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REPORT ON INNOVATIVE PRACTICES FOR WRM IN EU

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University of Nis

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1 Introduction

Water-related issues have become more complex and challenging in recent years, requiring more effective and efficient solutions to overcome these problems. Innovative solutions and valuable experience were gathered in academia and professional bodies alike, which are of great importance for future water resource managers. Therefore cooperation between the educational sector and water management professionals is indispensable. Several examples of innovative practices established in EU and Norway, successfully tackling water-related issues and future challenges, were presented at the workshop on "Innovative practices in the EU water sector: barriers and opportunities" in Vienna (May 2019). The examples covered various different aspects of water management including trainings of professionals and are detailed in this report. As water resources management represents a wide field with no clear delineation of boundaries, it is not possible to cover all innovations and practices in that area; instead, the report aims at developing a view of exemplary approaches towards innovations in terms of tackling various regionally different issues.

2 Austria

The management of (small) wastewater treatment plants (WWTP) as well as the sediment management of water bodies has become more and more important in recent years in Austria. Due to this fact, these topics were highlighted in the workshop and are described in the following sub-chapters.

2.1 Management of (small) wastewater treatment plants in Austria (based on Langergraber, 2019)

A presentation about management of (small) wastewater treatment plants in Austria was given by Günter Langergraber, Head of the Department of Water, Atmosphere and Environment of BOKU and trainer of courses provided by the Austrian Water and Waste Association (Österreichischer Wasser- und Abfallwirtschaftsverband, ÖWAV).

2.1.1 Introduction

Austria has a population of around 8.8 million on an area of roughly 84.000 km^2, whereby 1/3 of the population lives in cities, 1/3 in villages and 1/3 in rural, mountainous areas.

Around 1.800 wastewater treatment plants serve about 95% of the population (Table). These wastewater treatment plants have a capacity larger than 50 person equivalent (PE). The remaining 5% of the population live in single houses and small settlements (<50 PE) requiring on-site and decentralized wastewater treatment technologies. Hence, the estimated number of such treatment plants needed is 30.000 to 40.000.

Table 1: Number of wastewater treatment plants in Austria (BMLFUW, 2014)

Design size (PE_{60})	# WWTPs	% WWTPs	PE connected	PE connected
51 - 1.999	1'204	65.4	462'087	2.1
2.000 - 10.000	373	20.2	1'762'099	8.2
10.001 - 15.000	45	2.4	572'675	2.6
15.001 - 150.000	202	11.0	8'887'740	41.1
> 150.000	18	1.0	9'929'267	45.9
Sum	**1'842**	**100**	**21'613'868**	**100**

A survey focusing on small wastewater treatment plants found a number of around 27.500 facilities in total, whereby the actual number might be even higher. Table 2 presents the different treatment technologies of these wastewater treatment plants. The technologies (primary treatment only: 22.7%, conventional activated sludge (CAS) 25.6%, sequencing batch reactor (SBR) 19.1%, Vertical Flow (VF) wetland 20.2%) are most commonly used.

Table 2: Technologies of wastewater treatment plants with design size smaller than 50PE

Federal state	Total	Primary only	CAS	SBR	Trickling Filter	Fixed bed	Soil Filter	VF wetland	Unknown + other*
Burgenland	**20**	0	4	1	1	0	0	14	0
Carinthia	**6'961**	2'248	3'051	566	7	55	308	556	170
Lower Austria	**4'541**	256	452	2'513	33	24	81	893	289
Salzburg	**1'655**	304	234	274	82	53	368	279	61
Styria	**10'665**	2'385	2'532	1'044	374	334	378	3'276	342
Tyrol	**1'096**	660	92	107	39	4	80	61	53
Upper Austria	**2'398**	381	646	702	100	0	27	475	67
Vienna	**13**	1	6	3	1	1	0	1	0
Vorarlberg	**129**	14	7	28	2	4	66	4	4
Total	**27'452**	6'249	7'024	5'238	639	475	1'308	5'559	986
		22.7%	25.6%	19.1%	2.3%	1.7%	4.8%	20.2%	3.6%

* including 52 MBR and 131 RBC plants.

The time ranges of implementation of these technologies are shown in Figure 1. Most of the primary treatments were established before 1992. Between 1992 and 2016 the implementation of activated sludge treatments, SBRs and treatment wetlands was predominant.

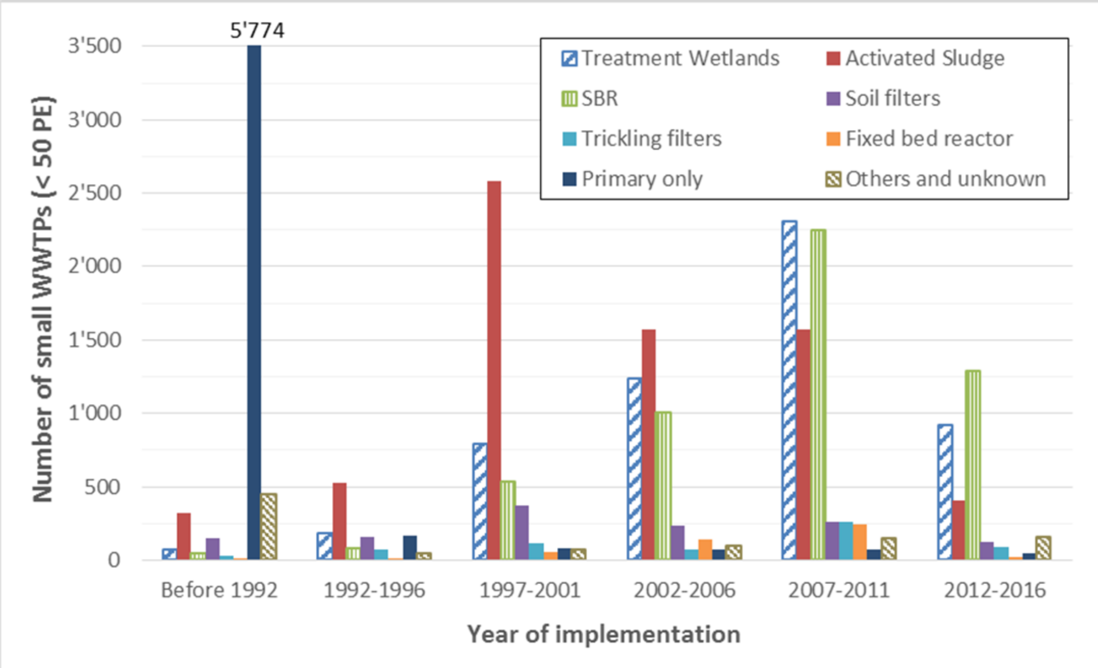

Figure 1: Years of implementation of different treatment technologies with design size smaller than 50 PE

2.1.2 Legislation

The legal requirements for wastewater treatment plants in Austria including limit values and required cleaning achievements are in line with EU regulations and summarized in Table 3. Additionally treatment efficiencies (85% and 95% for COD and BOD5) have to be met over the entire year. Requirements for facilities with design sizes smaller than 50 PE are not specifically defined. Therefore the values of facilities between 50 and 500 PE have to be applied. In the EU-wide regulations no values are given for wastewater treatment plants smaller than 2000 PE.

Table 3: Legal requirements of wastewater treatment plants in Austria

Parameter	1[st]AEVkA (regulation on emissions from WWTP)				91/271/EEC (treatment of municipal waste water)	
	50-500	500-5.000	5.000-50.000	>50.000	all areas *)	sensitive areas
BOD_5 (mg/l)	25	20	20	15	25	25
COD (mg/l)	90	75	75	75	125	125
NH_4-N (mg/l)	10	5	5	5	-	-
N_{tot}	-	-	70 % (>12°C)	70 % (>12°C)	-	15 mg/l 1) 10 mg/l 2) 70-80% 3)
P_{tot} (mg/l)	-	2 (>1.000 P.E.)	1	1	-	2 1) 1 2)

2.1.3 Management of small wastewater treatment plants

Permission to operate a small WWTP (smaller than 50 PE) is given by local authorities on a **case-by-case evaluation**. The European certification procedure for small WWTPs as described in the standard EN 12556-3 (2005) is not applied in Austria as the plants are currently only tested for their ability to remove organic matter. Nitrification - which is mandatory in Austria - is generally not required for small WWTPs in most other European countries.

In most federal states, the permission for operating a small WWTP is granted for a **period of 15 years**. After this period, the permission can be extended if the WWTP is still according to the state-of-the-art, meaning it is able to treat the wastewater according to the legal requirements.

To obtain the permission several local authorities **request** that owners have a contract for operation and maintenance with a company or that owners of WWTPs take part in the **training course for operators**.

The permit to operate a small WWTP also includes the frequency in which **self-monitoring** of the plant has to be carried out by the owner of the WWTP.

Below 50 PE, self-monitoring usually includes weekly routine checks if the WWTP is working properly and **monthly sampling and analysis** of the following parameters: temperature and pH of effluent, effluent concentration of **ammonia nitrogen** and settable solids, and (if applicable) the sludge volume.

For WWTPs larger than 50 PE, sampling and analysis have to be done more frequently (bi-weekly or weekly). All results gained from self-monitoring as well as operational and maintenance works have to be documented in an operations diary.

Besides self-monitoring, **external monitoring** is requested. Usually every two years external monitoring is requested for small WWTPs < 50 PE. In some federal states, the **period** of the external monitoring will be **extended**, e.g. to every three years, if owners of WWTPs successfully **complete the training course for operators.**

During external monitoring, effluent samples are also analyzed for BOD5 and COD. Besides, the operations diary including the data gained from self-monitoring are evaluated. Reports from external monitoring are sent to the local authorities for evaluation.

2.1.4 Overview of trainings for operators

The Austrian Water and Waste Association (Österreichischer Wasser- und Abfallwirtschaftsverband, ÖWAV) provides training courses to operators of wastewater treatment plants.

Special training courses are given for different WWTPs:

- for operators of small WWTPs (≤ 50 PE)
- for operators of WWTPs with 51 ≤ PE ≤ 500
- for operators of WWTPs with > 500 PE
- for sewer operators

2.1.5 Training for operators of small WWTP (≤50 PE)

A special training course for operators of small WWTPs (≤ 50 PE) has started in 2000. The Institute of Sanitary Engineering at BOKU University is responsible for the content of and running the trainings.

An overview of training courses conducted between 2000 and 2018 is listed below:

- > 200 training courses have been held (with about 4'700 participants in total)
- ca. 45 special courses for owners of treatment wetlands (with about 1'000 participants) and
- ca. 15 training courses (with about 300 participants) for operators of WWTPs at Alpine refuges (in collaboration with the Austrian and German Alpine Associations)

The training lasts for 1.5 days and comprises

1. theoretical knowledge on biological wastewater treatment, including main processes for organic matter and nutrient removal, and types of technologies applied;

2. basics on operation and maintenance requirements;

3. practical introduction to sampling and analysis (this part is carried out on a nearby WWTP which has a laboratory), analyses required for self-monitoring, methods available at larger WWTPs;

4. field trips showcasing small WWTPs with different technologies;

5. fundamentals of the legal requirements and subsistence system (this part is given by a person from the local authority with legal background).

Some impressions of the courses are shown in Figure 2.

Figure 2: Impressions of the courses for operators of small WWTP (≤50 PE)

2.1.6 Training for operators of WWTPs in the range 51 ≤ PE ≤ 500

For operators of WWTPs from 51 to 500 PE, a special course has been designed by ÖWAV with duration of 14 days.

In rural areas, WWTPs of this size are often organized as cooperative in which all members are responsible for the operation of the plant. Authorities often accept that the members of the cooperative can participate in the course for operators of small WWTPs with less than 50 PE even if the WWTP is larger than 50 PE.

2.1.7 Training for operators of larger WWTPs (PE > 500)

For operators of WWTPs with a design size of more than 500 PE a training over 3 years is required in parallel to working at their utility (2 years if a special qualification is present, e.g. professional electrician, metal worker, etc.). The training is subdivided into basic knowledge, specialization and exam.

Basic knowledge:

- Training on the job (2 weeks)
- Fundamentals (3 weeks)

Specialization:

- Laboratory (1 week)

- Mechanical engineering (1 week)
- Electrical engineering (1 week)
- Measurement technology (3 days)
- Advanced training (1 week)

Exam (1 day)

2.1.8 Training for sewer operators

A special training is provided by ÖWAV for sewer operators, which is held over 3 years in parallel to working at their utility (2 years if a special qualification is present, e.g. professional electrician, metal worker, etc.). The training is subdivided into basic knowledge, mandatory courses, additionally one elective course and exam.

Training over 3 years in parallel to working at utility (2 years if special qualification is present)

Basic knowledge:

- Training on the job (1 week)
- Fundamentals (1 week)

Mandatory courses:

- Sewer cleaning (3 days)
- Survey and rehabilitation (1 week)
- Operation and maintenance (1 week)
- Electrical engineering (1 week)

Additionally one elective course:

- Sewer inspection, evaluation of damages (1 week)
- Leak testing (3 days)
- Mechanical engineering (1 week)
- Business administration, organization (3 days)

Exam (1 day)

2.2 Sediment management of surface water bodies

At the Department of Water, Atmosphere and Environment of BOKU University a specialized entity, entitled "Christian Doppler Laboratory for sediment research and management" was established in 2017 for a duration of seven years. Its focus lies both on research in terms of sediment transport processes as well as the implementation of new tools and practices in sediment management comprising an important part of water resources management, particularly related to hydropower use and development. This is and will be of substantial importance to the countries of the Western Balkans as more of their hydropower potential is being used in the coming years.

2.2.1 Introduction

IEA World Energy Outlook predicts that 60% of all new energy investments over the next 20 years will be in renewables (IEA, 2015). The prediction for new hydropower production is 25% of all new renewables primarily due to potential in China, Africa, Latin America and South-East Asia. The estimated market potential for economically feasible hydropower projects is 9500 TWh (IJHD, 2015). Assuming a development cost of at least 200 million €/TWh, a future market potential for hydropower development should amount to more than 2000 BN €. Also the European organization Eurelectric increased its focus on hydropower in 2013 and predicted a growth of hydropower production from 550 TWh to 1000 TWh to achieve emission targets within EU by 2050 (IJHD, 2015).

While water resources are important for the production of climate-neutral energy (Renewable Energy Directive, 2009/28/EC), watersheds also provide important ecosystem services such as irrigation, drinking water, biodiversity and recreation (Millennium Ecosystem Assessment, 2010). Upcoming revision of hydropower licenses, implementation of the European Water Framework Directive (WFD, 2000/60/EC) and new national legislations (e.g. National river management plan in Austria) exert pressures on the hydropower industry by establishing targets for improved environmental conditions in regulated watercourses, potentially at the cost of power production. These drivers and pressures call for knowledge-based solutions and address the societal concerns.

One of the main economic, technical and ecological challenges in future, however, are the deposition, the treatments, and the disturbed dynamics of sediments in river catchments, which reduce the future market potential of hydropower significantly. Exemplarily Basson (2009) summarized and predicted in his work the loss in reservoir capacity for the different continents. He predicted that 80% of the reservoirs capacity (in average) will be filled up by sediments in (i) 2100 for Africa, (ii) 2035 for Asia, (iii) 2080 for Europe and Russia, (iv) 2060 for Central East and (v) 2060 for North America. Thus, due to a lack in awareness of those sedimentological challenges (e.g. lack of process understanding) various huge economical, technical and ecological problems emerge with an increasing relevance for hydropower industry, water management authorities and the society in future. Here, previous studies estimated for instance the annual replacement costs for the US with six billion US $ (Fan & Springer, 1990).

In Austria economical aspects are related to both the impact of the deposited sediments on hydropower production and the direct cost due to dredging of deposited sediment with the consequence of depositing (costs) of those reservoir sediments on waste disposal sites. For the latter, in 2016, the costs for depositing reservoir sediments in Austria are 10 – 20 €/m^3. In comparison, at the Danube, the average annual suspended sediment transport (partially depositing) is between two and four million m^3. In addition, about 350000 m^3 of bedload are transported annually in a cross sectional perspective. In other Austrian alpine river catchments, the annual sediment load is about 10 million m^3. Hence, from an economical perspective, if only one tenth of the average annual sediment yield has to be deposited, costs of about 10 to 20 million € per year would arise.

Technical problems concerning sediments in reservoirs are the decrease of the storage volume and issues such as clogging of the bottom outlet, or the intake into the pressure systems. Moreover, the abrasion of turbines (e.g. Francis or Pelton runners) or sediment bypass systems has to be mentioned as big challenges of hydropower use in river systems with high suspended loads. In addition, sediment depositions in backwaters of run-of-river hydropower systems probably cause problems concerning flood protection (e.g. due to the reduction in the hydraulic effective width). Other technical problems occur due to the remobilization of fines in terms of flooding (out of the reservoirs), and thus increase the damage potential downstream. Another challenge in future will also be given by the impacts of global warming on sediment production and run-off regimes.

Ecological problems in both alpine and large rivers occur due to mid- to long term shortcomings in sediment management, the interruption of the sediment continuum (sediment deficit) and the subsequent impacts in downstream river sections. In terms of flushing (surplus of fines), however, local fishing companies and non-governmental ecological organizations claim for additional costs (e.g. required stocking of fish due to impacts of flushing on instream population) or possibly try to stop the (technically required) reservoir flushing by legal means. Moreover, at the moment there are no objectively investigated (by laboratory or field studies) and validated thresholds for federal institutions in Austria provided by the scientific community (e.g. for harmful turbidity rates). Here, the interaction of instream hydraulics, sediment transport, river morphology and ecology are not adequately understood from a process perspective, and thus implementation of sustainable sediment mitigation measures in river management plans is missing. Furthermore, there is also a lack in standardized evaluation methods in Austria for detecting disturbances in the sediment regime. (Hauer et al., 2017).

2.2.2 Technologies in reservoir management

Reservoir management technologies can be subdivided into catchment-wide measures, as well as measures in the reservoir and at the dam (Figure 3).

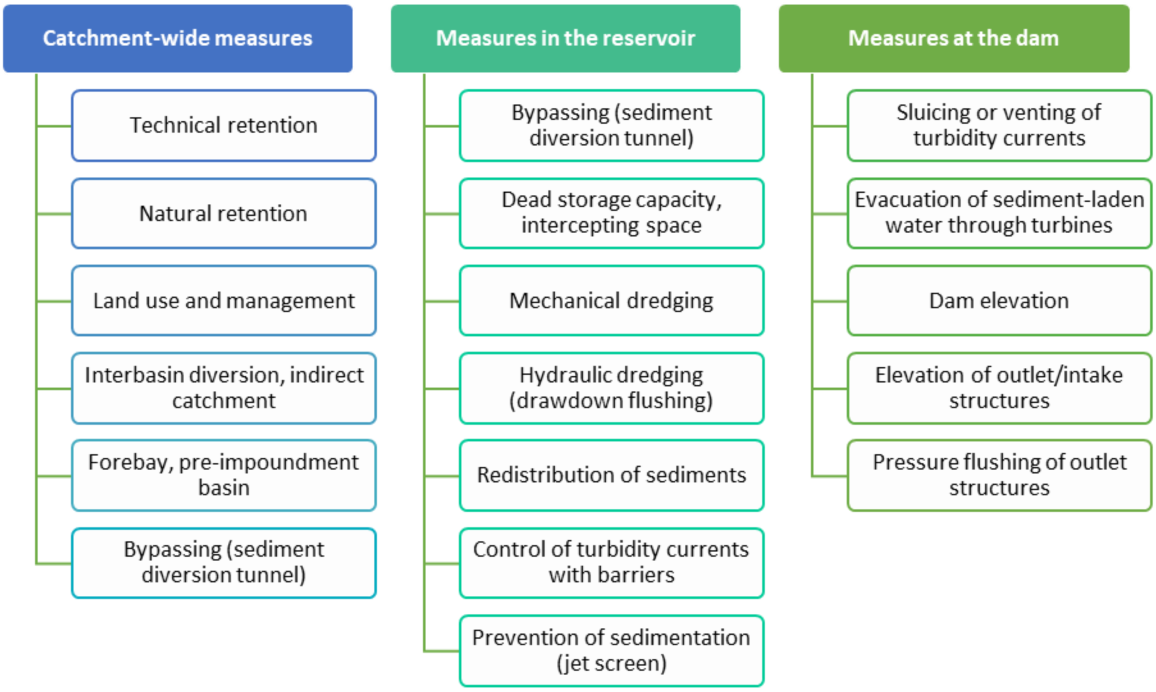

Figure 3: Technologies for reservoir management (Wagner et al., 2013; after Schleiss et al., 2010)

2.2.2.1 Catchment-wide measures

Following the approach of Schleiss & Oehy (2002) catchment-wide reservoir management techniques are (a) technical retention measures including, for example, torrent control, sediment retention basins, as well as coarse screens and sand traps, (b) natural retention measures, such as soil-bioengineering and plantations, (c) land use and management practices, for example, agricultural measures and woody debris minimizing erosion rates, (d) interbasin diversion (indirect catchment),

(e) the construction of a pre-impoundment basin at the entrance to the reservoir, and (f) bypassing sediments.

