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DT2.1.4. TRANSNATIONAL REPORT ON PROBABILISTIC MODELS APPLIED FOR HAZARDS AND RISKS IN THE PILOT AREAS

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SUMMARY

1. INTRODUCTION

This deliverable represents a Transnational report based on PA specific data and information on probability of the occurrence of different hazards and vulnerability models used, including protocol of sharing data exchange and information on probabilities.

The report is based on the deliverable DT 2.1.3. as well on the reports that the PA partners filled based on the guidelines/questionary for DT 2.1.4 which was provided by package leader.

The guidelines asked for defining:

1. Probability of occurrence for addressed hazards in the PA area which will have an impact on the vulnerable elements of WSS – based on the national institutional probabilistic models (floods, droughts, earthquake) and past experience with the frequency of occurrence of accidental pollution (group events based on the type of pollutant with intensity, duration and spatial distribution).

2. If there are no vulnerability models implemented, based on the vulnerable structural elements in WSS defined in DT 2.1.3, describe in plain text the vulnerability/impact components for four addressed hazards on these elements for the specific PA.

3. Information about the existing protocols for prevention, managing and reporting hazardous events and sharing them with national institutions/research institutions/local administration/other Water utilities… Provide information on web pages

Furthermore are given the collected data for each Pilot action.

2. ITALY (LP+PP10)

The Italian pilot site is water supply system connected to the Ridracoli dam, a reservoir located on the Adriatic slope of the "Tosco-Emiliano" Apennine in the Emilia-Romagna administrative region. It can store a maximum of 33 million cubic meters of water and is managed by Romagna Acque – Società delle Fonti company. The stored water is made drinkable by passing through a large drinking water treatment plant and is supplied to fifty municipalities in the provinces of Ravenna, Forlì-Cesena, Rimini and the Republic of San Marino, guaranteeing 950,000 inhabitants, as well as millions of tourists in summer, excellent water quality. The Ridracoli artificial reservoir is able to satisfy approximately 50% of Romagna's water needs and is part of a complex water supply system characterized, at a regional level, by a very high degree of network interconnection with the possibility of differentiating and integrating supplies with multiple types of sources, depending on the different needs and situations of availability.

Figure 1 – Ridracoli dam

The main characteristics of the distribution network have been described in DT2.1.2 and DT2.1.3.

2.1. PROBABILITY OF OCCURRENCE FOR ADDRESSED HAZARDS IN THE PILOT AREAS

An overview of the National Institutional databases and data on the occurrence of hazardous events is reported in Table 1.

Table 1: Summary table for Italy

ITALY		
	DESCRIPTION OF THE NATIONAL INSTITUTIONAL PROBABILISTIC MODEL	DATA ON THE OCCURRENCE OF HAZARDOUS EVENTS COLLECTED
FLOOD HAZARD AND WATER SUPPLY VULNERABILITY	• Flood hazard maps are developed according to the EU FD 2007/60 • no relation to the WSS vulnerability	• Data on occurred flood events are collected and organized in different catalogues at national and local level: - **AVI** (Aree Vulnerate Italiane) catalogue (http://sici.irpi.cnr.it/avi.htm) - **POLARIS** database (http://polaris.irpi.cnr.it/) - **Floodcat**, an operational multi-stakeholder online platform for recording flood events and associated damages - **ISPRA** annual reports on flood events occurred in Italy and relative damages. • No issues have been reported in the last years due to flood events for the Italian pilot area. • In the period 2010-2019, 6 positive extreme events that required managed spillway operations have been reported (18-3-2013; 30-1-2014; 10-2-2014; 11-3-2018; 13-5-2019; 24-12-2020) • Daily spillway volume are available for the period 1996-2018
DROUGHT HAZARD AND WATER SUPPLY VULNERABILITY	• Concerning the hydrological and hydrogeological drought, a probabilistic model is not available at national scale. • The status of "severity" (i.e. the degree of inability of the water supply systems of a given area to meet the ordinary water needs in case of water scarcity due to meteorological and hydrological drought) is assessed by the permanent Observatories for the Water Uses set up on each "Hydrographic District" based on an expert system approach. • When necessary, each Administrative region has the possibility to ask the relevant Observatory to declare the "high water severity" and then ask the Central Government through the National Civil Protection Department for the declaration of the "state of emergency" due to "water	• ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) annually delivers a report on Climate Indicators for meteorological drought: https://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente). The report concerns only the identification of the hazard and its occurrence, drought vulnerability of WSS is not reported. • Concerning the impact of drought on the water supply systems, no reporting structures exist both at national and at local level. • Nevertheless, the national civil protection has an internal reporting system with information on events in which it has been involved. This system, therefore, collects information on a significant yet limited set of extreme events and disasters.

	supplying crisis". Procedures are regulated by legislative decree n. 1/2018 and by the directive of President of the Council of Ministers issued on 26th October, 2012.	• Recently, hydrological and hydrogeological drought monito • • ring and analysis activities are gather through Observatories for the Water Uses (OWU) operating at Hydrographic District and National level, providing a drought report on the current status of the "water severity". (see also DT1.1.3) • The Italian pilot area is prone to water shortage crisis during periods of precipitation significantly under the mean. Significant drought events occurred in 2003, 2007 and 2017. • It is worth stressing that in 2017 the Council of Ministers declared the "state of emergency for water supplying crisis" after the request of the Emilia-Romagna region for the provinces of Parma, Piacenza, Bologna, Modena, Reggio Emilia, Ravenna, Forlì-Cesena, Rimini, the last three being supplied by the water supplied system connected to the Italian pilot area dam.
EARTHQUAKE HAZARD AND WATER SUPPLY VULNERABILITY	• A catalogue of impact related to seismic events is currently managed by ISPRA https://annuario.isprambiente.it/ada/downreport/html/6862. The Catalogue has not been specifically developed for WSS and for water supply. Relevant information could not be therefore immediately available. • INGV (Istituto Nazionale di Geofisica e Vulcanologia) collects and structures relevant information on national earthquakes (CFTI5Med Catalogue http://storing.ingv.it/cfti/cfti5/). • Currently a reporting structure, specifically focused on the impacts of earthquakes on WSS, does not exist.	• Concerning the Italian pilot area, on May 20, 2012 an earthquake measuring 5.8 Mw magnitude hits the area around Modena (Emilia-Romagna region, Northern Italy). During the following seismic sequence, two more main events were recorded on May 29th and June 3rd. The epicentre of the earthquake was located near the town of Mirandola, whose distance from the Ridracoli dam is approximately 125 km. Despite the proximity of the dam to the earthquake epicentre and, most of all, despite the proximity of some of the distribution infrastructures of the water supply system connected to the Ridracoli reservoir, Romagna Acque declared that no interruptions of the water occurred after the Emilia Romagna earthquake. No other impacts due to earthquake have been reported prior to 2012.
ACCIDENTAL POLLUTION HAZARD AND WATER SUPPLY VULNERABILITY	• In Italy there are no probabilistic model specifically dedicated to hazardous events occurring in WSS triggered by accidental pollution events. in 2003 ISPRA set up a Database on Relevant Incidents (Banca Dati Incidenti Rilevanti, BIRD, https://www.isprambiente.gov.it/it/pubblicazioni/rapporti/valutazione-dellimpatto-sullambiente-degli), where about 5000 cases occurred in Italy and worldwide are registered.	• ISPRA every year draw up a report at national level on the Environment that presents and analyses the current status through a set of 301 indicators gives a comprehensive assessment on the actual status of the environment in Italy, but without any report on hazardous events https://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente/annuario-dei-dati-ambientali-edizione-2019) • Concerning the impact of accidental pollution on the water supply systems in the specific, no reporting structures exist.

		•No specific events of accidental pollution been reported by Romagna Acque for the Italian pilot area •Limited cases of seawater intrusion have been reported by Romagna Acque on wells clusters located close to the coast

In Table 2 an overview of the internal database of hazardous events or vulnerability or impact is shown.

Table 2: Overview of the internal database of hazardous events or vulnerability or impacts

Water utility internal data and impacts on the water supply	• Such data are collected internally by the Water Utility but not reported
Water utility internal data (reported to other authorities) on any hazard/vulnerability	• Flooding: data and models for level of alarm and alert are managed at regional level by the "Functional Center" (Centro funzionale) of the Regional Civil Protection • Drought: basically possible failures in the water supplying are related to the actual level of reservoir, which is publicly available. Drought and water scarcity events, possibly leading to water shortage conditions, are managed after the water crisis of 2007 at regional level through specific operational procedures involving different institution (public health services, environmental agency, regional civil protection, water manager, etc.). Details on the management procedure in case of water crisis are described in DT2.1.3. Internal data on the status of the Ridracoli water supply system as a whole are shared in the framework of the regional coordination committee, coordinated by the regional Civil Protection • Accidental pollution. Data on water quality in case of accidental pollution or other quality issues are reported to other institutions (Local Health Agency, Regional Agency for the Protection of the Environment, Civil Protection System, Regional Administration etc.) only in case of impossibility to supply water partially of totally. • Earthquake. Any specific internal database exists
HACCP control points analysis - deviations	• No available
Other event-based data/information that supports the probabilistic modelling	• No available

2.2. VULNERABILITY MODELS AND IMPACT ON THE WSS ELEMENTS

Drought: Romagna Acque Società delle Fonti since 2019 has adopted a "management model" of the reservoir, developed by the University of Bologna - Department of Civil, Chemical, Environmental, and Materials Engineering. The model simulates the mass balance of the water supply system, taking into account the Inflow to the reservoir as a function of the precipitation and temperature on the recharge area, the monthly water needs (considering the maximum consumptions over the period 2009-2016) and the limits (min and max) of water that can be supplied to each area from the reservoir and from each of the local sources.
In the framework of MUHA, a user friendly tool named *INOPIA^QGIS^*, developed under a collaboration between CNR (LP) and DPC (PP10) and allowing for the quantification of the risk of shortage for a water supply system (multi-resources & multi-users) and supporting management decision, will be tested on the pilot area. The model currently adopted by Romagna Acque has basically the same goals but needed five years with significant associated costs to be developed. In the framework of the MUHA project, CNR (LP) and DPC (PP10) proposed to test the implementation of a general open source software not specifically designed for a given water supply system, but flexible enough to be customized by each water utility to its own system.

Flooding: The Italian regulation ('Directive of the President of the Council of Ministers _ Dir. P.C.M. 27 February 2004') states that dams must develop a lamination plan that determines the volume in the reservoir that has to be kept available to capture floodwaters for flood control purposes. For the Italian pilot area, a rainfall-runoff model commissioned by the managing authority of Ridracoli Dam (Romagna Acque company) to the Alma Mater Studiorum, Bologna University (Department of Civil, Chemical, Environmental and Materials Engineering, DICAM), has been developed and calibrated to reconstruct and simulate the inflow hydrographs to the reservoir. The hydrological model application (currently used for the present operational management of the reservoir) has been mainly focused on the analysis of water scarcity conditions, while the issue concerning the optimized management of incoming floods has not been addressed within a 'lamination plan'.

Earthquake. Currently, Romagna Acque Società delle Fonti does not have any model explicitly oriented to analyse the impacts of earthquakes on the water supply network, but has developed a partial hydraulic model strictly connected with the monitoring and real time control system. In the framework of MUHA, CNR (LP) will provide a suite of tools and methods, that have been developed in the last few years in several National and EU projects, to support vulnerability and resilience assessment of the water supply system managed by Romagna Acque. Specifically, the aim of such model(s) is to support analysing the potential impact of pipe failure events on the connectivity and efficiency of the system as a whole, thus supporting in the identification of the most crucial elements for guaranteeing a safe and continuous water supply, in the identification of weak points and in the selection of potential resilience-enhancing strategies.

Accidental pollution: A continuous quality monitoring system for ordinary conditions is already implemented. The vulnerability is addressed through the protection of recharge area, regulated by the Italian Legislative Decree (152/2006, Part III). In the framework of MUHA, new microbiological parameters in addition to those ones currently adopted to detect possible biological contamination will be tested and evaluated to reduce the monitoring time for microbiological contamination.

2.3. EXISTING PROTOCOLS FOR PREVENTION, MANAGING AND REPORTING HAZARDOUS EVENTS

Drought: During the emergency phase in 2007, a commissioner structure for the national level was set up at the Civil Protection Department and measures or action agreed to be triggered below specific “threshold levels” of the Ridracoli reservoir has been defined. The warning, pre-warning and alarm levels and associated measures and actions are reported in table 1 of DT2.1.3 (country report).

Flooding: No lamination plan is available. Currently, when the water level in the lake exceeds the height of the spillway (557.3 m a.s.l.), it is discharged into a "calm" basin downstream of the structure, and then returned to the riverbed.

Regarding the operation of the main dam (Ridracoli), there is a dedicated web page (https://www.romagnacque.it/acqua-in-diretta/diga-di-ridracoli/) which provides real time information on both the hydrological state of the system and of its structural behaviour. The operation of the dam is monitored in real-time with more than 900 measurement points, both located in the dam body and in the foundations, providing information on potential anomalies in the operation of the structure. Measurements are collected and elaborated three times per day and, in case of any anomaly, an alert is immediately issued (http://www.ridracoli.it/la-sicurezza-dati-tecnici/)

Accidental pollution: The quality parameters currently measured in ordinary conditions are reported with associated frequency in table 2 of DT2.1.3 (country report).

3. CROATIA (PP4)

3.1. PROBABILITY OF OCCURRENCE FOR ADDRESSED HAZARDS IN THE PILOT AREAS

An overview of the regional Institutional databases and data on the occurrence of hazardous events is reported in Table 1.

