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A Handbook for Training in Water Resources Management

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A HANDBOOK

for Training in Water Resources Management

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A HANDBOOK

FOR TRAINING IN WATER RESOURCES MANAGEMENT

Kosovska Mitrovica, 2020.

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PREFACE

This book was created within the project SWARM (Strengthening of master curricula in water resources management) funded by the Erazmus + CBHE KA2 program of the European Union. SWARM project implemented by a consortium made up of seven higher education institutions from the Western Balkans and of the six member countries of the program: University of Niš, University of Novi Sad, University of Priština in Kosovska Mitrovica, University of Montenegro, University of Sarajevo, Džemal Bijedić University of Mostar, Technical College of Applied Sciences Uroševac with temporary seat in Leposavić, University of Natural Resources and Life Sciences – Vienna, Norwegian University of Life Sciences, Aristotle University of Thessaloniki, University of Architecture, Civil Engineering and Geodesy – Sofia, University of Rijeka - Faculty of Civil Engineering, Universidade de Lisboa, and Public Water Management Company "Vode Vojvodine".

The main objective of the SWARM project is to educate water management experts in the Western Balkans in accordance with national and European Union policies. This objective is further broken down into the following specific objectives:

- To improve the level of competencies and skills in higher education institutions by developing new and innovative master programmes in the field of water resources management in line with the Bologna requirements and national accreditation standards.
- To design and implement new laboratories in Western Balkan higher education institutions, in cooperation with project partners from Program Countries.
- to develop and implement LLL (Life Long Learning) courses for professionals in water sector in line with EU Water Framework Directive.

This handbook is a product of the last specific objective stated above and is intended to support the lifelong learning program. To identify topics in the field of water resources management, a comprehensive survey of employees in the water sector in the Western Balkans was conducted. A total of 1,136 respondents participated in the survey. Based on the received answers, current topics in the field of water resources management were defined, which were marked as the most desirable for the training of professionals in the water sector. The manual should serve as a basis for employees in the water sector who will attend courses organized by higher education institutions from the Western Balkans as participants in the SWARM project. In addition, the manual can serve anyone interested in the water sector as a basis for obtaining up-to-date information on legal frameworks, technical and technological processes, IT tools, adaptation to climate change, limited availability of water resources, management of atmospheric water quality, use of used water, management flood and drought risk as well as innovative techniques in water resource management.

Marković Đurica
Gocić Milan

1 WATER MANAGEMENT AND CLIMATE CHANGE ADAPTATION

Emina Hadžić, Faculty of Civil Engineering, University of Sarajevo
Hata Milišić, Faculty of Civil Engineering, University of Sarajevo
Suvada Šuvalija, Faculty of Civil Engineering, University of Sarajevo
Suada Džebo, Faculty of Civil Engineering, University of Sarajevo
Ammar Šarić, Faculty of Civil Engineering, University of Sarajevo

Abstract

Climate variability significantly affects the availability and quality of water resources and increases the number and magnitude of hydrological extremes. The importance of studying variability and climate change, in order to determine their impact on the environment in general, and therefore on man and the economy, is a challenge that societies, either together, at the interstate level or individually, will have to address. In this regard, this chapter will discuss the importance of integrated water resource management and the application of some innovative solutions to reduce the negative effects on society.

Particular attention will be given to European water and climate change policy. The last chapter will give some examples of a new approach to urban water management, as well as the adaptation of infrastructure systems to climate change.

1.1 Introductory considerations

Climate variability has a significant impact on both the availability and quality of water resources and has the effect of increasing the number and magnitude of hydrological extremes. The importance of studying variability and climate change, in order to determine their impact not only on waters, but on the environment in general, and therefore on humans, is a challenge that societies will have to address, either jointly at the interstate level or independently. In order to determine the degree of vulnerability of the society and to determine strategies and plans for adaptation to the forecasted climate change, it is necessary to apply sustainable management of water resources.

Given the fact that there is no unique definition of the term Integrated Water Resources Management, the GWP suggested the following meaning of term "*Integrated Water Resources Management (IWRM) is a process that promotes the coordinated development and management of water, land and other related resources in order to maximize emerging economic and social wealth in an equitable manner, without* *compromising the viability of vital ecosystems"*. This approach to integrated water resource management enables the management and development of water resources in a balanced and sustainable manner, considering social, economic and environmental factors and interests.

