-12x
pH	4x-12x	4x-12x
Redox potential	4x-12x	4x-12x
Total suspended particles	4x	4x-6x
Alkalinity	4x-12x	4x-12x
Total hardness	4x-12x	4x-12x
Turbidity	4x-12x	4x-12x
Dissolved oxygen	4x-12x	4x-12x
KPK Mn	4x-12x	4x-12x
Total organic carbon (TOC)	4x-12x	4x-12x
Total nitrogen	4x-12x	4x-12x
Pollutants		
Iron	4x-12x	4x-12x
Manganese	4x-12x	4x-12x
Copper	4x-12x	4x-12x
Zinc	4x-12x	4x-12x
Chromium	4x-12x	4x-12x
Nickel	4x-12x	4x-12x
Aluminum	4x	4x
Barium	4x	4x
Beryllium	4x	4x
Vanadium	4x	4x
Cyanides	4x	4x
Fluorides	4x	4x
Azithromycin, erythromycin	-	6x
Sulfamethoxazole	4x	6x
Torasemide	4x	6x
Azithromycin-N-desmethylazithromycin	4x	6x

Memantine	4x	6x
Warfarin	4x	6x
Halogenated hydrocarbons	4x-12x	4x-12x
Aromatic hydrocarbons	4x	-

In 2019, in the Republic of Croatia, supervisory monitoring was carried out at 384 monitoring stations (Fig. 10), and operational monitoring at 118 monitoring stations (Fig. 11).

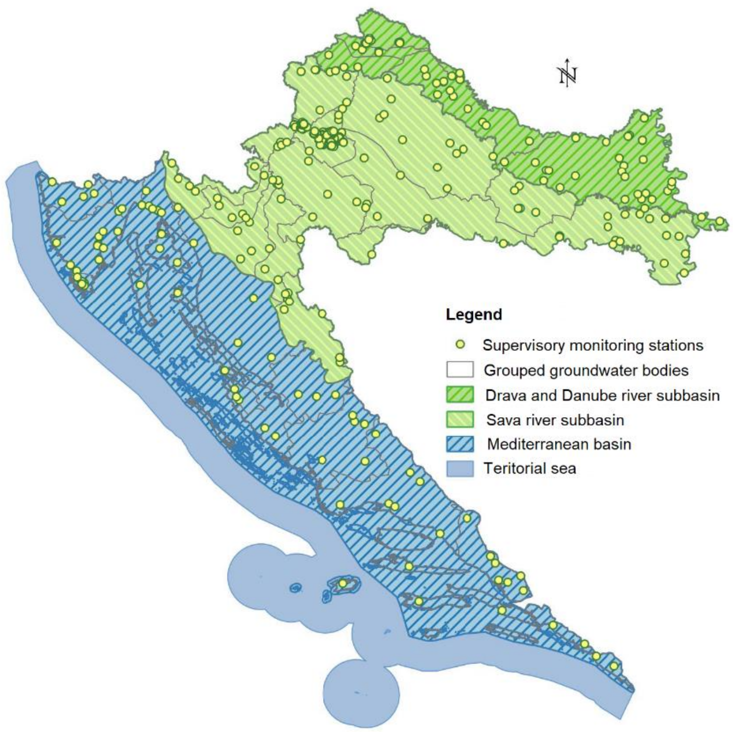

Fig. 10 Groundwater supervisory monitoring stations

Source: Hrvatske vode (2020), Izvješće o stanju podzmenih voda u 2019. godini

Fig. 11 Groundwater operational monitoring stations

Source: Hrvatske vode (2020), Izvješće o stanju podzemnih voda u 2019. godini.

In order to successfully implement adaptation measures, it is necessary to manage the entire infrastructure, and this includes:

- Maintenance and, if necessary, renovation of existing hydrotehnical facilities (pumping stations, reclamation canals, …)
- Construction of new hydrotehnical facilities

Given that the Neretva River is the largest cross boundary water body with more than 90 % of the basin in the neighboring Bosnia and Herzegovina, it is important to emphasize the importance of cross boundary impact of climate change and the impact of combined anthropogenic pressures due to changes in natural runoff in the basin. Therefore, on the Croatian side, it is necessary to carry out the planning of new interventions in this area, as well as measures for adaptation to climate change, taking into account the growing cross border impact.

4.2.1. NERETVA RIVER VALLEY

Most of the Dubrovnik-Neretva County is composed of carbonate rock, with limestone playing a dominant role. Intense tectonic movements and karst processes have shaped the environment of the reservoir. In the process of collapse, the rocks are affected to a great depth, so that channels and cavities and a very dense network of interconnected cracks develop in the subsurface. The main characteristic of the karst area is that all the rainwater that falls on them immediately sinks underground.

The drainage of groundwater accumulated in the limestone towards lower levels prevents the deposition of impermeable and low-permeability rocks of various lithological formations. Dolomites and dolomitic limestones of Triassic, Jurassic and Cretaceous or Eocene age are such barriers that stop the groundwater flows and make them appear as springs, or they are sucked upwards by the groundwater flow and spring to the sea as springs.

The well-known large karst springs in the coastal belt, in Konavle and in the Neretva valley, receive water through the permeable carbonate hinterland from Popovo polje and the Trebišnjica valley. Particularly large quantities of water flow at these springs during the wet period, when numerous springs are activated, especially in Mali Ston Bay, in Bistrina Bay, in the area between Dol and Slano and in the Konavle area.

The most important springs, which were captured for the water supply of the settlement and on which the water supply will be based in the future, are: Ombla spring, Norin river spring in Prud, Klokun, Modro oko, Duboka ljuta, Konavoska ljuta and Palata in Mali Zaton.

