PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.1

SET UP OF PILOT SCECIFIC MANAGEMENT PRACTICES

D.T2.1.4 DESCRIPTIVE DOCUMENTATION OF PILOT ACTIONS AND RELATED ISSUES

PILOT ACTION PAC2.4-1: *SOUTH DALMATIA - PRUD, KLOKUN AND MANDINA SPRING*

June, 2017

Lead Institution	Croatian Geological Survey
Contributor/s	Ivana Boljat, Ivona Baničček, Matko Patekar, Tihomir Frangen
Lead Author/s	Josip Terzić, Jasmina Lukač Reberski
Date last release	June 2017

Contributors, name and surname	Institution
Josip Terzić	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Jasmina Lukač Reberski	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Ivona Baniček	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Ivana Boljat	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Matko Patekar	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Tihomir Frangen	Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Daria Čupić	Croatian Waters

Contents

1. Introduction

The pilot action of the catchment area of springs Prud, Klokun and Mandina is a typical karst area characterized by very complex and intricate hydrogeological features. The area is poor in surface hydrography, and the springs that are involved in water supply are mainly located in the lower, southeastern part. Recharge area of these springs is connected with the distant upper parts of the catchment area, where the water moves in cascades from higher to lower erosion levels to the ultimate erosion base – the Adriatic Sea, partly via underground and partly by surface flow. Due to this, the quantity and quality of spring waters are influenced by all activities carried out along the entire catchment area; each negative activity is taken into account and in springs the cumulative effect is visible. Therefore, it is necessary to integrate and cautiously manage the entire recharge area because once the damage is done; it is very difficult to rectify it. This is also the reason, why this pilot action was selected for the PROLINE-CE project.

2. Basic data about pilot action

2.1. Geographical description

Springs Prud, Klokun and Mandina represent the discharge area of a large catchment that goes deep into the neighbouring BiH. The entire catchment area, from which a part of the water flows through the surface and/or underground pathways to the considered discharge area, extends to about 1,700 km^2, most of which is located in BiH. These studies are primarily focused on a part of the terrain within the borders of the Republic of Croatia (**Figure 1**). This area belongs to the central part of the world-renowned karst terrain: the Dinaric karst. The whole catchment area is composed of karstified carbonate rocks, within which karstic morphological forms were developed. In the discussed pilot area, there is also a growing number of morphological elevations that range from mountainous massifs of Biokovo and other mountains in BiH, through morphological plateaus and smaller hills, up to the fully developed karst fields such as the karst field (polje) in the Croatian part of the catchment area, Vrgoračko polje(Rastok) and Jezero.

Figure 1. Topographic map of the catchment spring area of Prud, Klokun, Mandina

2.2. Geological description

The geological structure of the research area is very complex, but not nearly as complex as hydrogeological relations, since they are further intricate due to morphological, tectonic, anthropogenic, climatic and many other factors. In the research area, the following lithostratigraphic units can be found (Velić & Vlahović, 2009; Marinčić et al., 1979; Raić & Papeš, 1982; Raić et al., 1977, 1978) (**Figure 2**):

Limestones and dolomites of the Lower Cretaceous (K_1) In the research area, limestones prevail in the Lower Cretaceous deposits, but the presence of dolomites and dolomite limestones

is also clearly noticed. Limestones differ from grainy to muddy, while the breccia that interchange with them can be associated with these limestones due to their hydrological properties, predominantly carbonate (calcitic) clasts and matrix. Because of the above mentioned, the rock mass is more or less uniformly tectonically broken and karstified and it can be associated with the same hydrogeological properties and functions in the polje. The thickness of this complex is relatively large and it is around 1000 m in the research area.

Rudist limestone of the Upper Cretaceous (K_2^{1-6}) In the entire catchment area within the state borders of the Republic of Croatia, the Upper Cretaceous rocks are typical for the karstic terrains of Dalmatia. They occupy the largest area of the Baćina lakes catchment basin within the Republic of Croatia. In areas where these deposits have been deposited continuously, they can reach up to 2000 m in thickness, but due to the interruption of sedimentation, most of them are thinner.

Limestone and Dolomites (Lower Jurassic, J_1)

Thick layered limestone and dolomite (Middle Jurassic, J_2) The fine grained dolomitic rocks are more common than the limestone, but have low water permeability.

Limestone and Dolomites (Upper Jurassic, J_3) Of all the Jurassic rocks in the area of exploration, these rocks occupy the largest surface. Different types of limestones are exchanged laterally and vertically with predominantly late-diagenic variants of dolomite. In the total rock mass, limestone prevails over the dolomites, which makes this rock mass similar to a large extent to the Cretaceous deposits which are more or less continuously deposited and which have similar hydrogeological properties.

Liburnian deposits, foraminiferous limestones and transitional deposits (Upper Palaeocene, Lower and Middle Eocene - Pc, $E_{1,2}$) They appear in relatively narrow elongated zones associated with the most important faults of the structural fabric. Foraminiferous limestones, which are by hydrogeological features very close to Cretaceous limestones, are most represented in the investigated terrain.

Flysch deposits (Middle and Upper Eocene, $E_{2,3}$) are the most common non-carbonate deposits in the Dinaric karst and often play a significant hydrogeological role. They are present in the discharge zone from the Mandine mlinice to Prud. Marls and siltstones are dominant, with sandstones following close behind. The thickness of the flysch deposits in the investigated polje is most likely around 500 m.

Lacustrine deposits (a-jQ_2) - In the investigated terrain, these deposits are present in the Vrgoračko polje (Jezero) and polje Rastok. In the area of the Vrgoračko polje (Jezero and Rastok), these deposits are presented with Cretaceous basement deposits, thickness of up to 15 m. on top of these sediments, there are some sandy clay deposits, but due to their extreme heterogeneity and irregularity they are difficult to isolate them.

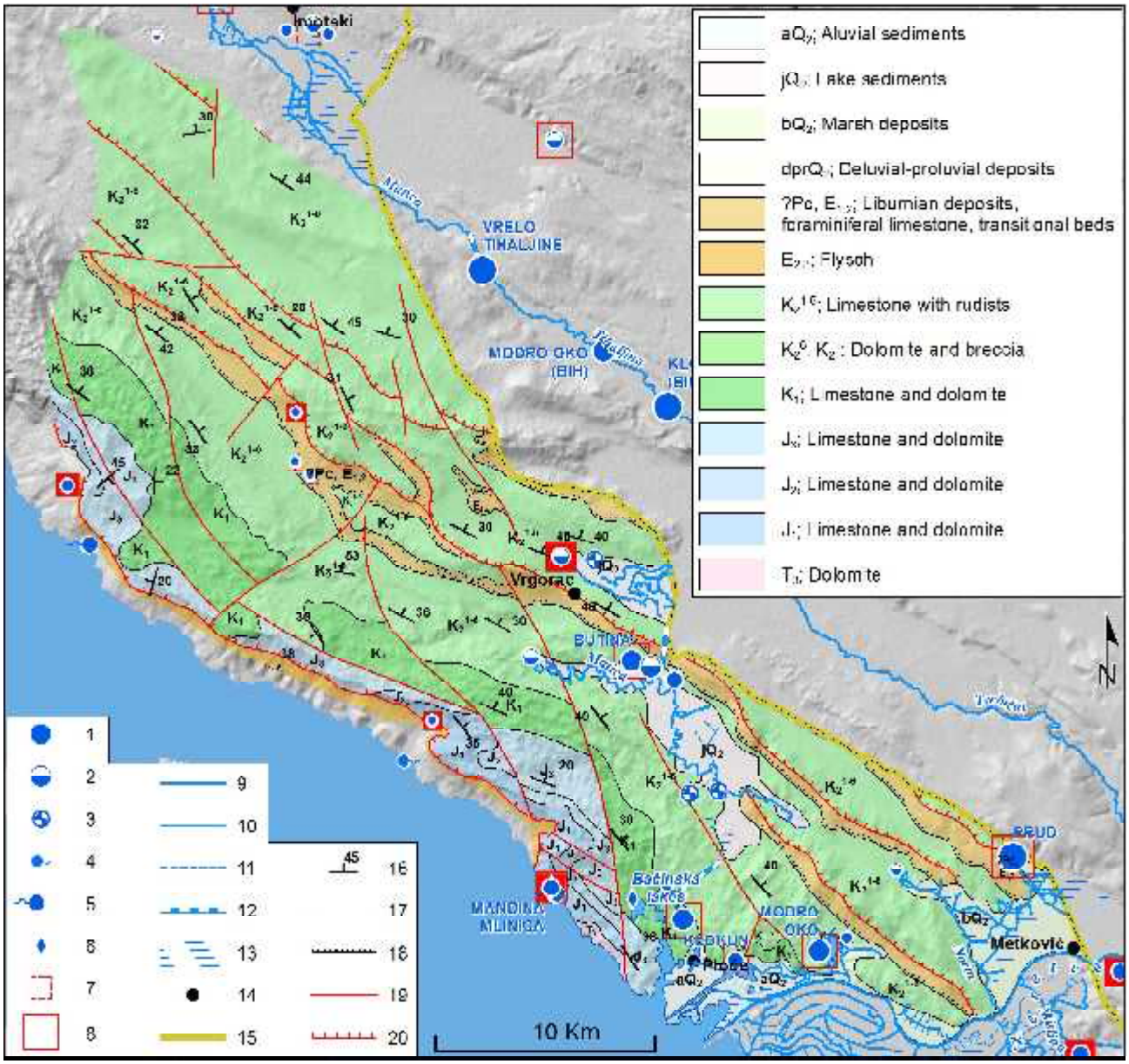

Figure 2. Geological map of the catchment area of Prud, Klokun and Mandina springs. Legend: 1 permanent spring 2 intermittent spring 3 estavelle 4,5 springs of different yield 7 rudimental water catchment 8 water catchment for the public water supply system 9-11 surface flow 13 flooded area, marshes 14 settlement 15 state border 16 layer position 17 normal lithostratigraphic boundary 18 erosive-discordant geological boundary 19 normal fault 20 reverse fault

After the sedimentation processes which lasted till Cretaceous, this area was subjected to a great number of active tectonic periods. For the hydrogeological relations certainly the most interesting ones are Quaternary and almost recent (neotectonic) periods. Major faults in the structural fabric and the deposit settings are mainly of the Dinaric orientation (NW-SE). Faults that are diagonal and perpendicular to the structures are also important for the hydrogeological relations, given that they often represent adequate medium for the development of major groundwater flow directions. The ground slowly descends towards the sea (cascades).