2.2.2.2 Measures in the reservoir

Frequently investigated and described innovative mitigation measures for sediment management in reservoirs are sediment bypass systems. The diversion of sediments through a tunnel (bypassing) can be seen as a preventive and catchment scale measure against reservoir sedimentation, as it inhibits the input of bedload and part of the suspended load into the reservoir, ensures sediment continuity during floods, and thus can improve river ecology and sustainability by preventing river bed erosion downstream the dam. As an alternative to bypassing, some authors propose the building of off-channel reservoir storages diverting clear-water from a weir, while sediment-laden water is left in the tributary / river with the advantage that all bedload can be excluded from the reservoir.

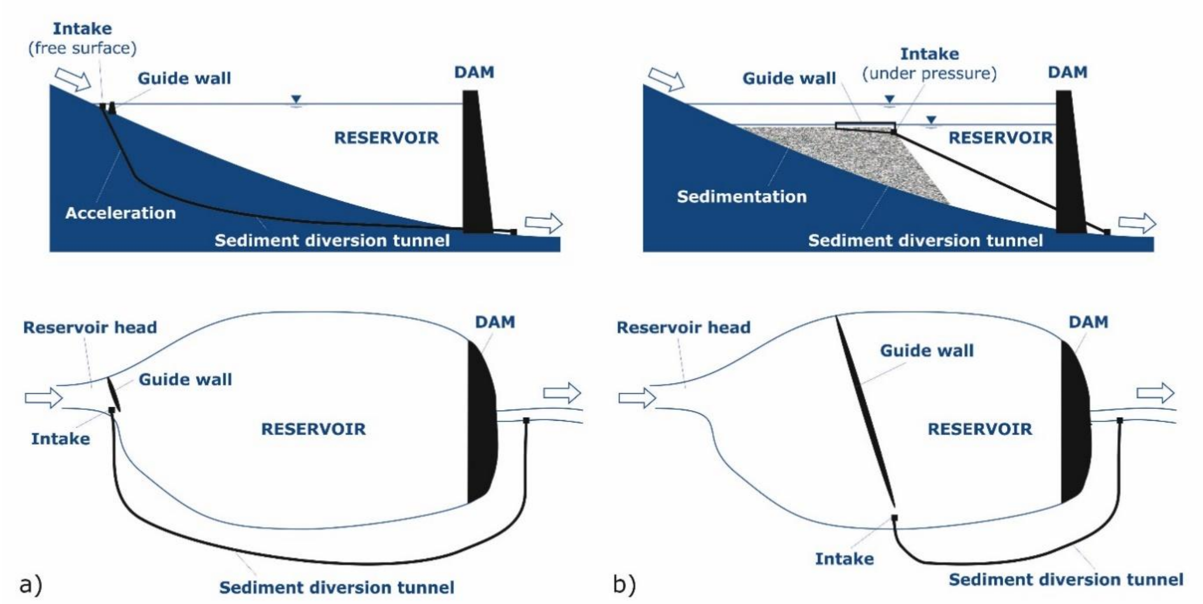

Figure 4: Schematic overview of a sediment diversion tunnel. Location of the intake structure a) at the reservoir head, b) inside the reservoir; longitudinal section (top) and plan view (bottom) (after Boes, 2011).

Other common management techniques in the reservoir can be summarized as measures removing sediments from the reservoir, such as mechanical dredging and hydraulic dredging (reservoir flushing). Regarding mechanical dredging, it can be distinguished between (i) dry dredging (often limited to areas near the embankments), using conventional construction machines and requiring maximum drawdown of the reservoir while at the same time keeping the turbines operating, and (ii) wet dredging, where no drawdown is necessary and sediments can be removed from the entire reservoir area. Here, special machines (pontoon dredge, suction dredge) are required and dredging efficiency is much lower. However, hydraulic dredging, i.e. the hydraulic removal of sediments by flushing the reservoir, is usually regarded as the simplest and most economic measure to deal with reservoir sedimentation. To reach the required shear stress a complete drawdown of the water level is necessary, which causes high losses in energy generation. Therefore, in the case of annual storage reservoirs, it is usually combined with other maintenance work. As opposed to free-flow flushing of a reservoir, some recent studies have investigated pressure flushing, which does not involve a complete drawdown of the water level. Thus, it has only marginal effects on useable reservoir volume, but it can help to keep intake structures free of sediments by developing a local erosion cone. Although necessary for ensuring the functionality of the hydropower plant, a flushing event can have considerable and far-reaching consequences from an ecological point of view (Hauer et al., 2016). Another management technique in the reservoir is the redistribution of sediments, but only if the storage is large enough to split into a sedimentation and a utilization area. Redistribution can be carried out either with mechanical means (dredging) or special constructions (groynes, screens, guide walls) that guide the flow of sediments. Approaches providing additional space for storing the expected sediment input over the next decades in a dead storage capacity of a new planned reservoir cannot be seen as innovative, sustainable measure, as this just postpones the problem of reservoir sedimentation to a later time instant.

2.2.2.3 Measures at the dam

Innovations regarding reservoir management techniques at the dam have recently focused on turbidity currents, as these currents, transporting fine material into the direction of the dam, have been recognized as the main driver for siltation of large alpine reservoirs. In general, measures to manage turbidity currents aim either at stopping them in order to prevent them from settling down at critical points, or at diluting them and consequently transporting them through the barrage. This includes the construction of impermeable and permeable barriers, such as dams and geotextile curtains, prevention of sedimentation with hydraulic means (e.g. jet screen), sluicing and venting, as well as dilution and subsequent evacuation of the sediment-laden water through the turbines. Additionally, there exist further constructive measures at the dam, for example, dam elevation or an elevation of intake / outlet structures that can allow usage of a reservoir that is subject to high sedimentation for a longer period of time. However, comparable to the provision of dead storage space the effectiveness of this measure is limited, and thus it cannot be regarded as sustainable. (Hauer et al., 2017).

2.2.2.4 Further innovations

In order to obtain the capability to effectively apply innovative management methods, information about quality and quantity of the sediments in a reservoir is indispensable. One such innovative method to gather relevant data is seismic profiling, originating from offshore technology (Figure 5). By standardization of this method for sediments in reservoirs, knowledge about layer depths of different grain sizes as well as their densities can be obtained.

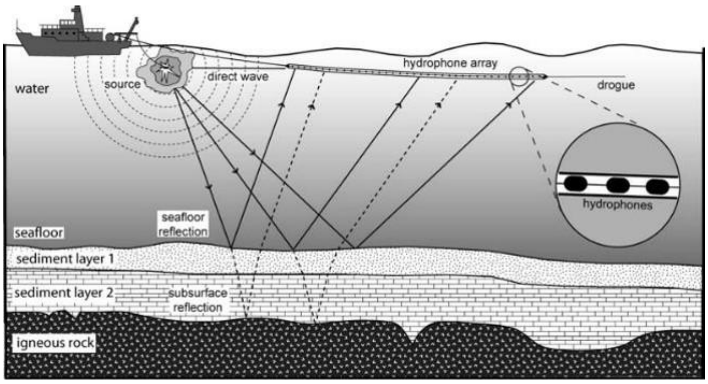

Figure 5: Scheme of seismic profiling technology (Source: www.schmidtocean.org)

Also the re-use of dredged material instead of deposition at a landfill can be seen as innovative management technique. In order to estimate potential future uses, the application of a roentgen diffractometer allows to determine the quartz content of the sediment. Quartz sand is a valuable raw material in the construction industry (e.g. grout, concrete), the water supply industry (i.e. filter) and further industrial fields. Hence instead of wasting the dredging material, if it features the appropriate quality, it can be used in an economically beneficial way instead.

2.2.3 Technologies in sediment management of rivers

While upstream reservoirs usually suffer from a surplus of sediments, downstream reaches often face problems of river bed erosion. Innovative management techniques are targeted at addressing the sediment deficit downstream of reservoirs either directly or indirectly. This chapter, based on Tritthart et al. (2019), highlights some innovative practices in this field.

2.2.3.1 Granulometric bed improvement

The core idea underlying the granulometric bed improvement is that larger gravels yield a higher resistance against being set in motion than smaller gravels due to the resulting inertial forces. Therefore, depending on morphological conditions, a layer (25 cm at the Austrian Danube) right below the river bed is either replaced by larger grain sizes (Figure 6) or this layer is added upon the river bed. Over time, this material mixes with both transported and subsurface gravels, yielding a sediment mixture which is coarser than the original but still within the natural grain size spectrum.

The allowance/replacement gravel mixture projected during the planning stage ranged between 40 and 70 mm at the Austrian Danube. Numerical modelling as well as physical model tests indicated a stable behavior of these grain sizes. However, field tests showed a higher mobility than expected of this grain size fraction. Finally, a larger grain size range of 32 mm to 120 mm yielded the best stabilization effect. The increased mobility of the gravel layer in the field test compared to numerical and physical model tests was credited to the presence of transport phenomena in the field such as gravel sheets and increased turbulent kinetic energy or small-scale turbulent structures.

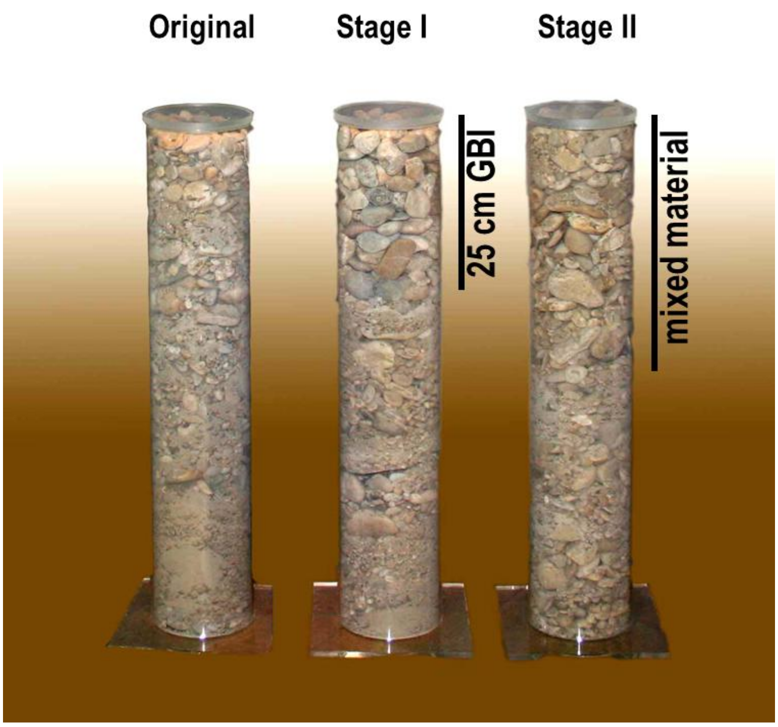

Figure 6: Concept of the granulometric bed improvement

2.2.3.2 Groyne modifications

Intensive river regulation by guiding walls and groynes was present at the Austrian Danube east of Vienna at water levels up to mean flow and still exists in many other locations. These structures channelize the flow and particularly during low-flow situations lead to increased bed shear stresses, which in turn facilitate river bed erosion. There are several possibilities to modify groyne structures in order to reduce their erosive effect:

1. Reduce the number of groynes, thereby lowering the channelization effect;
2. Reduce the crest elevation of groynes, hence minimizing the discharge spectrum during which the groynes affect the flow;
3. Reduce the length of groynes, thus effectively reducing the river width affected by channelization;
4. Change the inclination angle with respect to the river banks, with the effect of directing the flow towards the banks during groyne submergence (so-called attracting groynes), which leads to bank erosion and additional sediment availability to counter a sediment deficit.

At the Danube River east of Vienna all of the above variants were tested simultaneously in the field (Figure 7). In turn, strong sedimentation processes resulted. After performing a structural adaptation cycle of the measures based on the results of numerical models, a dynamic equilibrium of river morphology could be achieved, thus delivering proof that the innovative practices indeed work in the field.

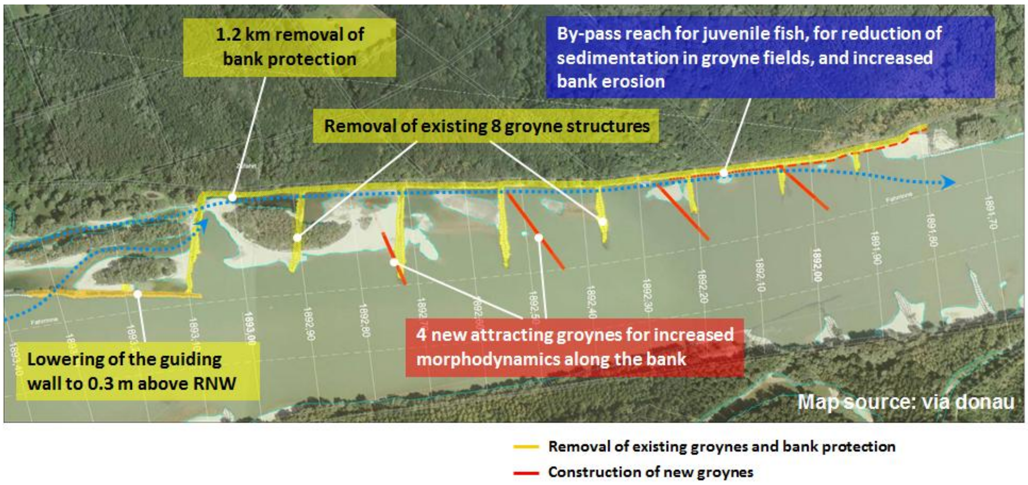

Figure 7: Groyne modifications and further river engineering measures (example Witzelsdorf)

2.2.3.3 Artificial island building

The concept underlying the construction of artificial islands is to create a flexible sediment buffer at the side of the navigation fairway. The island serves the purpose to achieve channelization and therefore increase the water depth during low-flow periods, but on the other hand it is erodible during higher river discharges and allows the river to carry sediment for gravel replenishment. The structures are unstable by design on the long term and thus need to be subject to maintenance operations. At the Danube east of Vienna as well as in the free-flowing section in the Wachau such islands were implemented successfully (Figure 8) and further ones in other reaches of the Austrian Danube are in the planning stage.

Figure 8: Artificial island building at the Danube River

2.2.3.4 Side-arm reconnection and other methods towards sustainable sediment management

Further innovative methods were implemented at the Austrian Danube to achieve a sustainable sediment management and also improve the ecological situation, in particular the connection between main river and its floodplains. The first notable modification was the reconnection of several side arms (Figure 9). The side arms were connected at discharges well below mean flow, thereby achieving flow passage during most of the year and thus restoring the original character of an anabranching river system. This has the further benefit of reducing the shear stress on the bed of the main branch of the river, as more flow is diverted through the floodplains, which in turn reduces river bed erosion. Moreover, the removal of rip-rap protection at all banks not directly exposed to the flow was aimed towards increasing the amount of sediment in the river by allowing lateral erosion processes.

Figure 9: Examples of reconnected side arms (photo credits: Haslinger, Pock)

3 Bulgaria

Innovation is a word often mentioned recently. You can hear it on TV, radio; you can read it in newspapers and in social media. But what actually is innovation? What does it mean innovative? In the field of water resources management – also a term often mentioned, when speaking of water, there are no many really innovative methods, approaches, facilities, etc. Sometimes, something well forgotten old method or approach is presented as new. Those, who are not specialist in the area, think about it as a "golden egg", but the well-informed specialists usually react with disregard.

The real innovations in WRM in Bulgaria are not so much, especially those which are already implemented in practice. The following is a short description of what is considered as "innovation" and "innovative" by the authors of this report. There may be some gaps or non-mentioned "innovations" from the point of view of other specialist in WRM in Bulgaria.

3.1 Update of Crop Water Requirements taking into account climate changes

Irrigation is one of the biggest consumers of water. In EU the share of water used in agriculture is appox. 40%. The case in Bulgaria until mid-1990s was the same, but in the new century the share of water used in agriculture (mainly for irrigation) dropped to some 15%. Nevertheless, in some Bulgarian regions the water abstracted for irrigation has significant share, which is difficult to be assessed, due to lack of water metering in irrigation canals. The River Basin Management Directorates had difficulties when issuing new permits, because there was no reliable reference on how much water is needed for irrigation of unit of land. Thus, it was hard to judge if the requested amount of water is adequate to farm size and crops grown, and if the water will be used efficiently.

As a result of a scientific research, done in cooperation between Institute of Soil Science, Agrotechnologies and Plant Protection, University of Architecture, Civil Engineering and Geodesy and National Institute of Hydrology and Meteorology, the crop water requirements for 7 specific agroclimatic zones in Bulgaria were updated. The original values, which were used till 2016, were published in 1986 and seemed rather outdated. In the new research it was taken into account the change and trend in air temperature, as well as the change and trend in precipitations, so, the net irrigation requirement increase on average with approx. 15% for 5 of the 7 agroclimatic zones. In order the use of the final document from the research to be facilitated, the net irrigation requirements were given for 3 different irrigation methods – furrow/border strip, sprinkler and drip irrigation. On the basis of the research the Council of Ministers of Bulgaria issued in 2016 an *Ordinance for water consumption rates* (in agriculture). As a result, the River Basin Management Directorates have reference values for net and gross irrigation requirements for 28 crops, irrigated by 3 different methods, for 7 agroclimatic zones in Bulgaria.

3.2 Optimization Tool for River Basin Management Directorates

Efficient use of water resources in order to decrease the pressure on water sources is one of the main aims in each country. Usually the efficient use is related with small water losses – both physical (seepage, leakages, etc.) and technological (mismatch between delivery and consumption, especially in irrigation). The other way for reduction of water abstraction, and thus, the pressure on water bodies, is decrease of consumption.

Both ways for increasing of the water use efficiency can be implemented, but in any case, investments are needed. It is well-known that investments in different interventions have different effect on reduction of water abstraction. Thus, an optimization approach and a relevant tool is needed to get the maximum effect with minimum investments.

A combined approach for solving the optimization tasks was proposed in a project "Assessment of water Balances and Optimisation based Target setting across EU River Basins (ABOT)". ABOT was one of the Pilot projects on Development of Prevention Activities to Halt Desertification in Europe, partly funded by DG Environment of the European Commission. The overall aim of the ABOT was to support the European Commission's effort to identify means and develop prevention activities to halt desertification in Europe, by focusing on complementing EU water resources balances elaborated in the framework of the System of Economic and Environmental Accounts for Water (SEEAW) and supplementing ongoing projects which tackle water scarcity, droughts and desertification. UACEG was one of the partners in the project. It was suggested to use WEAP (Water evaluation and planning) software. The advantages of the software are, as follows: (i) it solves a wide range of problems; (ii) it can be applied at the river basin level, several river basins, as well as the lower level; (iii) appropriate for analyzing various scenarios of what-if type; (iv) adaptive to farming practices; (v) suitable for detailed modeling of water demand; (vi) WEAP can work as COM Automation Server. In the project WEAP model was used together with Mathlab to estimate the effect of different measures for decrease of water losses and water abstraction.

The approach is just a suggestion – as methodology and applications used. It is not yet adopted for use in River Basin Management Directorates in Bulgaria. The results of the project, the approach and the way the WEAP software was used together with Mathlab are presented to teaching staff from Western Balkan countries during the staff training held in UACEG-Sofia in the end of May 2019.