As for water monitoring of the Neretva water body (larger area), in 2019. monitoring surveillance was carried out at 11 stations and operational monitoring was carried out only at 1 station out of total 11 stations. Within PILOT AREA, 5 monitoring stations are listed: Butina, Banja, Prud, Klokun and Modro Oko, shown in Fig. 12. Two stations (Doljani and Žitomislići) were added to the map because they are relevant to the PILOT AREA, although they are located in neighboring Bosnia and Herzegovina.

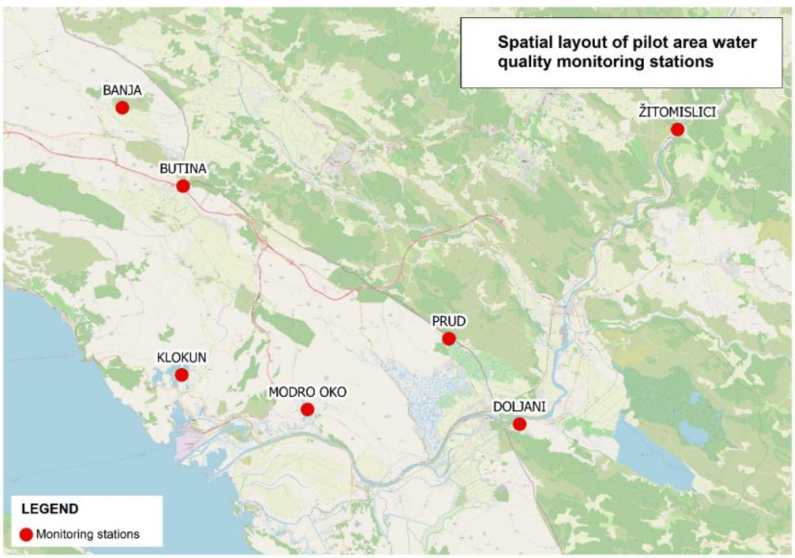

Fig. 12 Spatial layout of pilot area water quality monitoring stations

In addition to monitoring and operational controls conducted at the national level, the PILOT AREA has established long-term monitoring of salinization of surface and groundwater and agricultural soils by the University Zagreb Faculty of Agriculture (Fig. 13) and the University Split Faculty of Civil Engineering, Architecture and Geodesy (Fig. 14). Surface water is sampled at 15 monitoring stations (monthly sampling) and groundwater is sampled at 7 shallow piezometers with a depth of 4 m (monthly sampling) located in close proximity to the soil monitoring stations. Groundwater samples were also collected monthly at four pairs of shallow (10 m) and deep (35 m) piezometers, but not throughout the year, but during the period from May to October with simultaneous measurements: pH, electrical conductivity, salinity and water temperature. A total of 15 physicochemical parameters, HCO_3^-, NH_4 – N, NO_3-N, NO_2-N, PO_4-P, Cl^-, SO_4^{2-}, Ca^{2+}, K^+, Mg^{2+}, Na^+, TOC) were analyzed in all samples.

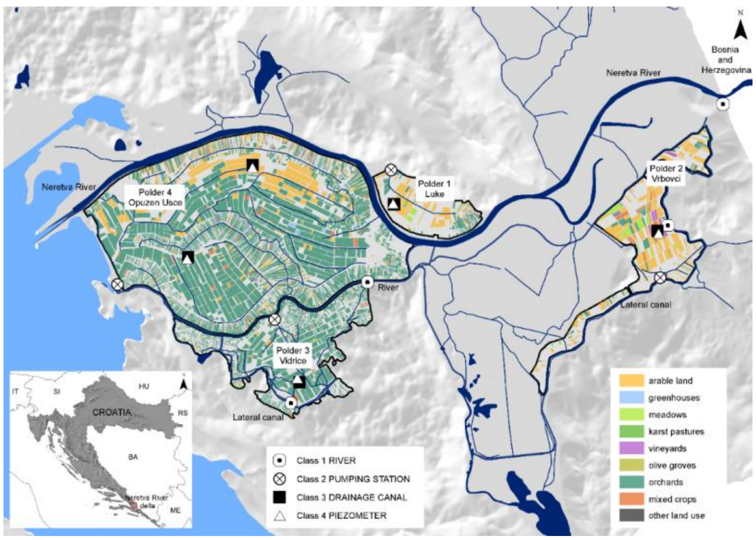

Fig. 13 Geographical setting of the long-term (2009-present) monitoring of salinization of surface and shallow groundwater and agricultural soils operated by the University of Zagreb Faculty of Agriculture. The map shows four polders (the black line indicates the boundary of each polder), agricultural land use and locations of monitoring stations in the lower Neretva Valley (Croatia)

Fig. 14 Geographical setting of the long-term (2009-present) monitoring of salinization of groundwater operated by the University of Split Faculty of Civil Engineering, Architecture and Geodesy.

5. GROUNDWATER EXPLOITATION

5.1. Italy: Costal aquifers exploitation (Ravenna and Fanno)

5.1.1. FANO

ASET S.p.A. has a groundwater monitoring network constituted by 28 water wells localized on the Metauro valley and directly managed by the company. Anyway, the groundwater constitutes only a really limited resource of the local drinking water supplied by the company to the population. This is mainly because of the high nitrate concentrations measured in the groundwater, usually higher than 50 mg/l which is the limit recommended by the World Health Organization and by the Italian Regulation (**European Directive 91/676/EC** and **D.M. n.5046 of the 25/02/2016**). The main resource of the distributed drinking water is supplied by the superficial water of the Metauro river, taken:

- in the inner parts of the valley (Tavernelle town, about 15 km SW of Fano) and then processed through a drinking method, before being delivered by the inter-municipal Aqueduct at the pick-up points located in Municipality of Fano;
- in Cerbara (about 8 km SSW of Fano) and used to partly recharge the aquifer in the Torno area (Fig. 15).