2.3. Pedology

South Dalmatia consists mostly of limestone and dolomites. The most prevalent terrain is bare limestone karst with all members of the evolutionary series of soils on limestone, except in valleys with a large area under hydromorphic soils: fluviosol, histosol, hypogley and amphygley, both in the Neretva valley and in the karst field, as well as rendzina, regosol, anthropogenic soils of glass and plastic houses-rigosol and hortisol on flysh (**Figure 3**).

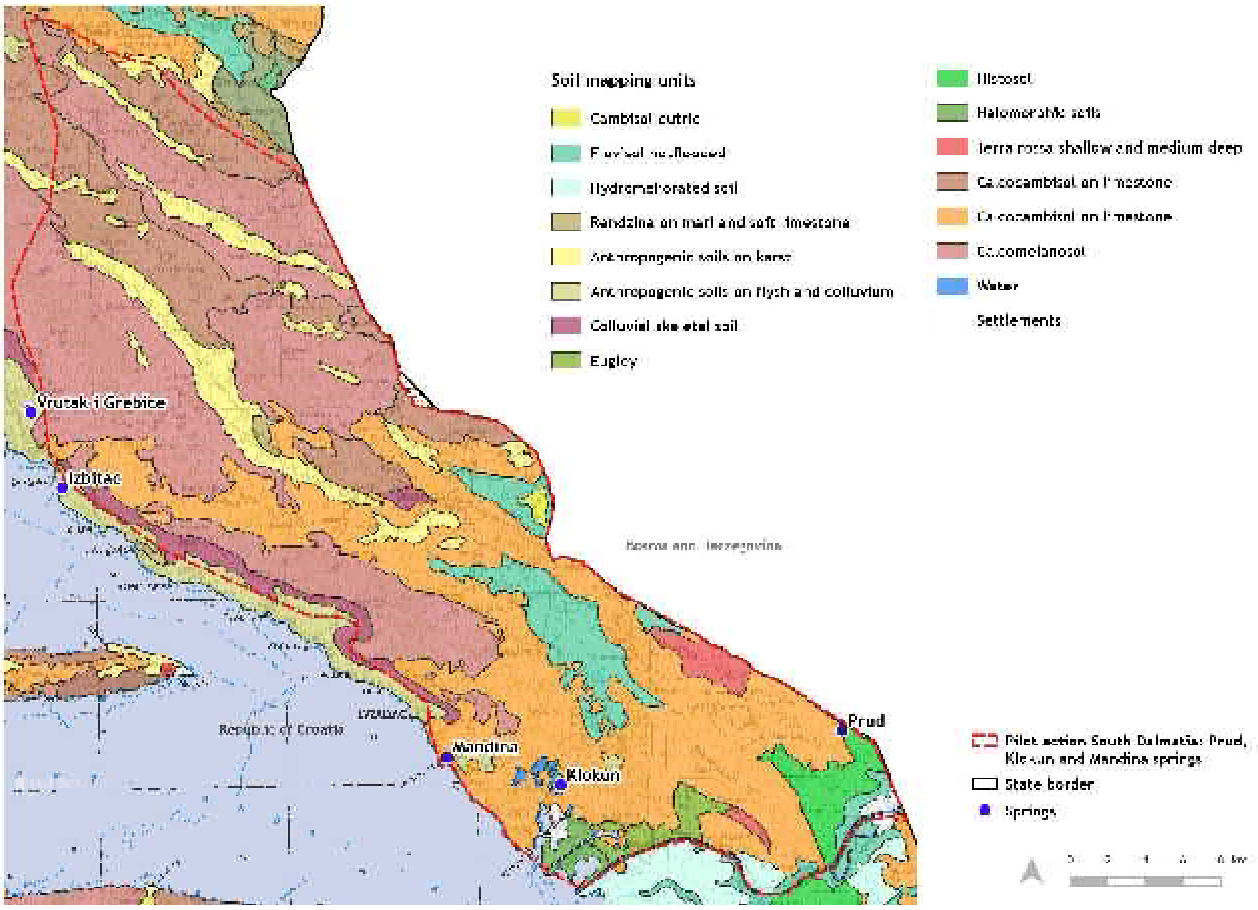

Figure 3. Pedological map (reference: Croatian Environmental Agency)

2.4. Climate characteristics

According to the data of the Climate atlas of Croatia (Zaninović et al., 2008; Perčec Tadić, 2010) the mean annual temperature range from 6 to 15 °C (**Figure 4**) and the mean annual precipitation in the research is around 1200 to 1600 mm (**Figure 5**). The mean annual air temperature was analyzed based on the air temperature data collected from 152 main and climatological stations, while the mean annual precipitation for the period 1961-1990 is analyzed

based on the measurements of mean daily precipitation amounts collected from 567 main, climatic and rainstorm stations.

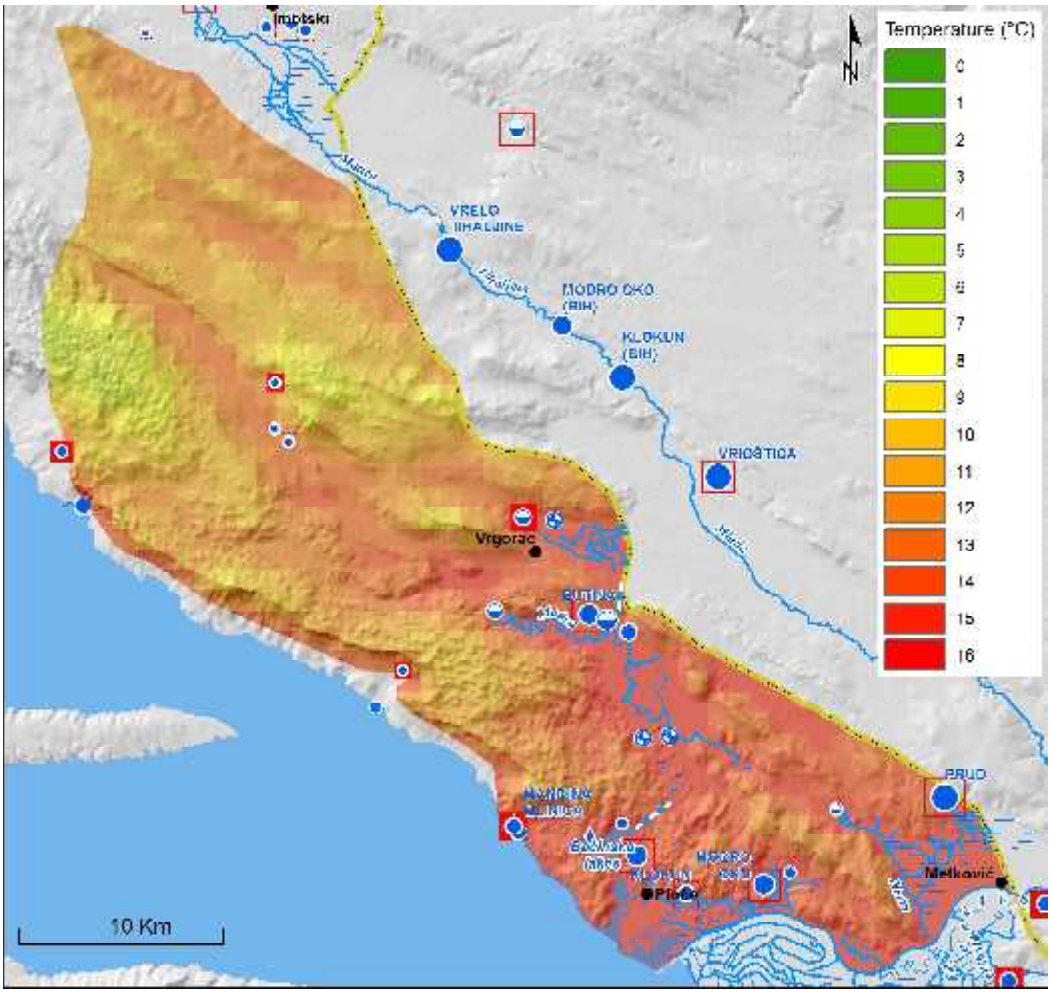

Figure 4. Mean annual temperature map (according to the data from Climate atlas of Croatia (Zaninović et al., 2008; Perčec Tadić, 2010)