3.3 From Recycling to Circular Economy

As a result of UN Sustainable Development Framework and EU's Circular Economy Action Plan a research work for implementation of these ideas and concepts in the field of Wastewater treatment began in UACEG. A Project BG05M2OP001-1.002-0019: „Clean technologies for sustainable environment – waters, waste, energy for circular economy", funded by European Regional Development Fund and Bulgarian Operational Programme "Science and Education For Smart Growth" was launched in 2018. UACEG participates in the project together with partners from other 3 Bulgarian universities, 3 Research Institutes of Bulgarian Academy of Sciences, private companies.

Considering the wastewater treatment, there are three pathways towards a circular economy in that area: (i) to improve treatment to increase the quality of the primary and the excess sludge, so that they can be re-used; (ii) to develop a completely new treatment technology, not producing sludge; (iii) to reduce pollutants at the source, which will enable the production of "cleaner" wastewater not requiring deeper treatment.

Targeting the second pathway a research work on implementation of Algy-based wastewater treatment technology started. The big challenge is to find suitable algae, and then to upscale the laboratory model to real wastewater treatment plant.

This topic was also presented at Training for teaching staff, held at UACEG in the end of May 2019.

3.4 Use of Solar Pumps for Irrigation

The idea of using Solar energy for driving pumps for irrigation is not a new one. The advance in science and technologies made possible this to be implemented in practice on affordable price. The solar cells/panels, pumps, auxiliary equipment are produced by different companies, so it is easy to construct desired system.

The big problem appears when the designer has to choose the pump, its design capacity and power. This is due to the fact that energy produced by the sunlight varies not only during the day, but also during the week, the month, etc. It is also dependable of the clouds, the latitude of the site, etc. The lack of methodology how to select pump, its rated power, and how to combine pump, Solar cells and irrigation system provoke research in that area.

4 Croatia

Croatia became member of EU in 2013. Since then many activities in water management sector have been focused on applying new legislation and applying to EU funds, mostly in water supply and sewage systems and flood protection.

In order to understand water management in Croatia first a short introduction to water management framework and the financial framework in water sector development and afterwards some of the active and planned projects in water resource management will be shortly presented. This part was presented during the "Workshop on innovative practices in the EU water sector: barriers and opportunities" in Vienna 8.-10.05.2019. by Nevena Dragičević.

In the third part of this report different forms of collaboration of UNIRIFCE with stakeholders and other HEIs is presented as examples of good practice and that could be implemented on other HEIs. This part about promoting public-private partnership and collaboration with HEIs was presented during the "Workshop on innovative practices in the EU water sector: barriers and opportunities" in Vienna 8-10.05.2019. by Barbara Karleuša.

4.1 Water management framework in Croatia

Water management in Croatia is organized in several levels of public administration (Figure 10). The first level represents the government of the Republic of Croatia. The second level is comprised of ministries and state administrative organizations. The third level is comprised of government agencies, state owned companies and governmental associations. At the third level of public administration is Croatian Waters, an agency responsible for water management activities as a public service.

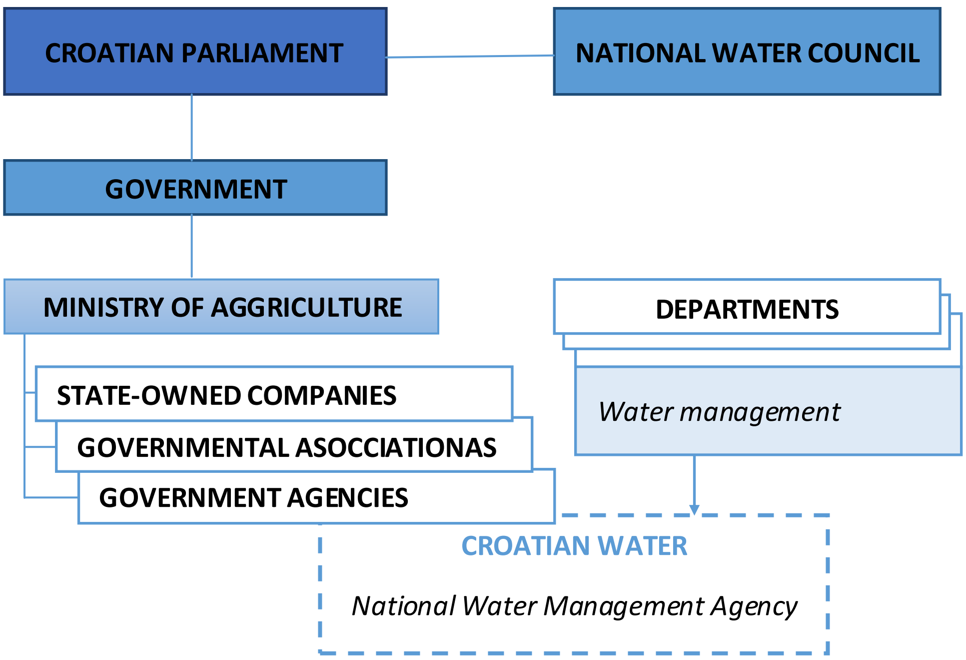

Figure 10: Water management framework in Croatia

4.1.1 Croatian Waters

Croatian Waters is a legal entity for water management established by the Croatian Government based on the Water Act. It governed by Management Board with General Manager on top. Croatian waters is organized based on the territorial and functional principles and divided into two basic organizational units (www.voda.hr):

1. The Head Office
2. Water management departments

In the Figure 11 the organization scheme of Croatian Waters is presented.

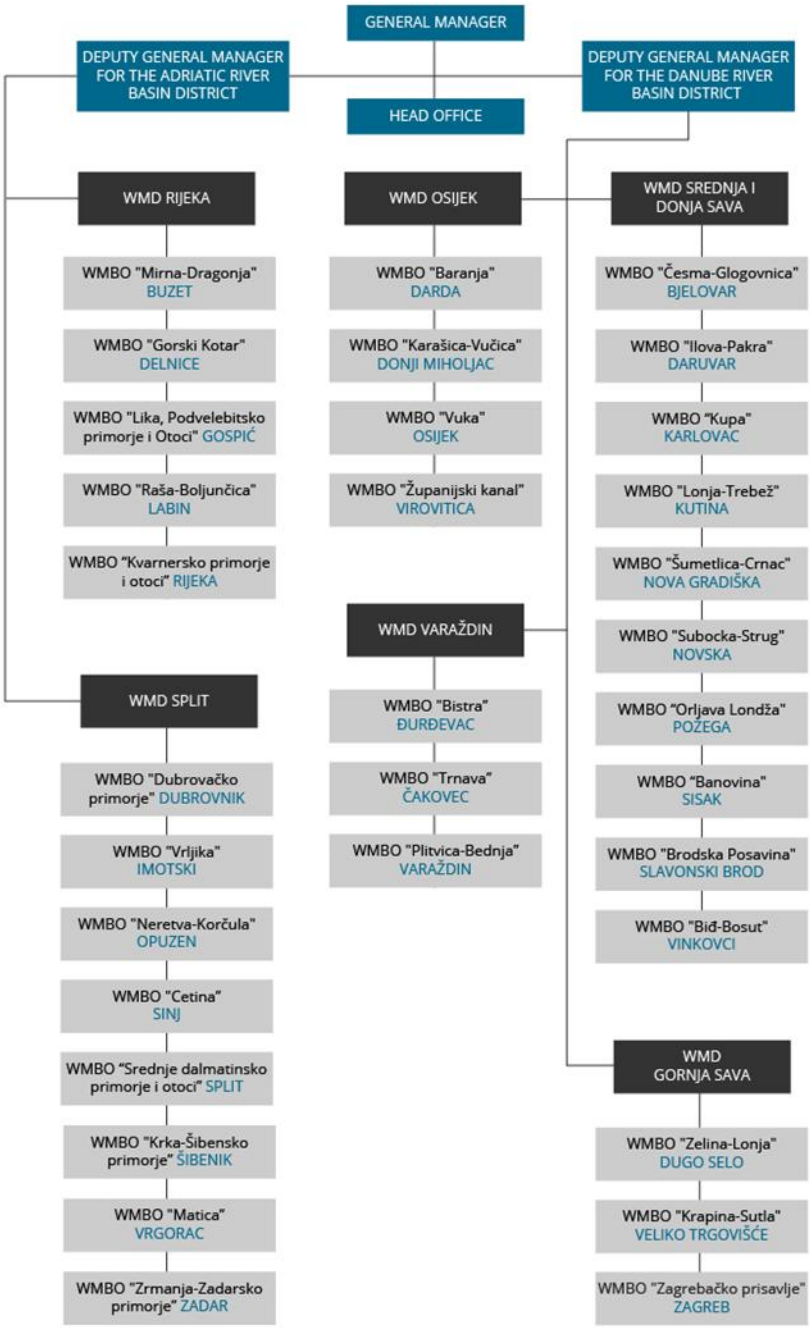

Figure 11: Organization scheme of Croatian Waters

The Head Office is divided into departments, services and the Water Management Institute, as well as units and the Central Water Management Laboratory, and the Central Flood Defense Centre.

There are the following departments (www.voda.hr):

- Department of Development,
- Department for Protection from Adverse Effects of Water,
- Water Use Department,
- Water Protection Department,
- Department for Planning and Technical Control,
- Financial Department,
- Legal and Personnel Department,
- Department for Information and Communications Technology,
- Department for EU Co-financed Projects,
- Department Supporting the Preparation and Implementation of EU Projects.

Croatian Waters has also the responsibility for managing water and public water estate as well as flood protection structures.

4.1.2 Legislation

The legal framework for water resources management in Croatia is based on several acts and other legislative documents and programs:

1. The Constitution of the Republic of Croatia
2. The Water Management Strategy
3. The Water Act
4. The Water Management Financing Act
5. The Long-Term Program for Construction
    a. Long-Term Programme for Construction of Water Regulation and Protection Structures for Amelioration Structures
    b. Long-Term Programme for Construction of Municipal Water Facilities
6. River Basin Management Plan
7. Implementation Plan for Water Utility Directives
8. Financial Plan

4.1.3 Financial framework for water sector development

For the past 10 years development projects in water sector have been intensified due to attempts to achieve water management standards within the given time frames defined by the European legal framework and with the aim to make the most out of non-refundable funds available from various EU. There is also a permanent increase in requirements for continuous monitoring of water bodies. At the same time, there is an increase in frequency of flood and high water events, which requires considerable efforts in maintenance of functionality of existing flood protection systems and operational flood defenses. Due to climate change, droughts are also expected in the near future, so the preventive measures are intensively implemented in a form of water supply system and irrigation systems development (Đuroković and Biondić, 2019).

The sources for financing water resource management in Croatia are as follows:

a. EU Structural Funds & Cohesion Fund

b. Ministry of Construction and Physical Planning

c. Croatian Water

d. Water Utility Companies

By entering in the EU the Republic of Croatia has gained access to European Structural Funds (ESI) and Cohesion Fund. For the time period from 2014. Up to 2020. the overall funds at the disposal for Croatia from EU Funds are shown in Figure 12.

Figure 12: Financial support for EU Funds at disposal for Croatia for the time period from 2014. – 2020.

Croatia has at its disposal 10,676 billion EUR from Operation programme Competitiveness and Cohesion 2014-2020 (approx. 74%) and European Regional Development Fund (approx. 26%). For this time period the emphasis is given on water and sewage utility development which will be financed through Operational programme Competitiveness and Cohesion 2014 – 2020 with the budget of 1,05 billion EUR. For flood protection Croatia has at its disposal has 215 billion EUR from European Regional Development Fund.

Two development directions are given within the Operational Program Competitiveness and Cohesion 2014-2020: (i) Climate change and risk management and (ii) Environment protection and resources sustainability.

Under Climate change and risk management emphasis is given on strengthening the disaster management system. Environment protection and resources sustainability is intended for the investment in water sector, both development and improvement of public water supply systems and development and improvement of water sewage systems.

Strategical frame for using European Structural Funds is based on:

a. Partnership Agreement

b. Operational Programs (4 active programs)

c. Common National rules and legislations

d. Law for establishing an institutional framework for use of European Structural Funds in the Republic of Croatia for the period 2014-2020

e. Regulation governing the competence of individual bodies for each European Structural Fund instrument

4.2 Projects in Water Resource Management in Croatia

4.2.1 Water supply, sewage utility and irrigation system development

Providing sufficient amount of drinking water for the population is one of the most important water resource management aims and objectives. In the Republic of Croatia 94% of population has access to water supply systems and overall 86% of population is connected to public water supply systems (Figure 13).

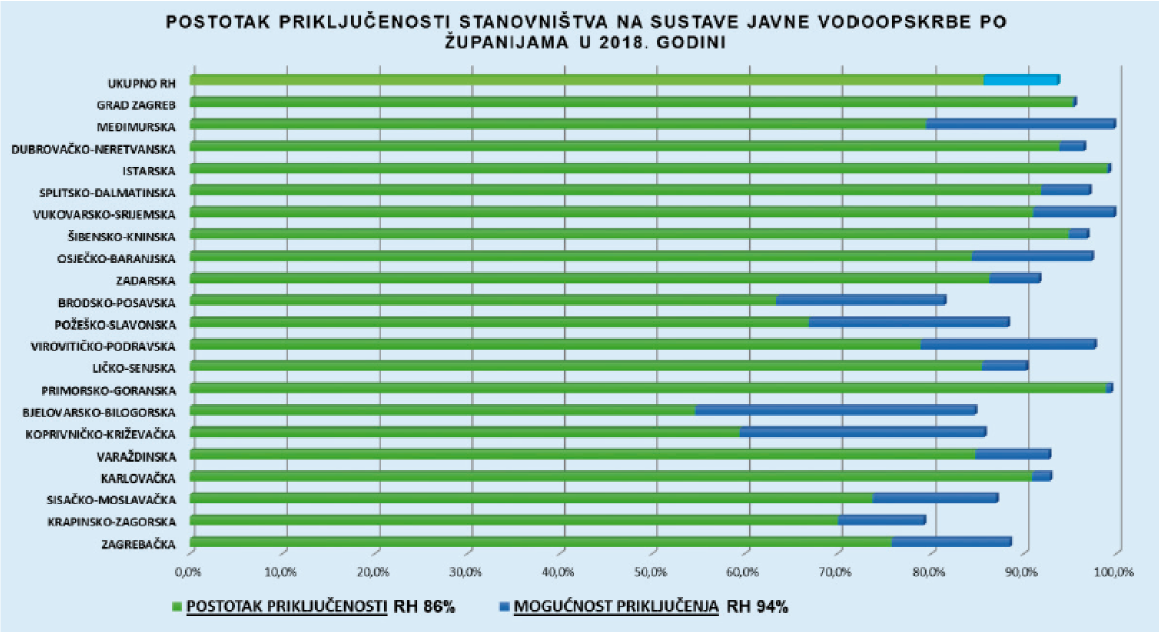

Figure 13: Population connected to public water supply systems presented by counties in Croatia (Đuroković and Biondić, 2019) – green 86% connected to public water supply system, +blue 94 % that has the possibility to be connected to the water supply system.

In Croatia there are 551 water supply zones (310 public water supply zones, 241 local water supply zones) and individual water supply zones. Water for less than 5000 inhabitants or less than 1000 m3/day is delivered in 180 public water supply zones (58,1%). In 184 local water supply zones (76,3%) water is delivered to more than 50 inhabitants (www.voda.hr).

Investments in reconstruction and development of water supply systems in Croatia have an aim to ensure rational water resource exploitation and water use, stability in water supply and economic stability of public utility providers (Đuroković and Biondić, 2019).

One of the mail aims defined by Water Framework Directive is to improve drinking water quality and increase the percentage of population connected to water supply systems (Đuroković and Biondić, 2019). It is also important to mention that water loss in water supply systems in Croatia is approx. 50%. From overall 38 approved EU projects, 2 of them are intended for the water supply system development with overall financial cost 782,000,000.00 Kn.

There are 245 public sewage systems. 46% inhabitants in Croatia are connected to the sewage system, and 35.3% have the waste water treated before disposal. From 38 approved EU projects 36 of them are intended for the sewage systems development with the overall cost 10,72 billions Kn (Đuroković and Biondić, 2019).

Active and announced projects related to development of water supply systems and sewage systems in Croatia are given in Table 4.

Table 4: Active and announced investment sewage utility systems development projects in Croatia (Đuroković & Biondić, 2019; www.voda.hr)

R.br.	Rok usklađenja s Direktivom	EU projekt	Ukupni prihvatljivi trošak (HRK)	Udio EU sufinanciranja (HRK)	Mjesec stupanja na snagu ugovora o donaciji	Udio EU sufinanciranja (EUR)
1	2020	Petrinja	344.922.279,52	244.894.803,91	07.2016.	32.223.001
2	2018	Rovinj	223.862.868,00	160.585.512,68	12.2016.	21.129.673
3	2020	Krk	510.913.257,00	369.138.660,00	07.2017.	48.570.876
4	2018	Osijek - faza2	200.679.737,00	146.679.832,00	07.2017.	19.299.978
5	2018	Poreč - faza 2	286.542.747,00	212.068.854,34	07.2017.	27.903.797
6	2018	Virovitica - faza 2	131.826.659,90	92.561.675,96	07.2017.	12.179.168
7	2018	Županja - faza 2	56.817.385,96	40.403.030,74	07.2017.	5.316.188
8	2018	Vukovar - faza 2	314.144.301,00	221.837.433,00	07.2017.	29.189.136
9	2018	Nova Gradiška - faza 2	125.507.952,04	88.204.554,76	07.2017.	11.605.862
10	2023	Vodice - faza 2	84.233.985,37	62.205.110,15	07.2017.	8.184.883
11	2018	Varaždin	684.664.161,00	488.738.903,00	10.2017.	64.307.750
12	2023	Varaždinske Toplice	49.684.723,00	35.422.661,00	10.2017.	4.660.876
13	2018	Rugvica - Dugo Selo	173.079.910,00	121.542.125,00	10.2017.	15.992.385
14	2018	Donja Dubrava	189.080.650,00	135.652.414,41	10.2017.	17.849.002
15	2020	Mursko Središće	181.777.310,00	128.773.937,90	10.2017.	16.943.939
16	2020	Jastrebarsko	135.413.711,45	97.836.673,60	10.2017.	12.873.247
17	2018	Vinkovci	384.560.952,11	272.134.035,00	12.2017.	35.807.110
18	2018	Đakovo	213.851.627,05	152.261.357,46	12.2017.	20.034.389
19	2020	Pleternica	141.426.792,10	99.099.103,00	12.2017.	13.039.356
20	2018	Požega	171.777.186,90	124.444.841,93	12.2017.	16.374.321
21	2018	Lipik - Pakrac	153.546.408,40	110.389.119,39	12.2017.	14.524.884
22	2018	Valpovo - Belišće	271.578.968,00	189.561.114,00	12.2017.	24.942.252
23	2020	Nin - Privlaka - Vrsi	317.776.078,40	224.974.341,34	01.2018.	29.601.887
24	2018	Velika Gorica	398.890.121,00	268.788.163,00	01.2018.	35.366.864
25	2018	Šibenik	397.025.090,00	272.004.105,52	03.2018.	35.790.014
26	2018	Zabok - Zlatar	478.479.348,21	321.355.962,44	05.2018.	42.283.679
27	2018	Rijeka	1.761.563.462,00	1.256.548.480,00	07.2018.	165.335.326
28	2023	Betina - Murter	124.691.413,00	85.645.395,61	06.2018.	11.269.131
29	2020	Novska	98.905.027,68	70.105.921,45	07.2018.	9.224.463
30	2018	Umag - Novigrad	445.355.470,66	316.810.294,39	07.2018.	41.685.565
31	2018	Vrbovec	151.383.610,12	101.532.059,45	07.2018.	13.359.482
32	2023	Novi Vinodolski	367.636.276,28	261.119.567,03	07.2018.	34.357.838
33	2023	Novalja	248.353.489,69	172.494.435,80	07.2018.	22.696.636
34	2018	Sinj	302.669.801	211.610.086	04.2019.	27.843.432
35	2018	Kutina	390.731.725	262.967.284	04.2019.	34.600.958
36	2018	Bjelovar	205.978.311	147.681.300	04.2019.	19.431.750
UKUPNO:			10.719.332.796,84	7.568.073.149,26		995.799.098

Approximately 17 sewage system development projects are waiting for the approval (Table 5) and projects in faze of document preparation are given in Table 6.