Table 3: Summary table for Croatia - Golubinka catchment area

1.	DESCRIPTION OF THE NATIONAL INSTITUTIONAL PROBABILISTIC MODEL	DATA ON THE OCCURRENCE OF HAZARDOUS EVENTS COLLECTED
FLOOD HAZARD AND WATER SUPPLY VULNERABILITY	Zadar county has created a risk assessment study where impact of numerous hazard is described in detail. Risk matrix tables are included which are defined by probability and consequences, impact on human health, economy and social stability in regard to most probable event and an event with the worst case scenario. But there are no WSS vulnerability models.	Only information on several severe events in recent years is available with no relation to vulnerability modelling. Nothing could be sent.
DROUGHT HAZARD AND WATER SUPPLY VULNERABILITY	Zadar county has created risk matrix tables defined by probability and consequences, impact on human health, economy and social stability in regard to most probable event and an event with the worst case scenario of a heat wave. But there are no WSS vulnerability models nor drought hazard maps.	Only information on several severe events in recent years is available with no relation to vulnerability modelling. Nothing could be sent.
EARTHQUAKE HAZARD AND WATER SUPPLY VULNERABILITY	Zadar county has made a map of earthquake prone areas for the return period of 475 years. A hazard assessment was conducted for critical infrastructure - electric energy supply, transport, water supply, communication centres and cultural heritage; description of events in case of earthquakes of various intensity. They created risk matrix tables defined by probability and consequences, impact on human health, economy and social stability in regard to most probable event and an event with the worst case scenario. But there are no WSS vulnerability models.	The map could be sent.

ACCIDENTAL POLLUTION AND WATER SUPPLY VULNERABILITY	Degree of water endangerment is imposed to the WSS relative to the accidental pollution by the state water law inspector and divided into three levels which are described in more detail in D.T2.1.3. The proposed protocol is set by the OG (5/2011) in respect to the ISO 22000:2018 system for safe human consumption water use. No WSS vulnerability modelling is conducted.	No data available.
OTHER	Zadar county has created risk matrices for epidemics and pandemics, forest fire hazard, storm hazard, industrial accidents.	

The Zadar water utility has no probabilistic analysis of hazardous events and/or vulnerabilities. Data collected from the monitoring sites are sent to the Croatian Institute for Public Health, Croatian waters, Ministry of Environmental Protection and Energy, Croatian Bureau of statistics and sanitary inspection. There are information on discrepancies and malfunctions, but there is no data available in electronic form at the moment.

Details are collected from Critical Control Points (chlorination) depending on whether there are objects with people on site or automated chlorination. There are plans to install automatic chlorination on all locations, which will be monitored through the Control and Monitoring System. The reports are submitted to the person responsible for handling of hazardous chemicals who verifies them and submits them to the Laboratory. Also at each sampling for physicochemical and microbiological analysis of water, the laboratory technician checks the concentration of free residual chlorine. If the prescribed deviation is found between the set concentration and the measured one, the calibration of the automatic chlorination device is performed.

3.2. VULNERABILITY MODELS AND IMPACT ON THE WSS ELEMENTS

In order to properly assess water resources vulnerability of the Bokanjac-Poličnik catchment area which is under the Zadar water supply jurisdiction, it is necessary to observe the catchment areas separately.

Hydrogeological characteristics of the Bokanjac-Poličnik basin mainly relate to groundwater. There are very few surface waters (Miljašić ravine and Zlokovnica) and their impact on the hydrology of the left bank is negligible, as well as several artificial reservoirs (Vlačine, Grabovac). The main geological features of this basin are highly permeable carbonate rocks and karst fields. The karst field of Ravni Kotari is covered with red soil mixed with karst, and is therefore of lower water permeability. The same can be said for Bokanjačko blato, which is a degree of lower water permeability due to lake deposits.

The endangerment of this basin comes mostly from accident situations on roads, illegal landfills and inadequate use of agricultural protective equipment, as well as the discharge of wastewater without treatment.

The entire catchment area of the Muškovci - Berberov buk pumping station is very different climatically, geographically and geologically. It can be divided into Lika, Velebit and Northern Dalmatia which are characterized with karst fields and therefore permeable carbonate rocks predominate. One part of the water affected by the Muškovci catchment on the right bank of the Zrmanja (Sekulića vrelo, Dorinovac, Čavlinovac, Manišino vrelo and Čavle) comes from karst springs or abysses of the Gračac and Štikad fields, and the other part is surface river water affected by the Berberov buk catchment. Both interventions with the collection pipeline are brought to water intake works Dolac. Surface catchment of the river Zrmanja is mainly used in summer dry periods, when water needs are increased due to tourist season.

Considering that the main pumping station in the system is Dolac, and any hazard that would have an impact on the pumping station, would cause the interruption of water supply for a large part of consumers. It is very difficult to estimate the duration of water supply interruptions, depending on the type of hazard and damage to the pumping station or pipeline. For this reason, Dolac is deemed the most vulnerable. In addition, the pumping station is located in the Muškovci -Berberov buk basin, which has still no established sanitary protection zones that would cover two local self-government Units. Upstream from Berberov buk there is increased construction and tourist activities.

Zadar water supply representative suggested that the best course of action would be to invest in research projects in order to expand the water intake works network, as to avoid dependence of the entire system on one spring.

3.3. EXISTING PROTOCOLS FOR PREVENTION, MANAGING AND REPORTING HAZARDOUS EVENTS

There is no information available for prevention protocols upon inquiry, besides for accidental pollution which has been described in more detail in D.T2.1.3. Data in Table 3. was collected from the Zadar county vulnerability assessment study from June, 2019.

Source:https://zadarska-zupanija.hr/images/dokumenti/68/PROCJENA%20RIZIKA%20O%20VELIKIH%20NESRECA%20ZA%20ZADARSKU%20ZUPANIJU.pdf

4. CROATIA (PP5)

4.1. PROBABILITY OF OCCURRENCE FOR ADDRESSED HAZARDS IN THE PILOT AREAS

An overview of the National and regional Institutional databases and data on the occurrence of hazardous events is reported in Table 14.

Table 4: Summary table for Croatia - Istarski vodovod

	DESCRIPTION OF THE NATIONAL INSTITUTIONAL PROBABILISTIC MODEL	DATA ON THE OCCURRENCE OF HAZARDOUS EVENTS COLLECTED
FLOOD HAZARD AND WATER SUPPLY VULNERABILITY	Flood hazard maps are developed on a national level but no relation to the WSS vulnerability. http://korp.voda.hr/	Probably available in Croatian Waters. On the WU level, only information on several events is available with no relation to vulnerability modelling. (See D2.1.3.) Nothing could be sent.
DROUGHT HAZARD AND WATER SUPPLY VULNERABILITY	In a way analysed in DMCSEE centre and the integrated observation an modelling application (https://droughtwatch.eu/), (only general droughts, status and severity) On a regional/county level there are two documents defining the probability and consequences, impact on human health, economy and social stability associated with various hazards: - *Istrian County Protection and Rescue Plan, October 2017* - *Assessment of the endangerment of the population, material and cultural goods and the environment from disasters and major accidents of the County of Istria, October 2017* Drought vulnerability of WSS is not modelled.	no systematic analysis of the impact of the droughts on the water supply systems. Nothing could be sent.
EARTHQUAKE HAZARD AND WATER SUPPLY VULNERABILITY	Existence of National seismic map. http://seizkarta.gfz.hr/ On a regional/county level there are two documents defining the probability and	Specific analysis of the functioning of the water supply systems after the earthquake is not a defined procedure.

	consequences, impact on human health, economy and social stability associated with various hazards: - *Istrian County Protection and Rescue Plan, October 2017* - *Assessment of the endangerment of the population, material and cultural goods and the environment from disasters and major accidents of the County of Istria, October 2017*	Nothing could be sent.
ACCIDENTAL POLLUTION AND WATER SUPPLY VULNERABILITY	Hazards imposed to the WSS relative to the accidental pollution are defined by the decrees on the water protection zones. Allowed and prohibited activities are defined and the prevention measures are indicated. The control points defined by the HACCP address hazards for the accidental pollution, after the water is already in the water supply system. No WSS vulnerability modelling is conducted.	No data available.
OTHER	Existence of National seismic map. On a regional/county level there are two documents defining the probability and consequences, impact on human health, economy and social stability associated with various hazards: - *Istrian County Protection and Rescue Plan, October 2017* - *Assessment of the endangerment of the population, material and cultural goods and the environment from disasters and major accidents of the County of Istria, October 2017*	No data available.

IVB has a log files for pipe brake occurrences, water quality monitoring, chlorination points and several SCADA elements sensors.

General data on occurrence of the four hazards is given in T2.1.3.

4.2. VULNERABILITY MODELS AND IMPACT ON THE WSS ELEMENTS

There are no vulnerability models implemented in Water Utility of Istria (IVB).

Based on the past experiences further are listed the major WSS components that can be highly impacted by the addressed hazards:

Flood:

Source Sv.Ivan – water treatment plant and pumping station Sv.Ivan – a failure of this components can result in the water distribution disruption which can affect around 10000 inhabitants. A time to normalize the water distribution is estimated at 5 days.

Water treatment plant and pumping station Butonega - a failure of this components can result in the water distribution disruption which can affect around 800 inhabitants. Time to normalize the water distribution is estimated at 5 days.

Drought

Source Gradole - a shortage of water at this component in a summertime can result in the water distribution disruption which can affect around 50000 residents and around 12000 tourists. A time to normalize the water distribution is difficult to estimate as it directly connected with the precipitation forecast. Additionally, by experience this water source has elevated turbidity after a prolonged water shortage which can also prolong the time to normalize the distribution.

Accidental pollution

All the four water sources of Water utility of Istria (IVB) can be affected by accidental pollution and the belonging catchment caused by:

- industry
- sewage system
- landfill
- transportation
- air pollution and infiltration trough rainfall
- other

Based on the type of pollution and the affected source it depends how big would the impact be. It is quite difficult to define the normalization time as the AP source and quantity can vary significantly as well the adequate solution.

Generally the most vulnerable water source is the **source Sv.Ivan** which doesn't have the interconnectivity with other water sources and in case of closing the water source around 10000 inhabitants would be affected.

Earthquake

Water source Sv.Ivan, Water source Gradole – beside the impact that the earthquake which can have on the underground water distribution connected with the source itself, this two water sources are interconnected with a pumping station and a water treatment plant. If any of these components experience a structural damage it could have a big impact on the water distribution. It is estimated that in case of a structural damage a time to do a repair on the object is from 15-45 days, depending on the severity of damage.

Also, the earthquake could impact only the electric system and no the WSS components, but it would also mean a disruption in a percentage of supplied water.

In summertime Source Gradole can impact around 50000 residents and around 120000 tourists, while Sv.Ivan impacts around 10000 inhabitants.

Butonega artificial lake – this lake has a significant role in the WSS of Istarski vodovod. Its water is used as a water source, and it goes on a water treatment plant which is designed for a 2000l/s capacity, although the actual production is now 1000 l/s.

In case of the earthquake damaging the artificial dam and in case of dam breakage, this water source can't be counted for water suppling for a longer period of time, depending of a dynamics of dam repairing. Estimation is that the repair can last from 3-9 months depending on the severity of damage. The impact on the inhabitants is estimated to 90000 inhabitants (including the inhabitants from WU Vodovod Pula, as Butonega is also suppling their WSS) plus around 170000 of tourists in summertime.

Butonega pumping station and treatment plant – in case of a structural damage it could have a big impact on the water distribution. It is estimated that in case of a structural damage a time to do a repair on the object is from 15-45 days, depending on the severity of damage. In summertime the impact would be around 90000 residents and around 170000 tourists, while Sv.Ivan impacts around 10000 inhabitants.

Source Bulaž – although there is a possibility of structural damage caused by earthquake, the impact on the water supply system would be very low as the source is primarily used as a backup source in case of scarcity of water in Source Butonega and Source Gradole.

Distribution pipelines – all the major distributive pipelines has a high risk of earthquake damage. Based on the location of the location of the hazardous event the impact to the water supply system can be relatively low to high.

It is estimated that the repair time can be measured in hours (6-24 hours) for location plus at least 24 hours for a complete distribution normalization.

4.3. EXISTING PROTOCOLS FOR PREVENTION, MANAGING AND REPORTING HAZARDOUS EVENTS

The internal and obligatory protocols for managing the hazardous events are described in D2.1.3. in detail.

Beside the reports considering water quality which is reported the Croatian Institute for Public Health, Croatian waters, Ministry of Environmental Protection and Energy, Croatian Bureau of statistics and sanitary inspection and the internal reporting of HACCP CCP there are not defined any other reports in case of hazardous events.

5. SERBIA AND MONTENEGRO (PP3+PP8)

5.1. PROBABILITY OF OCCURRENCE FOR ADDRESSED HAZARDS IN THE PILOT AREAS

An overview of the National and regional Institutional databases and data on the occurrence of hazardous events is reported in Table 5.