In the Tavernelle extraction point, about 600 l/s are catched from the Metauro river. Of this rate, ~200 l/s are addressed towards the Fano municipality, while the remaining part is directed to other municipalities located nearby. Additional ~100 l/s are extracted from the Metauro river in the Cerbara area (Fig. 3). A little less than a half of this flow (~43 l/s in 2020; Fig. 15) is injected in the Torno area (Fig. 3) in order to recharge and dilute the phreatic aquifer, partially reducing the nitrate concentration. The limited role of the groundwater regarding the drinking water supply is also testified by the low extraction rates measured in the ASET S.p.A. wells. In fact, only about 10.1 l/s are extracted, on an annual average (Fig. 15), in the municipal territory by these wells. This rate increases in the summer season (July-August), in accordance with the lower hydrometric levels of the Metauro river that cause a decrease in the extraction rates from this latter.

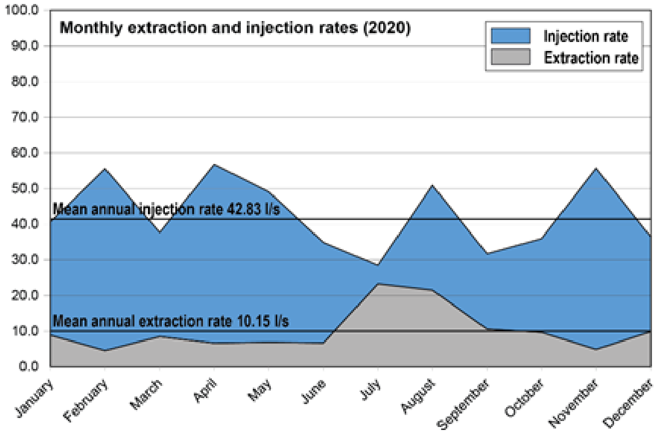

Fig. 15 Extraction and injection rates related to the Metauro river phreatic aquifer. Data are related to the year 2020.

Unfortunately, due to lack of data, the exploitation rates of groundwater reported in Fig. 15are just a supposed lower limit of the anthropic pressure on the aquifer. In fact, 4,175 registered private wells are located in the municipal area (Fig. 16a), and ~2,450 falls inside the alluvial valley, i.e. the study area (Fig. 16b). Of these wells, ~1,560 are classified as domestic (i.e., for irrigation of small areas), ~710 as agricultural and ~170 as industrial. The impact of these wells on the water extraction rate quantification is difficult to be assessed, as there is no automated system that counts this data. In fact, has been estimated through 29 self-declarations of industrial or agricultural well-owners sent to Aset in 2018, that an additional ~2.3 l/s (on an annual average) is extracted from the phreatic aquifer. This data represents only 3% of the total industrial/agricultural wells registered in the area, and consequently just a small part of the real extraction rate that insists on the groundwater.

Finally, the water coming both from the Cerbara area and from the production wells of the Torno area (Fig. 15) flows to a storage tank where it is then mixed with all the other waters (both the purifier of "S. Francesco di Saltara", and the municipal wells) and fed into the network. Before the input in the aqueduct, the water is examined with a special remote-

Commentato [MZ2]: PLS Check this

control system to verify its quality, with particular reference to the concentration of nitrates.

In the framework of the Ambit Plans, as defined by D.Lgs 152/06, particular attention is paid to the optimization and implementation of the water resource, also from an economic point of view. In the case study of Fano, ASET S.p.A. develops a water loss recovery policy through an annual program for the repairing and upgrading of the aqueduct network in those sections where the poor state of conservation of the pipes prevents normal supply to users, intending to increase the efficiency of the pipelines and to save money thanks both to the recovery of losses and to the decrease in pipeline maintenance.

The pursuit of the water loss recovery policy has prompted ASET S.p.A. to use technologies suitable for the flow control mechanisms and pressures of the district systems, allowing the self-regulation of pressure within sections of the water network (called districts), belonging to the drinking water distribution systems. This is aimed to achieve: i) a significant reduction of water leaks caused by the normal state of the plant (due to cracks in the pipes, leakage in joints, etc.); ii) a significant reduction in the fraction of the end-users water consumption that would be wasted; iii) a reduction of pipe stress and consequently the possibility of creating new cracks and iv) a reduction of energy consumption. The reduction of the pressure in the inlet pipe to the district, modulated in relation to the daily trend of the volumes of water consumption and the most unfavorable dispensing points to be achieved, has allowed positive results in the framework of the planned objectives.