Table 5: Sewage utility systems development projects waiting for the approval in Croatia (Đuroković & Biondić, 2019; www.voda.hr)

R.br.	Rok usklađenja s Direktivom	EU projekt	Ukupni prihvatljivi trošak (HRK)	Udio EU sufinanciranja (HRK)	Udio EU sufinanciranja (EUR)
1	2018	Kaštela - Trogir	1.151.030.595	805.091.444	105.933.085
2	2018	Zaprešić	547.040.890	387.792.012	51.025.265
3	2018	Karlovac 2	358.563.762	255.631.263	33.635.693
4	2023	Đurđevac	279.304.765	195.155.349	25.678.335
5	2023	Cres Lošinj	387.020.156	263.355.489	34.652.038
6	2023	Pitomača	209.623.645	149.341.788	19.650.235
7	2023	Semeljci	175.653.809	121.734.196	16.017.657
8	2023	Otok - Trilj - Dicmo	197.987.900	132.887.000	17.485.132
9	2018	Beli Manastir	116.682.963	84.133.032	11.070.136
10	2018	Imotski	229.412.805	161.715.085	21.278.301
11	2018	Split - Solin	1.469.780.807	1.010.626.601	132.977.184
12	2018	Zadar	453.641.772	313.659.755	41.271.020
13	2020	Ivanec	171.005.120	119.397.596	15.710.210
14	2018	Našice	166.258.570	116.380.962	15.313.284
15	2020	Jelsa - Vrboska	378.933.698	259.088.936	34.090.650
16	2018	Koprivnica	480.196.682	327.758.639	43.126.137
17	2018	Metković	358.929.889	253.969.379	33.417.023
UKUPNO			**7.131.067.828**	**4.957.718.525**	**652.331.384**

Table 6: Sewage utility systems development projects in preparation faze in Croatia (Đuroković & Biondić, 2019; www.voda.hr)

R.br.	Rok usklađenja s Direktivom	EU projekt	Ukupni prihvatljivi trošak (HRK)	Udio EU sufinanciranja (HRK)	Udio EU sufinanciranja (EUR)
1	2020	Slatina	212.090.247	150.338.903	19.781.435
2	2018	Dubrovnik	658.109.826	468.939.447	61.702.559
3	2020	Ploče	200.479.000	138.663.000	18.245.132
4	2018	Ivanić Grad	216.208.446	143.609.000	18.895.921
5	2018	Križevci	257.204.575	180.711.934	23.777.886
6	2020	Pula Sjever	332.377.103	236.328.430	31.095.846
7	2018	Pula Centar	650.825.442	491.958.951	64.731.441

There are also several irrigation system development projects active (Table 7) and planned (Table 8).

Table 7: Active irrigation systems development projects in Croatia (Đuroković & Biondić, 2019)

Red. br.	Županija	Naziv projekta	Površina (ha)	Procijenjena vrijednost projekta s PDV-om (Kn)	Odobrena sredstva -prihvatljivi trošak (kn)	Osnovni podaci o projektu	Dinamika izgradnje	
		Ukupno 9 projekata	3.623	372.000.000	356.838.836		Početak izgradnje	Rok (mjeseci)
1	Virovitičko-podravska	Novi Gradac - Detkovac	750	45.000.000	43.113.195	zahvat iz r. Drave; CS 440 l/s; TDM 23,21 km; 175 priključaka;	13.8.2018	14
2	Virovitičko-podravska	Đolta	161	14.000.000	12.421.215	2 zdenca 2x30 l/s; TDM 7,46 km	13.8.2018	14
3	Vukovarsko-srijemska	Sopot	704	37.000.000	36.970.650	zahvat iz r. Bosut; CS 480 l/s; TDM 16,79 km	21.8.2018	14
4	Vukovarsko-srijemska	Blata - Cerna	500	35.500.000	34.291.812	zahvat iz vodotoka Bitulja (Bid); CS 322 l/s; TDM 15,12 km; 153 priključka;	2.8.2018	14
5	Brodsko-posavska	Orubica	326	48.000.000	45.283.895	zahvat iz r. Save, CS-1 338 l/s; CS-2 288 l/s; TDM 10,35 km; 99 priključaka	23.8.2018	31
6	Istarska	Červar - Porat - Bašarinka	490	106.500.000	104.192.118	mikroakumulacija 865.000 m3; CS 150 l/s; TDM 22,03 km, 227 priključaka	12.4.2019	36
7	Zadarska	Baštica 2. faza	150	23.000.000	22.889.973	CS 60 l/s; TDM 19,15 km; 89 priključaka	10.8.2018	15
8	Zadarska	Lišansko polje	232	34.500.000	32.309.630	2 zdenca 40 l/s; mikroakumulacija 80.000 m3; CS 120 l/s; TDM 9,90 km; 41 priključak	13.9.2018	24
9	Dubrovačko-neretvanska	Glog	310	28.500.000	25.366.348	zahvat iz Male Neretve, CS 242 l/s; TDM 19,20 km; 187 priključaka	31.8.2018	26

Table 8: Planned irrigation systems development projects in Croatia (Đuroković & Biondić, 2019)

Red. br.	Županija	Naziv projekta	Površina (ha)	Procjenjena vrijednost investicije s PDV-om (Kn)
	Ukupno 9 projekata		4.179	386.979.639
1	Osječko-baranjska	Poljoprivredni institut Osijek	165	13.148.250
2	Osječko-baranjska	Mala šuma Veliki vrt	78	9.427.750
3	Osječko-baranjska	Budimci - Krndija	600	26.268.357
4	Osječko-baranjska	Dalj 1.faza	730	78.635.155
5	Virovitičko-podravska	Kapinci Vaška - 2. faza	750	36.884.000
6	Vukovarsko-srijemska	Lipovac	800	68.121.375
7	Vukovarsko-srijemska	Ervenica	680	65.576.837
8	Zadarska	Donja Baštica - Grabovac	102	8.514.000
9	Šibensko-kninska	Donje Polje - Jadrtovac	274	80.403.915

4.2.2 Flood protection development and other projects

Croatian Waters manage more than 32 000 km of natural river network (10 203 km 1st order rivers, 21 905 km 2nd order rivers) and more then 30 000 km of canals for melioration. Flood protection system consists of 60 multi-purpose accumulations, 44 retentions, 3 dewatering channels, 2 joined canals, 9 drainage tunnels, 900 km of lateral canals, and large number of regulation and protection water structures.

On yearly basis Croatian Waters invest 700.000.000,00 Kn in flood protection.

Investments to upgrade, rebuild, complete and develop the existing flood protection systems to achieve a high level of protection of the target population on priority river basins in Croatia and thereby reducing flooding and their negative socio-economics impacts are financed through Ministry of Environmental Protection and Energy, Croatian Water and EU Funds.

Climate change and risk management section of Operational Programme Competitiveness and Cohesion 2014-2020 predicts various projects from flood protection related projects to hazard risk mitigation and protection shown in Figure 14.

Out of 215 million EUR at disposal for Croatia from EU funds, 150 million is intended for the project related to flood protection. Currently there are 5 active projects related to flood protection (prevention, protection and readiness) (Table 9).

Figure 14: Finished and active investment project in flood protection, pipeline construction and hazard risk mitigation and protection in Croatia (www.voda.hr)

Table 9: Status of flood protection projects in Croatia (Đuroković & Biondić, 2019)

POZIV	NAZIV	IZNOS	STATUS	
1	2	3	4	
KK.05.2.1.01	Priprema studijsko dokumentacije za projekte upravljanja rizicima od poplava	38.099.375	Završen	●
KK.05.2.1.06	Modernizacija lijevoobalnih savskih nasipa od Račinovaca do Nove Gradiške	369.744.025	Provedba	●
	Projekt zaštite od poplava grada Ogulina	183.519.600	Poziv	●
	Projekt unaprjeđenja negrađevinskih mjera upravljanja rizicima od poplava u Republici Hrvatskoj	353.049.774	Poziv	●
	Projekt zaštite od poplava karlovačko - sisačkog područja	900.287.000	Priprema	●

4.3 Promoting public-private partnership and collaboration with HEIs

The Faculty of Civil Engineering as part of the University of Rijeka (UNIRIFCE) stresses in its MISSION the importance of contributing to the development of the city, region and Republic of Croatia and in its VISION the importance of collaboration with other public institutions and business partners in the country but also internationally (http://www.gradri.uniri.hr/en/about-the-faculty.html).

UNIRIFCE Mission

Faculty mission is education and professional development of academic staff in the field of civil engineering and related technical and natural-science branches of knowledge based on principles of scientific work and higher education inseparability.

The mission is also to promote civil engineering profession and raise awareness about its significance for sustainable development within wider community by simultaneously promoting academic principles and contributing to the development of the city, region and Republic of Croatia.

The Faculty acts upon principles of academic integrity and professional ethics, academic freedom, public responsibility and equal opportunities for all staff members and students and accepts international quality standards in assessing its activities.

UNIRIFCE Vision

The Faculty sees itself in the future as an active and internationally recognized factor in promoting the existing and creating new knowledge in the field of civil engineering and related scientific branches through synergy with higher education at all levels based on learning outcomes and life-long education.

In its path, the Faculty will continue its active cooperation with other University constituents and University of Rijeka programmes by promoting competence, creativity and professional and social accountability of its staff and students. The Faculty will also promote cooperation with public institutions and business partners and be involved in European and world research and higher education field through international cooperation and mobility programmes.

Collaboration with other public institutions, including other HEIs, but also private firms is done within scientific and research projects, professional work, collaboration agreements, Faculty committees, organization of the Faculty Open day, educations held by teachers and students for the public, etc.

Some models of collaboration will be explained in the following text as examples of good practice that could be applied in the WB countries universities.

4.3.1 Collaboration with stakeholders within projects

UNIRIFCE has experience in collaboration with other public institutions and firms through different types of projects related to water resources management:

- international and bilateral projects funded by EU,
- bilateral projects funded by countries involved,
- other scientific, research and professional projects.

From the list of EU funded projects in water management interesting recent projects were:

- CC WATER S, South East Europe, Transnational Cooperation Programme; SEE-TC, (2009-2012)
- DRINKADRIA - Networking for Drinking Water Supply in Adriatic Region; IPA ADRIATIC CBC Programme 2007-2013, (2013-2016)
- ŽIVLJENJE – VODA! / ŽIVOT – VODA! – ŽIVO; European Regional Development Fund – ERDF Operational Programme; Slovenia – Croatia (OP SLO-HR) 2007-2013, (2014-2015)
- INTEGRATED HEAVY RAIN RISK MANAGEMENT – RAINMAN; INTERREG Central Europe, (2018 -2019)

The collaboration within these projects had two forms:

- UNIRIFCE being partner in the project (DRINKADRIA and ŽIVO)
- UNIRIFCE being external expert to other croatian institution(s) that is (are) partner(s) in the project (CC WATER S and RAINMAN).

The strategic project DRINKADRIA was co-financed by the EU within the program IPA Adriatic Cross Border Cooperation (CBC) 2007 – 2013. The Project started on November 1st, 2013, and finished in October 2016 (Karleuša, 2016; http://drinkadria.fgg.uni-lj.si/). The project budget was 6,600,000 EUR.

The Project aim was to develop a base for strategies and procedures for secure cross-border water supply with specific emphasis on water resources management in trans-boundary context, climate change and specific socio-economic aspects of the Adriatic region.

Significant financial resources were invested in improvement of existing water supply systems in the region, and possibilities of cross-border connection of existing water supply systems were analyzed.

In DRINKADRIA project the partnership consisted of: 5 water utilities, 4 authorities, 7 research institutions and 1 association (Figure 15).

PARTNERS

Area Council for Eastern Integrated Water Service of Trieste (CATO)	Italy
VERITAS Joint Stock Company Multiutility Water Service of Venice	Italy
Optimal Territorial Area Authority n.3 Marche Centro – Macerata	Italy
Italian National Council Water Research Institute (CNR-IRSA)	Italy
Water Utility of Nova Gorica	Slovenia
University of Ljubljana	Slovenia
Region of Istria	Croatia
Water Utility of Istria	Croatia
Faculty of Civil Engineering University of Rijeka	Croatia
Croatian Geological Survey	Croatia
The Jaroslav Černi Institute for the Development of Water Resources	Serbia
Water Supply and Sewarage Association of Albania	Albania
Hydro-Engineering Institute of Sarajevo Faculty of Civil Engineering	Bosnia and Herzegovina
P.C. Utility Neum	Bosnia and Herzegovina
Public Utility „Vodovod i kanalizacija“ Nikšić	Montenegro
Region of Ionian Islands	Greece
University of Thessaly	Greece

Figure 15: DRINKADRIA project partnership structure (http://drinkadria.fgg.uni-lj.si/)

The issue of efficient and effective cross-border water supply and water resources management was addressed in its complexity through six work packages (WP).

Work package 1 (WP1) covered Project management and coordination. It included coordination of activities between the partners during various meetings, by on-line communication and referent group meetings, preparation of activity reports and project progress reports etc.

Work package 2 (WP2) covered communication with the general public and dissemination of Project results. Communication and dissemination activities included production of promotional materials and publication of results for all interested stakeholders through the project website (www.drinkadria.eu), scientific and professional journals, conference proceedings and media.

Work packages WP1 and WP2 were led by the lead partner Area Council for Eastern Integrated Water Service of Trieste.

Work package 3 (WP3) covered capitalization and sustainability of the Project, which also included the period after its completion. This package was led by Institute for Development of Water Resources “Jaroslav Černi”. Within this work package national workshops were held in all countries that participate in the Project. It was important to involve bilateral commissions, local and regional government units, utility companies, educational institutions and others in the Project, in order to inform them about the Project activities so that they can contribute to Project results and use them in future.

Within Work package 4 (WP4) which was led by the UNIRIFCE cross-border water resources management issues were analyzed. Regulations of the countries involved in the Project related to water resources management were analyzed, in order to develop a common basis for the protection of transboundary water resources which are used in water supply. Partners applied common approaches and methodologies for analyzing the impact of climate change (CC) on water resources availability. Using different scenarios of changes in water demand in the future, the Water Exploitation index (WEI) was calculated for total use and for drinking use in order to analyses the risk in test areas [5]. Water quality trends in test areas and impact of changes in land-use (due to CC and future development) on water resources quality were analyzed too.

Work package 5 (WP5) was dealing with cross-border water supply systems management. Within this work package, which was led by the University of Ljubljana, the following activities were under implementation: historical overview of cross-border water supply, analysis of existing and potential cross-border cooperation, development of protocols and procedures for effective cross-border water supply and the development of economic model. They were necessary for the analysis of current status of CBWSS and long-term planning of cross-border and regional water supply systems.

Within work package 6 (WP6), led by VERITAS Joint-Stock Company, pilot actions were carried out, i.e. investments which should result in more effective water supply and water resources management. This work package consisted of three activities: development of common analytical framework, individual pilot actions/investments, and development of rules and documentation of experiences.

Research institution as UNIRIFCE were mostly involved in developing new methodologies and approaches that could be used in all countries involved in the project, but they also provided support to water utilities in pilot actions implementation, development of hydraulic models and analyses. The problem in this kind of EU funded projects is the obligation for the partners involved to co-finance the 15% of budget with their own financial resources.

Another model of collaboration on EU funded project was the RAINMAN project where UNIRIFCE was external expert to Croatian Waters to provide support in part of project activities implementation. UNIRIFCE worked on improvement of the methodology for analyses of heavy rainfall in Croatia (preparation of PDF and IDF curves, the regionalization, definition of the "design storm". The RAINMAN project partnership is presented in Figure 8 (https://www.interreg-central.eu/Content.Node/RAINMAN.html).

Figure 16: RAINMAN project partnership structure (https://www.interreg-central.eu/Content.Node/RAINMAN.html)

Another type of project was the bilateral Croatian – Japanese project on: Risk Identification and Land – Use Planning for Disaster Mitigation of Landslides and Floods in Croatia (Ožanić et al., 2013). Main activities carried out by project partners within 4 working packages (Figure 17) were:

- Definition of hazard zones using a methodology for assessing susceptibility and hazards based on local geological, hydrological, hydraulic and landslide conditions
- Establishment and development of early warning systems for landslides, flash-flood and debris-flow adapted to hydrological and geological conditions in Croatia
- Development of risk mitigation measures that can be instituted through urban planning
- Dissemination and use of the results should ensure significant benefits for the local and regional communities that are directly and indirectly threatened by landslides, flash-floods and debris-flow.

Included institutions in Croatia were:

- University of Rijeka – Faculty of Civil engineering
- University of Zagreb
- University of Split
- Croatian Geological Survey
- Croatian Waters
- Croatian Hydrological and Meteorological Survey
- Local authorities

Included institutions in Japan:

- Kyoto University, Disaster Prevention Research Institute (DPRI)
- Niigata University
- International Consortium on Landslides (ICL)

The project was financed and supported by:

- JST (Japan Agency for Science and Technology)
- JICA (Japan International Cooperation Agency),
- Ministry of Science, Education and Sport Croatia

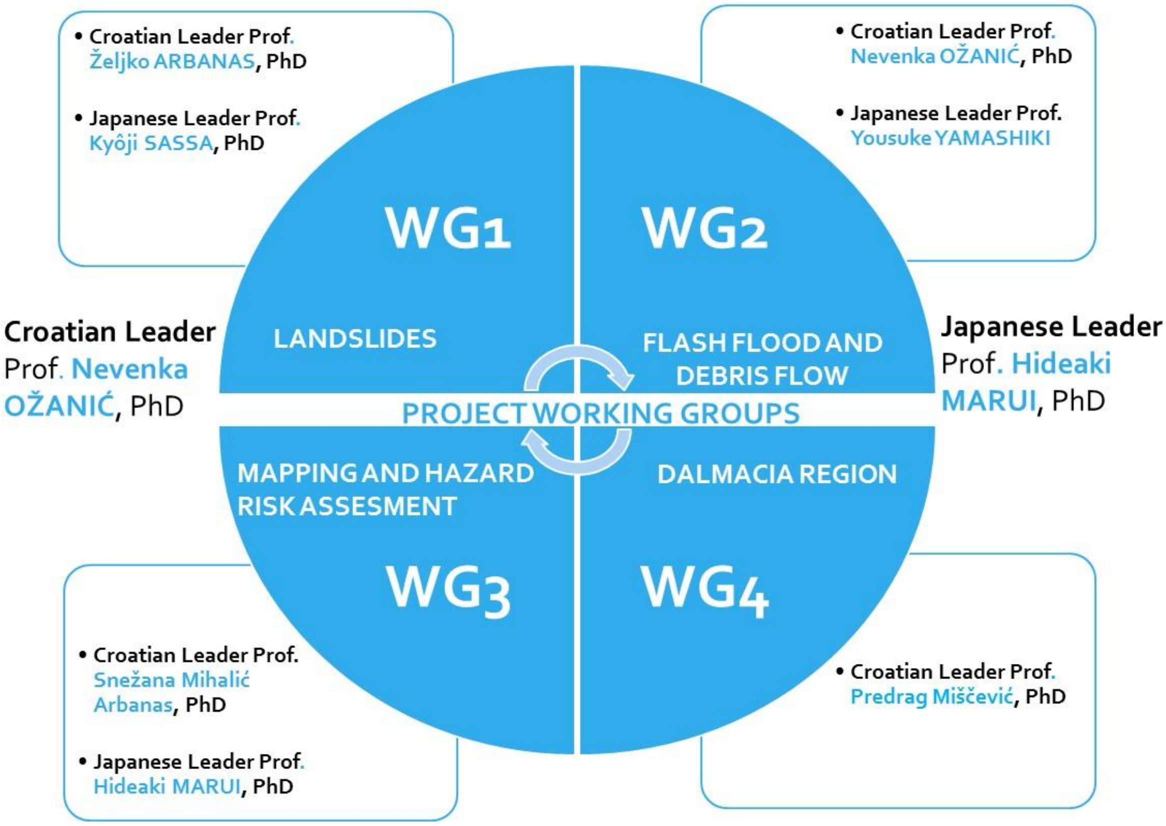

Figure 17: Working packages in the bilateral Croatian – Japanese project: Risk Identification and Land – Use Planning for Disaster Mitigation of Landslides and Floods in Croatia

Other UNIRIFCE scientific and research projects in water management field were/are funded by: the Ministry of Science, Education and Sport, the Croatian Science Foundation, the University of Rijeka (priority given to „smart specialization" projects), but also public institutions like national parks (projects: Hydrodynamics of Plitvice Lakes and Monitoring of morphological changes in Korana River).