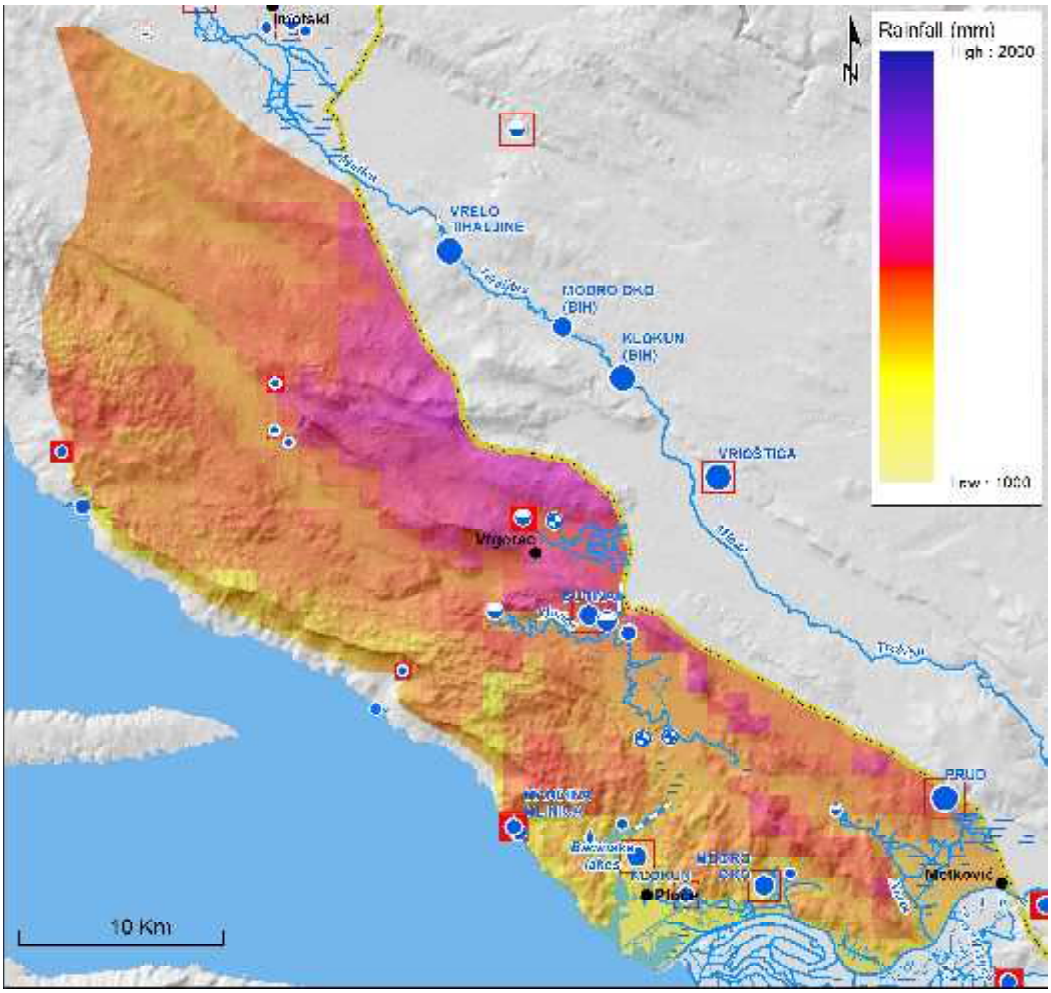

Figure 5. Mean annual precipitation (according to the data from Climate atlas of Croatia (Zaninović et al., 2008; Perčec Tadić, 2010)

2.5. Hydrology

2.5.1. Surface waters

For a karstic terrain like this, poor surface hydrography is typical and the main surface flows are usually associated with the poljes (**Figure 6**). At the contact of the poljes and karstified rock deposits in the background springs usually occur and create a surface flows which on the other end of the polje sink to the next erosion level. Prud, Mandina and Klokun springs outflow at the lowest erosion base, to which water gradually descend by underground and surface flows from the upper parts of the catchment area.

This is a hydrogeologically and hydrologically complex system of a sinking river which bears as much as five names in different parts of its course. In the highest horizon (app. 900 m above sea level), it starts its flow as the Ričina, flows through Posuško polje as the Suvaja, enters the Vrljika in Imotsko polje, sinking into the Sajinovac sinkhole near Drinovci in Herzegovina under

the name of Matica. After 2 km of underground flow, it resurfaces as Tihaljina, after which it has a continuous surface flow, but nevertheless changes its name three more times, at first into Sita, then into Mlade, and eventually into Trebižat, its best-known name, as which it enters the Neretva river. In its course it has losses which appear as inflows in the neighbouring drainage basins, including in the drainage basin of Prud spring. Due to the transboundary character of the aquifer of Prud spring which discharges only 300 m from the border between Croatia and Bosnia and Herzegovina, with practically its entire catchment situated in neighbouring Bosnia and Herzegovina.

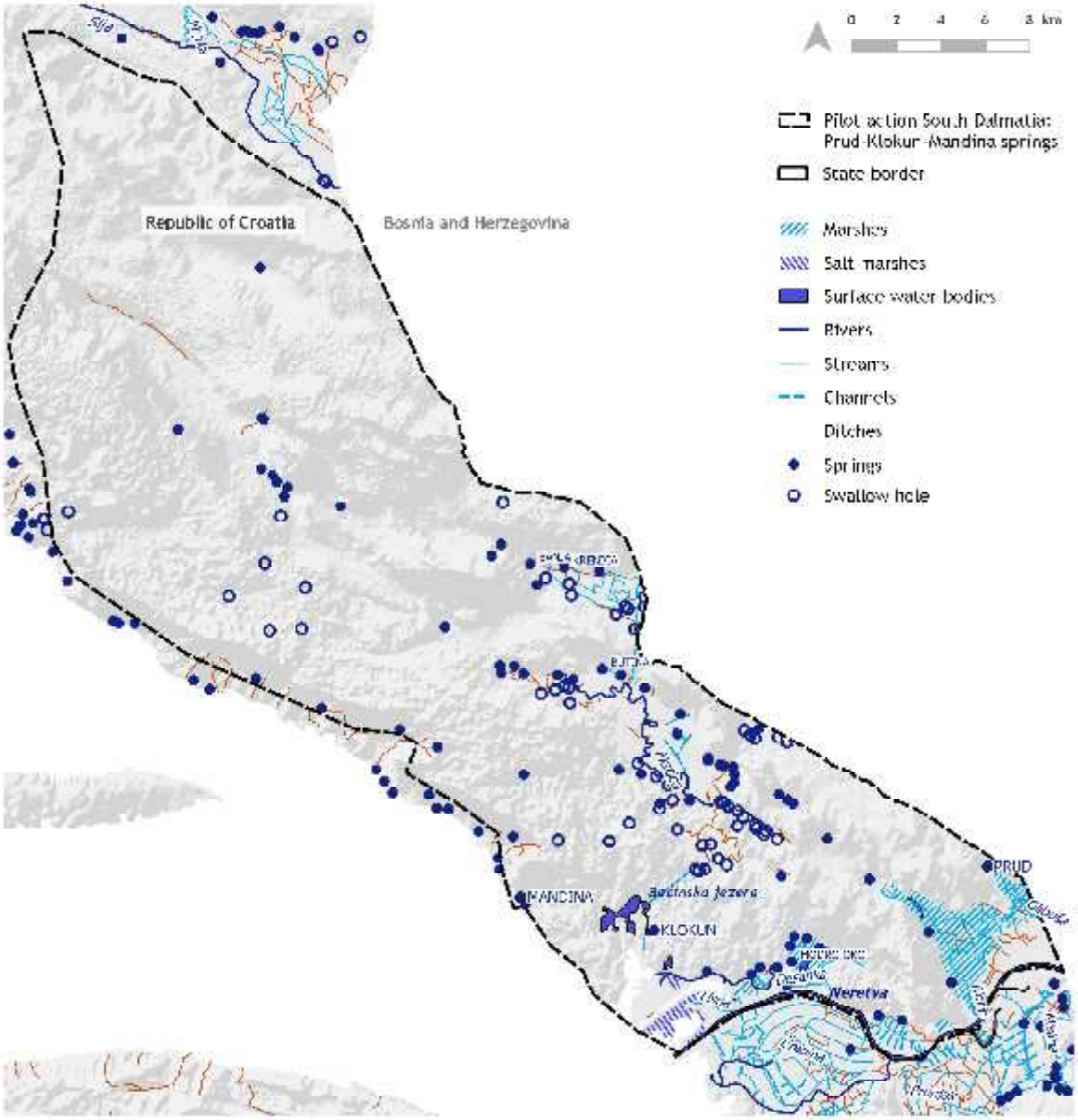

Figure 6. Hydrographic network

The largest surface flow in this area is Matica in Vrgoračko polje (**Figure 6**). During normal water levels, Matica flows from the Vrgoračko polje through the sinkholes and canal in Baćina lakes.

The main watercourse in the Rastok polje is Matica Rastoka, which is for the purpose of the Rastok irrigation system, connected to the upper Mlade River in BiH.

2.5.2. Flood issues

In the rainy season of the year, the sinkholes and canals of Vrgoračko and Rastok poljes do not have enough capacity, so the poljes get flooded. As highlighted in the 'Flood mitigation plan of the local water network of the Splitsko-dalmatinska County', all current works on the design of these poljes have had the basic aim of shortening the duration of the floods or reducing the maximum water level in order to enable better conditions for the agricultural production in the polje. Numerous hydrotechnical works (the Rastok tunnel that drains water from the Rastok to the Vrgoračko polje, the Krotuša tunnel that drains the water from the Vrgoračko polje in Baćina lakes), which reduced the level and duration of the poljes flooding, were carried out, but the floods were not prevented. For this reason, a new drainage tunnel is planned to drain water from the Vrgoračko poljeto Birina lake, which would also help to improve the ecological quality of the lake (Splitsko-dalmatinska County). **Figure 7** represents flood risk potentially significant areas.