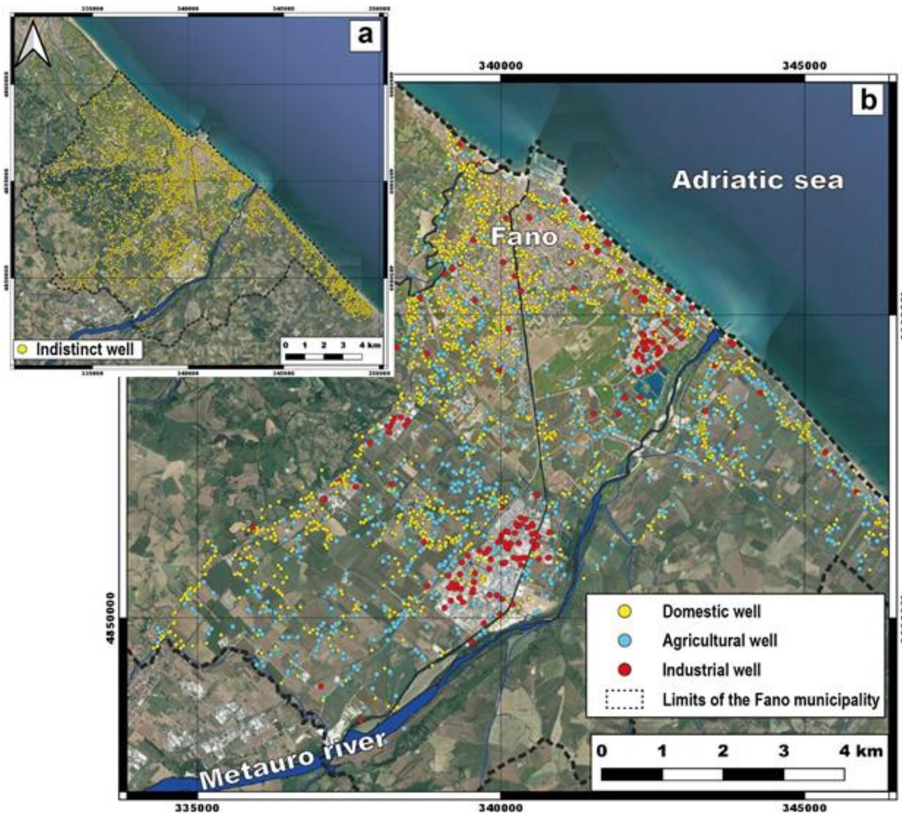

Fig. 16 a) Location of the registered wells in the municipality of Fano; b) location of domestic, agricultural and industrial wells in the study area (updated to 2020).

Another tool used by the water manager is the so-called "Remote Reading" applied to water users, which is an advanced management instrument that, in addition to allowing the reading of consumption remotely, allows to detect in a timely manner the presence of leaks in the public network and in private plants, permitting a quick decisive action. The leaks are accounted by means of a device connected to the entrance to the district that measures the incoming water. The volume of leakage within the district result from the difference between the amount of water measured by the device and the overall water recorded by the user meters in the district.

5.1.2. RAVENNA

The Emilia-Romagna coast consists of low, sandy coast and, to the north, of a delta lagoon system at the mouth of the Po river. In the northern part, the area behind the coast lies at lower altitudes than sea level and contains wetlands with a very significant natural environment. The southernmost part of the coast is instead characterized by almost continuous urbanization.

Fig. 17 SEQ Figure * ARABIC 10 Framework map of the study area

The study area is located in the northern part of the Ravenna coastal zone (Fig. 17) and is characterized by intense exploitation of surface and deep waters. Deep and Shallow aquifers are continuously monitored as seen in the previous section. The exploitation of the groundwater resource is developed through a series of public and private wells. As visible in Fig. 17, the study area does not have many wells except for private agricultural use and often very modest concessions. The wells are exploitable only after a concession by the Emilia Romagna Region, which imposes the maximum and the average flow rates. In addition, they report the annual volume that can be exploited from the well. Currently, there is no monitoring system of the actual flow rates from deep aquifers. The impact of these wells on the water extraction rate quantification is difficult to assess as there is no automated logger system for these data.

The coast and the first inland area is a dynamic environment whose balance depends on the interaction between natural factors, such as sea level variation, weather and sea conditions, river sediment supply, subsidence and human factors. Climate change will contribute to altering these complex mechanisms, worsening environmental quality and decreasing the safety of the area and its suitability for human activities. In particular, coastal areas are subject to numerous pressures resulting from human activity (aquaculture, fishing, tourism, urbanization and pollutant loads from the hinterland), which make them particularly vulnerable to sea warming and rising and to the variability of freshwater supplies from river basins.

In the post-war period, the Ravenna area has experienced a strong industrial development thanks to the creation of an oil refinery and the development of natural gas reservoirs discovered inland and in the nearby off-shore. The exploitation of water resources (both deep and superficial) and of hydrocarbon resources (especially from the '70s to the '90s) has led to a significant subsidence problem in the Ravenna coastal area. Mining activities essentially ceased at the end of the last century (this significantly decreased the local induced subsidence rate) and only cyclic underground storage activities remain, which negligibly affect elevation changes in the area (about 1-2 mm/year measured by ARPAE in 2016/2017). The actual subsidence trend in the study area is shown in Fig. 18.

Commentato [MZ3]: Check this

In addition to the anthropic activities report above there is the local effect of climate change that can be summarized as follow:

- relative mean sea level rise (i.e. sea level rise due to climate change plus land subsidence: 5,6 mm/year from 1994 to 2016 (data from ENEA);
- Coastal erosion;
- a decrease in precipitation of about 25/50 mm/year in the period 1991-2006 compared to the period 1961-1990 (ARPAE data, Fig. 19);
- a 10 m^3/s decrease of the maximum discharge of the Lamone river (ARPAE data);
- an increase in average temperatures: maximum +0.4°C per decade over the last 50 years, minimum +0.2°C per decade (ARPAE data);
- marine ingression and intrusion
- salt contamination of soil and groundwaters;
- increase of tropical species;

Commentato [MZ4]: Check this

The combined effect of climate change with the progressive increase of the mean sea level, low land elevation (often lower than mean sea level as shown in Fig. 14), and deep and surface waterbody exploitation resulted in a certain fragility of the coastal zone and natural wetlands that host important biodiversity. An example of this fragility is shown in Fig. 13 where the coastal areas subject to saltwater ingression is reported.

The inland areas are characterized by wetlands that are in continuous evolution. In natural conditions, they are ecologically dynamic environments, in which the rivers periodically penetrate, changing the water in a constant outflow and regularly renewing the seabed. This condition must be maintained to preserve the natural elements that characterize these wetlands.