We can certainly confirm the fact that, in the past, water management was predictable and conservative regarding climate change. Traditional planning of water management systems was based on historical hydrological and climatological data, assuming their stationarity over time. However, for some time now, it is impossible to approach water resource planning with these assumptions. In all recent analyzes and forecasts relating to the use, protection of water resources and protection against the adverse effects of water, the impact of climate variability, i.e. long-term climate change, under different scenarios must also be analyzed.

The current way of managing water resources from unsustainable production and consumption needs to be gradually changed, starting with a systematic approach to the development of guidelines, strategies and policies for integrated and holistic management of water resources, in line with the sustainable development goals. Climate change is a growing threat and will be a challenge to all mankind by the end of the 21st century. There is scientific and political consensus that climate change is already happening to a significant extent. It has been endorsed by the adoption of several international agreements (including the Paris Agreement on Climate Change, which has been in force since 4 November 2016).

The effects of climate change depend on a range of parameters, so the intensity of impacts varies depending on geographical location (Figure 1.1). The vulnerability of the economy to the effects of climate change, especially on water management, agriculture, forestry, energy, fisheries and tourism, can also have a negative impact on overall social development. Therefore, it is very important to implement timely adaptation measures to the observed climate variability. It is certain that the cost of investing in climate change adaptation measures today will reduce the cost of repairing possible damage in the future. Innovative measures that contribute to climate resilience and contribute to reducing adaptation-mitigation co-benefits are particularly interesting. It should also be stressed that when talking about water resources, the effects of climate change are expected to increase in the future, including floods and droughts, water and soil acidification, and sea level rise.

Figure 1.1 - Climate change hotspots in the region West Balkan (Sources: World Bank, United Nations, 2011.)

1.2 Water and climate change – policy framework

1.2.1 Briefly about Climate changes

The climate is changing, it has always changed at many levels, from global to regional and then to local. Well, we can say that human adaptation to these changes is as old as human civilization.The climate of an area is defined on the basis of mean values, extremes and other statistical parameters of meteorological conditions over a period of time (months, years). It is influenced by the overall climate system, which is composed of the atmosphere, hydrosphere, cryosphere (ice), soil and biosphere. Climate is just an "external" manifestation of complex and nonlinear processes, within a highly complex climate system in which they participate, and interact with one another: the atmosphere, oceans, ice and snow, processes on the ground (lithosphere) and the biosphere, including man.

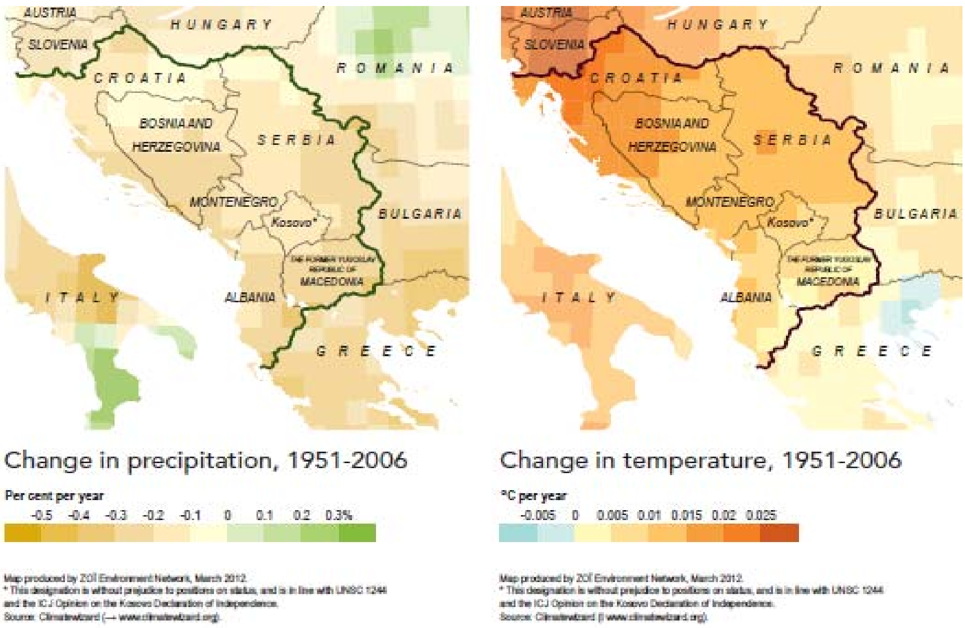

Figure 1.2 - Climate change in the region West Balkan (Sources: World Bank, United Nations, 2011.)