Table 5: Summary table for Serbia and Montenegro - WU Nikšić

	Description of the national institutional probabilistic model	Data on the occurrence of hazardous events collected
FLOOD HAZARD AND WS VULNERABILITY	Flood hazard maps are developed in Montenegro but no relation to the WSS vulnerability	No data to sent
DROUGHT HAZARD AND WATER SUPPLY VULNERABILITY	In Montenegro, there is an established system of drought monitoring through the calculation of the STI index and drought maps have been developed. There is no specific relation to WSS vulnerability.	Montenegro: no systematic analysis of the impact of the droughts on the water supply systems. Nothing could be sent.
EARTHQUAKE HAZARD AND WATER SUPPLY VULNERABILITY	Seismic hazard for the territory of Montenegro has been defined on several occasions by applying different methodological approaches (*Map of seismic regionalization of the territory of Montenegro, Map of seismic zones of Montenegro according to the maximum horizontal acceleration of the soil for a return period of 475 years and 10% probability of exceeding in 50 years).*There is no specific relation to WSS vulnerability.	Montenegro: no systematic analysis of the impact of the droughts on the water supply systems. Nothing could be sent.
ACCIDENTAL POLLUTION AND WATER SUPPLY VULNERABILITY	Hazards imposed to the WSS relative to the accidental pollution are defined by the decrees on the water protection zones. Allowed and prohibited activities are defined and the prevention measures are indicated. The control points defined by the HACCP address hazards for the accidental pollution, after the water is already in the WSS.	Events are monitored by the competent inspector
OTHER		

General remark:

LLC “Vodovod I kanalizacija” Nikšić have not had numerous hazard events with direct impact on WSS in the past. However, they have been observed, and for sure some of them have had direct, and more frequently indirect impact on the damages in WSS (in majority cases pipe cracking or turbidity pollution). Statistical analyses of hazard events and its impact could be done in three direction:

1. Through the direct analyses of such observed events with impact on WSS Nikšić,
2. Through the indirect analyses of available data (climate, hydrological, and earthquake)
3. Through the analyses of pipe breaks.

More detailed analyses for these three approaches are given in the following text.

1. These events are numerated in D.T2.1.3. More precisely:
   Drought: Available water production data (period 2016-2020) were compared with known information about the water shortage in dry period of the analyzed years, and some conclusion have been made. Period of five years is too short to make some relevant conclusion about the probability of drought occurrence and trends. Additional “problem” related to water scarcity issue in WSS Nikšić is that water demand has increasing trend last several years.

   Accidental pollution: Practically the only pollution in WSS Nikšić is turbidity. Similar problem, as in a case of drought, is serries of data. Just data of the last seven years exist. We can see that a little bit more cases with turbidity higher than 1 NTU has happened in the second part of this series, but this is too short period, and nothing relevant could be said related to probability of occurrence.

   Flood: As noted in D.T2.1.3, defects of pipes due to errosion exist, and most often occur on pipelines made of solid materials (asbestos cement, cast iron, steel, ductile, etc.), usually at the joints. Many of them are indirect consequence of flood, but there is no such evidence.

   Earthquake: No direct damages have been registered on WSS Nikšić due to earthquakes in the past. The occurrence and magnitude of the earthquakes in the last several decades are given in the text below.

2. Drought and Floods: Some statistics related to these hazards could be done on the indirect way. Available temperature (T) and precipitation (P) data exist for meteorological station Nikšić, and hydrological (Q) data for gauging station Duklo (Nikšić center) on Zeta river. All three series are on the monthly level, and they are given as annexes at the end of this deliverable (Annexes 1, 2 and 3). In addition to analyses of these three parameters, idea is to analyze some indices, and to try to find drought or flood tendency.

   In the first step temperature monthly, seasonal, and annual graphs are shown on Fig. 1.

   Regarding seasons, winter comprises months December, January and February, Spring comprises March, April and May, Summer comprises June, July and August, and Autumn comprises months of September, October, and November.

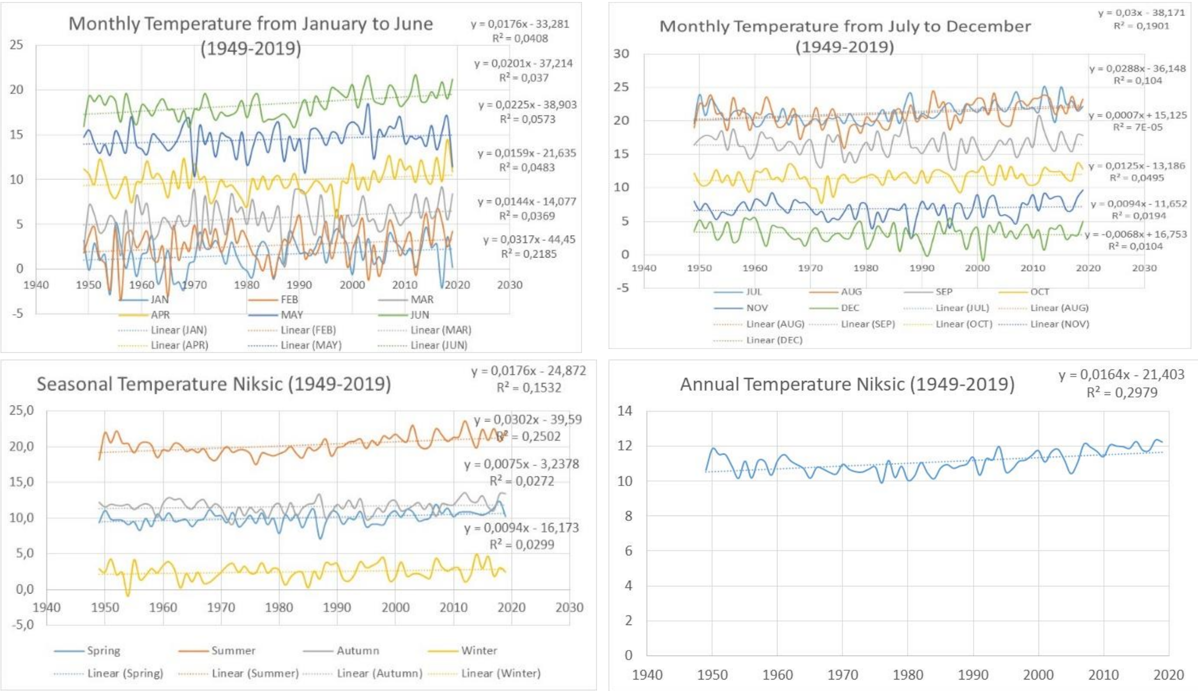

Figure 2: Monthly, seasonal, and Annual temperature (⁰ C) in Nikšić (1949-2019)

Table 6: Yearly trends of the monthly, seasonal and annual T, and changes in ⁰C/10 years, for period 1949-2019.

	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Trend (⁰C/year)	-0,0068	0,0176	0,0201	0,0225	0,0159	0,0144	0,0317	0,030	0,0288	0,0007	0,0125	0,0094
Trend (⁰C/10 years)	-0,068	0,176	0,201	0,225	0,159	0,144	0,317	0,30	0,288	0,007	0,125	0,094
Season	Winter			Spring			Summer			Autumn		
Trend (⁰C/10 years)	0,094			0,176			0,302			0,075		
Yearly Trend (⁰C/10 years)	0,164											

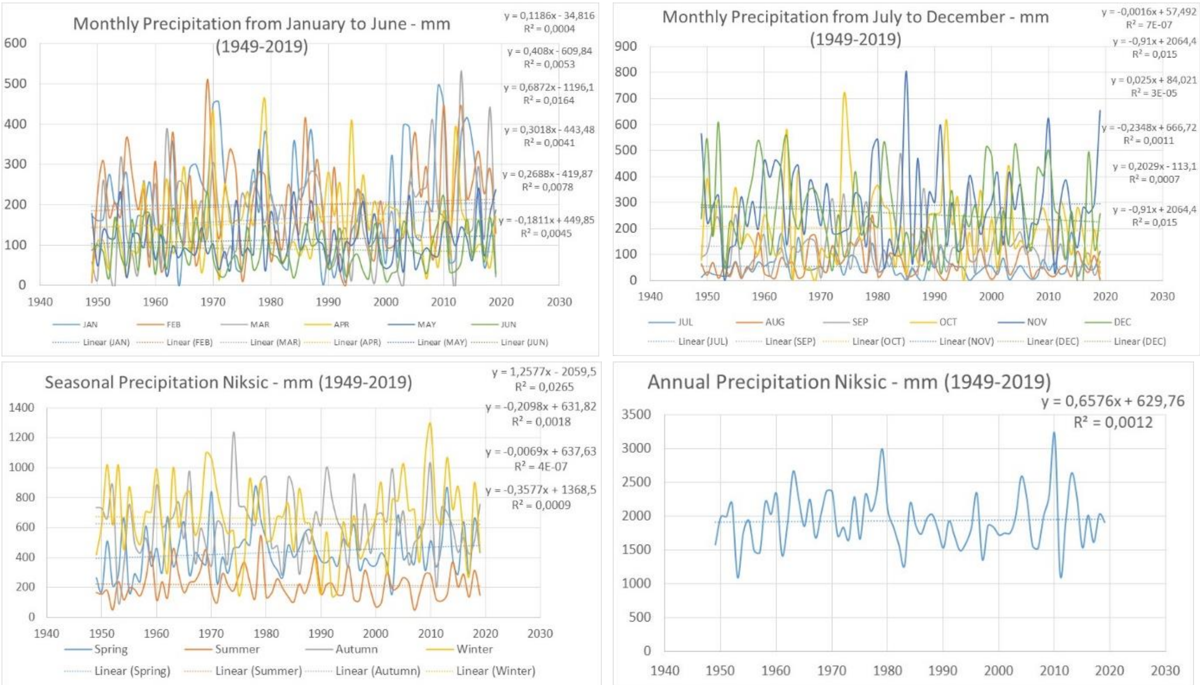

Figure 3: Monthly, seasonal, and Annual precipitation (mm) in Nikšić (1949-2019)

Table 7: yearly trends of the monthly, seasonal, and annual P, and changes in %/10 years, for period 1949-2019.

Table 2	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Trend (mm/year)	-0,91	0,1186	0,408	0,6872	0,3018	0,2688	-0,1811	-0,0016	-0,91	0,025	-0,2348	0,2029
$P_{average}$ (mm)	268,6	196,0	194,7	160,8	161,3	108,1	89,4	52,7	72,7	139,0	207,9	281,5
Trend (%/10 yrs)	-3,39	0,61	2,10	4,27	1,87	2,49	-2,03	-0,03	-12,52	0,18	-1,13	0,72
Season	Winter			Spring			Summer			Autumn		
Trend (%/10 yrs)	-0,54			2,89			-0,97			-0,01		
Yearly Trend (%/10 yrs)	0,34											

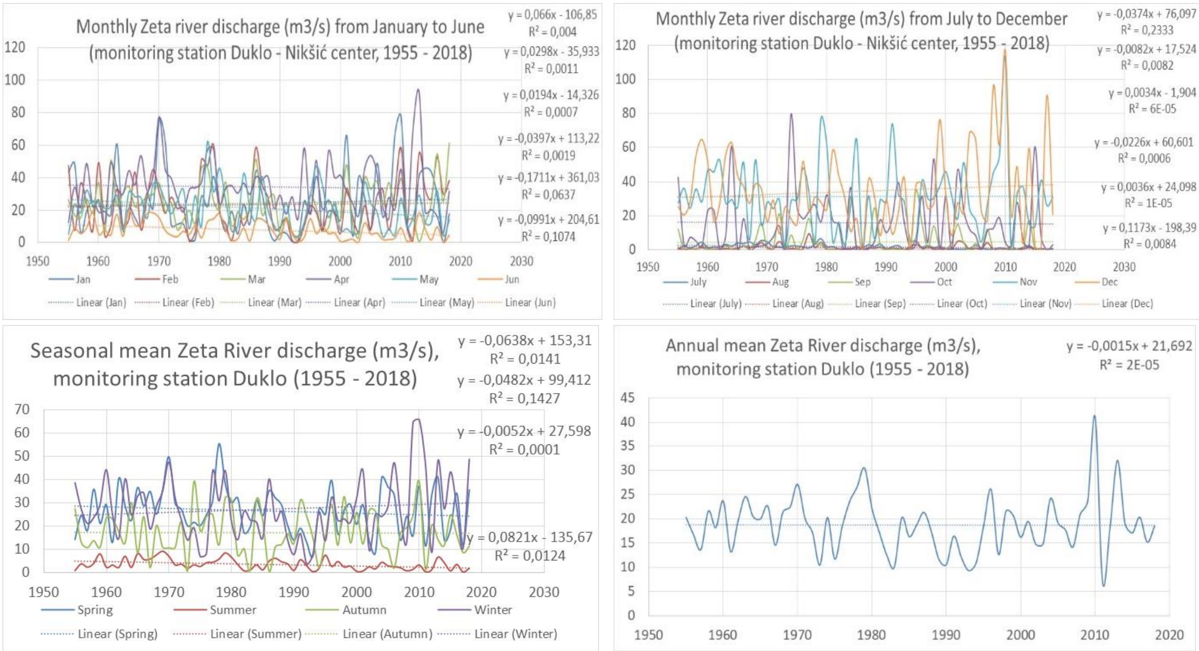

Figure 4: Monthly, seasonal, and Annual flow (m3/s), at Zeta river, mon.st. Duklo (1949-2019)

Table 8: yearly trends of the monthly, seasonal, and annual Q, and changes in %/10 years, for available period 1955-2018.

	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Trend ($m^3/s/year$)	0,1173	0,066	-0,0369	0,0194	-0,0397	-0,1711	-0,0991	-0,0374	-0,0082	0,0034	-0,0226	0,0036
$Q_{average}$ (m^3/s)	34,6	24,2	23,2	24,1	34,3	21,1	7,8	1,8	1,2	4,8	15,7	31,2
Trend (%/10 yrs)	3,4	2,7	-1,6	0,8	-1,2	-8,1	-12,7	-20,3	-6,6	0,7	-1,4	0,1
Season	Winter			Spring			Summer			Autumn		
Trend (%/10 yrs)	3,0			-2,4			-13,3			-0,3		
Yearly Trend (%/10 yrs)	-0,1											

Remarks based on Figures 2-4, and Tables 6-8, are as follows:

- Annual T increase about 0,16 ⁰C per decade, which is very similar with the other T stations in country and wide region,
- The highest T increase is registered in the summer (0,30 ⁰C per decade), after that spring (about the annual average), while in autumn and winter is a little bit lower than 0,1 ⁰C per decade. December is the only month with slightly decreasing trend,
- Annual P trend is about zero – no significant up or down trend,
- Very important increasing trend is observed for spring, and significant decreasing trend is observed for summer. In winter small decrease of P is registered, and there is no changes in P sum in autumn,
- The highest absolute monthly P trend is registered in August, and the sign is negative (-12,5%/decade),
- The river flow trends are in line with precipitation: annual about zero, the highest seasonal trend is in summer (decreasing – 13.3%/decade), and important increasing trend is in winter (3.0%/decade), in season with already highest values od flow.