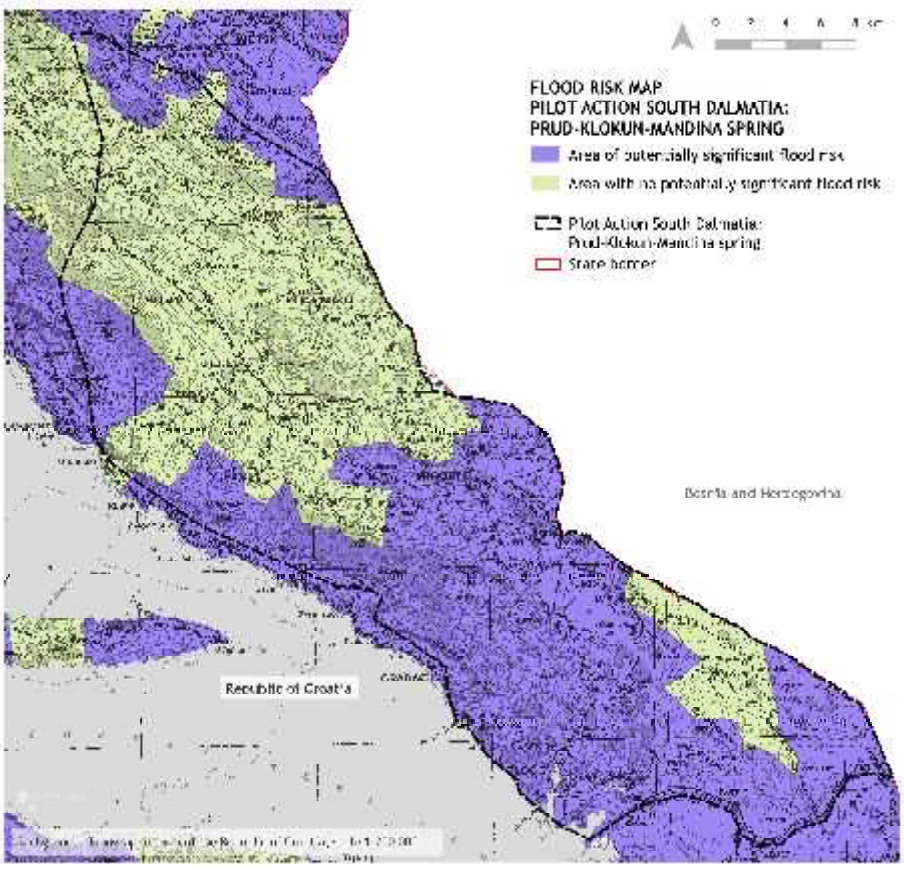

Figure 7. Flood risk map

Prud spring itself is the origin of the Norinska River, the right tributary of the Neretva River but it is outside the boundaries of the investigated area.

It is important to highlight the results of research related to the climate change we are facing in the last decades. Based on three different climate models (RegCM3, Aladin and Promes) assessment of impact of projected climate change on water resources in catchment area in southern Dalmatia has been done. Identified changes in the main water balance of Prud spring for the period 2021-2050 in relation to the period 1961-1990 ranging from -1,4 % to, as much as -52,3 % (Lukač Reberski et al., 2015). Despite uncertainties arising from climate models, it is very important to take into account such high values of scenarios and serious and urgent consider the measures that should be taken in case of future realization of these predictions.

2.6. Hydrogeology

In the pilot site carbonate rocks froming karst-fissured aquifers are dominating (**Figure 8**. This clearly points to the fact that it is a permeable karstic and generally open area where water is easily and rapidly infiltrated (in high percentage) and through which it quickly flows (especially in the major water directions, connected karstic channels, fractured and fault zones). A good part of the water from the upper, the north or the upstream area, flow underground toward investigated springs, while the other part flows parallel to the geologic structures towards the Neretva River that is situated beyond the catchment area. In addition to the significant barrier that separates the karst from the shore of the seaside, it can be mentioned that the karst poljes themselves with their Quaternary sediments appear to function as hanging barriers, and in their northern and north-western edges springs usually appear, in the central zones estavelles, while in the eastern and south-eastern edges sink hole zones develop. Regardless of whether the springs in the north/northwestern edges are discharging or have dried up, the flow of groundwater under the karst poljes continues on. Because of this, the barriers of the poljes are classified as hanging. Similar is the occurrence of smaller and thinner flysch deposit series that behave similarly in the hydrogeological sense (as barriers).

The boundaries between the sub-catchment areas of Klokun, Mandina and Prud are very rough, they are not borders in the true sense of the word, but are zoning boundaries that vary in time and space depending on the hydrological conditions, and the spring's catchment areas mostly overlap.

Prud, Klokun and Mandina are the most important springs located in the discharge zone of this great catchment area. Prud is a big karst spring which represents the easternmost boundary of the discharge zone. It is situated close to the boundary with Bosnia and Herzegovina (BH). Prud is a spring (Figure 9) that has a very high average discharge (app. 6 m^3s^{-1}), as well as a very high minimum discharge (app. 2 m^3s^{-1}) (Terzić et al., 2015). The Klokun spring discharges are in the range from 92 l/s up to 2.5 m^3/s (Ivičić & Pavičić, 1996).

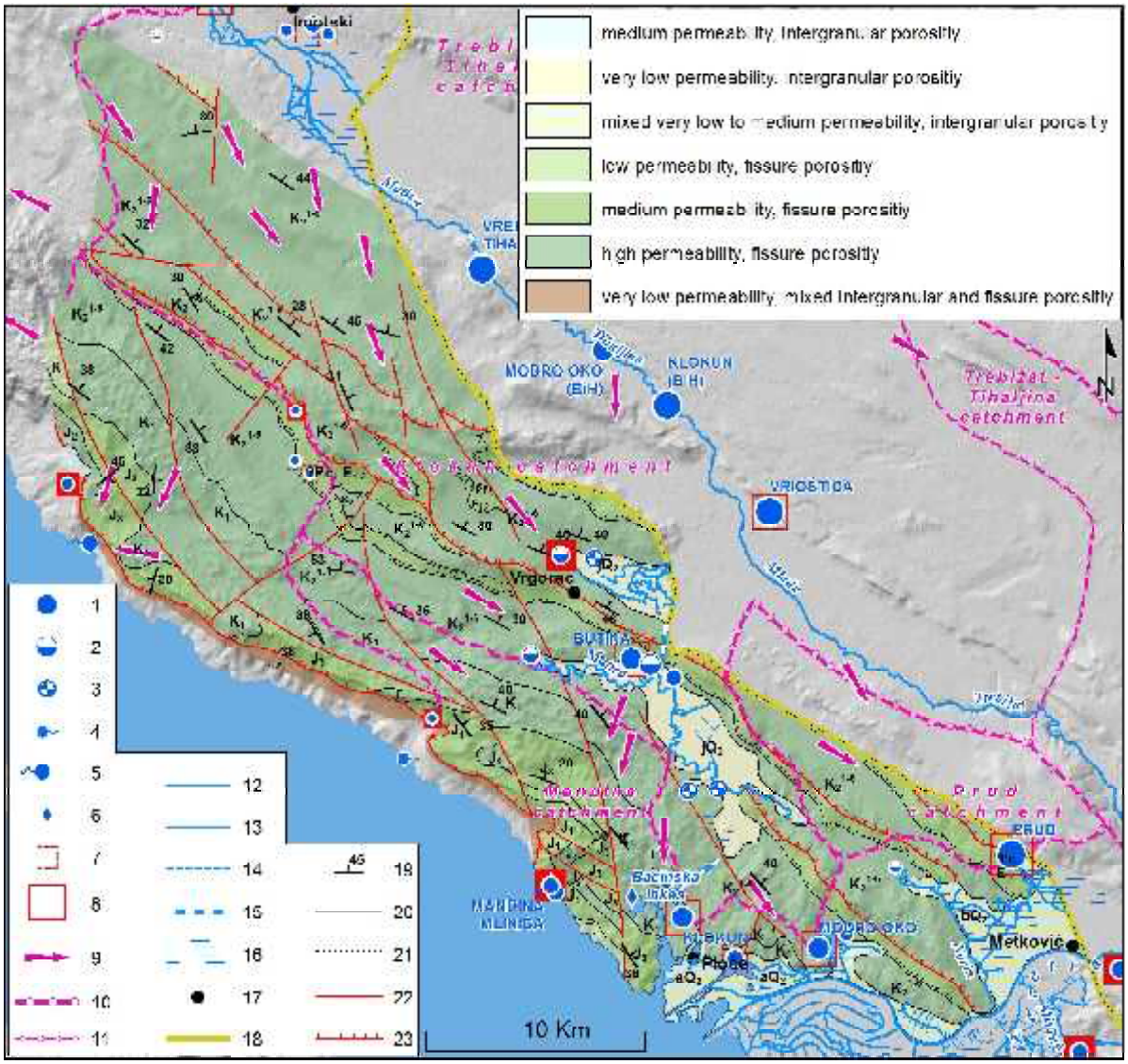

Figure 8. Hydrogeological map of the catchment spring area of Prud, Klokun and Mandina. Legend: 1 constant spring 2 intermittent spring 3 estavelle 4,5 springs of different abundance 7 primitive capture 8 public water supply drainage 9 groundwater flow 10 watershed 11 presumed watershed 12-14 surface flow 15 16 flooded area, wetland 17 settlement 18 state border 19 layer position 20 Normal lithostratigraphic boundary 21 erosion-discordant geological boundary 22 normal fault 23 reversal fault

Figure 9. Prud spring

Mandina mlinica is situated in the westernmost part of the discharge zone. It is a coastal brackish spring that has several origin places. The spring forms a pond that is surrounded by stone, and through the man-made duct outflow discharges into the sea (Figure 10). An old capture is located 20 feet away from which water was sometimes pumped for water supply, but now is neglected and is no longer used. They assumed that they belonged to the same drainage system, but after recent groundwater tracing in the sink holes, the tracer appeared 2 and a half days later on the capture station. In general, the entire Žrnovnica bay is characterized by numerous spring sites, on the shore, but also under the sea in the form of a submarine karst spring called “vrulja” that are clearly visible only during high groundwater levels. It is estimated to have a discharge of 0.5 to 4 m^3/s.