This requires:

- high availability of water during all the periods of the year, but especially at the end of winter and, for possible emergencies caused by drought and hot periods, in summer;
- more intake points (both for safety reasons and for better hydraulic circulation);
- efficient drains (to govern levels and allow flushing).

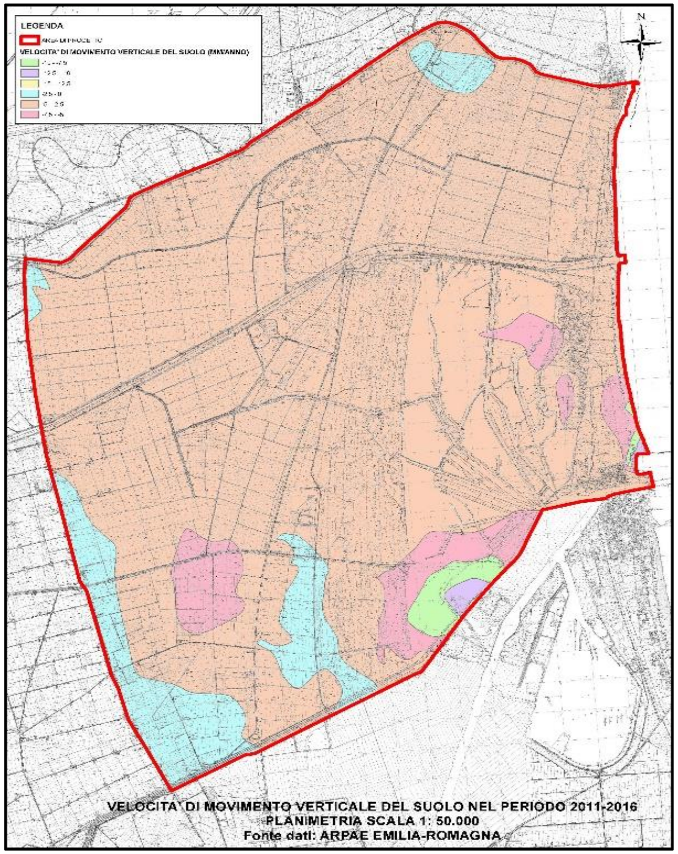

Fig. 18 Map of vertical ground movement of the study area.

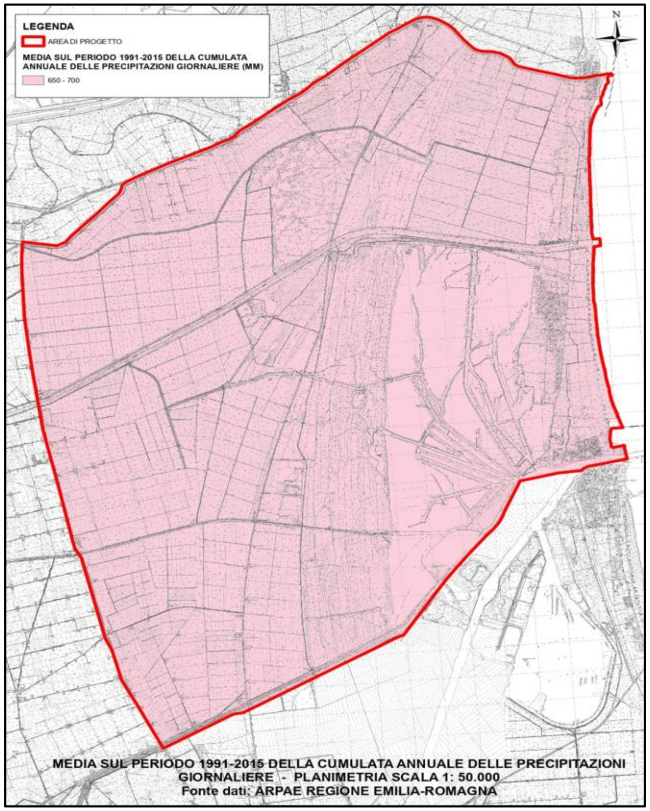

Fig.19 Average over the period 1991-2015 of the annual cumulative daily precipitation.