The climate elements considered in its definition are insolation, air temperature, air pressure, wind direction and speed, humidity, precipitation, cloud cover and snow cover. They change under the influence of climatic factors or modifiers (latitude, relief, land and sea distribution, currents, altitude, rotation, revolution, atmosphere, distance from the sea, lakes, soil and vegetation, and human influence). Statistically significant changes in mean status or variability in climate variables that persist for decades or longer are called climate change. The climate can change over a longer period, so it is very important to differentiate the climate change of an area from the variability of the climate within a particular climate period (Figure 1.2). We can speak of climate change only when there is a significant and lasting change in the statistical distribution of climate elements (or weather phenomena), usually over a period of several decades up to several million years (Figure 1.3).

The causes of climate change are divided into natural and anthropogenic. Natural astronomical causes are related to changes in solar radiation, changes in Earth's orbit, while natural geophysical causes are related to volcanic eruptions, including tectonic disturbances, viewed on a geological time scale. The sun's radiation has changed little over a long period of time, and to date, variations in solar radiation have little effect on the global climate. Astronomical factors are related to Milankovic cycles (a theory that interprets the occurrence of ice ages as a consequence of Earth's astronomical movements). Through his research, Milankovic (1879-1958) discovered that periodic changes in the eccentricity of the Earth's trajectory and the slope of the Earth's axis are the cause of long-term climatic changes, that is, the appearance of ice ages (Milankovic cycles). He established the basic period of approximately 100,000 years, and the secondary periods of approximately 400,000 and 125,000 years, in which significant changes in the amount of solar radiation result from changes in the eccentricity of the Earth's trajectory. In addition, he found a period of change in the slope of the Earth's axis of approximately 41,000 years, leading to a decrease in solar radiation in higher latitudes. Volcanic eruptions can also affect the climate, because eruptions release gases and large particles (aerosols) into high atmospheric layers that reflect back solar radiation.

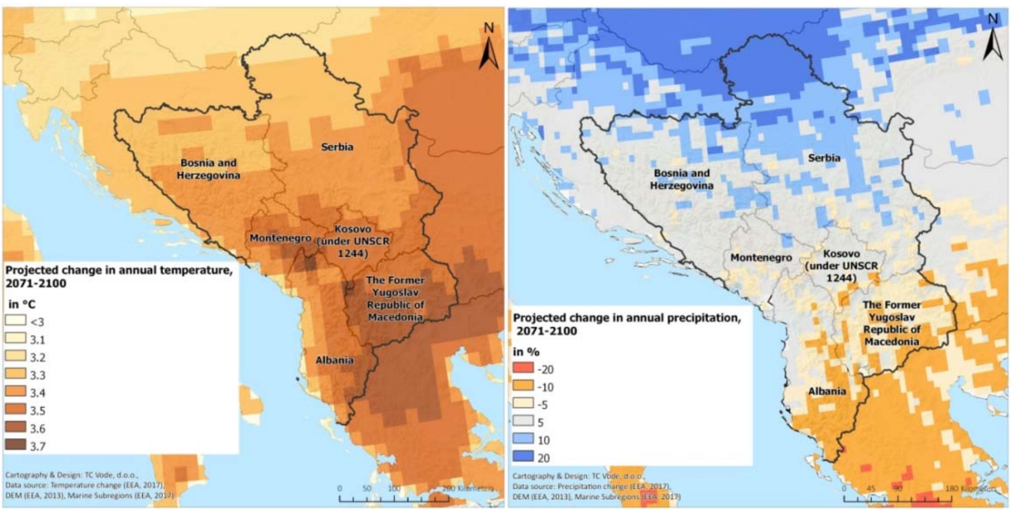

Figure 1.3 - Change in annual temperature (left) and precipitation in the period 2071–2100 compared with the baseline period 1971–2000 (Globevnik, L. et al,2018)

Note: These maps show projected changes in annual temperature and precipitation in the period 2071–2100 compared with the baseline period 1971–2000 for the emission scenario RCP8.5. Model simulations are based on the multi-model ensemble average of many different RCM simulations from the EURO-CORDEX20 initiative.Data source: EEA, 2017a (Temperature & precipitation change).

Human impacts on the climate can be seen most easily through various forms of human activities, such as urbanization, deforestation, and increased arable land. Consumption of fossil fuels (in energy production, transport, agriculture, etc.) contributes to an increase in the concentration of carbon dioxide (CO_2), aerosols and other gases in the atmosphere and thus contributes to the greenhouse effect, which in turn leads to global warming and ozone depletion.