Figure 10. Mandina mlinica in the Žrnovnica bay

Klokun is a spring located in the central part of the drainage zone. The spring forms a pond that is paved with a stone (**Figure 11**), and with a short surface flow goes towards Baćina lakes. The spring is captured for the local water supply. It is characterized by a increased turbidity during the time of severe precipitation in the hinterland (catchment area). The minimum yield of the Klokun source is 140 L/s (Biondić et al., 2009).

Figure 11. The status of high and low water on the Klokun spring

2.7. Land use

As it can be seen on the Corine land cover map, almost half of the pilot area is mostly covered with transitional woodland-shrubs, agriculture areas with significant areas of natural vegetation, sclerophyllous vegetation and natural grasslands (**Figure 12, Table 1**). Agricultural areas are mostly linked with karst poljes.

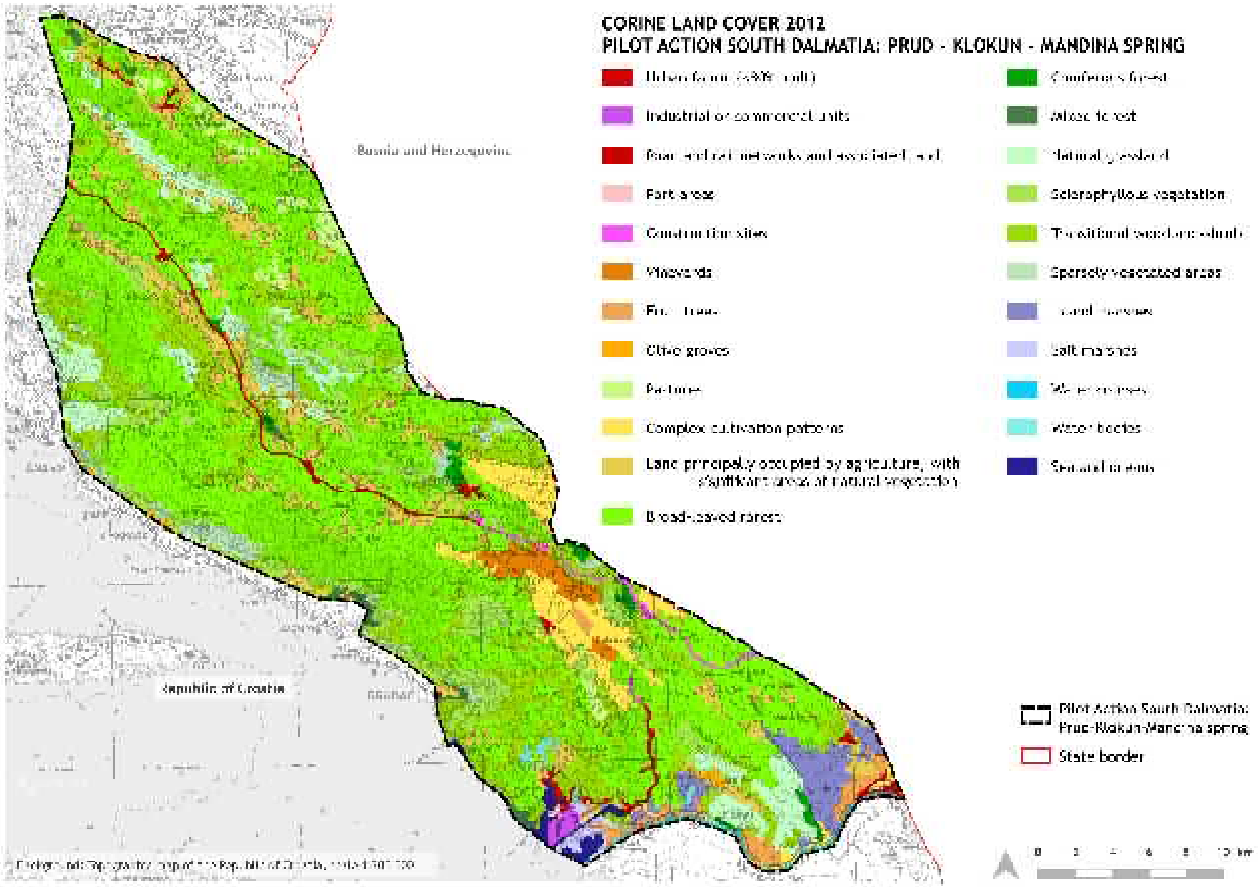

Figure 12. Land cover based on CORINE 2012

Table 1. Percentages of particular land use of the pilot action

Corine Land Cover in the Pilot Action South Dalmatia: Prud-Klokun-Mandina spring			
CLC code	CLC category	Area (km^2)	%
311	Broad-leaved forest	379.19	47.60
324	Transitional woodland-shrub	121.26	15.22
243	Land principally occupied by agriculture. with significant areas of natural vegetation	64.95	8.15
323	Sclerophyllous vegetation	49.21	6.18
321	Natural grasslands	44.80	5.62
242	Complex cultivation patterns	29.54	3.71
411	Inland marshes	16.93	2.13
333	Sparsely vegetated areas	15.50	1.95
231	Pastures	10.80	1.36
222	Fruit trees	10.77	1.35
221	Vineyards	9.59	1.20
122	Road and rail networks and associated land	6.50	0.82
312	Coniferous forest	5.97	0.75
112	Urban area (<80% constructed)	5.68	0.71
523	Sea and oceans	5.63	0.71
313	Mixed forest	4.39	0.55
133	Construction sites	3.72	0.47
421	Salt marshes	2.87	0.36
511	Water courses	2.56	0.32
121	Industrial or commercial units	2.42	0.30
223	Olive groves	2.04	0.26
512	Water bodies	1.96	0.25
123	Port areas	0.30	0.04

2.8. Protected areas

The Republic of Croatia has numerous diverse and preserved natural and semi-natural habitat types with the abundance of species. Some of these valuable natural assets are protected either by national legislation or in accordance with international agreements, conventions and legislation of the European Union. In the pilot action South Dalmatia Prud-Klokun-Mandina springs, areas protected with Nature Protection Act (OG 80/13) that also correspond with the IUCN categories, are presented in the Table 2 and Figure 13.

Table 2. Areas protected with Nature protection Act within the pilot action Imotsko polje springs

Protected areas			
Category	**Subcategory**	**Name**	**Area (ha)**
Nature park		Biokovo	7399.57
Special reserve	Ornithological	Prud	235.68
Special reserve	Ornithological	Pod Gredom	552.0
Special reserve	Ornithological	Orepak	97.0
Significant landscape		Modro oko i jezero Desne	333.86
Significant landscape		Predolac-Šibenica	0.001