UNIRIFCE is also involved in many professional projects in water management, and teachers/researchers are actively involved in different expert groups, councils, comities on local regional and also national level where they can give their contribution to water management.

4.3.2 Collaboration with firms that develop specialized software

UNIRIFCE has a long collaboration with the firm Studio Ars Ltd.

Studio Ars Ltd. is a privately held company which was founded in 1990 located in Matulji, Croatia, Europe (http://www.studioars.com). Since the very beginning their main goal has been the implementation of CAD technologies in civil engineering and related engineering fields. Their activity is based on Autodesk technology. Their main product is the Urbano infrastructure design software, and within it Hydra and Canalis applications, for designing water supply and sewerage systems.

UNIRIFCE teachers collaborated with Studio Ars in the early stages of Urbano Canalis and Hydra development, but today the collaboration includes the application of this software in teaching and preparation of master thesis at UNIRIFCE. Students are offered a short course about the use of the software, but also students have the support from Studio Ars team during the preparation of their projects/master thesis.

4.3.3 Other forms of collaboration with stakeholders

Besides collaborating on different scientific, research and other projects UNIRIFCE collaborates with stakeholders in other forms:

- Through the Committee for Cooperation with the Community and the Industry
- Organizing practical / field teaching for students with the help of stakeholders
- Participation of stakeholders in teaching (lectures)
- Participation of stakeholders in UNIRIFCE Open day activities
- Organization of LLL programs and other educations for stakeholders

In 2013 the UNIRIFCE council adopted the Rulebook on Cooperation with the Community and the Industry (www.gradri.uniri.hr). Based on this rulebook the Committee for Cooperation with the Community and the Industry was established with the following tasks:

- Promoting and establishing cooperation with the Community and the Industry
- Participation in quality assurance of study programs
- Promotion of professional work
- Helping students in finding firms for their internship, field work, preparation of master thesis and other student activities
- Organizing professional lectures
- Promoting activities in collaboration with Alumni Club of UNIRIFCE
- Helping students find employment
- etc.

The Committee is formed by:

- Vice dean for business relationships
- 2 teachers
- 4 external members from the Community and Industry (1 of them is the president of the UNIRIFCE Alumni club)

Stakeholders are involved in organising practical / field teaching for students, Figure 18 and Figure 19. Students from hydraulic engineering and urban engineering on master study have many field teaching activities. On average annual field activities in the area of water resources management (on first and second year) are:

- Visit to the water supply and sewage system utilities of Rijeka city (drinking water sources, reservoirs, pumping stations, chlorination station, waste water treatment plant)
- Visit to the water resources in rivers Gacka and Lika catchments (hydropower system: dam and hydropower plant Sklope (Figure 10), regulated water courses and canals for Lika and Gacka water, tunnel, natural water springs of river Gacka, …)
- Visit to a marine port (Ičići or other)
- Visit to water sources used for water supply of Istria Region (spring Bulaž, reservoir and drinking water treatment plant Butoniga)
- Etc.

Figure 18: Field visit to water resources and water management systems in Lika and Gacka rivers basins, 2016.

Figure 19: The ship of Croatian Waters on Danube River on which students participated to measurements carried out by Croatian Meteorological and Hydrological Service and measured data elaboration, 2009.

UNIRIFCE involves stakeholders in teaching in two ways:

- as teachers – external experts that teach the whole courses
- as invited lecturers (experts from Croatian waters, water utilities, waste management companies, software...) that participate in few lessons.

An interesting opportunity to strengthen the collaboration of UNIRIFCE teachers and students with stakeholders is the Open day event. The UNIRIFCE Open day programme in 2019 consisted of (Figure 20):

- Presentation of the UNIRIFCE, with the guided tour of the building and laboratories
- Presentations held by different stakeholders to show employment possibilities to students (potential employers, design firms, construction firms, ...)
- Presentation of innovative procedures, methodologies and equipment that are used at UNIRIFCE, presenting UNIRIFCE expertise that can be offered to stakeholders.

Figure 20: UNIRIFCE Open day programme in 2019 (wwww.gradri.uniri.hr)

UNIRIFCE collaborates with many HEIs. One of collaboration that lasts more than 10 years is the collaboration with University of Lancaster, UK providing them with support to organize their field course entitled: Water and environmental management in Mediterranean context. Within this course students from geography study programme spend a whole week in Croatia learning about the water and environmental management through numerous field visits (visit to the water supply utility of Istria, visit to Croatian waters in Rijeka, visit to the transboundary catchment of River Dragonja, investigating the public water supply and sewage system in Lovran by questioning local inhabitants…). In the building of UNIRIFCE part of the student workshops are organised and the final exam is written. Students of UNIRIFCE enrolled in Water management course at the master level at actively participate in the activity of investigating the water supply and sewage system in Lovran by questioning local inhabitants, helping in translating the questions and answers, but also asking questions that they have prepared. In this way they develop their professional but also soft skills and the knowledge of English language.

Another interesting collaboration of UNIRIFCE with other Croatian HEIs (UNIZG, UNIOS, UNIST) in civil engineering was the project Development and preparation of the Croatian Qualifications Framework in Higher Education of Civil Engineers. The aim of the project was to align civil engineering studies (and also in the area of water resources management) with new needs and qualification standards to achieve a socially acceptable level of knowledge - new tools, new education models that are aligned with strategic and development goals and labour market needs. The project was funded by EU.

UNIRIFCE is also active in educating the wider public especially younger generations starting from kindergarten age about different topics including water management issues. Within the course Water management (on master level) a part of students' activities is to organize a workshop for children in kindergarten or in elementary school. This year a workshop in a kindergarten near the University Campus was organized. The theme was: "What is the color of water?", but the topic was much wider: use of water, water protection, water characteristics, hydrological cycle… Students used PPT presentations, coloring books, experiments, talked and discussed with children on water related topics on the level appropriate for children. This activity helps students to develop soft skills and raises awareness in public about water resources management issues staring from kindergarten age.

5 Greece

The Water Framework Directive could be considered a pioneering initiative on Water Resources Management in EU. In this framework, selective implementation processes of the WFD such as the monitoring programme of the water resources in Greece coupled with modern technologies, e.g. telemetric system, are considered truly innovative approaches on WRM. Moreover, the water-energy-food-environment nexus concept could foster the WRM in an integrated and innovative way.

The following paragraphs focuses on the modern technologies for monitoring of water resources and on the nexus concept. Both aforementioned subjects were synoptically presented during the Vienna Workshop.

5.1 Telemetric monitoring of water resources

The Water Framework Directive (WFD) is considered to be one of the most ambitious and comprehensive pieces of European environmental legislation to date. It aims to ensure that all European waters are protected according to a common standard. The primary target of the WFD is the introduction of coordinated "programmes of measures" for achieving at least a "good status" of water quality for most European rivers, coastal and underground waters. The WFD was incorporated into Greek legislation with Law 3199/2003, which was published in the Official Gazette in 2003 (FEK/A/280/9.12.2003).

Among its objectives, the WFD sets out the requirements (Article 8) for the monitoring of surface water status, groundwater status and protected areas in order to establish a coherent and comprehensive overview of water status within each river basin district. Furthermore, according to Article 14 of the WFD, Member States should encourage the active involvement of all interested parties in the implementation of the Directive, not only regarding the development of a river basin management plan, but from the very beginning of the implementation of the Directive, i.e. during the processes of transformation into national laws, characterization and analysis of water bodies, establishment of monitoring programmes and development of the measures. (Skoulikaris et al. 2012)

Telemetric monitoring systems have long been used in the water sector, for remotely monitoring river flows, water quality, and reservoir level to aid water resources management or assist in flood early warnings [Thomson et al. 2012]. However, it was only the last years that the technological emergence in the fields of (Skoulikaris et al. 2018) :

i. electronics and microelectronics, such as advancements in new sensor technologies and automated controls,
ii. energy efficiency and autonomy, e.g., the use of photovoltaic panels coupled with electric batteries which have limited life range,
iii. communication technologies with GPRS/GSM extended coverage,
iv. computer technology with the creation of microprocessors and unlimited storage capabilities, and
v. costs in terms of the large cost decrease trend of the aforementioned technologies, boosted the continuous monitoring capabilities of the telemetric monitoring system.

5.1.1 Greek National monitoring programme

After a long period of discussions with the competent bodies the National Monitoring Network of the quantitative and qualitative status of water was (re)formed through the JMD 140384/2011 "Designation of the National Monitoring Network of the quality and the quantity of waters with definition of the measurement points (stations) and the bodies liable for their operation, according to article 4, paragraph 4 of L.3199/2003 (A' 280)".

The National Monitoring Network includes 449 monitor stations in rivers, 53 stations in lakes, 34 in transitional waters, 80 in coastal waters and 1392 stations in groundwater bodies (total number of stations: 2008, from which 616 are in surface water bodies and 1392 in groundwater bodies) (**Figure 21**). Stations are divided into surveillance stations and operational stations. Stations are divided into two categories: Surveillance and operational. Surveillance stations operate in water bodies of good status for a certain period of time (one year), while operational stations run continuously on water bodies which fail to achieve good status (i.e. an operational station may be characterized a surveillance station if the status of the system is improved and has reached a good status).

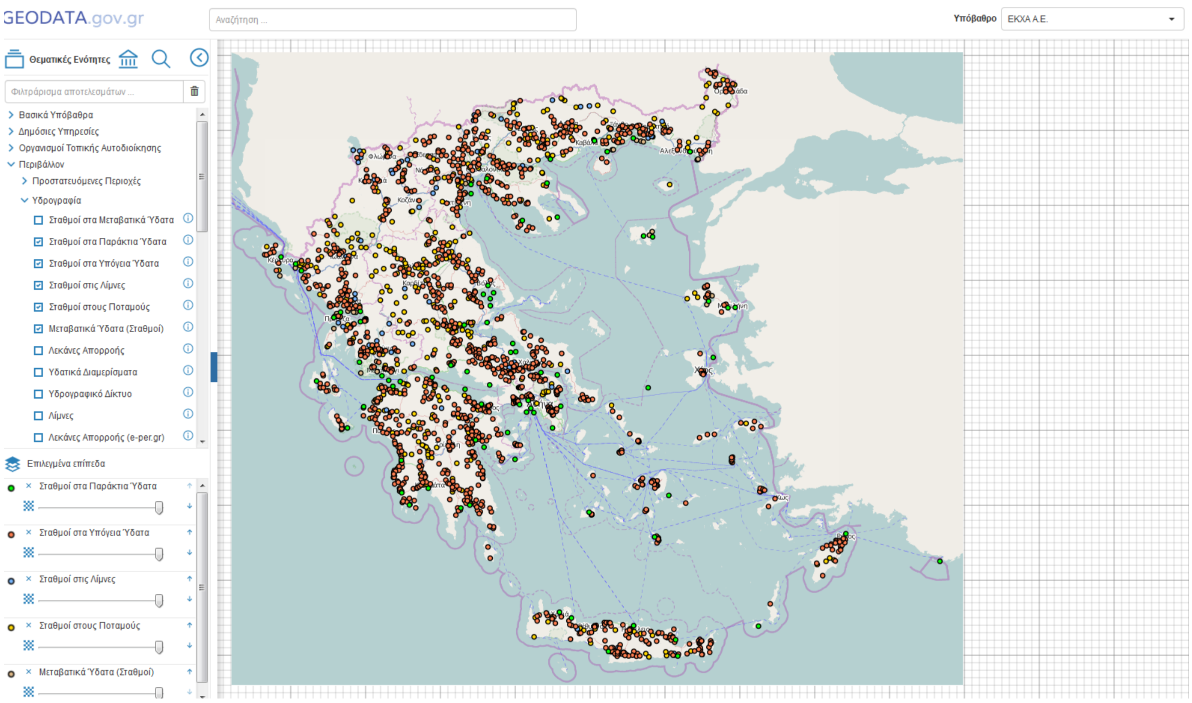

Figure 21: Representation of monitoring network of surface, groundwater, coastal and transitional water bodies.

The reformed National Monitoring Network meets fully the requirements of the Water Framework Directive (2000/60/EC) (Article 8 and Annex V), as well as the Directives on nitrate pollution from agricultural sources (91/676/EEC), for groundwater (2006/118/EC) and for priority substances (2008/105/EC).

The following bodies undertake the operation of the Network under the supervision of the Special Secretariat for Water according to the aforementioned JMD 140384/2011:

- General Chemical State Laboratory (GCSL)
- Hellenic Centre for Marine Research (HCMR)
- Institute of Geology & Mineral Exploration (IGME)

- Greek Biotope/Wetland Centre (EKBY)
- Municipal Water and Sewerage Company of Larissa (DEYAL)
- Land Reclamation Institute (LRI)

5.1.2 Telemetry monitoring systems

The monitoring of water bodies is a key management tool that contributes to the achievement of general and specific management objectives within river basins (Skoulikaris et al. 2012). Monitoring is necessary because it contributes to the evaluation of appropriate management measures and to national objectives being achieved against a background of international and European legal frameworks. Monitoring tools form a critical part of the entire monitoring process in a river basin, particularly when the overall aim is to prevent floods.

Traditional monitoring methods focus on in situ field measurements and on collecting samples for laboratory tests. In cases where flood prevention is the objective of monitoring, traditional monitoring methods cannot be implemented, since the lag time between precipitation and flood events at a river basin scale of a few hundred kilometers does not exceed the time span of a few hours. In order to monitor extreme events the use of state of the art near real time monitoring technologies is necessary. Telemetric monitoring (Figure 22) provides precise measurements of the volume of the water flow in real time in order to provide data for an early warning system for flood risks.

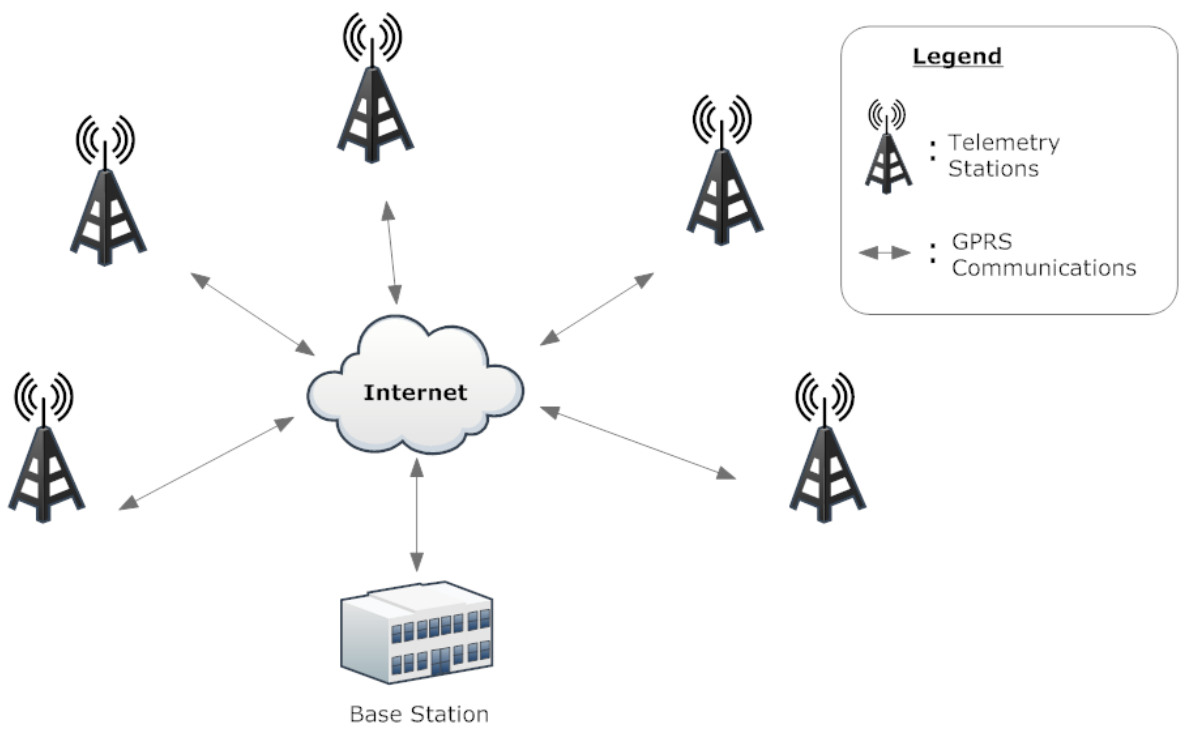

Figure 22: Schematization of telemetry equipment configuration.

It is proposed up to date telemetric monitoring configuration to be used to monitor the water flow volume, Figure 1. The configuration consists of two principal components: the field equipment and the base station equipment. The field equipment includes measuring sensors, a data logger system and a modem, while the gateway equipment includes the database and the appropriate software. More precisely, the field equipment, which is used for the in situ measurements, is a compact, energy independent telemetric station kit that can be placed at constant cross sections parts inside the river bed. Each station is equipped with a Doppler flow meter sensor connected to the data logger and the modem. The data logger stores measurements locally for a two month period, in order to avoid measurement losses due to connection problems with the base station. The modem which is based on GPRS data communication is used for the real time transfer of the measurements to the base station and also for the remote control of the stations parameters.

The base station is the physical place where the measurements from the telemetry stations' network are gathered. The gateway provides the real time communication with the modems of the stations. With the use of appropriate software, the telemetry data are saved to a database. For example, a SQL 2008 database can be adopted as an appropriate tool. The communication between the base station and the telemetry stations is performed through the internet and is bidirectional, meaning that the gateway receives data but also transmits configuration data to the stations.

The system architecture described above ensures to a great extent the accuracy of the gathered data. Nevertheless, regular manual supervision (based on certain protocols) of the operational status of the stations and its sensors remains an indispensable factor for achieving high standards of remotely gathered flow measurements data (Wagner et al 2006). These monitoring protocols are based on the peculiarities of each station and the identified parameters and ensure the reliable and uninterrupted operation of the stations. The standard protocol is a series of procedures that must be performed routinely at all continuous volume water flow stations. These procedures are fully described in the United States Geological Survey (USGS). Site characteristics, such as stratification or dynamic, rapidly changing environmental conditions, may make it necessary to modify the standard protocol.

5.1.3 International case studies

On the field of monitoring networks, the importance of groundwater resources is denoted by the Global Groundwater Monitoring Network (GGMN). GGMN is a participative, Web-based network of networks that was set up to improve quality and accessibility of groundwater monitoring information and subsequently the knowledge on the state of groundwater resources at global scale. GGMN is a UNESCO IHP programme, implemented by the International Groundwater Resources Assessment Centre (IGRAC) and supported by many global and regional partners. The GGMN portal (https://ggmn.un-igrac.org/) contains information on the availability of groundwater monitoring data through space and time, and through the portal, groundwater level data and changes can be displayed on a regional scale.

Users are allowed to upload, interpolate, and analyze the groundwater data using the following options:

- ❖ Representative groundwater point measurements can be uploaded as well as can be transferred from a national system via Web services, while the data can be displayed showing the mean, range, or change in groundwater level for a selected time period.
- ❖ Point measurements can be combined with proxy information and personal expertise to create groundwater level maps. Produced groundwater maps can be shared via the online GGMN Portal.

- Time series analysis can be performed for each point measurement location to better understand temporal changes of groundwater levels. The time series analysis is a step by-step procedure to identify trends, periodic fluctuations and autoregressive model. Time series analysis helps defining optimal monitoring frequencies, one of the key components of groundwater monitoring network design.