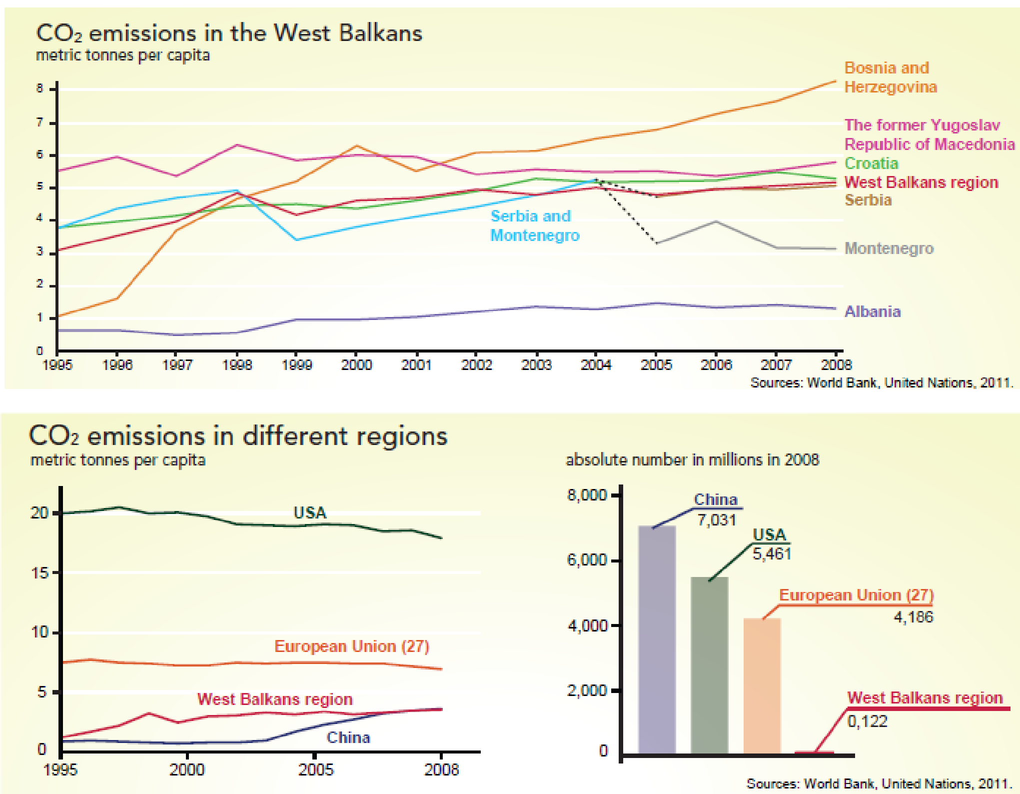

Figure 1.4 - CO2 emission in different regions (Sources: World Bank, United Nations, 2011.)

According to the IPCC IV Report (IPCC, 2007), since the mid-last century, more specifically since the 1970s, human influence on the rise in mean temperature on Earth has been directly linked to its activity. Specifically, the global mean concentration of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) has increased due to human activities (Figure 1.4). Thus, since the mid-20th century, the term climate change has been used almost exclusively when referring to climate change resulting from human activities that most often adversely affect ecosystems. However, the impact of other factors contributing to climate change should not be forgotten.

Through the First Report of the Intergovernmental Panel on Climate Change (IPCC, 1990), a global consensus on the impact of man on climate was virtually reached, and was at the same time the basis for the United Nations Framework Convention on Climate Change. In this connection is also the definition of climate change adopted by the United Nations Framework Convention on Climate Change (UNFCCC, 1992). However, the notion that humankind very likely has an influence on the global mean climate that is discernible from natural variability at seasonal and decadal timescales (IPCC, 2007) raised concern about our vulnerability to various aspect of this climate variability.

1.2.2 Consequences of climate change

The gradual warming of the atmosphere causes numerous and far-reaching consequences for the entire human community. Despite its strong technological development, human civilization is still intrinsically linked to nature and natural systems and is directly dependent on the processes that take place in them and is ultimately still not sufficiently resilient to extreme climate variability.

The direct consequences of climate change such as rising temperatures, melting ice, rising sea and ocean levels and changing precipitation patterns can cause significant problems in the functioning of human society. The production and availability of food and water, human health, transportation, energy supply are just some of the elements that underpin the functioning of human communities, which are dependent on climatic conditions and climate variability. It can be said that the incidence of droughts and floods has increased in some parts of the world and that such a trend is linked to climate change (IPCC, 2012). According to climate forecast scenarios, it is very likely that humanity will be at increasing risk of such occurrences in the future. If there were to be a dramatic reduction in greenhouse gas emissions, the effects of past emissions would be felt for many years to come.