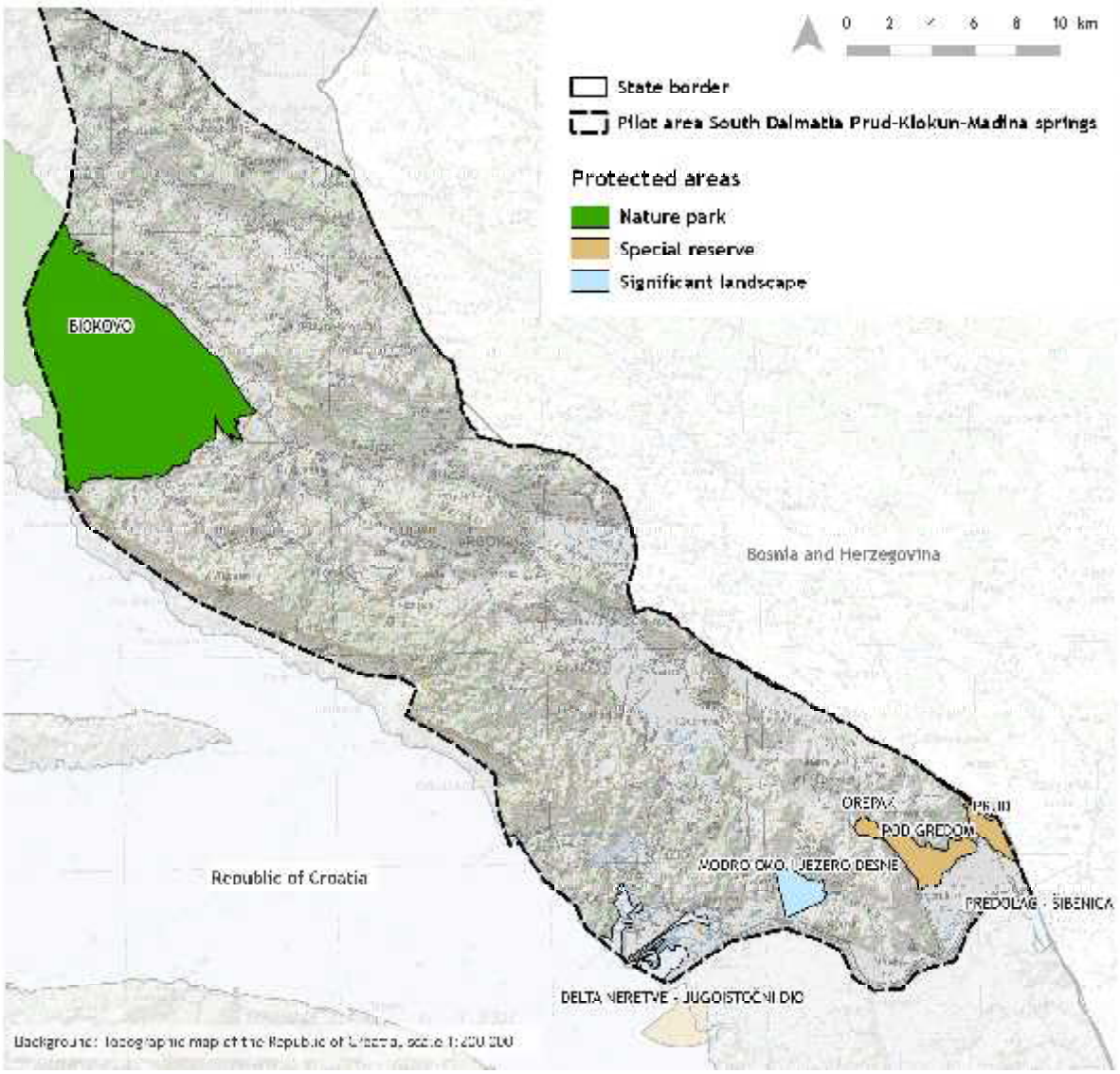

Figure 13. Protected areas within pilot action South Dalmatia Prud-Klokun-Mandina springs

Category special reserve refers to part of land and/or sea of special hour of special significance for its uniqueness, rarity or representativity, or habitat of endangered wild species and it is of particular scientific significance and purpose. Nature park Biokovo is situated in the northwestern part of the pilot area and encompasses a part of the Dinaric Mountains with the distinctive and varied wildlife, rich Mediterranean, Boreal and Central European flora and variety of geomorphologic phenomena and formations (caves, karrens, sinkholes, closed depressions created by stagnant water, pits etc.).

There are three special ornithological reserves within the pilot action. Special ornithological reserve Prud covers the wetland area east of the settlements Vid and Prud, upper part of the Norin River and area north of the Glibuša. It is part of the Neretva River downstream area with the abundance of wetland vegetation. The remains of wetland area that stretch east of the Matica River and north of the Norin are proclaimed as special reserve “Pod Gredom” due to its

significant wetland flora and fauna. Special reserve Orepak along with above mentioned special reserves is exceptional because of the Neretva's reed beds which are crucial for bird migrations and wintering.

Oligotrophic Lake Modro oko and lake near settlement Desne are protected within the category "significant landscape" because of their characteristics as flooded karsts depressions with an abundance of waters and wetland biotopes. Significant landscape Predolac-Šibenica represents the most valuable and preserved forest complex in the Municipality of Metković.

Areas of natural values that are protected in accordance with the Directives of European Union are areas:

- Special Protection Areas (SPA) in accordance to the Birds Directive (Council Directive 2009/147/EC),
- Special Areas of Conservation (SAC) in accordance to the Habitats Directive (Council Directive 92/43/EEC)

The Republic of Croatia contributes to the ecological network Natura 2000 by designating most important areas for each individual species and habitat type listed in the annexes to the directives. Natura 2000 areas that are within the pilot action South Dalmatia Prud-Klokun-Mandina springs are listed in the Table 3 and presented in Figure 14.

Table 3. Natura 2000 areas within the pilot action South Dalmatia Prud-Klokun-Mandina springs

Natura 2000 areas			
Sitecode	**Sitetype**	**Name**	**Area (ha)**
HR5000031	B	Delta Neretve	9601.70
HR5000030	B	Biokovo	7399.57
HR2001315	B	Rastok polje	782.67
HR2001046	B	Matica-Vrgoračko polje	293.06
HR2000951	B	Krotuša	145.51
HR2001242	B	Izvor Vir	66.98
HR2001449	B	Izvor Dropulića vrilo	61.62
HR2001350	B	Podbiokovlje	17.89
HR2001321	B	Jasena ponor	8.38
HR2000007	B	Betina velika jama	0.78
HR2000019	B	Čoćina jama	0.78
HR2000179	B	Velika špilja kod Antunovića	0.78
HR1000030	A	Biokovo i Rilić	25336.08
HR1000031	A	Delta Neretve	9601.70

Neretva River and its tributaries comprise the largest complex of wetland habitats in the Croatian coastal zone, with well-developed coastal and other wetland vegetation. Also, Neretva River Delta is designated as internationally important wetland under the Convention on Wetlands

(Ramsar, 1971). Even though large parts of wetland area are lost due to spreading agricultural production, the delta, lagoons and brackish water are still important habitats.

Rastok is the second largest karst field (polje) within the borders of Vrgorac situated at the southern end of Dalmatian Zagora. It stretches in NW-SE direction, from eastern slopes of Matokit and settlement Banja to the border with Bosnia and Herzegovina. The specific feature of Rastok is the existence of many abysses through which the surface waters and the flow of Matica drain. Matica-Vrgoračko poljeis protected due to its distinctive characteristic as polje with numerous speleological forms, Matica River that supplies permanent and periodical springs in the northwest part of the polje and provides special habitat for many endemic fish species.

Krotuša karst field is one of the sinking areas of Matica River located in southeastern part of polje Jezero where waters of Matica River are drained into Baćina lakes through natural sinkholes and tunnel Krotuša.

Springs Vir and Dropulića vrilo are important sites for *Proteus anguinus*.

The southern part of Podbiokovlje is located in the northwestern part of pilot action area near the Adriatic coast. It is covered with the agricultural land.

Jasena ponor is situated near Vrgorac as a part of the karst field Jasena which is fertile and cultivated area facing the difficulties of inadequate water drainage during the season of high precipitation, which causes flooding. The water usually drains through the pit Jasena Ponor. The underground lake of Jasena ponor is situated at a depth of about 180 m.

Betina velika jama is a karst pit significant for the species *Stygofiaptomus petkovskii*. It is more than 60 m deep and has very deep underground lakes, whose water is used for nearby agricultural irrigation.

Biokovo and Rilić mountains with their submediterranean white oak forests, aleppo pine groves and dry grasslands are important flyover area for migratory cranes and Honey Buzzards.

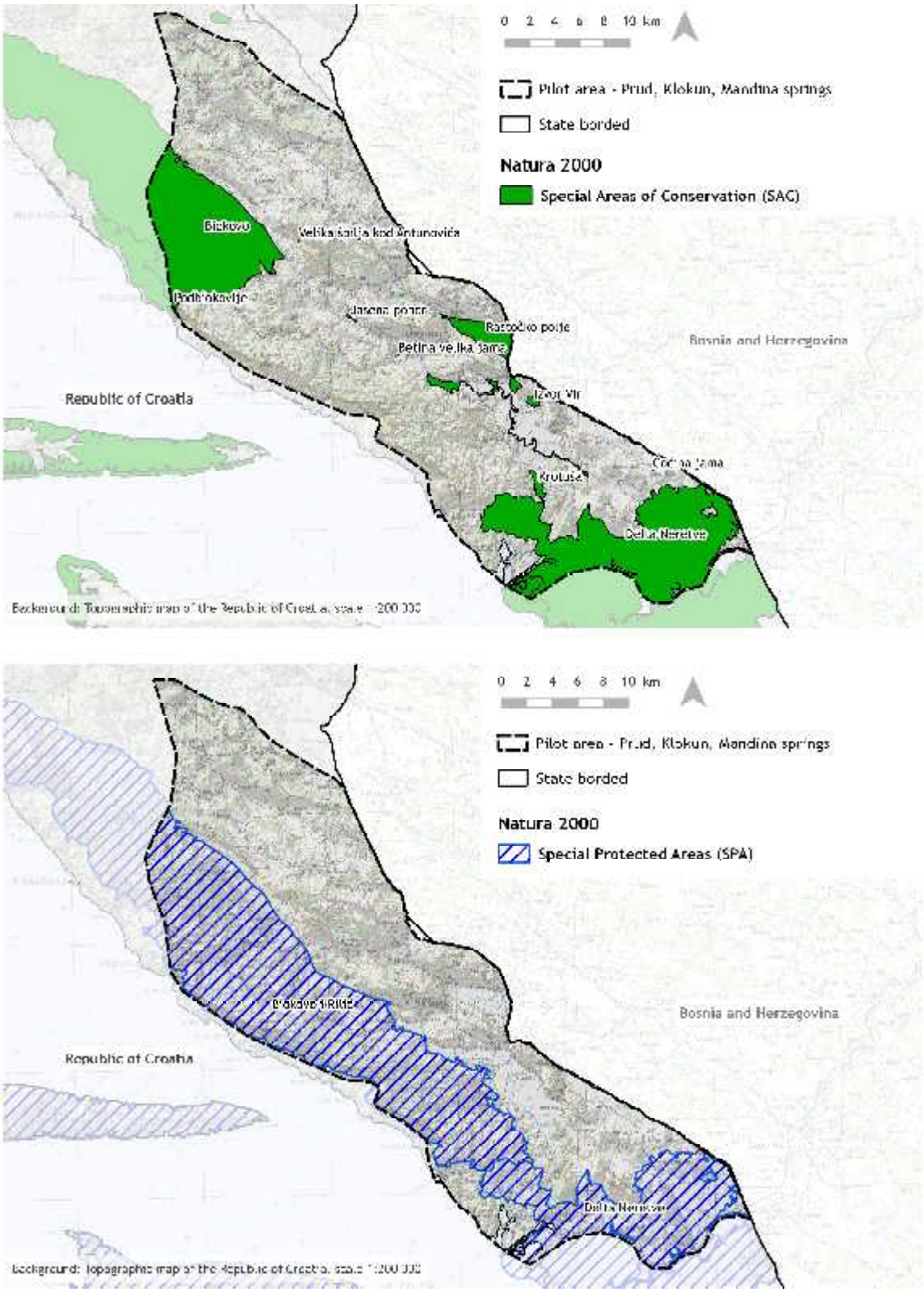

Figure 14. Natura 2000 areas within Pilot action South Dalmatia Prud-Klokun-Mandina springs (reference: Bioportal)