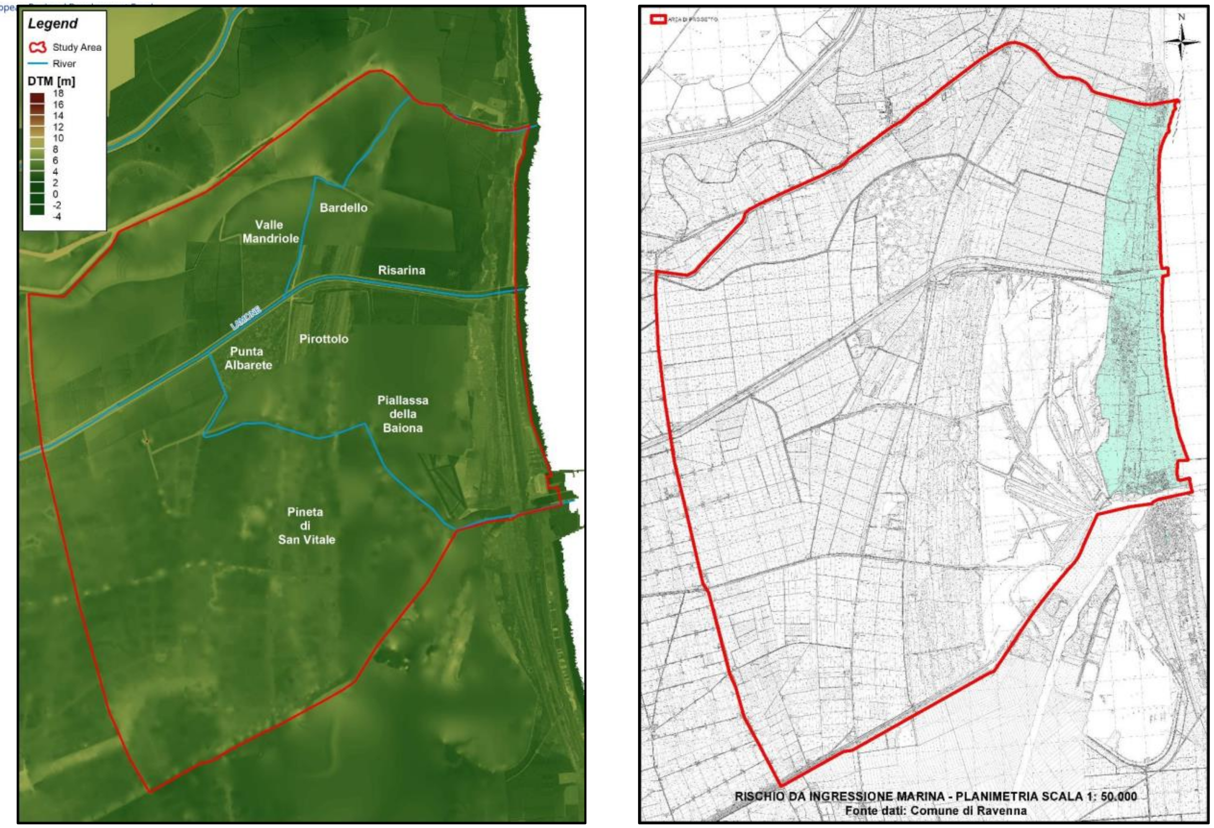

Fig. 20 Risk of marine ingression in the study area

Historically, the Ravenna territory has always been affected by the presence of vast marshy areas generated by the dynamic nature of the morphology of the territory, strongly influenced by the phenomenon of coastal progradation (Bondesan et al, 1995). This advancement of the coastline, enhanced by sediments transported largely by the Apennine Rivers and the Po River, has generated over the centuries the current coastal territory of the province of Ravenna. At the same time, the phenomena of subsidence and eustasy have then kept part of this territory below sea level, favoring the formation of large marshland complexes of both fresh and brackish water (Bondesan et al, 1995, Buscaroli et al, 2011). The marshy areas were extended not only in the coastal area but also in the inner territories of the Bolognese plain, especially in the south of the Po di Primaro (today Reno), as widely documented by the cartographies of various historical periods (Fabbri et al, 1987). The increasing demand for agricultural land over the centuries has required several land reclamation works that have drained most of the marshland complexes, radically transforming the landscape and cultural aspect of the territory (Fabbri et al, 1987). Punte Alberete and Valle Mandriole,

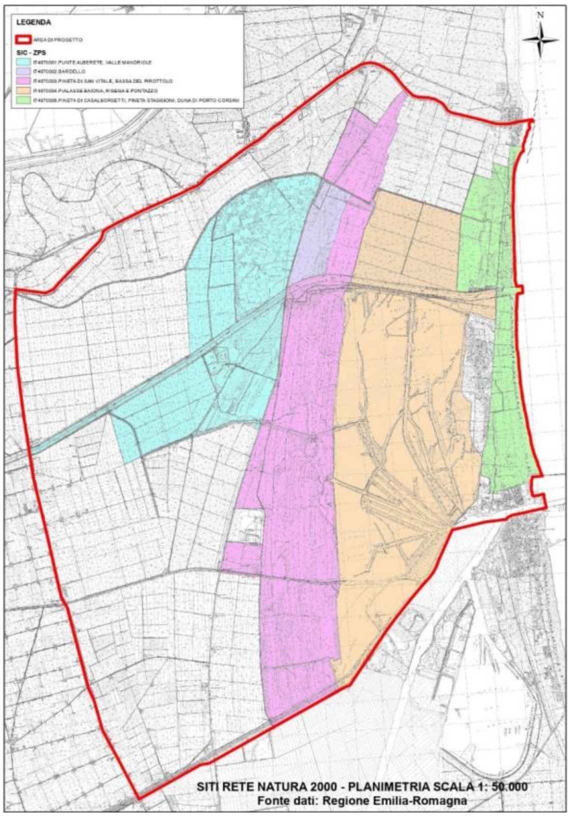

Fig. 21

together with the neighboring Bassa del Bardello, represent what remains today of the ancient freshwater marshland complexes of the Ravenna plain (Lazzari, 1994). The origin of the two biotopes of Punte Alberete and Valle Mandriole traditionally dates back to 1839 during an exceptional flood event that caused the breaking of the banks of Lamone river near Ammonite (RA), and that caused the flooding of almost 8000 ha of land in the territories north and west of Ravenna (Lazzari, 1994). The papal government later decided to transform the flooded area into a "floodplain" of the Lamone River with the intent to proceed to the reclamation of these territories. For more than a century, the floodwaters of the Lamone River were poured into the wide swamp, favoring the Apennine sediments to deposit, which slowly buried it generating new agricultural lands. At the beginning of the '60s of the XX century, from the original 8000 hectares of marshland only about 570 hectares distributed between Punte Alberete, Valle Mandriole and the neighboring “Bassa del Bardello” remained (Lazzari, 1994). In this period, some environmental activists, recognizing the environmental and ecological value of the marshlands, succeeded in preventing the definitive filling of the marshlands by interrupting the reclamation operations. Because of the environmentalist effort, the area of Punte Alberete was declared an oasis of faunal protection in 1968. As to Valle Mandriole, it was necessary to wait until 1977 when both wetlands were established as "wetlands of international importance" protected under the Ramsar Convention (Lazzari, 1994).