Practically, climate change cannot be stopped in the short term. Greenhouse gas emissions are projected to increase over the next few decades, so it is impossible to expect the positive effects of mitigation measures for many years to come (IPCC, 2007). For this reason, at the international level, special attention has recently been given to adaptation measures, that is, adaptation measures to climate change. Adaptation involves finding ways to reduce the sensitivity of natural systems and human communities to climate variability and change. Adaptations are essentially an increase in climate change tolerance. In all analyzes of possible measures for adaptation to climate change, it must be considered that all these projections are linked to a number of uncertainties.

These uncertainties are the product of the use of different forecasting methods (different models, scenario selection, selection of verification and forecasting times, use of modeling results from the global to the regional level, etc.), but also of the unreliability of the data (insufficient number and quality of individual data, discrepancies of different studies, etc.). However, it should be emphasized that these uncertainties are not of the same order of magnitude.

For example, it is quite reliable to predict that average and seasonal temperatures will rise, and much less that there will be a decrease in average annual rainfall, while it is particularly uncertain what the change will be at seasonal levels. In view of the many uncertainties, it is desirable that the measures to be taken to adapt to climate change do not have the unintended consequences in case of deviation from the foreseen changes. That is, it is desirable to apply such measures that would reduce the risk of climate change but would have other positive effects on society, the economy or the environment.

1.2.3 International climate policy

The beginning of addressing climate change within the United Nations is related to 1972, when the First Conference on Environment and Development was held in Stockholm. Thereafter, the World Climate Conference was held in Geneva in 1979. The first international scientific meeting on this subject was organized in Toronto, Canada, in 1988, when all the countries were called upon to reduce greenhouse gas emissions by 20% by 2005 from the level they were in that year. The United Nations General Assembly then declared climate change a "common concern of humanity" in 1988, when the Intergovernmental Panel on Climate Change (IPCC) was established. The task of this body was to produce a report on the climate change situation, its causes and consequences, and to encourage states and the International Community to agree on measures and moves to reduce greenhouse gas emissions and manage climate change.

The second United Nations Conference on Development and the Environment was held in Rio de Janeiro in 1992, when the United Nation Framework Convention on Climate Change (UNFCCC) was adopted. The Convention seeks to regulate the negative impacts of climate change. It was initially an internationally non-binding contract aimed at stabilizing greenhouse gas concentrations to a level that would allow ecosystems to adapt to climate change naturally, so that food production is not compromised, and to enable development in a sustainable direction. In 2011, the

Convention became a legally binding international document. After its signature and ratification, it became part of the domestic law of the 194th countries in the world.

States Parties have made certain commitments, which they must fulfill. Article 4 of the Convention discusses the common but also different responsibilities of states, which is essentially a recommendation to states that they should reduce their emissions by the amount they previously released into the atmosphere as much as they can afford at that moment.

The Convention on Climate Change is supplemented by the Kyoto Protocol, which was adopted in 1997 in the Japanese city of Kyoto. The Protocol entered into force in 2005. It imposes an obligation to reduce greenhouse gas (GHG) emissions as a percentage of the 1990 benchmark. for 38 industrialized countries, including 11 countries with economies in transition in Central and Eastern Europe.

1.3 Climate Change and European Water Dimension

1.3.1 Climate policy in EU

The EU ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 1998. Under the Kyoto Protocol, the EU has adopted a 20% reduction target by 2020. In 2015, the European Union ratified the Paris Agreement and announced a national contribution (NDC), in line with the Paris Agreement, of at least 40% reduction in gas emissions greenhouses by 2030 compared to 1990.

The European Union has developed a set of strategic and legal documents related to climate change. The document directly addressing this issue is the EU White Paper on climate change adaptation. With this document, the EU set the framework for tackling community-based adaptation and at the same time obliged its members to take a serious and strategic approach to address these issues. Climate change has significant negative socio-economic consequences. This general threat requires a flexible management mode, which enables the involvement of all important sectors, notably agriculture, water management, forestry, nature protection, public health and energy.

It must be acted upon immediately, as extreme weather, droughts and heat waves caused by climate change will be even more intense in the future. One of the regions recognized as being vulnerable to climate change is the region of Southeast Europe. So far, several regional initiatives have been launched to enhance climate change capacity in this part of Europe. First of all, it became clear that mitigation measures were not sufficient and that it was practically impossible to stop climate change in the short term. For this reason, it is necessary to develop and implement adaptive measures to mitigate the effects of climate change. Adaptation measures are slowly becoming one of the priorities in global policy, so there is a need for all countries to develop climate change sensitivity assessments and appropriate adaptation plans.