5.2 The energy-water-food-environment nexus concept

5.2.1 Introduction

Energy is undoubtably a significant factor for economic development with the link between energy and economic development to be also known as "energy-based economic development" (EBED) (Carley et al. 2011). Towards this direction, and by taking into account recent policies about the mitigation of the environment degradation due to energy production, renewable energy resources appear to be one of the most efficient and effective solutions fostering the coupling of renewable energy and sustainable development (Ibrahim 2010). Hydropower can be considered as an instrument of sustainable economic development, while the significant roles of energy and water in sustainable development and the fundamental goals of providing access to energy and water were among the main issues of the World Summit on Sustainable Development.

In this regard, the interdependencies between water resources, energy production and provision of food, known as the NEXUS approach, as well as the links between water and the ecosystems, are pivotal to sustainable development. From a water perspective, food and energy systems are users of the resource, from a food perspective energy and water are inputs, while from an energy perspective, water as well as food (e.g., biomass in form of energy crops) are generally an input and food is generally the output (Bazilian et al. 2011). The nexus approach recognizes the interdependencies of water, energy, and food production and aims to systemize the interconnections to provide a framework for assessing the use of all resources and to manage trade-offs and synergies (Hellegers et al. 2008). Consequently, actions undertaken in one of the aforementioned sectors have imminent impacts to all others, therefore making the a-priori identification of these linkages to be of great importance in order to help target synergies and avoid potential tensions.

On the other hand, demand for energy-water-food is increasing by demographic and climatic change drivers that increase the stress on these critical domains. At the scale of the Mediterranean basin, both in terms of population growth and climate change impacts, the basin is characterized as a hot spot. This means that the Mediterranean is bound to confront numerous threats due to water scarcity, concentration of economic activities in coastal areas, augmented energy demands for covering the cooling demands and reliance on climate-sensitive agriculture (Anagnostopoulou et al. 2017.

Hence, it is believed that the nexus approach could innovatively contribute to the WRM in an integrated way. All the water related factors/users such as the hydropower production plants, the irrigated agriculture and the environment are parts (variables) of the problem and a solution, i.e. the integrated water resources management will be based on all the so called variables.

5.2.2 EU and the nexus concept

Cross-sectoral partnership is a key feature of Transforming our World: The 2030 Agenda for Sustainable Development. The integration of cross-sectoral policies has also received expanding attention in the European Union strategies. The impact assessment accompanying the Communication, Clean Energy For All Europeans [2], emphasizes that the availability of water resources, in particular for hydropower, and extreme weather events are likely to affect the power supply in various ways, e.g. thermal generation threatened by a lack of cooling water

The EU Commissioners for agriculture and the environment have launched a Task Force on Water and Agriculture that is intended to develop a longterm transition to sustainability for EU agriculture with regard to water issues [3]. Building on early lessons learnt from energy, water and food security in developing countries, the Commission's Directorate-General for International Cooperation and Development (DG DEVCO) has started the Nexus Regional Dialogue Programme to develop policy recommendations and action plans for future investments in Africa, LatinAmerica, Central Asia and the EU neighbourhood.

In this context, the goal of the EU Joint Research Centre (JRC) Water-Energy-Food-Ecosystem (WEFE) Nexus project is to help, in a systemic way, the design and implementation of European policies and strategies that are dependent on water in order to identify areas for EU policy convergence, coordination and integration. By combining expertise and data from across the JRC, the WEFE-Nexus project provides support to several Commission DGs, informing crosssectoral policymaking on how to improve the resilience of water-using sectors such as energy, agriculture and ecosystems. The specific objectives that will achieve the overall goal of the project are:

- ✓ Analysis of the most significant WEFE interdependencies by testing strategies, policy options and technological solutions under different socio-economic scenarios for Europe and beyond. The project will help implement several EU policies (e.g. the Common Agricultural Policy, the Water Framework Directive, the Energy Union and the EU Development Policy) as well as initiatives and agreements at international level (e.g. the Sustainable Development Goals and the Union for the Mediterranean).
- ✓ Evaluation of the cross-sectoral impacts of changing availability of water due to climate change, land use, urbanisation, demography in Europe and geographical areas of strategic interest for the EU (Africa and the EU's closest eastern and southern neighbours) by using an integrated approach, including the socio-economic dimension, to improve policy coherence, develop synergies and negotiate trade-offs.
- ✓ Delivery of country and regional scale reports, outlooks on anomalies in water availability, a toolbox for scenario-based decision-making, and science policy briefs connecting the project's outcomes to the policy process.

5.2.3 Application of the Nexus approach in Greece

The aim of energy water food agriculture approach in a case study in Greece (Skoulikaris 2019) is focused on analysing the impacts of climate change on multipurpose hydropower projects dealing with hydro power generation and agricultural economy. A cascade of mathematical models and tools (hydrology modelling, hydropower simulation models and hydrosystem simulation) were interconnected to assess the impact of the A1B emission scenario as derived by a specific regional climate model. The produced results demonstrate the dependencies between the energy-water-food nexus and the need for joint actions and common policies for adaptation to the climate change reality.

The methodology was applied to the transboundary Mesta/Nestos river basin, shared between Bulgaria and Greece, which is included in UNESCO's International Network HELP programme (Hydrology for Environment, Life and Policy) https://en.unesco.org/themes/water-security/hydrology/programmes/help. The aim of this programme is to promote methodologies for the integrated management of water resources at a basin scale, combining hydrology with environmental protection, social impacts and policy management (Bonnell 2004).

The Mesta/Nestos river basin is located in the Balkan Peninsula in South Eastern Europe, is shared between Bulgaria and Greece and is one of the 14 transboundary river basins in the Balkan's region (Figure 23). The river flows some 255 km and its catchment area covers 6,218 km^2, of which 2,863 km^2 (46%) belongs to Greece, Figure 1. The past estimated mean runoff, 1965-1990, of the Mesta/Nestos River is 20 to 30 m3/s with the maximum discharges to be rarely above 150 m^3/s while the minimum flow was often lower than 10.0 m3/s particularly during the summer period. The observed flood discharges in the Greek part of the basin are estimated between 1000-1300 m^3/s.

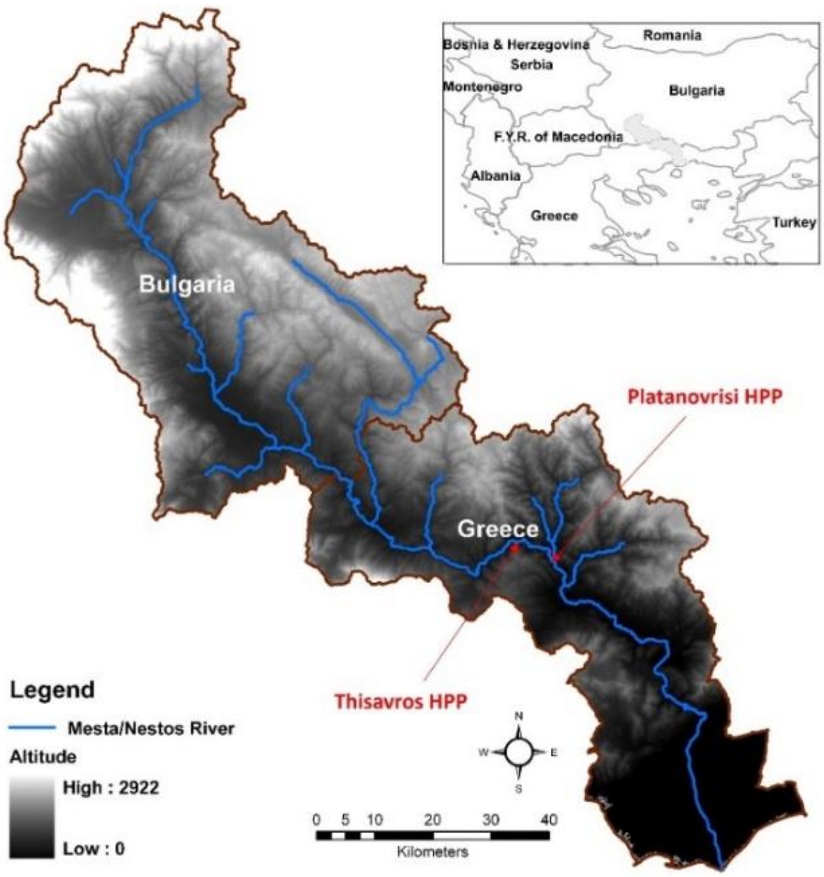

Figure 23: The transboundary Mesta/Nestos river basin and the two large hydropower plants in the Greek part of the basin.

In terms of future discharges, the precipitation fluctuations have direct impacts on the river runoff. As revealed by the hydrological modelling procedure, a decrease of 34.4% of the river discharges is projected.

At the same time, since water is the fuel of hydropower projects, the reduction of discharges, i.e. the water that inflows in the reservoir, will also have negative impacts on the HPP operation. In terms of power production, the results of the research presented that the projected generated power will be approximately 50% and 62% less for the periods 2016-2050 and 2051-2016 respectively, in comparison with data from the decade 2004-2013.

The produced results also emphasised the fact that the food sector, i.e. the irrigated agriculture, is highly dependent on the available water volumes stocked in the reservoir and the operation management of the HPP. Thus, the future lack of water under the A1B scenario coincided with the extended water stressed period in the decade of 2055-2065.

Based on the aforementioned, it seems likely that the outcome of managing the three areas of the energy water food nexus holistically would lead to a more optimal allocation of resources, improved economic efficiency, lower environmental impacts and better economic development conditions. However, due to the vastness of the individual areas and the difficulty of considering energy, water and food together, the current implementation of an integrated management of the nexus has not reach sufficient standards of penetration in national and international policies.

6 Norway

Norway is connected to the European Union as an EFTA country, through the Agreement on the European Economic Area (EEA). General information about Norway is depicted in **Figure 24**. The WFD was formally taken into the EEA-agreement in 2009, granting the EFTA countries extended deadlines for the implementation. EFTA-counties reporting obligations are to the EFTA Surveillance Authority (ESA).

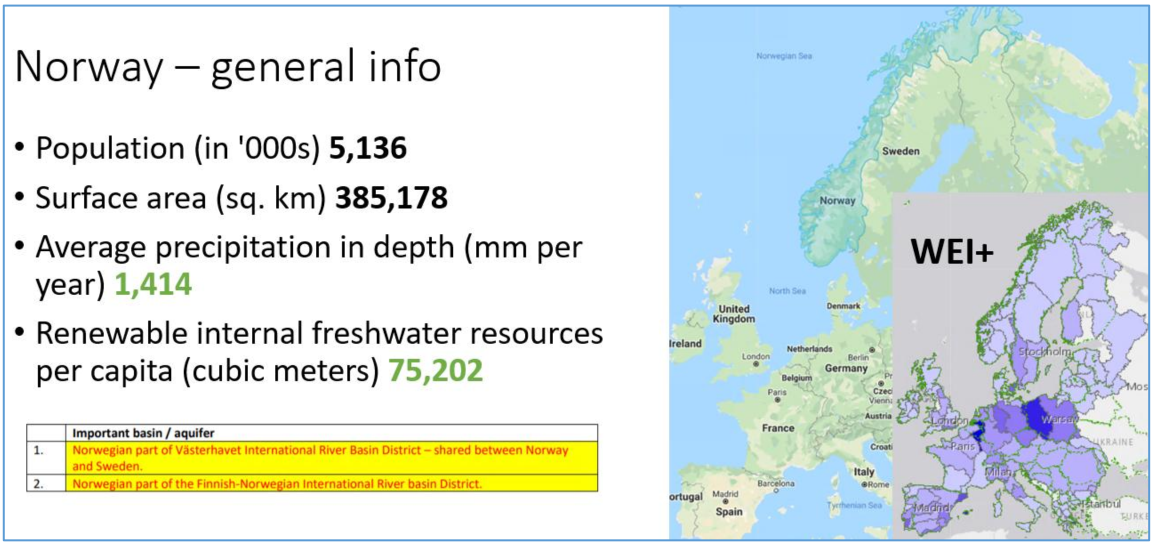

Figure 24: Norway – General information

Although the overall water risk in Norway is low to medium especially compared to the rest of Europe (Figure 25), the water management plays an important role in this EEA country.

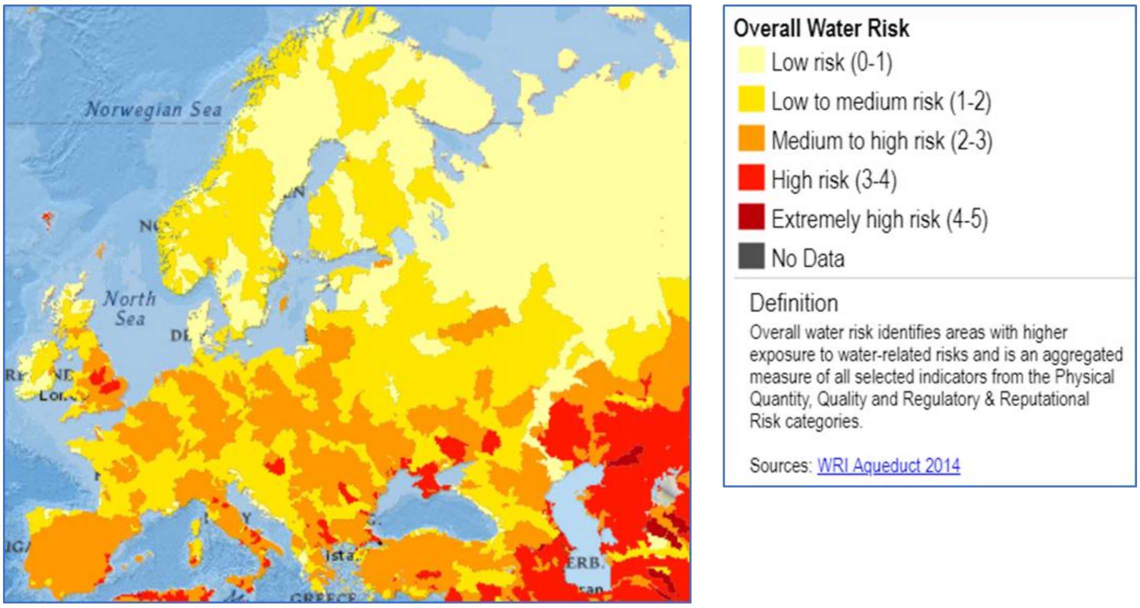

Figure 25: Overal water risk in Europe

The WFD was transposed into the Norwegian Regulation on a Framework for Water Management, normally referred to as Vannforskriften (The Water Regulation), entering into force in 2007. Norway has taken full part in the Common Implementation Strategy (CIS) for the WFD since it was established in 2001. Norway performed a voluntary "pilot phase" implementation of the WFD in selected sub-districts across the country from 2007 until 2009, thus gaining the experience of River Basin Management planning. River Basin Management Plans for the selected sub-districts in the pilot phase were adopted by the County Councils in 2009, and approved by the national Government in June of 2010. River Basin Management Plans (RBMPs) covering the entire country will be prepared from 2010 until 2015, synchronized with the time schedule of the second cycle of implementation in the EU.

6.1 Status of WRM practices

The Water Resource Management in Norway is organized as shown in Figure 26.

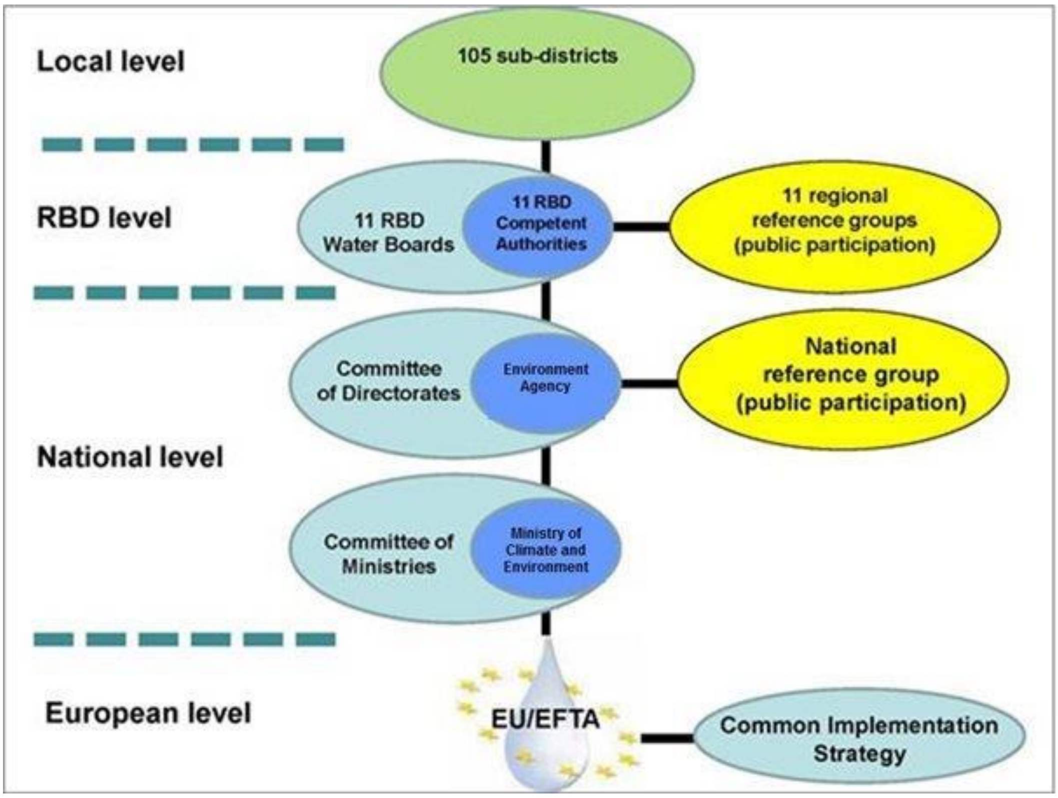

Figure 26: Norway – Organisation of Water Resource Management

6.1.1 National level

Water Resource Management (WRM) has been established in Norway mainly through implementation of the EU Water Framework Directive (WFD). The Ministry of Climate and Environment is the coordinating ministry (responsible for the Pollution Control and the Natural Diversity Acts), in close collaboration with the Ministry of Petroleum and Energy (responsible for the Water Resources Act). The Committee of Ministries is the national coordination mechanism at ministry level. See more information here: http://www.vannportalen.no/english/wfd-implementation-at-national-level/ The ministries have evaluated the WFD implementation 2010-2015 based on experiences, and are currently consulting on possible adjustments of the Water Regulation to simplify and streamline the water management organization and work ahead:

https://www.regjeringen.no/no/aktuelt/endring-i-vannsforskrift-horing/id2573678/ The River Basin Management Plans approved in 2016 are the first cycle plans in Norway, and will be revised by 2021. Only then will we be able to assess if the periodic revision of the plans has been effective.

The status of Norway´s water bodies is depicted in **Figure 27**.

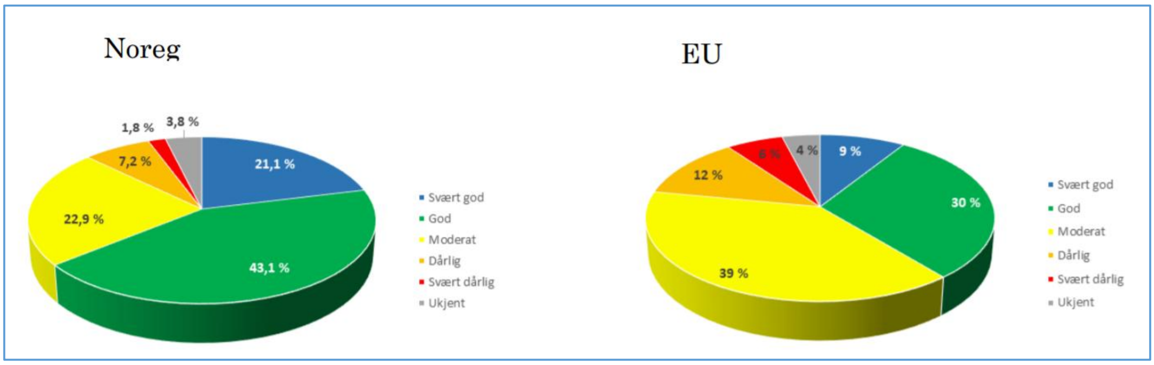

Figure 27: Norway – Status of water bodies

6.1.2 Regional level

Many sub-districts (basins) with significant water management challenges have Basin Water Boards with have representation from the Municipalities, relevant authorities and stakeholders. See more information about the basin water boards here: http://www.vannportalen.no/english/river-basin-management-planning-at-district-level-in-norway/ In a number of these of the sub-districts, the authorities involved join efforts to hire a dedicated water coordinator to facilitate the collection of local data and knowledge, assist the municipalities in water management, and facilitate the public participation and enhance local support for improving the water status. In sub-districts (basins) with limited water management challenges, and overall good water status, there is less need for a comprehensive organisation and water coordinator. This means we have diverse levels of basin organization in Norway, and it is difficult to set an exact score.