All these points indicate that drought hazard has very significant, and flood hazard significant increasing tendency.

If we analyse correlation between precipitation and river flow (flow is corrected multiplying with $P_{average}$ and divided with $Q_{average}$; monthly or annual level), it can be seen on Figure 5 very good correlation on annual level, while in dry months correlation is a little bit lower. However, these graphs told us that conclusion regarding trends made for precipitation are relevant to some extent for river flow.

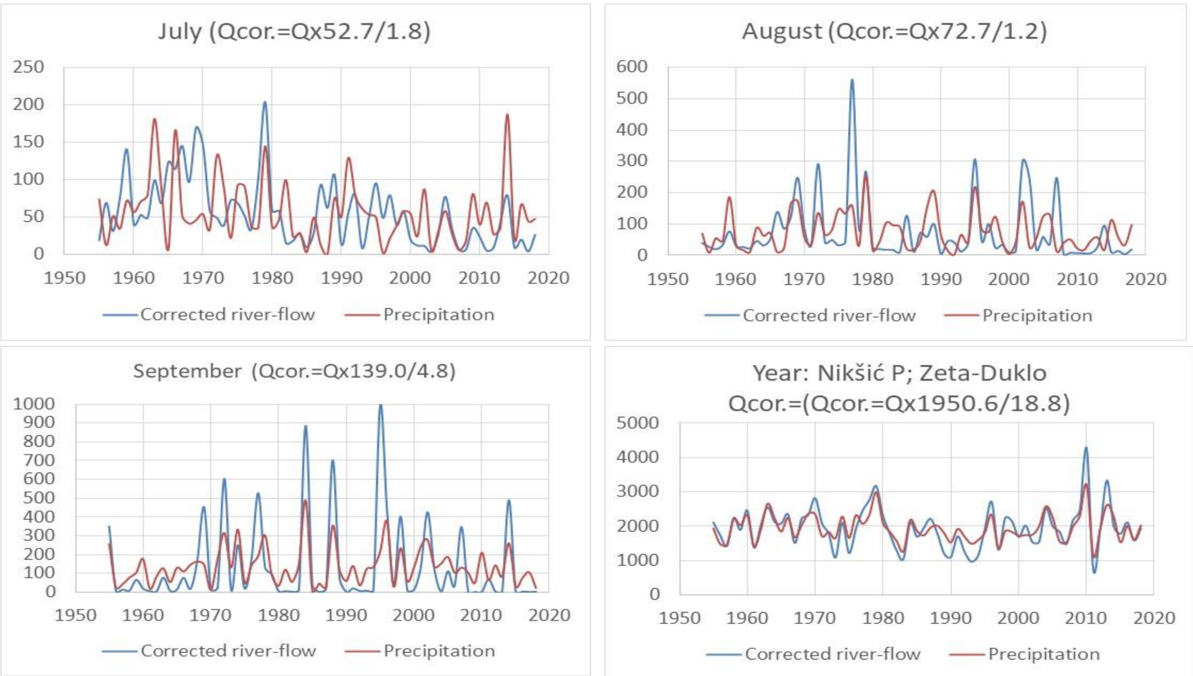

Figure 5: Monthly, seasonal, and annual flow (m3/s), at Zeta river, mon.st. Duklo (1949-2019)

Another way to have some information about the probability and tendency of drought and flood occurrence is to analyse available river-flow (period 1955-2018) and precipitation (period 1949-2019) monthly data. We have 12x64 = 768 river-flow monthly data, and 12x71 = 852 precipitation monthly data. Monthly data form the series and occurrence of 1%, 3%. 5% and 10% for floods, and 99%, 97%, 95% and 90% for droughts have been analysed. Table 9, and Figures 6 and 7 show relevant river-flow, and occurrence and tendency of monthly data for drought and flood.

Table 9

	Drought				Flood			
Occurrence →	99%	97%	95%	90%	10%	5%	3%	1%
Relevant river-flow (m^3/s)	0,100	0,165	0,240	0,522	45,3	55,0	61,5	77,0
Tendency (No. of months/10 years)	0,073	0,215	0,278	0,253	0,042	0,071	0,073	0,055

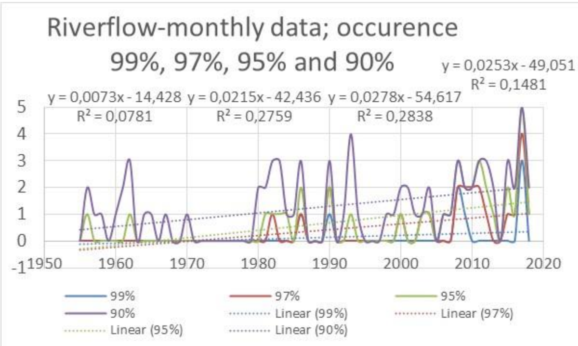

Figure 6: No. of months per year and tendency for drought (period 1955-2018)

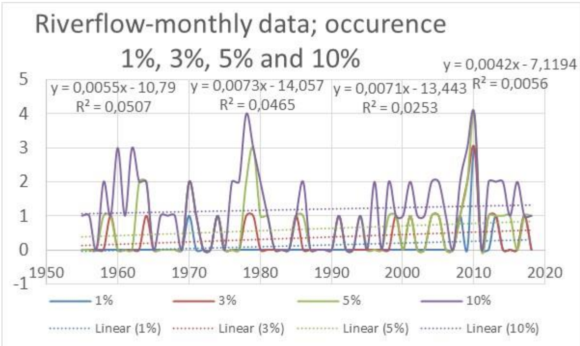

Figure 7: No. of months per year and tendency for flood (period 1955-2018)

Due to fact that period for P is different (longer) than period for Q, and that trend results depend (sometimes significantly) of the number of analysed years, Table 10 shows results for two periods (relevant precipitation for two periods are practically the same): 1955-2018 (the same as for river-flow), and 1949-2019 (the longest available). Figures 8 and 9 show relevant P, and occurrence and tendency of monthly data for dry and wet conditions, just for the longest period (1949-2019).

Table 10

		Dry conditions				Wet conditions			
Period	Occurrence →	99%	97%	95%	90%	10%	5%	3%	1%
1955-2018	Relevant Precipitation (mm)	1,3	9,3	17,3	28,3	338,0	418,0	471,5	566,4
	Tendency (No. of months/10 yrs)	0,028	0,039	0,016	0,014	-0,006	-0,009	0,020	-0,001
1949-2019	Relevant Precipitation (mm)	1,3	9,2	17,5	28,5	338,5	417,1	473,0	568,2
	Tendency (No. of months/10 yrs)	0,017	0,026	-0,025	-0,061	0,029	0,004	0,011	-0,007

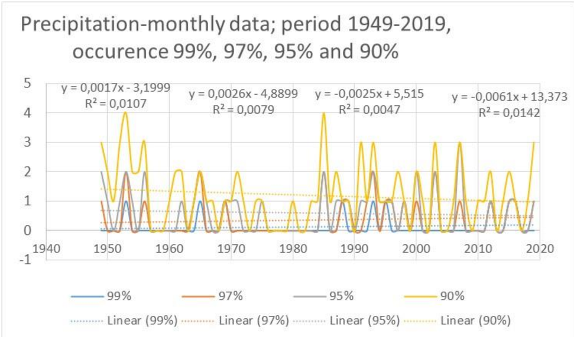

Figure 8: No. of months per year and tendency for dry conditions (period 1949-2019)

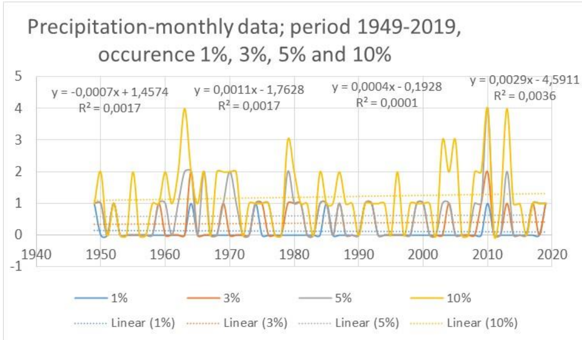

Figure 9: No. of months per year and tendency for wet conditions (period 1949-2019)

Analysing table 10, we could say that period 1955-2018 a little bit more favorizes tendency of dry conditions than period 1949-2019. But both periods do not show significant changes in monthly precipitation for all analysed occurrence in Nikšić. Contrary to that, table 9 shows that river-flow has increased for all occurrence, and for both hazards, drought and flood. Especially significant increases have been observed for drought, at occurrence 97%, 95% and 90%. This means, that in addition to precipitation change, other changes have also important role on the changes in river-flow. They are not in the focus of this deliverable, just it could be said that some of the important factors are temperature (and evapotranspiration), human water demand and changes in land covering.

So, it is interesting to analyse indices which categorize dry and wet conditions, and related trends. For this purpose, two widely applied indices, De Martonne aridity index (DMI), and Ped drought index (PED), have been analysed. Both of them use just monthly data of temperature (T) and precipitation (P) for their calculation. As known, De Martonne annual index is calculate using the following formula:

$$DMI_a = \frac{P}{T+10} \qquad (1)$$

where are:

P-annual sum of precipitation in mm; T-annual average temperature in ^{0}C; DMI_a - De Martonne annual index. If we calculate De Martonne monthly or seasonal index the formulas are as follows:

Monthly index

$$DMI_m = \frac{12 \bullet P}{T+10} \qquad (2)$$

P– monthly sum of precipitation in mm,

T – monthly average temperature in ^{0}C,

DMI_m - De Martonne monthly index.

Seasonal index

$$DMI_s = \frac{4 \bullet P}{T+10} \qquad (3)$$

where are:

P- sum of precipitation for 3 seasonal months in mm,

T – average temperature for 3 seasonal months in ^{0}C,

DMI_s - De Martonne seasonal index.

Other drought index used for a description of the drought frequency and intensity is the Ped index. Ped drought index was calculate using the following formula:

$$PED = \frac{\Delta T}{\sigma T} - \frac{\Delta P}{\sigma P} \qquad (4)$$

where are:

ΔT- anomaly of T in ⁰C, relative to a given period, ΔP- anomaly of P in mm, relative to a given period,

σT- standard deviation of temperature (in ⁰C), σP- standard deviation of precipitation (in mm),

PED- Ped drought index (on annual or monthly or seasonal level, depending on used T and P data).

Several classifications could be found in Literature for De Martonne aridity index. The differences between them are not great. We have used the classification shown in Table 6. Ped drought index climate classification is standard in Literature in most cases and is shown also in Table 11.

Table 11: Climate classification according to the De Martonne's aridity index and Ped drought index

De Martonne index (DMI)	Climate classification	Ped index (PED)	Climate classification
DMI < 10	Arid	3 ≤ PED	Severe drought
10 ≤ DMI < 20	Semi-arid	2 ≤ PED < 3	Moderate drought
20 ≤ DMI < 24	Mediterranean	1 ≤ PED < 2	Insignificant drought
24 ≤ DMI < 28	Semi-humid [1]	-1 ≤ PED < 1	Moderate or neutral
28 ≤ DMI < 35	Humid	-2 ≤ PED < -1	Insignificantly wet
35 ≤ DMI < 55	Very humid	-3 ≤ PED < -2	Moderately wet
55 ≤ DMI	Extremely humid	PED < -3	Extremely wet

[1] Maybe more adequate expression for this DMI class would be "moderate"

Analysed period was 1949 – 2016. For the aim to analyse temporal changes, this period is divided on three subperiods: 1949-1970; 1971-1993; and 1994-2016. Data are analysed on annual and seasonal level (but only spring and summer). Just the most interesting results of both indices are shown in the following text.

De Martonne index show extremely humid conditions on annual (92) and spring (87) level, while summers are under the class "humid" (29). Figure 10 shows that spring DMI index increase, while DMI summer index decrease. Annual DMI index has no significant tendency, and annual values for three subperiods are practically the same (93, 92, 91).

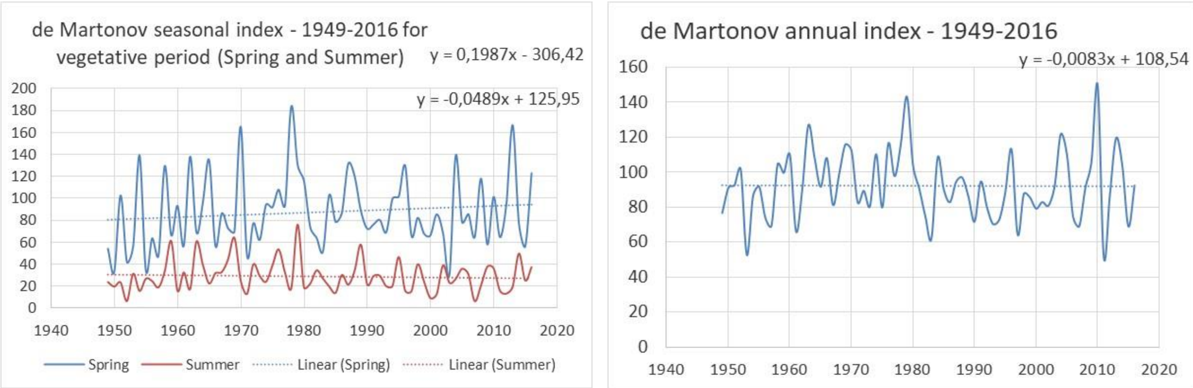

Figure 10: Spring, summer, and annual graphs of De Martonne index for Nikšić (1949-2016)

Semi-arid and Arid drought conditions on annual, spring and summer level for three subperiods are shown on Figure 11 (number of years).