The European Union has set such objectives in its strategic documents on climate change. How are the countries of Southeast Europe clearly committed to EU membership, they will certainly need to pay particular attention to the development of appropriate documents and the development of their adaptive capacity in the near future. Climate change vulnerability assessment and adaptation planning are extremely complex processes that require the analysis of all sectors of society and the involvement of numerous experts and other stakeholders.

1.3.2 Water policy in EU

The Water Framework Directive (Directive 2000/60 / EC of the European Parliament and of the Council - WFD) was the result of efforts by the European Commission to create a document that will provide modern integrated water protection and long-term sustainable water management. It is also the most important document for the European space, designed to improve and integrate the way water bodies are managed within the European Union and the accession countries. It provides a framework for action by the European Community in the field of water policy.

Due to increased environmental problems and changes resulting from degradation of water quality and changes in the availability of its quantities, this directive proposes a solution to sustainable water management as part of sustainable development. The approach to this is to ensure integrated water management. The concept of integrated water management is based on documents such as the conclusions of the Dublin Conference on Water and the Environment (1992), the recommendations of international conferences in Rio de Janeiro and Rome (1992), and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992).

The WFD provides a very clear plan for achieving good status for all water bodies, whereby the mechanisms and specific measures required to achieve 'good standing' are left to the discretion of each EU Member State. On 23 September 2007, the European Parliament and the Council of the European Union adopted a Directive on the assessment and management of flood risks (Directive 2007/60 / EC). The aim of the Directive is to establish a framework for the assessment and management of flood risks in order to reduce the adverse effects on human health, the environment, cultural heritage and economic activity. The directive was created as a continuity of the European Water Directive. Namely, there was a need to fill the gap created in the WFD, which did not give adequate importance to this important and indispensable area of the integral water resource management plan.

Another very important EU Directive, among others, is Nitrate Directive 91/676 / EEC, which aims to protect water quality by reducing pollution of groundwater and surface water by nitrates from agricultural sources. The aim is to promote good practices in agricultural production. Also, the Nitrate Directive forms part of the WFD. The Drinking Water Quality Directive 98/83 / EC refers to the quality of water intended for human consumption to protect human health. The Council Directive 91/271 / EEC on urban wastewater treatment was adopted in the early 1990s to protect the environment from urban effluents as well as discharges from certain industrial sectors.

1.4 Climate change and impacts on water

Water is a prerequisite for life on earth and is key to sustainable development. It is undoubtedly clear, no matter what the extent of human involvement in the process of global warming is, especially in urban areas, that the global climate crisis increases variability in the water cycle and affects water quality.

These changes are disproportionately affecting rich and developed societies, and the poor and underdeveloped, and therefore more vulnerable societies. They depend on a number of contributing factors, including population growth, GDP, urbanization, changes in land use, diminished soil quality, environmental degradation, loss of biodiversity, etc.

Climate change impacts are highly variable and uneven. Some regions are experiencing prolonged periods of drought, others with increasing and frequent flooding and storms, while some face both extremes. Impacts due to rising sea levels affect coastal areas. At the same time, increased demand for water, increased pressures on water resources, increased pollution, increasing energy and food demand lead to progressively more difficult trade-offs for this limited and valuable resource, especially in areas of the world already facing water stress. For these reasons, it is often said that climate change is most directly felt through water.

1.4.1 Climate change impacts on water

Climate change affects the integral management of water, both from the point of view of resource availability and from the point of view of water use in a broad sense. The impact of climate change on the hydrological regime is, for the time being, very difficult to quantify, i.e. to distinguish from the impact of other anthropogenic activities on the catchment area (urbanization, flood protection, inappropriate technological solutions, dynamic development, etc.). However, for whatever reason, certain changes are taking place, and if they continue, could threaten the availability of water for various purposes and the maintenance of the ecological functions of water. This situation imposes a stricter water management framework, that is, it sets as an imperative agreement on new common criteria and goals for sustainable water management.

In the EU Member States, climate change considerations are largely qualitatively presented in terms of river basin management processes, within the first River Basin Management cycle (RBM) foreseen by the Water Framework Directive (WFD). The Policy Paper proposal on water management in the first cycle of river basin management placed particular emphasis on ensuring that the established Programs of Measures are sufficiently adaptable to future climate conditions (the so-called "climate-check" of the Program of Measures based on available knowledge, information and data). For the second and third cycle of river basin management is

expected that climate change be fully integrated into the process of river basin management. When things are so positioned, access to adjustments through river basin management in the context of the WFD includes 1) an effective long-term follow-up (in order to identify indicators of climate change in order to react in due time), 2) an assessment of the potential additional impacts of climate change on pre-existing anthropogenic pressure, and 3) incorporating this information into the formation of measures (especially for proposed measures that will have a longer-term impact).