6.1.3 Norwegian concept of ownership

The municipalities own the majority of the water and wastewater infrastructure in Norway. Some municipalities have organised the service in inter-municipal companies. E.g. Lillestrøm plants are owned by 5-6 municipalities. In 2012, the Norwegian parliament approved a law on municipal water and wastewater infrastructure, stating that the infrastructure has to be owned by the municipalities and cannot be privatised. The concept today is to keep in public ownership, but run as private companies. A single Norwegian household pays on average 7000 NOK (850 EUR) in total fees for water and wastewater services. A schematic diagram of Norwegian water supply and wastewater infrastructure is shown in **Figure 28**.

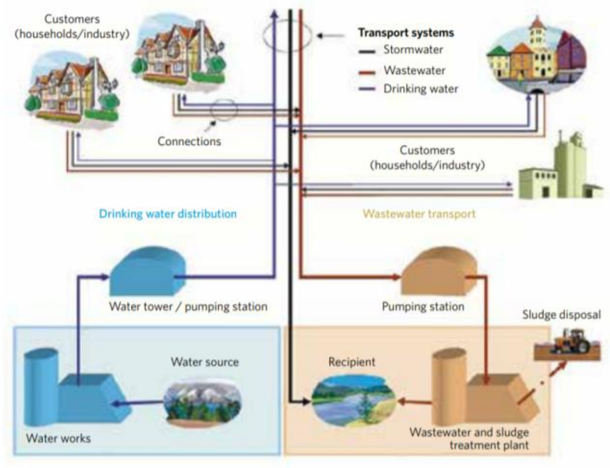

Figure 28: Norway – Schematic diagram of water supply and wastewater infrastructure

6.2 Pressures and Priorities

Pressure types in lakes and rivers of Norway are depicted in Figure 29.

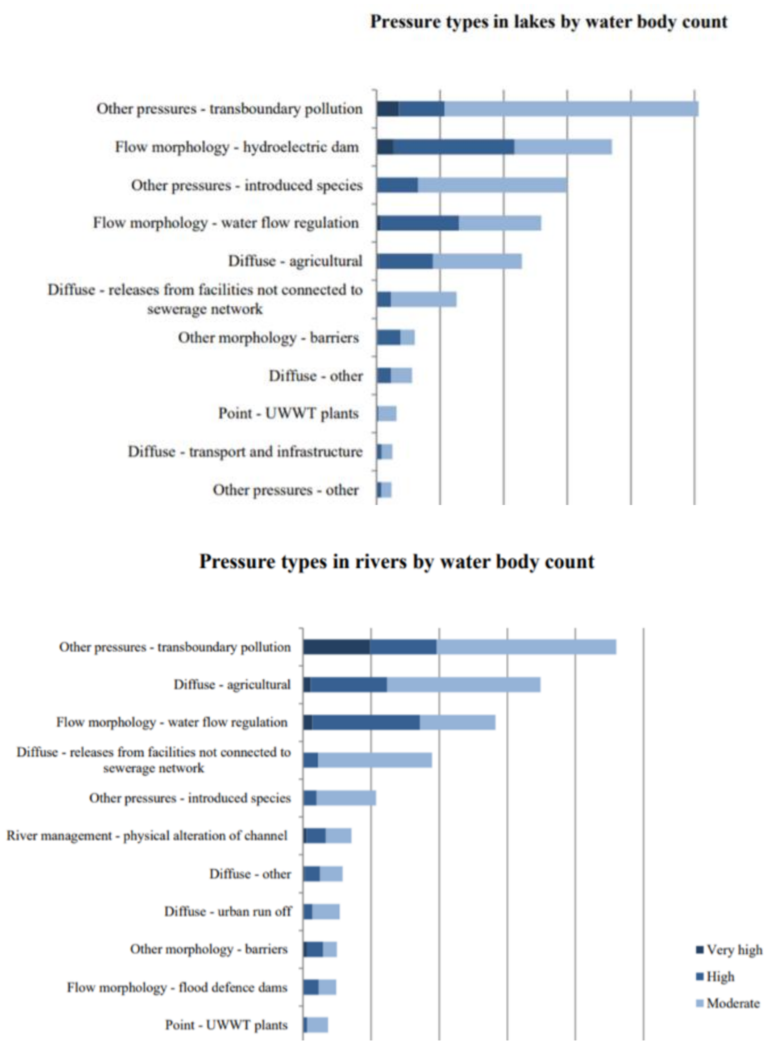

Figure 29: Norway – pressure types in lakes and rivers

Priority water resources challenge areas (**Figure 30**):

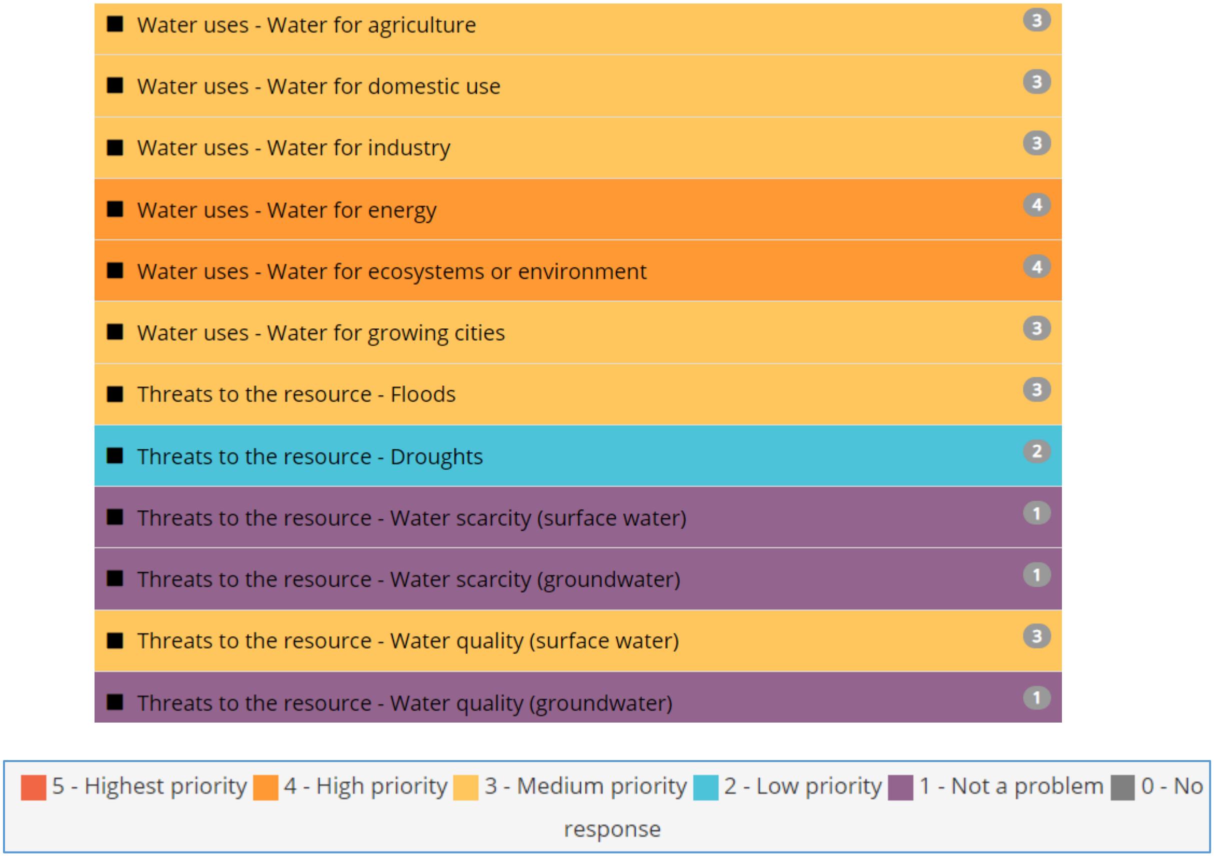

Figure 30: Norway – Priority water resource challenge areas

Priority water management challenge areas (Figure 31):

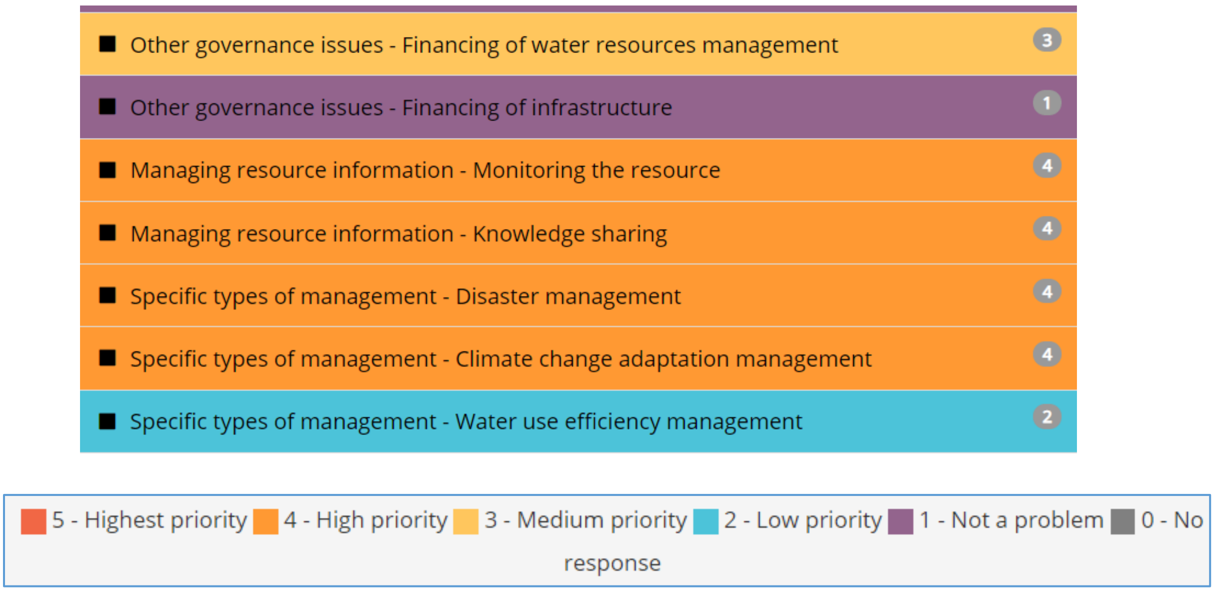

Figure 31: Norway – Priority water management challenge areas

6.3 WRM instruments

Norway has abundant availability of freshwater resources, compared to all other European countries:
http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Freshwater_resources_%E2%80%94_long-term_annual_average_(billion_m%C2%B3)_V3.png

Monitoring of water quantity (surface and groundwater) is carried out by the Hydrological department of the Norwegian Water Resources and Energy Directorate: https://www.nve.no/hydrology/

Permits for water use that can have noticeable negative impact on water quantity and flow (for instance reduction of natural minimum flow) are given mainly by the Norwegian Water Resources and Energy Directorate, according to the Water Resources Act: https://lovdata.no/dokument/NL/lov/2000-11-24-82

Permits for smaller interventions are delegated to the County Council (hydropower under 1 MW), the Municipalities (infiltration to groundwater), the County governor (cases of water shortage), and the Norwegian Geological Survey (drilling for groundwater): https://lovdata.no/dokument/DEL/forskrift/2000-12-15-1270

Water use for drinking water and irrigation purposes has limited negative impact in Norway, due to the abundant availability of freshwater resources. Large hydropower projects that include water storage dams constitute the most important pressure with significant impact on water quantity in Norway. Requirements for minimum flow has generally been part of hydropower licenses since the 1980s. For older hydropower projects, a national screening has been carried out to prioritize licenses to be revised with the aim of assessing possibilities for introducing minimum flow: http://publikasjoner.nve.no/rapport/2013/rapport2013_49.pdf, and a final decisions on licenses to be revised 2016-2033 was part of the government approval of the River Basin Management Plans in 2016: https://www.regjeringen.no/no/aktuelt/kjempeloft-for-bedre-vannmiljo/id2506703/

Permits for activities causing pollution are regulated in the Pollution Control Act, managed at national level by the Norwegian Environment Agency: https://lovdata.no/dokument/NL/lov/1981-03-13-6 Norway is implementing the Industrial Emissions Directive, and permits for industry normally include requirements concerning monitoring, as well as mitigation measures based on best available technology. Transportation and Agricultural sectors are only partly covered by the Act. The Environment Agency issues permits to larger industry activities. The issuing of permits for smaller activities causing pollution are delegated to the County Councils and the Municipalities, respectively. There might still be issues for improvement concerning implementation of management instruments at regional and local level.

Water related ecosystems are mainly managed at national level by the Norwegian Environment Agency, based on the Natural Diversity Act: https://lovdata.no/dokument/NL/lov/2009-06-19-100?q=naturmangfoldloven Management instruments include management plans for protected or priority species and ecosystems, measures against invasive species etc.

River Basin District Management Plans (RBMPs) aiming at protecting or restoring good ecological status for all of Norway's national and International River Basin Districts (RBMPs) compliant with the

WFD were developed 2010-2015, were adopted by regional councils at the end of 2015, and approved by the Government in 2016: http://www.vannportalen.no/plandokumenter/planperioden-2016---2021/

Measures to mitigate negative effects from hydropower production are managed by the environment authorities as part of the licensing requirements, and may include ecological measures as fish passes, habitat improvements, removal of barriers to continuity, and even fish stocking and release: http://www.miljodirektoratet.no/no/Publikasjoner/2017/Mai-2017/Oppfolging-av-naturforvaltningsvilkar-i-regulerte-vassdrag/

Salmonid and inland freshwater species are additionally managed according to a specific law on fish stock management: https://lovdata.no/dokument/NL/lov/1992-05-15-47

A national action plan for natural diversity was approved by the parliament recently (201): https://www.stortinget.no/no/Saker-og-publikasjoner/Saker/Sak/?p=64248 Development and implementation of the new management instruments outlined in the action plan will require several years of effort.

The Norwegian Water Resources and Energy Directorate administers a comprehensive flood management system that includes guidelines and expert guidance in mapping programs for flood inundation and quick clay slides, several guidelines for land use planning, planning and financial and practical assistance for building physical flood protection works such as levees and embankments, a flood warning system, and an emergency preparedness system. For more information see https://www.nve.no/flaum-og-skred/ and www.varsom.no

The Norwegian Environment Agency assists the Ministry of Climate and Environment on Climate Change Adaptation (CCA) matters and is responsible for maintaining and developing the Norwegian portal for climate change adaptation intended to support the society in Norway in preparing for the consequences of climate change. The portal offers comprehensive information about ongoing work on climate change adaptation in Norway, lessons learned and relevant research, developments and publications: http://www.klimatilpasning.no/infosider/english/

"Crisis-information" http://www.kriseinfo.no/en/ is the official Norwegian website providing valid and secure information to the general public before, during and after a crisis. The website presents updated and coordinated information from relevant Norwegian authorities and emergency actors. Extreme weather and floods are among the possible crisis covered.

The Norwegian Water Information System "Vann-Nett" (**Figure 32**) was developed as a management and information tool to facilitate the implementation of the EU Water Framework Directive: http://www.vannportalen.no/verktoy-og-kart1/vann-nett/ Water managers in relevant authorities at all levels may use it as a management tool, and stakeholders as well as the public can use it to access information.

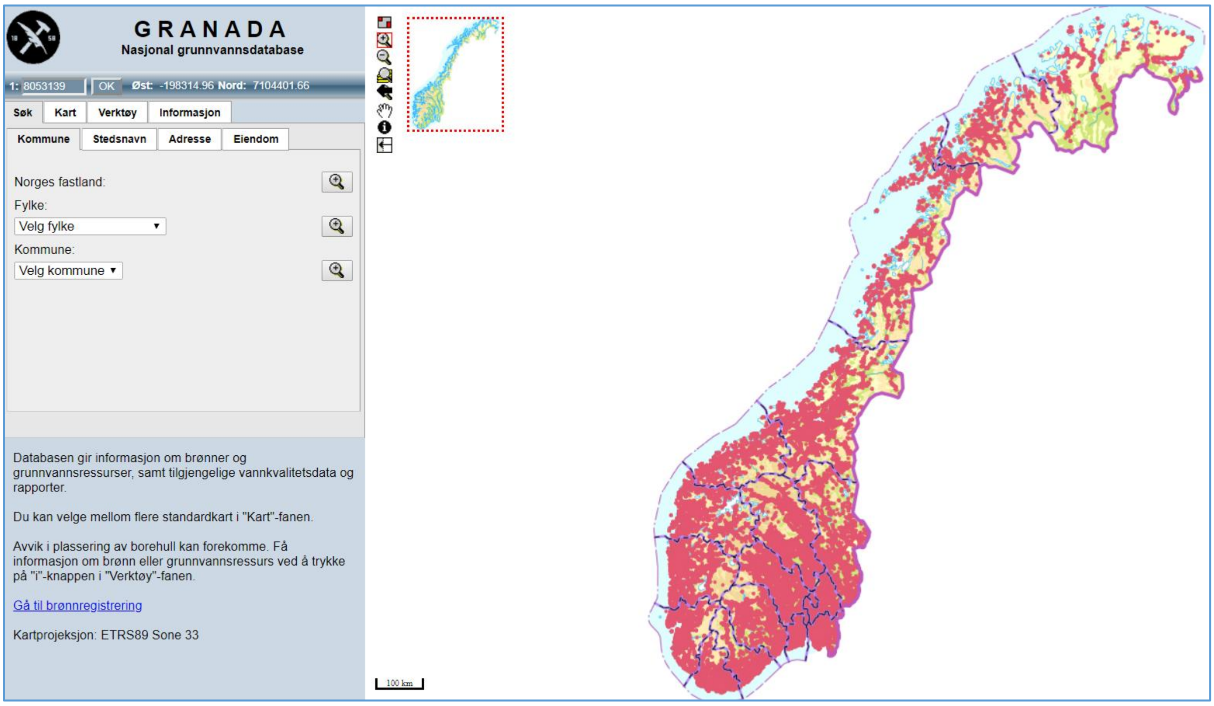

Figure 32: Norwegian Water Information System "Vann-Nett"

6.4 Innovations, R&D

6.4.1 DNA for biomonitoring of water quality

In accordance with the European Water Framework Directive, the Nordic countries monitor the ecological status of waterbodies to assure that either their good status persists, or that current status improves. Traditionally in biomonitoring, individuals in samples from a specific waterbody are identified based on morphological characteristics to the degree of taxonomic resolution possible e.g. species, or more generally taxa. In a second step, the sample taxa list is compared to a list established earlier for reference-condition. The degree of deviation from the expected reference condition is used as the basis for the assessment of the status of the waterbody the sample was taken from.

Traditional taxa identification underlies current assessments but requires high taxonomic expertise and therefore comes at a relatively high price. There are fewer expert taxonomists and training of future experts is in decline. Reliable identification of microscopic organisms is a slow process and the time lag between sampling and obtaining results is long. Finally, in most countries funding for biomonitoring campaigns is in decline. Fortunately, breakthroughs in genetic methods can solve the aforementioned problems.