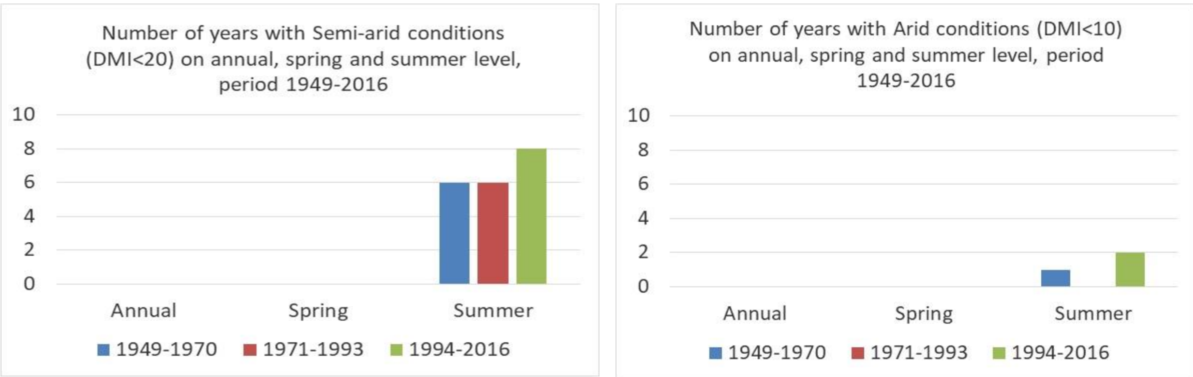

Figure 11: Number of years with De Martonne index under Semi-arid and Arid conditions

Ped index has higher value in the last subperiod, compare to first and second (-0,3, -0,5, +0,8), and the graph for yearly and summer have important increasing trend, while for spring is also upward, but significantly lower (Figure 12).

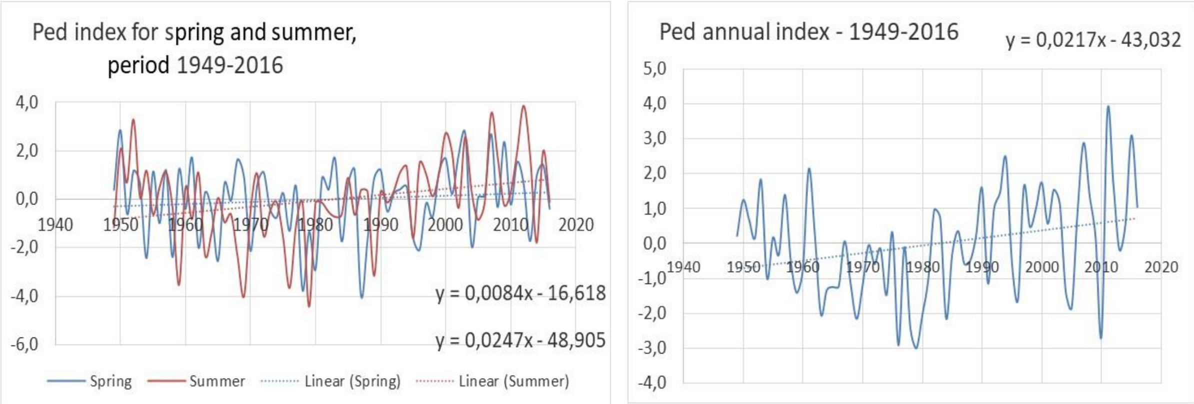

Figure 12: Ped index for spring, summer and annual level, period 1949-2016

Moderate drought and severe drought conditions on annual, spring and summer level are shown on Figure 13, as the number of years in three subperiods.

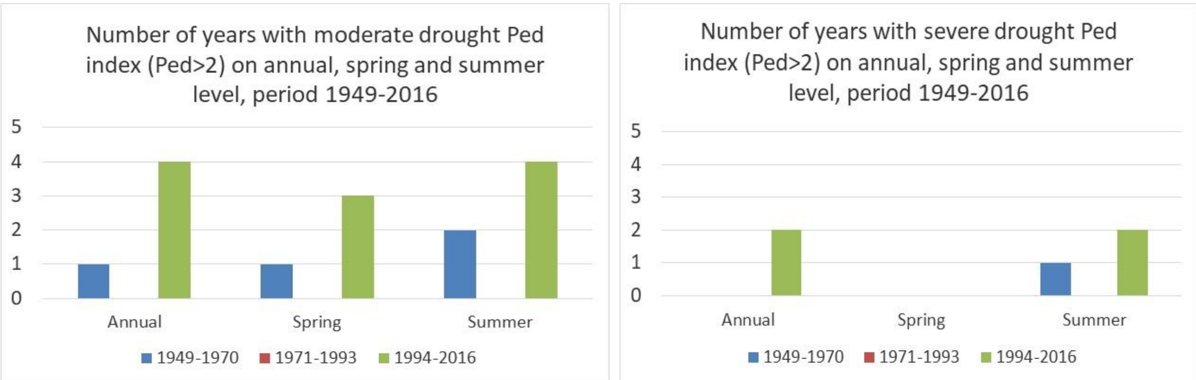

Figure 13: No. of years with Ped index under moderate drought and severe drought conditions

These analyses of De Martonne and Ped indices confirm remarks given after T, P and Q analyses, that drought hazard has very significant probability (during dry period), and flood hazard significant, but much less probability (during wet period) of increasing tendency.

If we estimate drought hazard with the numbers, on the monthly level during dry period, negligible drought (occurrence 90%) could be expected one in two years, small drought (occurrence 95%) one in three to five years, and significant drought (occurrence 97%) one in five to ten years.

Estimation of flood could not be done with the numbers, due that daily data, which are necessary for such estimation, are unavailable – just stay the claim of above paragraph that flood hazard is likely to occur just a little bit more in the future (on monthly level).

Earthquake:

Modern regional geophysical surveys and precise satellite and geodetic observations reliably indicate that the Mediterranean area, during a very long geological time, represents a zone of intensive confrontation of the continental masses of Europe and Africa. In its slight translational movement to the north (at a speed of about one centimeter per year), the African tectonic plate collides strongly with the southern margin of the European continent, which moves in the direction of the southeast (approximately the same speed).

As a result of the collision of these two segments of the lithosphere of enormous proportions, in the rocks of the contact zone, from the middle of the Mesozoic geological era to the present day, very turbulent and diverse tectonic processes take place as well as volcanogenic activities, which are stimulated by the created voltage field, forming a very diverse orogenic and geological complex of the earth's crust of that space.

The area of present-day Montenegro is characterized by very intense seismicity as a consequence of the described geodynamic processes. Thousands of strong and very strong earthquakes were registered in the previous period. The Montenegrin coast is a particularly seismically active area, as evidenced even by old archival materials. Special mention should be made of the seismogenic zones of Ulcinj, Budva, Boka Kotorska and Skadar Lake, which, in recent or distant history, generated very strong earthquakes (June 13, 1563 - Boka Kotorska, July 25, 1608 - Boka Kotorska, April 15, 1979 –between Ulcinj and Bar).

The general characteristics of seismic activity in Montenegro and its immediate surroundings, over the past few centuries, can be expressed by the frequency of strong and devastating earthquakes in this area. During that period, on average, at least one earthquake measuring VII on the Mercalli scale occurred every 3 years, an earthquake with an intensity of VIII every 15 years, and on average every 60 years, a devastating or catastrophic earthquake with victims.

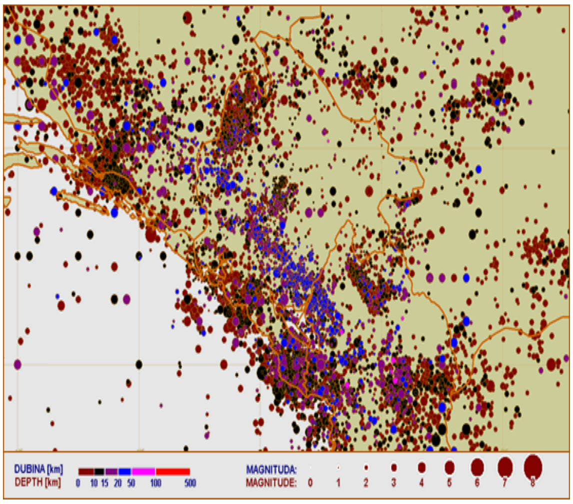

Figure 14: Epicenters of registered earthquakes

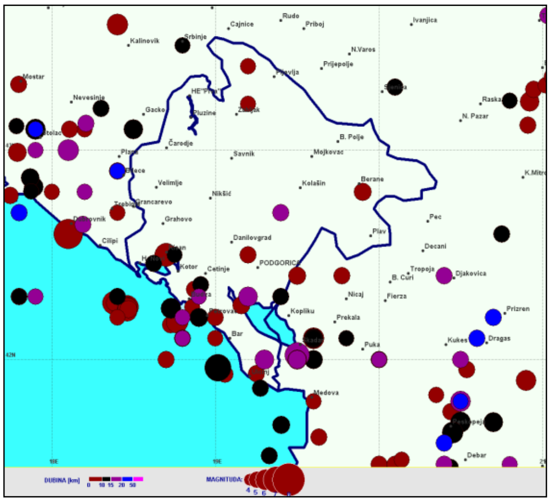

Figure 15: Epicentres of big earthquakes in in Montenegro for the past 5 centuries
Montenegro for the past 5 centuries

Relatively deep seismoactive structures can be seen on the maps, for example in the zone of a large tectonic trench, which stretches in the direction of the Dinarides, from northern Albania, through Podgorica, Danilovgrad and Bratogost, in the far west of Montenegro and further west to Herzegovina. The position of this trench can be recognized by the fact that relatively deeper hypocentres of the earthquake (blue circles) are located in it.

Catastrophic earthquake that occurred on April 15, 1979. at 07:19, with a magnitude of 7.0 on the Richter scale, caused destruction with an intensity of IX degrees of the Mercalli scale on the entire Montenegrin coast. The epicentre of this earthquake was located in the Adriatic Sea, between Ulcinj and Bar, at a distance of 15 km from the coast. 101 people lost their lives in Montenegro and 35 in Albania. The following cities were damaged: Ulcinj, Bar, Petrovac, Budva, Tivat, Kotor, Risan and Herceg Novi, and 250 settlements were destroyed. By the end of 1979, 90 strong aftershocks were registered, with a magnitude greater than or equal to 4.0, over 100 earthquakes with a magnitude of 3.5 - 4.0, as well as almost 10,000 weaker earthquakes.

Figure 16: Illustration of the levels and types of destruction of buildings in the earthquake of April 15, 1979: detail from the old town of Budva, hotel "Slavija" in Budva, Monastery "Gradiste" in Buljarica, Hotel "Agava" in Bar, then the detail of damage in the port of Bar

The southwest of Montenegro was destroyed several times in the period from the 15th to the 17th century. Also, in 1905, the far southeast was affected by the devastation caused by the Skadar earthquake (northern Albania). Significant induced seismicity can be registered in the area of the artificial reservoir HPP "Piva", located in the north-west of Montenegro, which is a consequence of changes in hydrostatic pressures of the reservoir on the surrounding rock masses, in the phases of its filling and discharge.

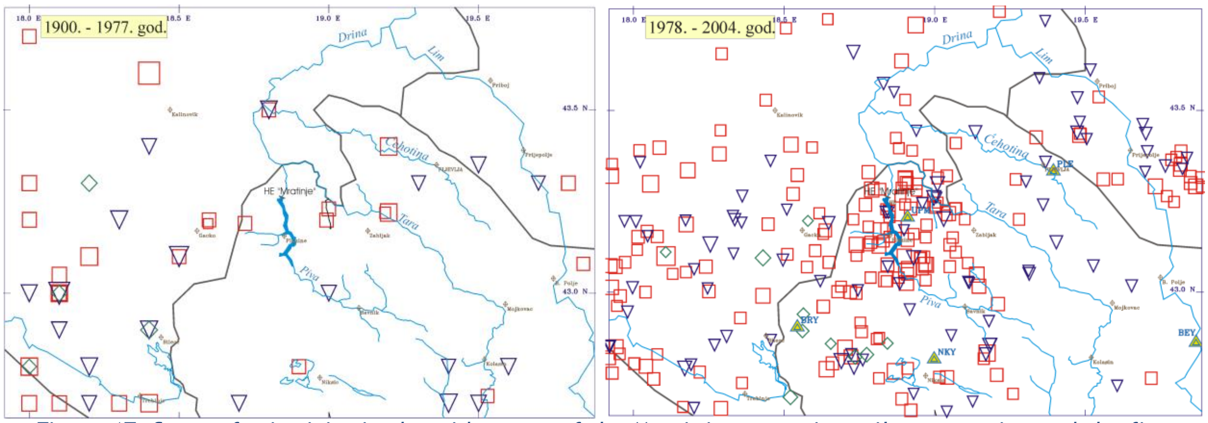

Figure 17: State of seismicity in the wider zone of the Mratinje reservoir until construction and the first filling (left) and in the period after the first filling (right)

The number of earthquakes in the territory of Montenegro varies within very wide limits. Figure 18 summarizes the maximum intensity of the earthquake which covered the area of Montenegro until nowadays (expressed in the MCS intensity scale), based on the entire documentation of seismological material.