Therefore, Member States are at least expected to clearly demonstrate that climate change projections have been considered in both pressure and impact assessments, monitoring programs and measures. According to the Floods Directive, climate change should be considered as early as the first cycle of flood risk planning in the framework of the preliminary flood risk assessment, based on the information available, as well as in subsequent planning cycles, when reviewing and updating the preliminary flood risk assessment and flood risk management plans.

Also, it must be borne in mind that some studies suggest a possible increased incidence of torrential flooding in the lower basin, with the degree of reliability of these predictions is also quite low, primarily because of the problems of transition from global to regional models and the precision of the procedure in the case of small basins (Figure 1.5). Previous analyzes of the availability of water quantities for different uses have low reliability of forecasting trends, but it can be generally said that most models predict a decrease in water quantities in these areas as a consequence of an increase in average temperatures and a decrease in precipitation. This is especially true in the summer months when a significant reduction in the available water supply is expected.

The anticipated increase in water use due to climate change, as well as the eventual reduction of rainfall and, consequently, the flow in the watercourses, will, especially in the summer, low water period, increase the pressure on surface water bodies regarding their quality. These pressures are most significant for water bodies, which at the moment, due to their natural characteristics, are extremely poor in water during low-water, mostly summer periods.

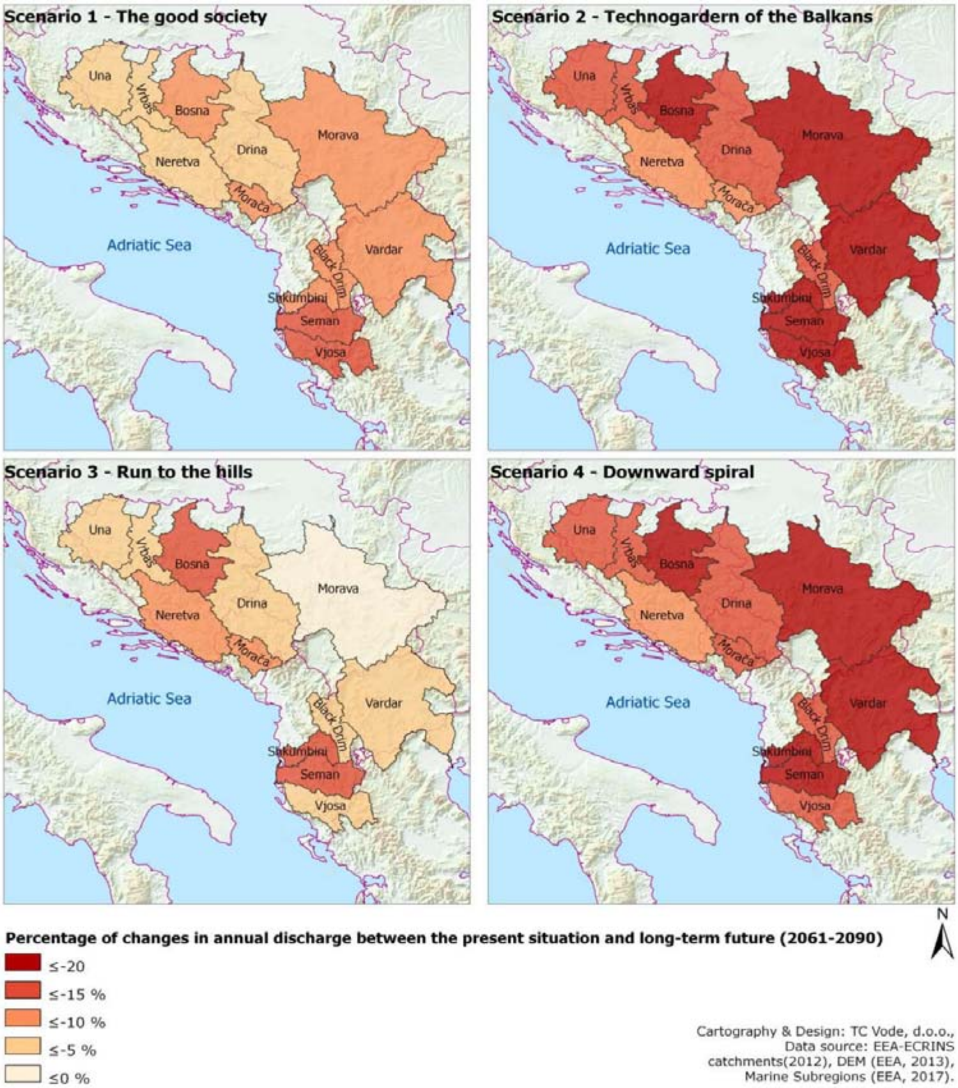

Figure 1.5 - Percentage of change in annual discharge between the present situation (1970–2000) and long-term future (2061–2090) in the selected catchments (Globevnik, L. et al,2018)