The main emphasis in the SCANDNAnet project (Figure 33) is on comparing the performance and applicability of DNA -metabarcoding approaches to traditional identification of routine monitoring samples. The use of this method for genetically identifying and managing taxonomical data will simultaneously stretch the speed and accuracy limits of current taxonomic identification and provide previously unavailable taxonomic data. We will assess the strength of the novel genetic identification method to improve biomonitoring of pressures of change, improve ecosystem health and biodiversity assessments, and ecosystem service identification and preservation.

SCANDNAnet covers a geographically very large extent by using samples from the annual national monitoring programs of all Nordic countries. The novel advances made during this project can directly be put into use in the national monitoring programs of the Nordic countries and will have far reaching impact in Europe and beyond. Through intensive dialogue with relevant national and international stakeholders our results will help facilitate cost-effective, standardized DNA-based biomonitoring and create a significant societal impact by promoting reliable future aquatic ecosystem status and service management.

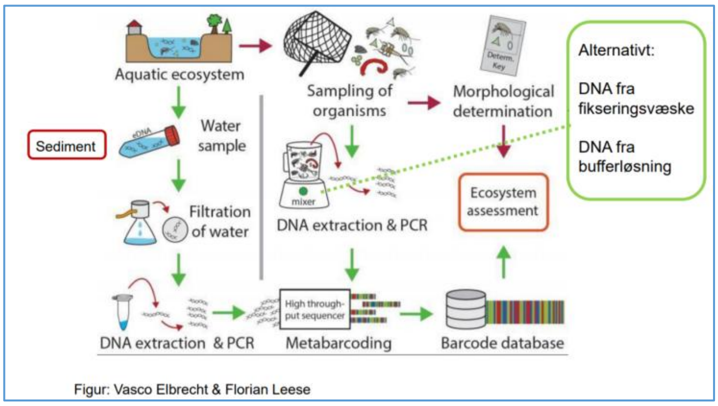

Figure 33: Schema of the project SCANDNAnet

6.4.2 Satellite data for monitoring of coastal waters and lakes

There are several projects (concept is depicted in Figure 34), combining satellite data and monitoring applying sensors. For example, Ferrybox has analysed a large chlorophyll-a data set sampled by the Ferrybox on the ferry between Oslo and Kiel and compared it with data sampled in the Danish NOVANA programme. A partnership consisting of NIVA Denmark Water Research, Norwegian Institute for Water (NIVA), Aarhus University and DHI has: (1) Collated relevant data (chlorophyll- a, salinity and temperature) from various sources (i.e. the Ferrybox on the Oslo-Kiel ferry, from the NOVANA programme, from satellite and from modelling activities), (2) assessed uncertainty for temperature, salinity and chlorophyll- a, and (3) transformed Ferrybox-based data to a data product aligned with chlorophyll-a data sampled under the NOVANA programme. The derived data product has been quality assured and submitted to the Danish EPA for their use regarding specific activities, e.g. Initial Assessments under the Marine Strategy Framework Directive and Water Framework Directive, Danish reporting to HELCOM and OSPAR and for reporting of NOVANA.

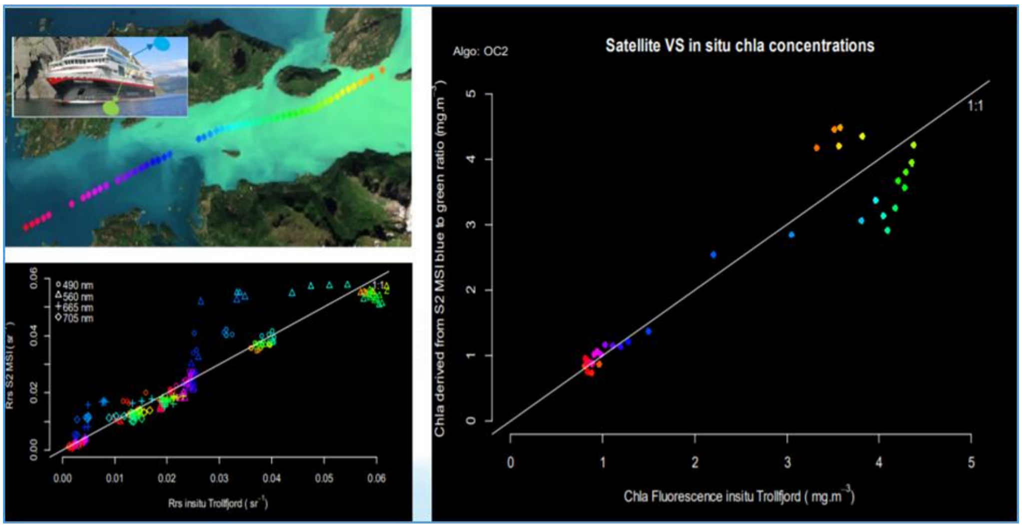

Figure 34: Concept of satellite data for monitoring of coastal waters and lakes

6.4.3 Non-target screening

The already substantial number of different organic chemical substances emitted to, and circulating in the environment is increasing. Due both to this growing number of chemicals, and the accumulating knowledge of their potential negative environmental and health effects, the number of emerging contaminants in Europe and elsewhere is also increasing. In regular environmental analysis, a targeted approach is generally used, i.e. the analyses of interest are selected before making measurements. However, the problem with targeted methods is that chemicals, which are not initially anticipated, are not detected regardless of how high their concentration might be. Thus the non-target approaches are needed to identify the unknowns and to reveal a more complete profile of contaminants. In this study (Figure 35) we utilized modern techniques, such as high and low resolution time of flight mass spectrometry (TOF-MS) combined with either ultra-high-performance liquid chromatography (UPLC), gas chromatography (GC) or multidimensional gas chromatography (GCxGC) to analyze wastewater, sludge, sediment and biota samples. This approach proved to be useful, a number of anthropogenic compounds have been tentatively identified and included: pharmaceuticals and personal care products, plasticizers and flame retardants, polymer additives, and other well-known persistent organic pollutants. Additionally, full-scan acquisition allows retrospective analysis for emerging contaminants years after the data has been acquired.

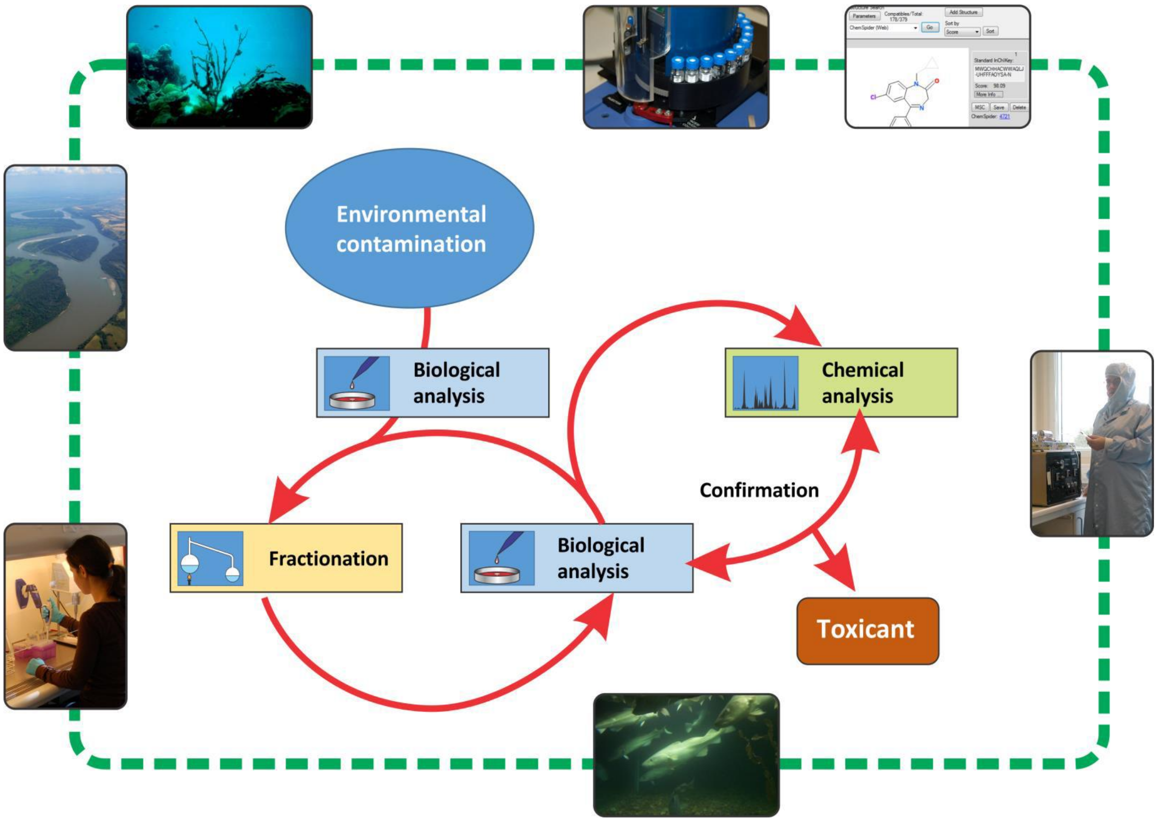

Figure 35: Concept of non-target screening

7 Portugal

In Portugal, there were some innovative actions about the knowledge, the planning and the management related to the freshwater resources. From those actions, the ones concerning the contribution of the university towards an improved knowledge are briefly mentioned.

7.1 Large scale hydrological modelling

Hydrological models, or water balance models, simulate the time changing water flows in a watershed and the occurrence of water along the soil profile and the river network. This type of models is routinely used to evaluate the hydrological behavior of watersheds in many applications, such as river flows forecasting, infrastructures design and operation, water availability assessment and its dependence on external factors like climate or land use change.

Simpler lumped models assume spatially uniform watershed characteristics, a larger computing time step and a smaller number of conceptual elements to represent the water flow and storage through the basin. Model complexity arises when the spatial distribution of input variables and watershed characteristics is considered and physically based equations with many parameters are used to represent the water flow through the watershed. However, data and computer power availability and the advent of geographic information systems have led to a trend of using increasingly complex models, instead of simpler models requiring less data and a shorter learning effort. Several authors have questioned this approach and have shown that simpler lumped and conceptual models can explain a large part of the stream flow variance and are nearly as accurate as the complex ones.

In this research, we focus on the ability of parsimonious hydrological models to simulate the watershed water balance and to compute river discharge, when compared with more complex models such as the SWAT model. The simplicity of such models is a clear advantage in many parts of the world where data and hydrological expertise limit the use of more complex models.

Modeling large river basins also requires the ability to include in the simulation the use of water by a large and wide variety of stakeholders and the operation of infrastructures, such reservoirs, diversions and powerplants. The models must assist the user to make estimates of the amount of water that needs to be supplied in order to meet present and future water demands scenarios, by taking into account social, economic, technical and environmental changes affecting the modeled system. Generic simulation models are useful to obtain information and understanding on the needed management steps that improve the water system management and planning processes. As the impacts of climate change are expected to intensify, models will become more needed and used as a way to predict scenario supply-demand water allocation interactions and will become invaluable in the assessment of the impacts on water operating rule modifications in order to set sustainable water management and supply measures. Appropriate intervention can reduce the impacts of climate change on water allocation and supply, resulting in mitigating economic, social, and environmental measures in water supply systems. Numerous generic models exist for multi-purpose water resources systems simulation and optimization.

Case studies include watershed in Brazil (São Paulo and Bahia) and in southern Europe (Iberian Peninsula), characterized by a highly interannual and seasonal variability of both precipitation and streamflow. Consequently, water resources planning and management is conditioned by recurrent long periods of droughts, which will be further aggravated by climate change.

Data availability is also a concern when simulating large river basins. When in situ ground observation measures of precipitation is difficult the use of remote sensors installed in satellites can be very useful in overcoming this challenge, enabling the improvement of the spatial variability description of this variable and the extension of data series. A number of standard products offering precipitation estimates on a regular basis is now available and may be used for water planning and management purposes.

7.2 Assessing water scarcity: the droughts

Droughts are generally associated with the persistence of low rainfall, soil moisture and water availability relative to the normal levels in a given area. They are among the most complex and least understood regional natural extreme hazards, affecting more people than any other one. They are also recurrent events especially in regions with pronounced natural hydrological temporal variability as many of the Southern Europe. Different from other extreme hydrological events (floods), droughts remain a less visible natural risk, whose impacts are not systematically recorded and by the time they are perceived it is already too late to mitigate their consequences.

Due to the high susceptibility of Portugal to droughts occurrence a research about the subject was initiate almost a decade ago about the subject and widely applied inside and out of Portugal. It is a stepwise methodology, which comprehends:

- Selection of the drought index (selection strongly constrained by the available hydrological information). The drought index used was the standardized precipitation index, SPI. Basically, the SPI quantifies the precipitation deficit at different time scales (from 1 to 24 months), which reflect the impact of droughts on the different types of reservoirs of fresh water at the watershed level.

- Definition of homogeneous regions regarding the spatial pattern of the drought index based on principal component analysis, PCA, and on cluster analysis.

- Characterization of the droughts in terms of their spatial extent, severity (maximum value), duration of the periods under droughts conditions, magnitude (cumulative intensity) and frequency.

The frequency assessment aims to tackle the following questions: has the frequency of the drought events changed over time, regardless their severity, i.e., regardless the amount of the precipitation deficit? Because droughts are a pointwise process, a specific methodology was also developed, namely the Kernel occurrence rate estimation method (KORE) coupled with bootstrap confidence bands.

7.3 Water resources management and climate change adaption in transboundary basins

Water resources planning under climate change is particularly trying in transboundary basins, a condition that cannot be ignored in Europe where transboundary basins cover more than 80% of the continent's land surface.

The problems of climate adaptation are amplified in transboundary basins because a plan must be agreed across the border, as well as among policy sectors and government levels. The involvement of a larger number of stakeholders and the absence of a common planning, legislative and regulatory framework makes reaching a consensus more difficult.

Yet, strong cooperation is needed to develop an efficient and effective adaptation strategy in transboundary contexts. The sharing of resources generates a common understanding of the arising vulnerabilities that is key for a coordinated response. A joint analysis of the possible actions enlarges the set of options to address the threats, increases its efficacy and avoids transferring vulnerabilities from on part to the other part of the basin. It also ensures that each adaptation measure is implemented where it has the most impact to the whole basin and the least socio-economic cost.

In Southern Europe, the Mediterranean climate and current climate change projections add to these challenges. Water scarcity and substantial flow regulation by large storage reservoirs lead to very specific problems of water shortages, poor water quality and significant impacts to aquatic ecosystems. A large majority of the reservoirs is used for power production and is increasingly equipped with pump-storage systems to store energy produced from renewable sources. The reservoir operation is often dictated by the electricity price in the market, putting additional pressure into water resources.

Given the current climate projections, some drastic adaptation measures will probably be needed, defying the possibility of a step-by-step approach with flexible measures. The inexistence of common river basin organizations requires that governments must take the responsibility to reach a consensus and must be directly involved in coordinating their adaptation efforts. Adaptation efforts should be considered within the bi-national agreement for managing shared water resources, as well as in the River Basin Management Plans.

7.4 Trend analysis of increasing pollution in the groundwater bodies and the reverse of the trend

A few approaches were developed aiming at analyzing the trends in some hydrological time series and at relating those trends with the climate change issue. In the scope either of the surface water or of the groundwater the more common approaches use the Mann-Kendall test coupled with the Then Sen Slope to identify and to quantify the significant changes.

Regarding the groundwater the trend analysis aims to ascertain the following aspects:

- Trends in time series: in this case, the methodology should detect the statistical significance of downward or upward trends over time and their range of change;

- Trend reversal: the methodology should detect the occurrence of a reversal of a trend and mark the date on which this reversal occurred;

- Applicability of the methodologies to the context of APA (Environmental Protection Agency of Portugal): the methodologies should be easily integrated in global approaches with preference being given to tools that are included in free software packages;

- Correction of seasonality: the methodologies to be selected should correct the seasonality in the series, that is, this variability should not influence the final result.

According to the objectives, besides the Mann Kendall and Theil-Sen slope tests, LOWESS (Locally Weighted Scatterplot Smoothing) operator and Singular Spectrum Analysis were also applied aiming at to assess the trends related to the concentration of nitrate in Portuguese groundwater bodies and their reverse trends.

7.5 Assessing groundwater bodies chemical status

A specific methodology was also developed by IST to assess groundwater chemical status based on the following procedures:

- Comparison of mean values of Susceptibility Index, quantification of diffuse pressures and risk of contamination in the recharge area in order to assess vulnerability to contamination;

- Aggregation and analysis of monitoring data between specific dates;

- Comparison of the mean values calculated for the different parameters with the threshold values, as defined by the National Water Authority with values of groundwater quality standards and natural concentration values.

The Susceptibility Index (SI), an adaptation of the DRASTIC method, was developed with the intention of evaluating aquifer vulnerability with respect to diffuse agricultural pollution in hydrogeological settings typically found in Portugal. The main difference is the addition of a parameter defining land cover, thus abandoning the concept of a purely intrinsic vulnerability assessment method. The principal types of land use and their assigned ratings were provided by a team of Portuguese scientists. Three DRASTIC parameters were deliberately left out of the construction of the Susceptibility Index which include soil (S) and unsaturated zones (I), thus suggesting that their direct influence on the contamination linked to agricultural practices is of little importance. The last DRASTIC parameter not incorporated in the SI is the hydraulic conductivity of the aquifer as is already qualitatively represented by the aquifer media (A), resulting in an excessive weight of this factor in comparison with the others. The weight string for the SI was also determined by the team of Portuguese scientists. For a more complete description consult:

7.6 Identifying Groundwater Dependent Ecosystems

The Water Framework Directive (WFD), Directive 2000/60/EC in Annex II, points 2.1 and 2.2, establishes the obligation to identify and characterize all the bodies of groundwater associated with surface or terrestrial ecosystems that depend directly on them.

The chemical composition of the groundwater body shall be such that the concentrations of pollutants should not significantly reduce the chemical or ecological quality of the associated surface water, or to cause significant damage to groundwater dependent ecosystems.

IST developed a new methodology for the identification and characterization of groundwater dependent terrestrial ecosystems protected areas of the Natura 2000 Network (Sites of Community Importance and Special Protection) and Ramsar Sites in Portugal.

The methodology uses hydrological, hydrogeological and ecological criteria to determine the magnitude of dependence of specific fauna and habitats as well stygofauna.

It should be noted that the only situations considered were those in which the groundwater body has to comply with quantity (flow, level) and water quality requirements aiming to ensure the sustainability and biodiversity of the associated ecosystem.

8 Group discussion on innovative practices: Barriers and opportunities

Based on the presentations of the EU project partners at the Workshop on Innovative Practices in Water Resource Management a group discussion on this topic was initiated to transfer the knowledge to WB partners and identify barriers and opportunities in their countries. In this context a SWOT-analysis was performed by all project partners and moderated by the team from NMBU.

Figure 36 shows the identified strengths, weaknesses, opportunities and threats, whereby all answers were ranked according to an in-situ online voting of all project partners.

Focusing on the strengths of WB countries, existing human resources including well educated professionals especially in water-related and IT sectors, the creativeness and resilience of the citizens as well as the possibilities to learn from good examples and mistakes abroad were prioritized by the participants.

The evaluation of weaknesses identified a lack of cooperation and communication between politics and authorities, which might be based on poor understanding by political classes resulting in subpar water-related laws and political agendas. Additionally, corruption was highly ranked, which might be also related to the above-mentioned weaknesses.

According to the SWOT-analysis the opportunities for WB countries lie in learning from mistakes made abroad (EU, US, etc.), in possibilities to strengthen cooperation with EU partners (including funding opportunities) as well as with countries in the region. Existing information systems, the abundance of data and the ongoing digitalization (including artificial intelligence) might be additional opportunities for WB countries with well-educated citizens in the IT sector.

The main threats identified were corruption, an unstable political situation and lack of educated people in decision-making positions resulting in a lack of political willingness. In addition a holistic vision of water resource management and the public awareness on this topic are missing.

Figure 36: Barriers and opportunities in WB countries – Result of SWOT-analysis

The results of the SWOT-analysis will be considered in many ongoing and upcoming activities of the SWARM project. The development of competence-based curricula (WP2) as well as trainings of professionals (WP3) will benefit from a consideration of the findings. In addition, it is targeted to address the results in the development of master curricula and trainings (WP4).

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