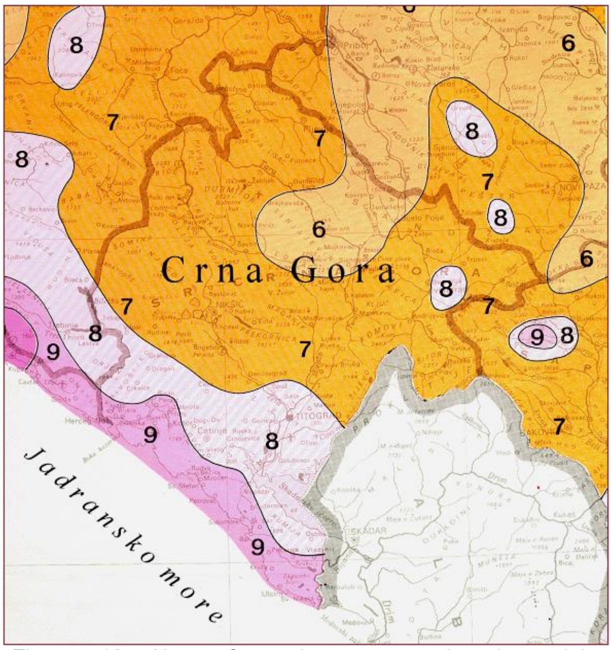

Figure 18: Map of maximum occurring intensities earthquakes on the territory of Montenegro

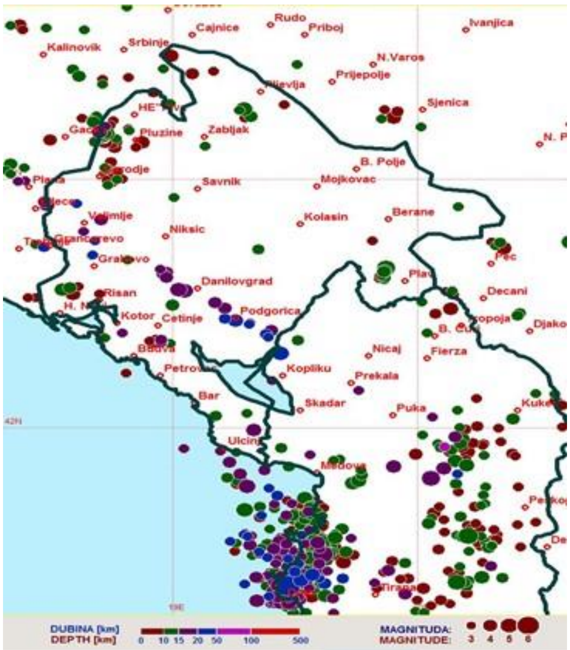

Figure 19: Epicenters of registered earthquakes in Montenegro for the period 2010-2020

During a normally seismically calm year, the Seismological Institute of Montenegro registers aproximately about 400 earthquakes, with magnitudes above 1.2 on the Richter scale. During seismically active years, that number can reach a figure of over 30,000 earthquakes above magnitude 1.0. Figure 18. present earthquakes in period 2010-2020, with magnitude above 3.0 on the RS.

The level of knowledge about the seismogenic characteristics of the northern Mediterranean and the Balkan region, since the devastating and catastrophic earthquake on the Montenegrin coast on April 15, 1979, has been extremely improved and today represents a valid basis for reliable determination of expected earthquake activities in future, as indicators needed for successful and reliable urban planning and design in Montenegro.

Seismic hazard expresses the probability of realization of a certain parameter of soil movement in a specific period of time.

Figure No. 19 shows a map of seismic regionalization for the conditions of the so-called middle ground, during 1982. This map contains the parameter of the basic degree of seismic intensity in the territory of Montenegro, and it highlights several zones of different levels of seismic hazard:

• southern, coastal region, Ulcinj-Skadar, Budva and Boka Kotorska zone, with possible maximum intensity in the conditions of the middle soil of IX degrees of MCS scale,

• Podgorica-Danilovgrad zone with a possible maximum intensity of VIII degrees of MCS scale,

• the central part of Montenegro with the northern region, including Nikšić, Kolašin, Žabljak and Pljevlja, is characterized by a possible maximum intensity of VII degrees of the MCS scale and

• isolated seismogenic zone of Berane, which can generate earthquakes with a maximum intensity of VIII degrees of MCS scale.

Figure 20: Map of seismic regionalization of the territory of Montenegro

Based on the data of the seismological database, using modern methods of numerical processing, a representative numerical seismogenic model for the territory of Montenegro was determined, necessary for the modern calculation of seismic hazard elements. Figure 20a shows a graphical illustration of the parameters of the expected maximum earthquake magnitudes over the next 100 years in Montenegro and the immediate surroundings, as one component of this numerical model of seismogenesis.

The established model of seismogenesis of the territory of Montenegro was applied in the appropriate modern numerical algorithm, in order to calculate the elements of seismic hazard for the components of the expected maximum soil acceleration and earthquake intensity (MCS scale) for several return periods. As a representative and instructive example of this process and the processing results themselves, Figure 21b shows a map of the expected maximum earthquake intensity for a return period of 200 years and a probability of realization of 70% for Montenegro and the surrounding area. It is obvious that the content of this map expresses the aspect of expected seismicity in much more detail than the content of the map in Figure 20, and as such, along with other products of seismic hazard calculation, can represent a much more reliable basis for spatial urban planning in seismic areas of Montenegro as a very important aspect of seismic risk control.

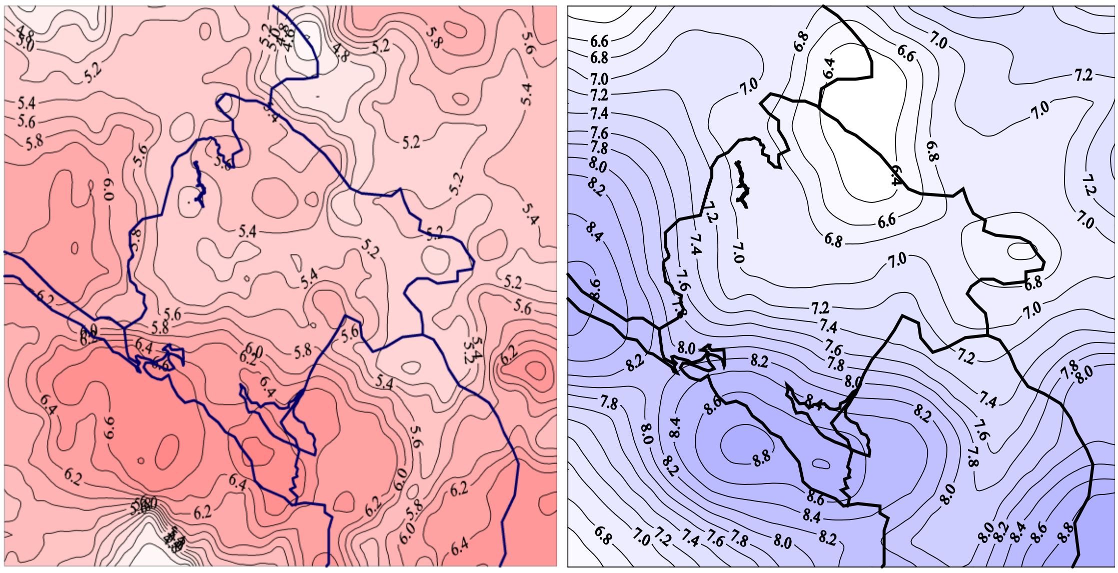

Figure 21a: Map of expected maximum earthquake magnitudes (Richter units) as components of the numerical seismogenic model of the territory of Montenegro; b) Seismic hazard map, with an element of expected maximum earthquake intensities (MCS) within a period of 200 years, with a probability of realization of 70%.

<u>Accidental pollution:</u> Already noted in point 1 that for such events data are very limited, so nothing relevant could be said about the tendency, and it is underlined also that such events are possible to occur on both Nikšić sources.

3. Pipe breaks. General information about pipe cracking are numerated in D.T2.1.3. Some more analyses are presented here:

Table 12: Pipe breaks per year by type of material and diameter

PIPE BREAKS PER YEAR											
Pipe diameter	**Tipe of material**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
DN<50mm	**Polyethylene**	841	487	691	585	501	493	502	651	402	507
	Galvanized Iron	872	593	550	720	488	665	563	799	485	535
Total (<50mm)		**1713**	**1080**	**1241**	**1305**	**989**	**1158**	**1065**	**1450**	**887**	**1042**
DN>50mm	**Polyethylene**	641	478	405	484	422	436	415	522	305	315
	Cast Iron	157	98	117	109	111	137	131	119	83	91
	Asbestos cement	231	127	162	187	167	178	120	192	116	121
	Steel	43	30	27	32	30	33	28	41	27	19
	Other	15	14	12	19	4	21	16	19	10	11
Total (>50mm)		**1087**	**747**	**723**	**831**	**734**	**805**	**710**	**893**	**541**	**557**
TOTAL:		**2800**	**1827**	**1964**	**2136**	**1723**	**1963**	**1775**	**2343**	**1428**	**1599**

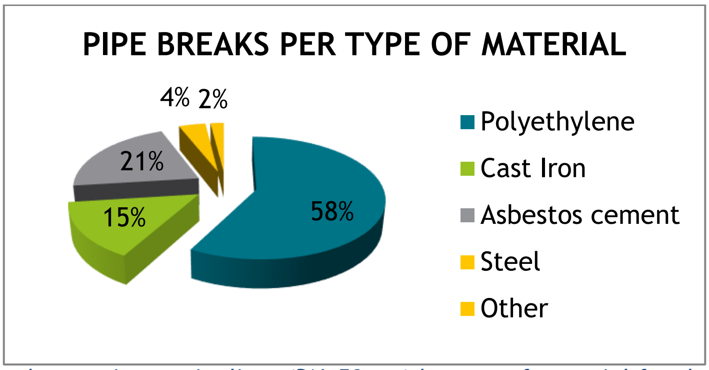

Figure 22: Pipe breaks on primary pipelines (DN>50mm) by type of material for the period 2010-2019

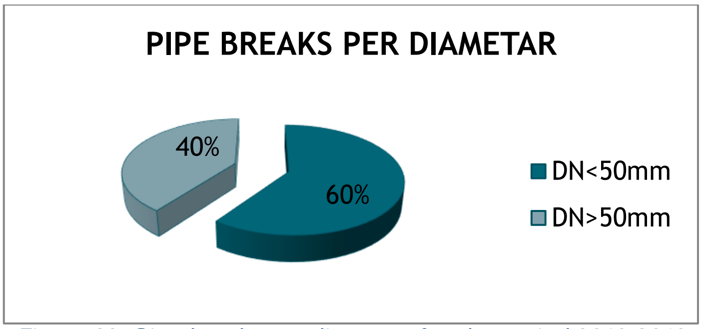

Figure 23: Pipe breaks per diameter for the period 2010-2019

Table 13: Pipe breaks, annually by settlements for the period 2010-2019

PIPE BREAKS ANNUALLY BY SETTLEMENTS										
SETTLEMENTS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Centar	893	604	664	756	498	586	497	702	399	498
Kličevo	372	228	265	291	241	241	243	328	198	202
Rubeža	98	57	38	81	64	72	59	70	41	37
Oštrovac	10	5	11	17	2	2	11	19	21	12
Ozrinići	222	151	137	170	136	151	148	210	108	124
Dragova luka	240	140	173	183	143	160	201	198	119	136
Gornje polje	326	207	217	322	206	265	195	220	194	171
Kočani	217	114	147	125	121	143	151	218	114	121
Vitalac	31	21	19	4	8	10	0	11	7	16
Ćemenca	43	31	30	28	72	87	35	49	21	28
Glibavac	28	11	20	17	12	17	25	9	14	19
Brezovik	25	9	21	9	16	13	7	14	21	15
Miločani	42	38	33	43	57	69	44	57	53	43
Straševina	253	211	189	190	147	147	159	238	118	137
TOTAL	2800	1827	1964	2136	1723	1963	1775	2343	1428	1559

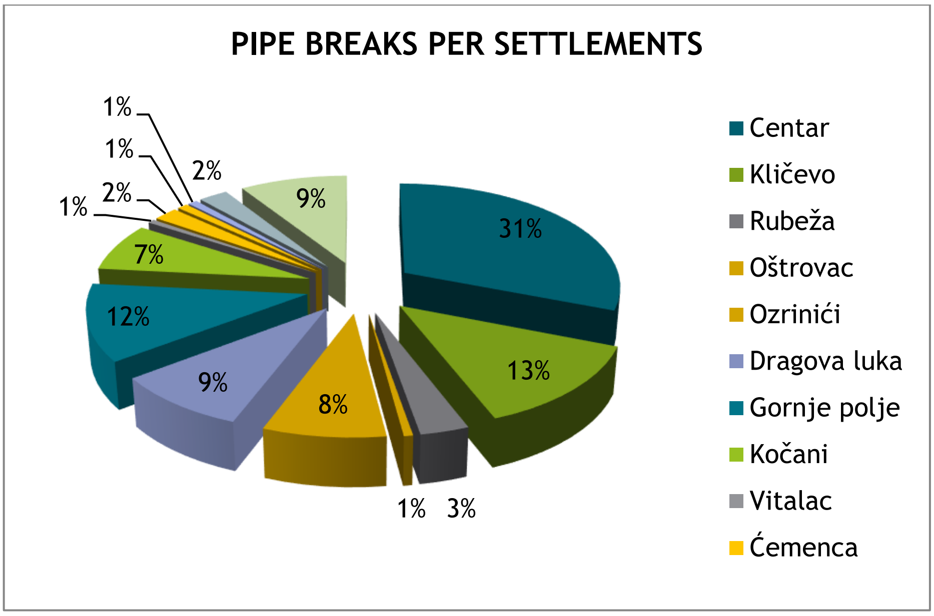

Figure 24: Pipe breaks per settlements for the period 2010-2019

Table 14: Causes of pipe breaks (2010-2019)