Starting from 1968, the management interventions aimed at maintaining the area of Punte Alberete began, with the aim of avoiding silting by natural floodings (Lazzari, 1994). To solve the problem, in 1972 the Civil Engineers of Ravenna definitively forced the course of the Lamone River between two banks and rectified it close to the sea, thus preventing the Apennine sediments transported by the river from depositing in the valleys (Lazzari, 1994) and definitively separating the two wetlands as we can see today.

In addition to Punte Alberete and Valle Mandriole, there is an additional small temporary wetland present within the historic San Vitale Pine Forest, an ancient forest complex adjacent to the two above-mentioned wetlands. It is a small pond of modest size developed in correspondence of an interdunal lowland whose presence is mainly linked to the intensity of rainfall. The ancient pinewood of San Vitale represents what remains today of an ancient and very extensive forest complex present in the Ravenna area since the early Middle Ages, composed mainly of domestic pine (Pinus pinea) (Fabbri, 1998).

The river Lamone and Reno are of vital importance to preserve the biodiversity of the marsh area and to mitigate the salinization on the coastal area and in the first hinterland. Unfortunately, freshwaters of these rivers are used intensively for agricultural practices and human water supply.

The Lamone river receives part of the water of the “Canale Emiliano Romagnolo” (CER) at Pieve Cesato (near Faenza). Part of the water is then diverted in correspondence of the crossroad called "Carrarino". The CER water is derived from the Po river with a variable rate according to the season. Basically, CER waters use the Lamone as a carrier to be brought to the Carrarino derivation, from which the water is brought to Punta Alberete and the “Valle della Canna" and then to the “ANIC" channel to serve the industrial area and as drinking water for the city of Ravenna. Currently the discharge water of the Lamone River, in the period between October and April, is free to flow directly into the sea, meaning the loss of a precious resource for natural environments and agriculture. In summer water must be artificially conveyed in the area from the Po River, entailing high energetically and economic cost. Allowing that this freshwater to be wasted impedes us to benefit from a precious resource to face the effects of climate change.

The waters of the Reno River are similarly used to recharge various ponds characterized by high salt concentrations. Recharge systems are carried out through a series of artificial channels and hydraulic systems (floodgates) in order to optimize the flow of freshwater within the natural marsh areas.

The area comprises about 500 hectares of wetlands characterized by the presence of freshwater environments that are increasingly difficult to maintain because of the increase of drought periods, meaning the scarcity of freshwater and a quality decrease in terms of physic-chemical parameters, especially over summer. Moreover, the area comprises very extensive woods (about 1,200 hectares) that require the presence of freshwater to counteract the salinization of the aquifers and soils, toxic for the trees, and 1.100 hectares of brackish water lagoon, that need fresh water to keep the right balance with the salty seawater. Finally, there are about 3,000 hectares of agricultural land threatened by the lack of fresh water and the consequent progressive salinization.

The regulation of surface water in this area is extremely complex and controlled mainly by the water of the Lamone and Reno rivers. In Fig. 22 we report a schematization of water circulation from Lamone river intake to the Punta Albarete and Mandriola wetlands.

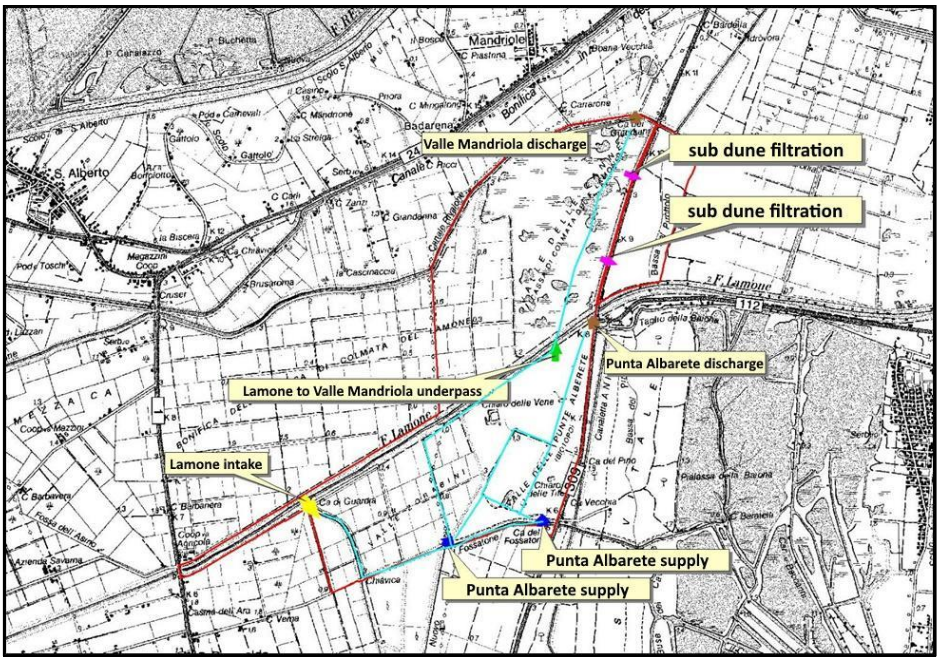

Fig. 22 Schematization of the water circulation from Lamone River in the Punta Albarete e Mandriola wetlands

5.2. Croatia: Coastal aquifers exploitation

Dubrovnik-Neretva County has a significant water potential, which is used for water supply and is divided according to the type of occurrence into: Spring water and groundwater resources. In PILOT AREA there are a total of 5 springs, 3 of which are located within the county. Within the county are the springs Prud, Klokun and Modro Oko, while the spring Butina is located in a karst field southeast of the town Vrgorac in Split-Dalmatia County and the spring Doljani is located about 2 km east of the town Metković in Bosnia and Herzegovinia. The spring Prud, located in the settlement of the same name, is the source of the Norin River. It is a karst-type spring and rises in a smaller lake, from which the Norin watercourse is formed. This source is used as the main intake for the Regional Water NPKLM. The installed capacity of the project is 382 l/s, or 12 000 000 m^3/year. From Hrvatske vode data (1978-2002), the maximum measured flow was 17.5 m^3/s (December 1987), and the minimum measured flow was 2.7 m^3/s (October 1999). Although according to the water permit it is allowed to capture 382 l/s, given the minimum measured flow of 2.7 m^3/s, much larger quantities can be captured at this source.