3. Water supply in the pilot action

3.1. Drinking water sources

Given that the Prud (Figure 1 and 8) is the biggest spring in this zone it is very important for the regional water supply of this area. It is captured for the Neretva-Pelješac-Korčula-Lastovo (NPKL) regional water supply system, as well as locally for Metković. Currently only 10% of its minimum capacity is used. Plans for the water supply network extension are underway, which should double the capacities. During the recent research period, which lasted from the end of 2013 to the mid of 2015, minimal measured discharge was 3.1 m^3/s, while the maximum was around 10.3 m^3/s (Terzić et al., 2015). A one million euro worth of works on the biological water treatment plant in Prud are in progress, as well as the project for the construction of a new sewage system. From annual distribution of July and August averages of abstracted quantities in comparison to average annual and highest monthly averages at Prud spring, it can be noticed that the highest water use is in August and July (Figure15).

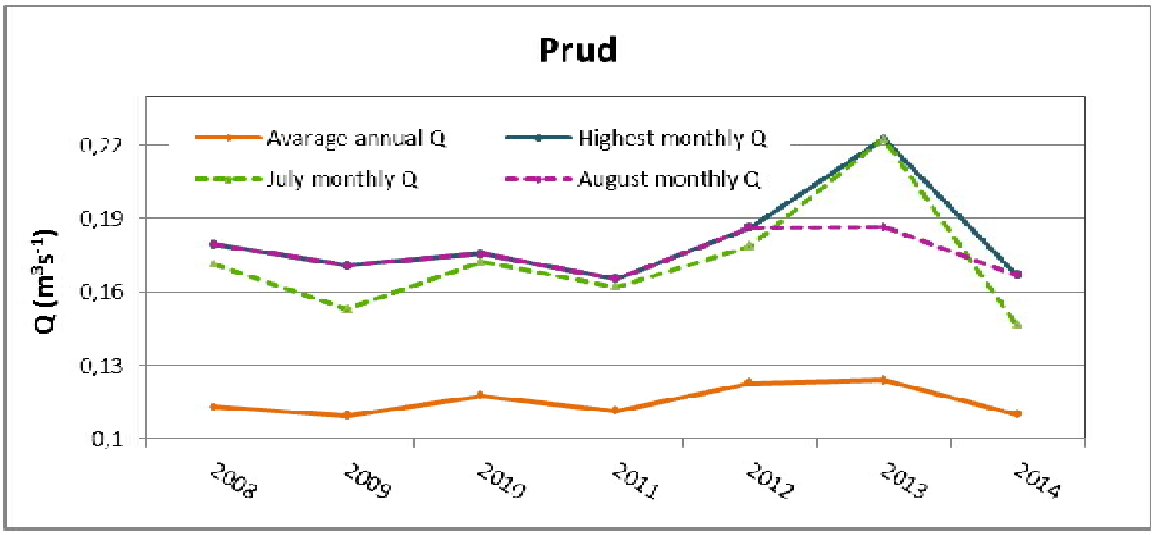

Figure 15. Distribution of the average annual abstracted quantities, highest monthly averages compared to July and August averages of abstracted quantities at Prud (2008-2014)(Lukač Reberski et al., 2015)

Klokun spring (Figure 1 and 8) is very important for the water supply system of the City of Ploče and its surroundings. For the City of Ploče 100 L/s of water are captured through 24 hours a day, while for the Gradac 40 L/s of water is captured in 14 hours a day. Pumps with a capacity of 100 L/s and two of 35 L/s have been installed. In the summer, all 170 L/s of water are captured. The system supplies 2,629 households with water (100% connectivity). Their water consumption amounts around 41% (about 220,000 m^3) of the total annual water consumption of the household of water supply area. As one of the important economic consumers in Ploče, the port of Ploče, the second largest Croatian port whose consumption is around 55% of the total annual consumption of economic entities in the Ploče area, should be highlighted. Although Klokun spring as the primary source of water currently meets the need for water, the inclusion of

alternative drinking water sources (the Modro oko spring) to reduce dependence on the existing source, is envisioned. Exceptionally large water supply system losses are noticed (in some directions, the loss values go around 70%). Despite such large losses, the system is functional and fully meets the current water supply needs, both in terms of pipeline permeability and pressure. Deterioration is one of the most important reasons for such high losses.

The Mandina spring (Figure 1 and 8) was once captured for the water supply, but it has not been used for a long time, and the old caption is neglected.

In addition to the mentioned springs which are located in the lowest zone of discharge, in the catchment area are two other springs captured for the local water supply of City of Vrgorac, the Butina spring and Banja estavelle (Figure 8). These are two separate water supply subsystems of the City of Vrgorac. Banja spring settles around 80% of the needs of the Vrgorac region, while Butina settles remaining 20%. The minimum capacity of Banja spring is 50 L/s and so is the installed pump capacity. The water is captured from a depth of 40 m. The capacity of Butina pump is 35 L/s. Recent observations (Terzić et al., 2015) over a two-year period, the lowest flow measured at Butina was 1.1 m^3/s and the highest 7 m^3/s.

3.2. Drinking water protection

The sanitary protection zones in the area of research have been proclaimed only for the Prud spring (**Figure 16**) and for smaller springs of Grebica, Vrutak, Orašje and Izbitac (**Figure 17**) located in the northwestern edge of the investigated area. For other springs used for water supply, sanitary protection zones have not yet been established. Although every spring/well in Croatia used for water supply should have defined sanitary protection zones, the existing Ordinance on determination of sanitary protection zones still does not have legal authority and it is impossible to initiate criminal proceedings in cases where no sanitary protection zones are established. In recent years, there have been some efforts for the Ordinance to get legal power for unfortunately the only way to improve the situation is to start fining polluters.