PIPE BREAKS BY CAUSE PER YEAR										
CAUSE OF PIPE BREAKS	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Age of material	2089	1348	1468	1583	1263	1446	1319	1882	1067	1172
Traffic	273	180	189	222	173	196	181	248	140	143
Poor quality of the installed material	76	60	57	61	57	61	52	49	47	51
Soil erosion	282	187	196	209	181	210	175	119	132	156
Construction errors	80	52	54	61	49	50	48	45	42	37
TOTAL	**2800**	**1827**	**1964**	**2136**	**1723**	**1963**	**1775**	**2343**	**1428**	**1559**

In the period 2010-2019 causes of pipe breaks are in percent as follows:

Age of material 75%

Traffic 10%

Poor quality of the installed material 3%

Soil erosion 9.5%

Construction errors 2.5%

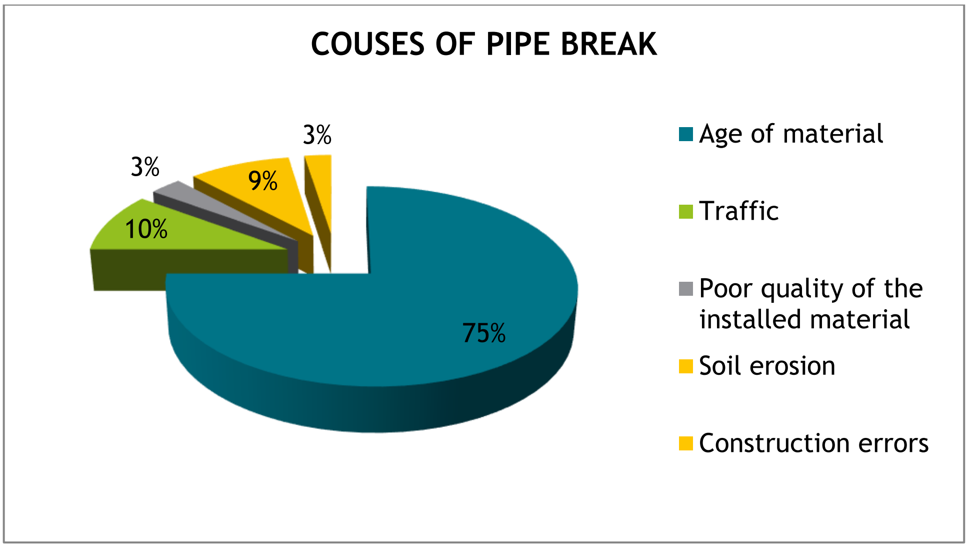

Figure 25: Causes of pipe break for the period 2010-2019

5.2. VULNERABILITY MODELS AND IMPACT ON THE WSS ELEMENTS

Detailed vulnerability models in WSS Nikšić do not exist, and vulnerable elements for 4 hazards are defined above, in point (2). The most important, and the most vulnerable WSS components which can be impacted by the hazard situation are shown on the figure 1.

Situations related to pipe's breaking are relatively frequent – it is a consequence of some old pipes, high pressure in the net, relatively fast pressure variation in the system, and soil errosion. Yearly No. of pipe breaks (PB) is shown on Table 15 and Fig. 27. for the last ten years. We can see decreasing trend of about 75 PB/year (if the first, 2010. year with very high No. of breaks is included in consideration), to maybe more reliable 35 PB/year (if the first, 2010. year is not included in consideration). This reduce of pipe breaks is a consequence of adapted measures in the last several years in WSS Nikšić.

Table 15

YEAR	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
No. of pipe breaks	2800	1827	1964	2136	1723	1963	1775	2343	1428	1599

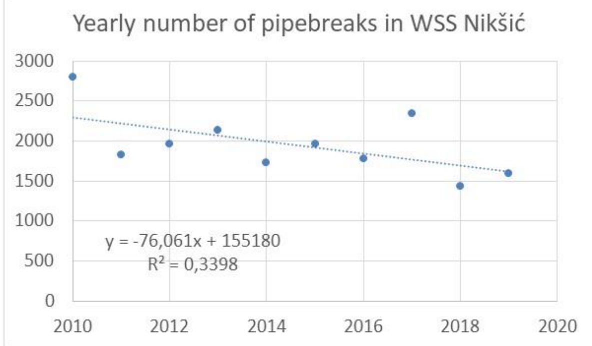

Figure 26

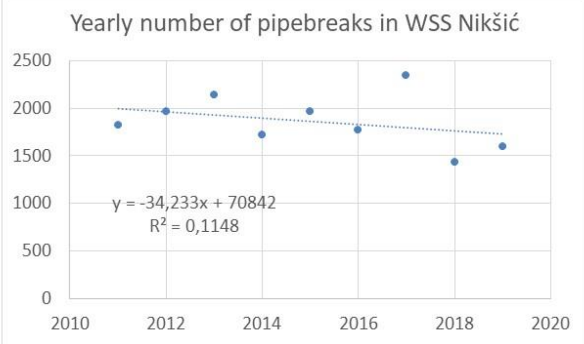

Figure 27: Yearly number of pipe breaks in WSS Nikšić with and without first year in series

Analysing the structure of failures that were repaired for the above period in the table, we concluded the following:

- 40% (or about 700/year) of the failures occurred are on the primary pipelines (DN>63 mm)
- Regarding the pipe material, break distribution in percent is about:
- Asbestos-cement - 21%
- Polyethylene - 58%
- Cast iron - 15%
- Steel - 4%
- Others 2%

Observing the history of failures on primary pipelines, we came to the conclusion that their occurrence is relatively evenly distributed in the settlements where these pipelines are located. Slightly more cases in the city centre than in the suburbs is likely a consequence of pressure variation.

In dry summer periods, the reduction of yields at springs affects the quality of water supply to users located at higher elevations of the terrain (where water is not supplied through pressure boosting plants) and users at the edge of the network. Water loss most often occurs at users in the settlements of Kličevo, Straševina, Oštrovac and Ozrinići.

5.3. EXISTING PROTOCOLS FOR PREVENTION, MANAGING AND REPORTING HAZARDOUS EVENTS

The Law on Protection and Rescue (Official Gazette of Montenegro, 13/07, 32/11 and 54/16) consists of provisions related to conducting preventive, operational and recovery activities as well as measures to mitigate and reduce risks of hazards. Plans for protection and rescue against different types of natural and man-made hazards at 3 levels (national, local, and company level) include preventive, operational and recovery measures which have to be carried out by protection and rescue actors. At the moment, LLC“Vodovod i kanalizacija“ Nikšić does not have its own protocols and procedures for prevention, managing and reporting in the event of any of hazards addressed by MUHA, except HACCP protocols regarding water safety. PP8s role, actions and reporting obligations in the case of any of the addressed hazards are an integral part of the plans and protocols prepared and adopted by the Municipality of Nikšić. LLC“Vodovod i kanalizacija“ Nikšić is obliged to inform the municipal authorities in case of any hazard that may endanger the quality of water and the water supply process in general. There is a regular communication and cooperation with Local Protection and Rescue Service in the function of performing protection and rescue tasks.

The municipality of Nikšić has developed Plan for protection and rescue from floods (July, 2013) which define steps in dealing with that hazard (flood protection and rescue measures in stages – preventive measures, rescue mesures, remedial measures). This Plan was prepared after huge floods occured in Montenegro in 2010.

6. GREECE (PP7)

6.1. PROBABILITY OF OCCURRENCE FOR ADDRESSED HAZARDS IN THE PILOT AREAS

An overview of the National and regional Institutional databases and data on the occurrence of hazardous events is reported in Table 16.

Table 16: Summary table for Greece

	DESCRIPTION OF THE NATIONAL INSTITUTIONAL PROBABILISTIC MODEL	DATA ON THE OCCURRENCE OF HAZARDOUS EVENTS COLLECTED
FLOOD HAZARD AND WATER SUPPLY VULNERABILITY	Flood hazard maps are developed at a national level according to the EU Floods Directive 2007/60 but no relation to the WSS vulnerability. https://floods.ypeka.gr/	Data currently not collected. The programme of measures of the Floods Risk Management Plan foresees the development of a national registry for flood events and an online platform (measure 08_24_07). Nothing could be sent.
DROUGHT HAZARD AND WATER SUPPLY VULNERABILITY	Groundwater bodies' drought vulnerability has been assessed in the Response plan for water scarcity and drought phenomena for the Water Districts being part of River Basin Management Plans (RBMP). The droughts vulnerability to cover drinking water supply has been assessed for all municipalities. However, there is no probabilistic model available.	There is no systematic recording and analysis of the impact of the droughts on the water supply systems. Nothing could be sent.
EARTHQUAKE HAZARD AND WATER SUPPLY VULNERABILITY	Seismic hazard map for Greece is developed as part of the earthquake regulation of the country (Earthquake Regulation-2000). https://www.oasp.gr/node/8 The map is presented in DT2.1.3 (figure 11, page 19). Specific vulnerability is not addressed.	No such data are gathered. Specific analysis of the functioning of the water supply systems after the earthquake is not a defined procedure. Nothing could be sent.
ACCIDENTAL POLLUTION AND WATER SUPPLY VULNERABILITY	Hazards imposed to the WSS relative to the accidental pollution are defined by the decrees on the water protection zones (guidelines for the delineation of the protection zones are given in the RBMPs). Allowed and prohibited activities are defined and	Events are monitored by the water utility. More data are presented in deliverable DT2.1.3.

	the prevention measures are indicated. Delineation of drinking water protection zones is ongoing in Greece. The control points will be defined at the Water Safety Plans. No WSS vulnerability modelling.	
OTHER		

DEYAL gathers data for the repair of failures (e.g. breaks). These data are internal data not reported to other authorities. Such data are presented for failures in the water distribution network per pipe material, per type of failure and per month for 2017-2020.

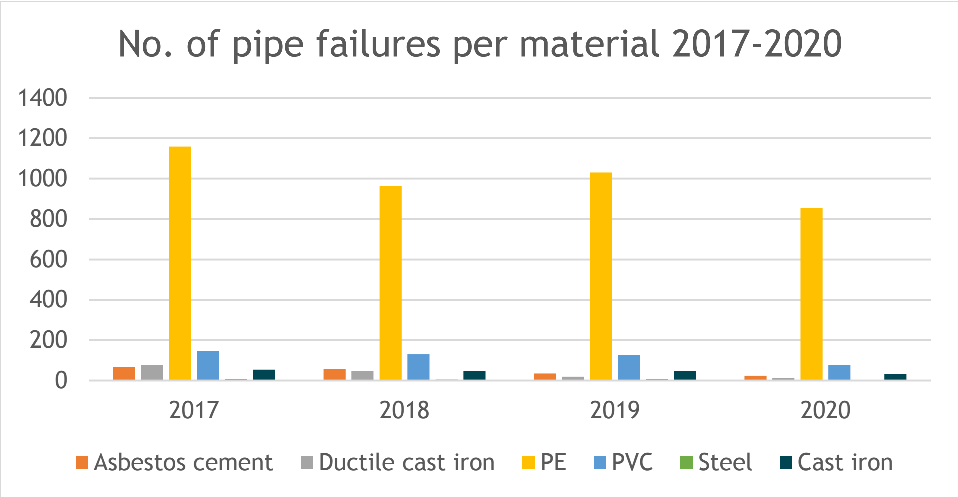

Figure 28: Number of pipe failures per pipe material for 2017-2020

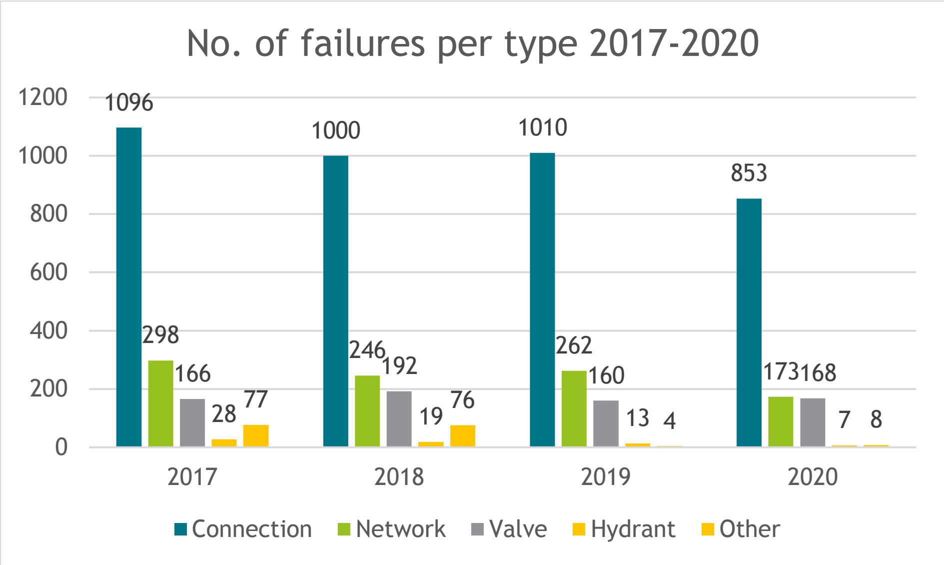

Figure 29: Number of failures per type (connection, network, valve, hydrant, other) for 2017-2020

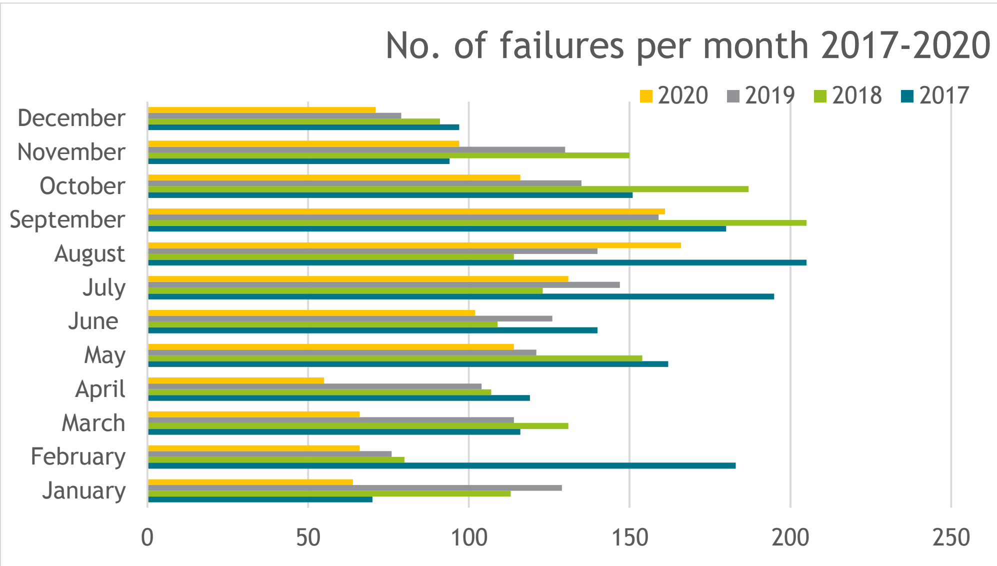

Figure 30: Number of failures per month, 2017-2020

Figure 28 shows the number of pipe failures per pipe material. The pipe material experiencing most of the failures is PE. Figure 29 shows the number of failures per failure type. Customer connections experience the majority of the failures, followed by distribution pipe networks. Failures show a decreasing trend since 2017. Figure 30 presents the number of failures per month.