The Klokun spring is located north of the town of Ploče and is used as the main project for the Ploče Water Supply System, which supplies the town of Ploče and the eastern part of the Gradac municipality in Split-Dalmatia County. The installed capacity is 170 l/s, or 2 500 000 m^3/year. This source is also of regional importance.

East of the town of Ploče there is a spring Modro Oko, from which 6 l/s are taken for the needs of the public water supply of the settlement Desna. No water permit has been issued for this spring, and it is estimated that it is possible to withdraw volumes up to 250 l/s, which is a great potential for the needs of the county's water supply.

The spring of Butina is located in the settlement of Dusina (Split-Dalmatia County). It is used as one of the interventions for the Water Supply System of the town of Vrgorac - the Kobiljača-Staševica subsystem (Pojezerje Municipality), where 35 l/s are affected for the needs of public water supply. No water permit has been issued for this spring either.

The Doljani spring is located in neighboring Bosnia and Herzegovina and is used as the main project for the Metković Water Supply System, which supplies the area of Doljane and Metković settlements and the municipality of Zažablje and affects a total of 140 l/s. No water permit has been issued for this source, and according to Hrvatske vode, the minimum registered yield is about 30 l/s and the maximum is 215 l/s.

The data provided by NPKLM (Fig. 23) for the period 2016-2020 show that the annual withdrawal at the Prud spring varies between 3.3 and 4.7 million m3 of water. The maximum allowable capacity is set at 382 l/s or 12 million m3/year. During this period, the abstraction varied between 28% and 39% of the maximum installed capacity, which means that the Prud spring is not used at its full capacity.

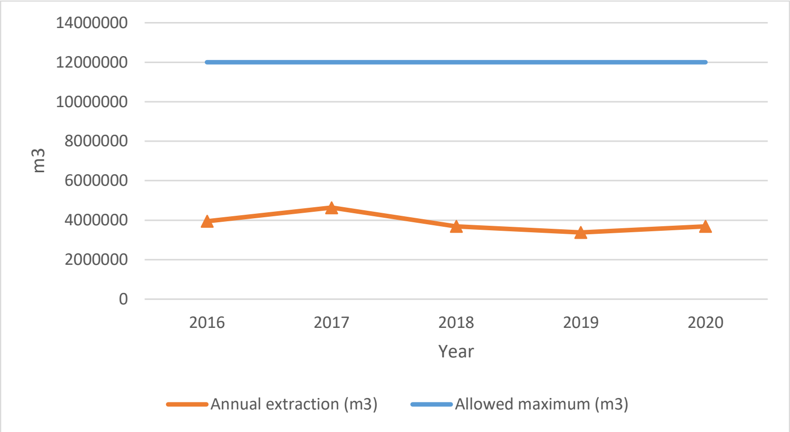

Fig. 23 Annual extraction at spring Prud 2016.-2020.

It is important to note that seasonal variability is typical of coastal aquifers, as shown in Fig. 24 for Prud Spring. Due to the significant increase in population during the tourist season, water withdrawal is also increased, on average by at least two times compared to the winter period. This situation is similar to the other sources mentioned previously. This seasonal variability is even more pronounced for the springs in the pilot area, since the water demand for agricultural production increases practically during the same period.

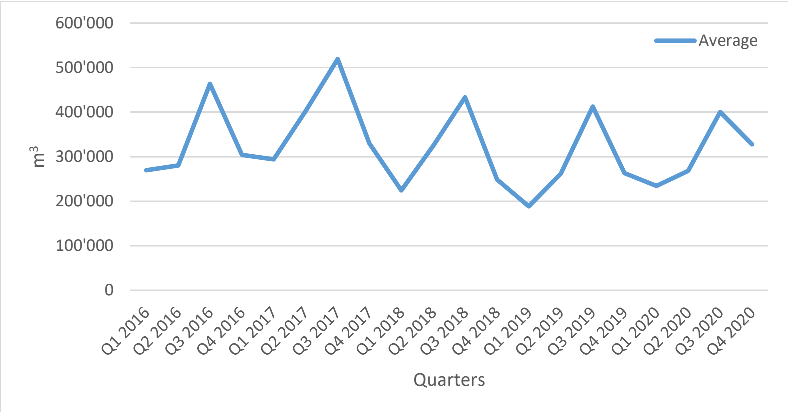

Fig. 24 Average quarterly extraction at spring Prud 2016.-2020.

5.3. Issues and Problems – overview for Italy and Croatia

The absence of a quantitative control on the management of the water resource in the Fano Municipality represents a criticism. As highlighted in the previous chapters, no data about the extraction rates related to private well owners are present, but the exploitation of the water resource from the very widespread private wells cannot be neglected. Another fundamental issue that needs to be deepen regards the natural recharge rates of the phreatic aquifer as, at the best of our knowledge, no detailed studies are present on the investigated area. The scarce knowledge on the extraction rates of water with respect to the recharging rates, makes difficult to have a reliable estimation of the renewability of the resource.

In Croatia, the main problem is lack of data on extraction rates all over the country, but especially in coastal aquifers. Also, there is evident need for more precise data on use of extracted water. Adequately established quantitate monitoring would contribute to more precise estimation of overall groundwater status.

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