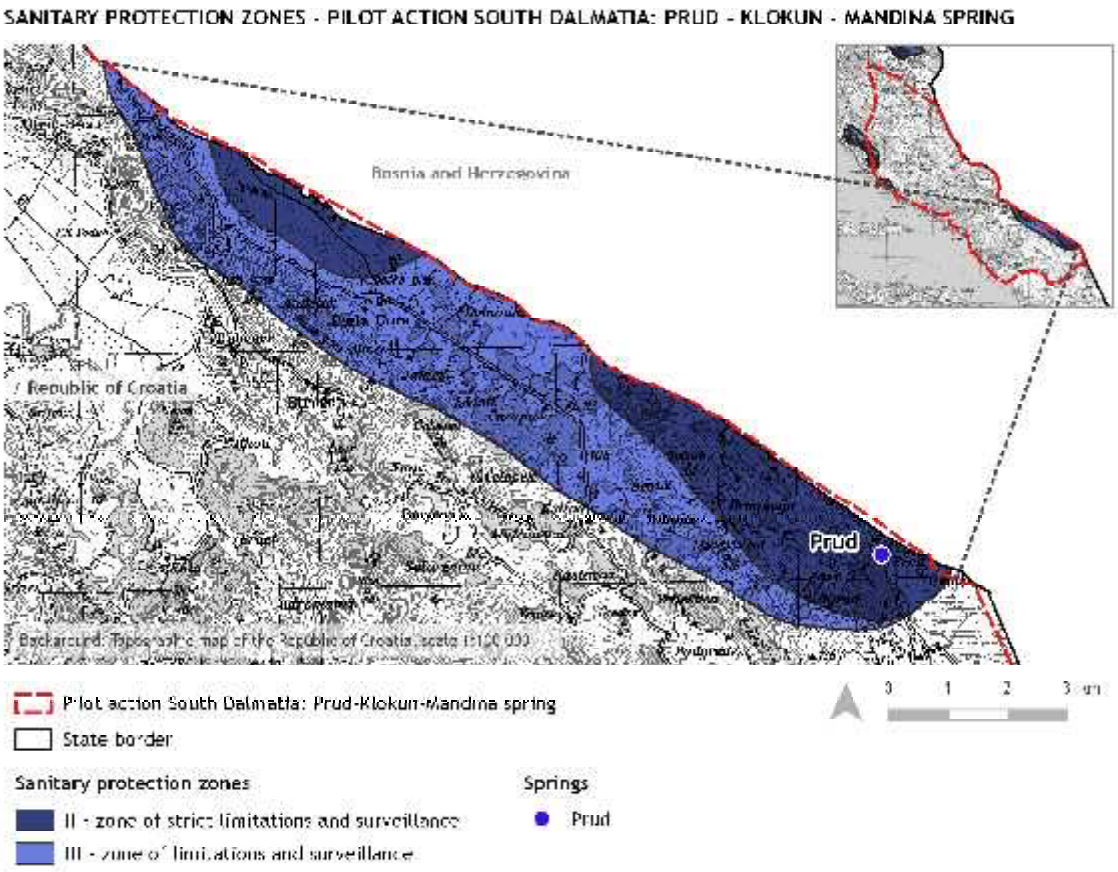

Figure 16. Drinking water protection zones for the Prud spring

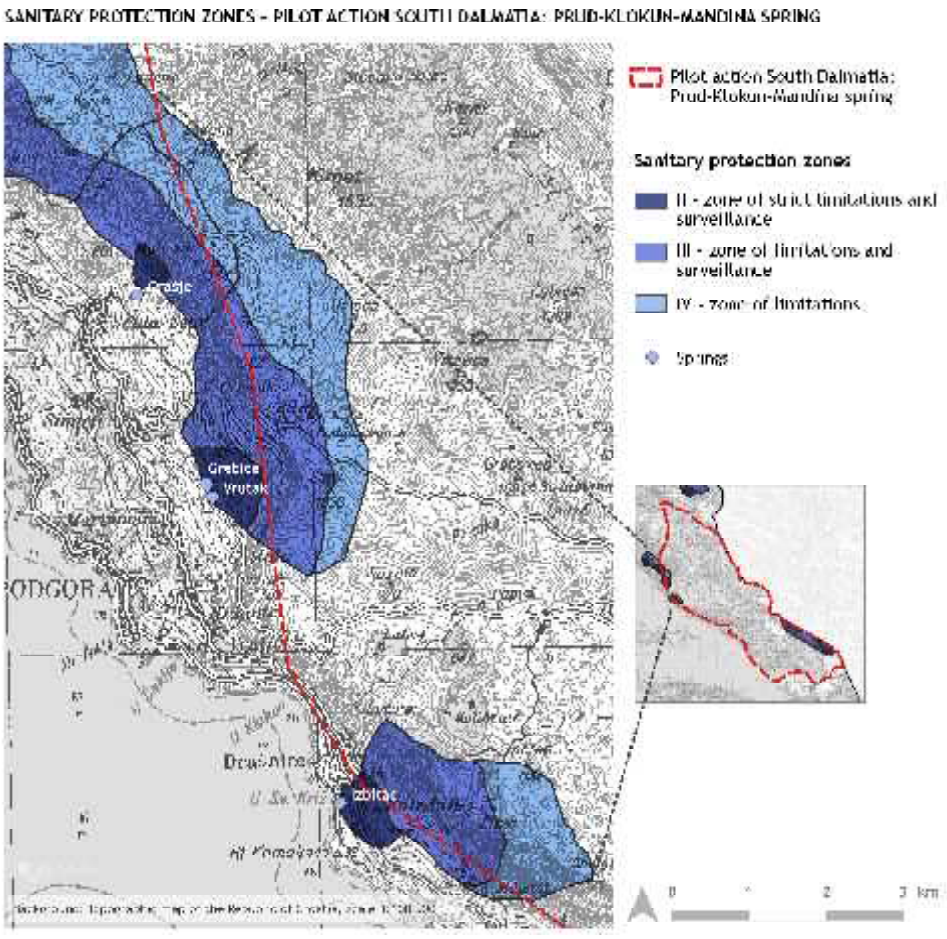

Figure 17. Drinking water protection zones for the springs Grebice, Vrutak, Orašje and Izbitac

Within the aforementioned recent studies, it has been established that the Vrgoračko polje, which is intensively farmed, belongs to the second zone of sanitary protection (according to the valid Ordinance). This fact should encourage the local population to turn to ecological farming because such production prohibits the use of most mineral fertilizers and almost all pesticides whose use is prohibited within the second zone of sanitary protection. The hydrogeological elaboration with the proposal should be made as soon as possible, and the decision on the sanitary protection zones of the Klokun should be made to become a legal obligation, not just the free will of the local population.

4. Main identified problems / conflicts

In the area of the Pilot Action "South Dalmatia: Prud, Klokun and Mandina spring", the following activities and phenomena that negatively reflect the quality and quantity of drinking water can be distinguished:

- Intensive agricultural activity in the Vrgoračko poljeand in the Neretva River valley,
- A separate problem is the drainage of karst fields (Rastok, Vrgoračko polje, Imotsko polje), which despite great efforts is still not adequately resolved. Regardless of numerous construction interventions (construction channel and tunnel for drainage of surplus water from the flooded poljes) poljes still occasionally flood,
- There is still a lot of deficiencies in the sewerage and wastewater drainage system, there are many households that are not connected to the sewerage network
- Illegal Waste Dumps
- Water supply system losses
- Unlike other watercourses in the area of Croatia, the large and medium annual flows rates in this area (Neretva (Metković) and Matica Vrgorska (Dusina)) tend to decrease,
- The majority of the springs which are located in the water supply system still do not have any defined or established sanitary protection zones
- Climate predictions for this area for the period from 2021 – 2050 point to the possibility of great loss of water resources.

Agricultural production in this area presents the greatest negative impact both on the quality and quantity of the water resources. Agricultural production is purely conventional and the use of pesticides and fertilizers is still under the motto of "the more the better". Despite the fact that in recent years it has been an ongoing struggle to optimize the use of protective agents, it will take years to change the awareness of the local community. Due to everything mentioned above, it is very important to carefully and professionally manage water resources in this area in order to achieve a balance between protection and the use of natural systems.

These conflicts and best management practices identified in T1 and D.T2.1.2 will be the focus of activities within this PA.

5. References

Bašić, Ferdo (2013): The soils of Croatia. Springer Science & Business Media, 179 p.

Biondić, R., Biondić, B., Rubinić, J., Meaški H., Kapelj, S., Tepeš, P. (2009): Ocjena stanja rizika cijelina podzemnih voda na krškom području u Republici Hrvatskoj, Geotehnički fakultet, Zagreb, 385 p.

Corine Land Cover Croatia: CLC 2012.

Ivičić, D. & Pavičić, A. (1996): Hidrogeološki istražni radovi za prijedlog zona sanitarne zaštite za izvore Klokun i Modro Oko. Arhiv HGI 62/96.

Lukač Reberski, J., Rubinić,J., Terzić, J., Horvat, B. (2015): Report on Water resources availability on test areas in Southern Dalmatia – catchment areas of spring Prud and Blatsko polje. Croatian Geological Survey (under the IPA Adriatc, DRINKADRIA project).

Marinčić, S., Magaš, N. & Benček, Đ. (1979): List Ploče – Tumač Osnovne geološke karte M 1:100.000 Institut za geološka istraživanja – Zagreb, Beograd.

Perčec Tadić, M. (2010): Gridded Croatian climatology for 1961–1990. Theor. Appl. Climatol. 102:87–103.

Raić, V., Papeš, J., Behlilović, S., Crnolatac, I., Mojičević, M., Ranković, M., Slišković, T., Đorđević, B., Golo, B., Ahač, A., Luburić, P. & Marić, LJ. (1977): List Metković – Tumač Osnovne geološke karte M 1:100.000.

Raić, V., Ahač, A. & Papeš, J. (1978): List Imotski – Tumač Osnovne geološke karte M 1:100.000. Institut za geološka istraživanja – Sarajevo, Beograd.

Raić, V. & Papeš, J. (1982): List Ston – Tumač Osnovne geološke karte M 1:100.000. „Geoinženjering“ Sarajevo, OOUR Institut za geologiju i Geološki zavod – Zagreb, Beograd.

Velić, I. & Vlahović, I., ur. (2009): Tumač geološke karte Republike Hrvatske M 1:300.000. ISBN 978-953-6907-10-6. Hrvatski geološki institut, Zagreb.

Terzić, J., Lukač Reberski, J., Frangen, T., Rubinić, J. (2015): Hidrogeološka istraživanja Baćinskih jezera, Hrvatski geološki institut, Zavod za hidrogeoologiju i inženjerski geologiju, Zagreb, 207 p.

Zaninović, K., Gajić-Čapka, M., Perčec Tadić, M., Vučetić, M., Milković, J., Bajić, A., Cindrić, K., Cvitan, L., Katušin, Z., Kaučić, D., Likso, T., Lončar, E., Lončar, Ž., Mihajlović, D., Pandžić, K., Patarčić, M., Srnec, L., Vučetić, V. (2008): Klimatski atlas Hrvatske / Climate atlas of Croatia 1961-1990., 1971-2000. Državni hidrometeorološki zavod, Zagreb, 200 str.

Web sources:

Bioportal, Available at: http://www.bioportal.hr/gis/

Betina velika jama - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2000007

Delta Neretve - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR5000031#4

Izvor Dropulića vrilo – Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2001449#4

Izvor Vir - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2001242#4

Jasena ponor - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2001321

Krotuša - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2000951

Matica-Vrgoračko polje - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2001046

Nature park Biokovo - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR5000030#4

Pedological map of Croatia, Croatian Environmental Agency, Avaiable at:

http://gis.azo.hr/gisapp/rest/services/AZO_PublicData/Pedoloska_karta/MapServer

Podbiokovlje - Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2001350

Rastok polje – Natura 2000 Standard data form, Available at: http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=HR2001315#4

Resolution for the preliminary assessment of the project for the ecological network for the extraction of surplus water from the Vrgoračko polje, Splitsko-dalmatinska County, Administrative department of Public utilities, Infrastructure and Environmental protection, Available at:

https://www.dalmacija.hr/Portals/0/docs/UOZastitaOkolisa/dokumenti/Rje%C5%A1enje/rje%C5%A1enje%20-%20hrvatske%20vode%20-%20vrgorsko%20polje0001.pdf