DEYAL keeps records for water quality and the water parameters monitored and analysed. The water utility reports water quality data to the Directorate of Public Health of the Region of Thessaly, regularly (once every three months) and to the Ministry of Health once every three years for the needs of reporting to the EC (https://ec.europa.eu/environment/water/water-drink/reporting_en.html).

Water quality data are also reported to the water quality monitoring platform of the Association of the Municipal Water Supply and Sewerage Companies (EDEYA) https://ydor.edeya.gr/dashboard.

DEYAL does not implement HACCP.

DEYAL gathers data related to accidental pollution as mentioned in Deliverable 2.1.3.

When a complaint is filled, the water utility investigates this complaint trying to identify the problem and its cause. Depending on the results from the analyses, the water utility takes the necessary measures. The data gathered refer to the complaint, the results from the analyses and the actions taken.

6.2. VULNERABILITY MODELS AND IMPACT ON THE WSS ELEMENTS

Floods: as there is no specific vulnerability model, DEYAL takes into consideration that some of its boreholes are located at the zone of potentially high flood risk (APSFR).

Droughts: drought vulnerability is assessed in the Response plan for water scarcity and drought phenomena for the WD of Thessaly. Municipality of Larissa is in medium drought vulnerability zone. Two of the three groundwater systems used as water supply sources are assessed to be in bad quantitative status.

Accidental pollution: accidental pollution can impact water sources and water supply networks. Point and diffuse pollution sources are identified in the River Basin Management Plans. The MWU elaborates water samplings and analyses according to the national legislation.

Earthquakes: DEYAL is located at the medium seismic hazard zone. There are not registered events related to impacts from earthquakes in the water supply system of DEYAL.

For all hazards further analysis is presented in deliverable DT2.1.3.

6.3. EXISTING PROTOCOLS FOR PREVENTION, MANAGING AND REPORTING HAZARDOUS EVENTS

Floods: The General Secretariat of Civil Protection (GSCP) has issued an emergency response and immediate / short-term management plan for floods (DARDANOS). The GSCP set the guidelines for regional and local (at municipality level) emergency response and immediate / short-term management plan for floods (DARDANOS). The municipality of Larissa is currently developing this plan which is expected to be approved by the municipality council soon.

Droughts: There is no existing protocol for prevention, managing and reporting of drought events. DEYAL is currently developing its masterplan to address all issues regarding alternative water supply sources.

Accidental pollution: The national institutional framework for drinking water quality apply. The Joint Ministerial Decree Γ1(δ)/ ΓΠ οικ.67322/6.9.2017 (Official Gazette 3282/B/19-9-2017) “Water quality for human consumption according to the European Directive 98/83/EC” and its amendments is in force regarding drinking water quality. DEYAL will delineate the protection zones at its water intake points.

Earthquakes: The General Secretariat of Civil Protection has issued an emergency response and immediate / short-term management plan for earthquakes (EGKELADOS). The General Secretariat for Civil Protection set the guidelines for regional and local (at municipality level) emergency response and immediate / short-term management plan for earthquakes (EGKELADOS). The municipality of Larissa is currently developing this plan which is expected to be approved by the municipality council soon.

In Greece, the Association of the Municipal Water Supply and Sewerage Companies (EDEYA) has developed a reporting platform for drinking water quality monitoring. The platform is available at: https://ydor.edeya.gr/dashboard

The water utilities insert the results from the drinking water laboratory analyses and they are available at the public and the central administration. The Ministry of Health supports this platform. The water utilities can use this platform to insert data for their water sources, the water protection zones, the sampling points and the laboratories performing water analyses. Currently, 93 municipal water utilities and the Water Supply and Sewerage Company of Thessaloniki have entered water quality data.

The General Secretariat for Natural Environment and Water (Ministry of Environment and Energy) developed the Water Services Monitoring Platform aiming to the monitoring and improving of national water services, in the context of Art.13 of J.M.D. 135275/2017 (http://wsm.ypeka.gr).

Table 17: Table of existing reporting mechanism for Greece

Greece	
Reporting system https://ydor.edeya.gr/dashboard	Water quality parameters (as described to the national legislation) for each sampling point
Reporting system Water Services Monitoring Platform (at http://wsm.ypeka.gr)	Water supply services including water cost, water price, operational data, etc. This platform is not available to the public

7. SLOVENIA (PP2+PP6)

7.1. PROBABILITY OF OCCURRENCE FOR ADDRESSED HAZARDS IN THE PILOT AREAS

An overview of the National and regional Institutional databases and data on the occurrence of hazardous events is reported in Table 16.

Table 18: Summary table for Slovenia

	Description of the national institutional probabilistic model	Data on the occurrence of hazardous events collected
flood hazard and water supply vulnerability	PA Kamnik: Flood hazard maps are developed according to the EU FD 2007/60 (see Atlas Voda), no relation to the WSS vulnerability	Data not collected - only collection system is general disaster collection system “AJDA” no relation to vulnerability modelling and impact analysis. Could be sent as an example.
drought hazard and water supply vulnerability	Drought hazard is improvingly monitored by the DMCSEE centre and the integrated observation an modelling application (https://droughtwatch.eu/), (only general droughts, status and severity) Only the identification of the hazard and its occurrence, drought vulnerability of WSS is not modelled.	no systematic analysis of the impact of the droughts on the water supply systems. Nothing could be sent.
earthquake hazard and water supply vulnerability	seismic maps are developed according to the EUROCODE 8 for the design of the structures. Specific vulnerability is not addressed.	Specific analysis of the functioning of the water supply systems after the earthquake is not a defined procedure and has not been considered by Kamnik water utility Nothing could be sent.
accidental pollution and water supply vulnerability	Hazards imposed to the WSS relative to the accidental pollution are defined by the decrees on the water protection zones. Allowed and prohibited activities are defined and the prevention measures are indicated. The control points defined by the HACCP address hazards for the	Events for PA Kamnik are monitored by the environmental inspector on national level (following the Water Act) - we’ll try to get some statistics/reports on the matter. Analysis of the functioning of the HACCP schemes is

	accidental pollution, after the water is already in the water supply system.	performed by the NIJZ (national institute of public health), we will provide examples of the hazardous event report for the NIJZ for PA Kamnik and also from other good practices from water utilities.
OTHER		

7.2. VULNERABILITY MODELS AND IMPACT ON THE WSS ELEMENTS

The vulnerability model for the Kamnik WSS is designed following the HACCP protocols, with the defined and checked HACCP critical control points. Other vulnerability models were not adopted yet.

The risk assessment is given on the basis of a technological scheme, risk descriptions, and many years of experience and known technological data. They have taken into account many years of experience in making the assessment of the HACCP group and the severity of the consequence (damage) and the probability of its occurrence. According to the analysis and

risk assessment in the company they carry out preventive measures, which are either prescribed internally or by legislation.

As defined in all HACCPs the risk analysis is made for different components of the Ivarje WSS. Following the mentioned analysis, the (only) critical control point is established at the chlorinator buster at the intake of the Ivarje water source as it is the only component of the system described with a "high" risk potential according to the risk analysis.

Other components handled in the Ivarje HACCP document are Drinking water source (recharge area), Intake of the water source, Reservoirs, Pumping stations and Distribution system. All of them are marked with a small or medium risk. For all components the biological, chemical and physical risk is taken in concern. Specifically, for all components the biological risk is marked as "medium" in comparison with the chemical and physical risks which are marked as "low" in every component with the exception of the physical risk at the Pumping stations and Distribution system which is defined as a "medium" risk – according to the high erosion and landslide area.

7.3. EXISTING PROTOCOLS FOR PREVENTION, MANAGING AND REPORTING HAZARDOUS EVENTS

Contingency management is organized based upon the document: Contingency plan in the case of the extraordinary events document (Načrt delovanja v izrednih dogodkih, 2020).

The Civil protection service is mentioned in the document just once in the introduction in to the scope of the purpose of the document which is establishing basic guidelines for operation at extraordinary events on water supply systems managed by the Municipal Company Kamnik

d. o. o. The aim is to ensure rapid and reliable action in the event of an emergency.

The instruction is also used in the supply of drinking water to the population by cisterns, where fire brigades, other contractors and civil protection participate.

In the aspect of the 4 specific MUHA hazards there is written following;

- LACK OF WATER DUE TO DROUGHT

If the amount of water at the springs is significantly reduced due to drought, so that it is no longer sufficient to ensure uninterrupted care, it is necessary to include in addition to austerity measures possible reserve water resources. A reserve water source is surface or groundwater that is covers the supply of drinking water in cases of shortage and has the user to use this resource 5 granted water rights. Before connecting the backup source, it must be thoroughly rinsed, clean and disinfect the connecting pipes.

Note: The contingency plan is concerning the drought even if the PA Kamnik do not have the drought risk occurrence history.

- NON-COMPLIANCE OF DRINKING WATER WITH THE REQUIREMENTS OF THE REGULATION

Non - compliance of drinking water can be determined organoleptically (eg: water turbidity) or by laboratory testing. If, after laboratory tests, water samples turn out to be non-compliant with the requirements of the Drinking Water Rules responisible person must:

- examination of the narrower or the wider surroundings of the water source,
- inspect the sanitary condition of the water intake facility (including drainage, catchments) and the immediate surroundings,
- inspects the drinking water in the water cell, checks the condition of the fittings and the tightness of the settlers (water cells);
- in case of observed - visual changes of water (muddy water - turbidity, sediments, foreign non-specific odour) mechanical cleaning and disinfection is carried out immediately (hyperchlorination) of all water collection areas in the building; if

necessary, establish a temporary disinfection of the water for as long as it takes appropriate investigations do not prove that the water is again suitable or. in accordance with regulations,
- if necessary, the water supply network is flushed (either completely or only individual parts) via hydrants, fenders and
- if necessary, disinfection (or hyperchlorination) of the water supply network is carried out.

These measures are carried out by the person responsible for ensuring health adequacy or. compliance of drinking water. In case of restriction or prohibition of the use of drinking water, the operator is also obliged to inform ZIRS (health inspectorate), NIJZ (national institute for public health) and NLZOH (national laboratory).

The main mitigation measure in case of the non-compliance is;

The measure of obligatory boiling of water before use for drinking or consumption purposes which is pronounced in the following cases:

- Unexpected occurrence of faecal contamination indicators (E. coli, enterococci) in the drinking water sample, anywhere in the system without water treatment or anywhere in the network after prepare drinking water if it is clearly not a transient phenomenon
- Failure of any phase in the process of operation of the drinking water treatment plant regardless on the results of microbiological tests
- Interventions in the drinking water supply system and failures that may occur microbiological contamination of drinking water, regardless of microbiological results tests
- Heavy, prolonged rain, short-term showers, melting snow, etc., which have resulting in proven increased opacity, altered sensory properties, or microbiological inconsistency of drinking water, anywhere in the system without preparation or anywhere in network after preparation
- **Natural and other disasters (floods, earthquakes, spills…)** and other unpredictable events with the possibility of drinking water pollution
- Occurrence or suspicion of an outbreak / water epidemic if the presumed cause is not immediately remedied

The Civil protection (CP) service action is not specifically addressed and described but CP and firefighters are in that case involved in the field reducing the risk and impacts of such events.

8. CONCLUSION

Based on the provided data it can be concluded that there is a general lack of vulnerability models and probability of the occurrence analysis on WU level and WSS elements for the addressed hazards.

On national level of the PA countries there exist a probabilistic models and hazard maps for Earthquakes and Floods.

All involved Water utilities in the PA do not have any obligation of reporting the addressed hazardous events to the national Institutions and no reporting system is defined.

The only obligatory reporting for WU in each country is regarding the water quality monitoring, which is done either by mail or by a national online reporting platform. Beside that some of the WU report the total annual water production, sold water and system losses to national Institutions.

Most of the WU have implemented HACCP which itself defines a reporting protocols and procedures. Beside HACCP, Water utilities have an internal reporting system about pipe breakage occurrences, water quality monitoring, chlorination points and SCADA elements sensors.