1.4.2 Adaptation to climate change

Adaptation to climate change involves undertaking a set of activities to reduce the vulnerability of natural and social systems to climate change, to increase their ability to recover from the effects of climate change, but also to exploit the potential positive effects that may also result from climate change. Examples of adaptation measures are the more efficient use of water resources; adapting building regulations to future climates and extreme weather; building flood defenses; developing and / or selecting drought-resistant crops; adapting to forestry practices less sensitive to storms and fires; and the release of terrestrial corridors to reduce pressure on species and facilitate their migration. Adaptation means anticipating the adverse effects of climate change and taking the appropriate measures to prevent or reduce the damage they can cause and reap the benefits.

Due to the complexity of climate impacts, adaptation needs to be strategically planned at all levels of government: local, regional, national, EU and international. It is therefore of priority importance to initiate the social process of adopting the concept of adaptation to climate change, to determine what impact climate change has, to determine the degree of vulnerability and to prioritize measures. In other words, it is necessary to take a strategic approach to the climate change adaptation process. To achieve this, the Adaptation Strategy aims to reduce the vulnerability of natural systems and society to the negative impacts of climate change, increase the ability to recover from the effects of climate change, and exploit the potential positive effects that may also be due by climate change.

Basic adaptation measures relate to the preparation of basic planning documents in the field of water. These measures ensure that all other measures in the individual branches of the water sector are harmonized. Specific adaptation measures are given for the three main areas, the water use area, the water defense area and the water protection area. The vision is to create resilience to climate change. In order to achieve this, the Adaptation Strategy sets the following goals:

- reduce the vulnerability of natural systems and society to the negative impacts of climate change;
- increase the ability to recover from the effects of climate change;
- exploit the potential positive effects that can also be a consequence of climate change;

In this regard, it is necessary to: strengthen and develop management measures with a view to rationalizing water consumption and its repeated use; favor the use of alternative water sources; implement spatial-planning measures in order to reduce the risk and adverse effects of floods in the endangered areas; monitor and model projections of possible changes; adopt legislation in the field of ensuring climate change adaptation; Strengthen structural measures / solutions (reduction of water losses in water supply systems); to plan the construction and revitalization of facilities (reservoirs) for the spatial and temporal redistribution of water; make timely reservation of natural areas and buildings with retention areas for controlled flood water intake, control stormwater runoff in urban areas, etc.

1.5 Contributing to better water management: Experiences from case studies across Europe

1.5.1 Urban Water Management - New Approaches as Contribution

New approaches to urban water management that have developed as response to climate change include a "greater respect" for natural laws, that is, a return to the natural hydrological cycle through solutions from nature. The goal is to mimic the natural hydrological regime of a particular urbanized area, in such a way as to retain as much stormwater as possible in the catchment area, reuse and naturally infiltrate. With this integrated approach, it is necessary to involve different professions in order to define the best possible solutions. In addition to experts in the field of hydrotechnics, experts in the field of urbanism, architecture, agronomy-horticulture, hydrogeology, transport, environment, sanitary engineering, and others should be included . There is a growing challenge in large cities to manage water, that is, to provide safe water supply and wastewater disposal, to manage waste, to protect against harmful effects of large waters, and to use water efficiently while creating a safe and comfortable environment (Howe et al, 2012). Given that more than half of the planet's population lives in urban areas and it is projected to continue to grow rapidly, cities are in urgent need of a new approach to water management. Figure 1.6 gives an overview of the various impacts that affect water management.

Changes within urban environments due to climate change and human activities, as well as all other impacts are shown to be long-term, and can be permanent, and are reflected in the following: Less transpiration due to reduced green spaces; Faster evaporation from impermeable surfaces Faster evaporation from impermeable surfaces than from permeable ones; Infiltration reduction; Shorter retention of smaller amounts of water in depressions and bars; Disturbances of natural ecological chains due to drying of bars and wetlands: Increased and accelerated stormwater runoff compared to natural ones, i.e. frequent flooding and rockfalls and landslides.

Figure 1.7 give a comparison of different changes in runoff in natural and urbanized area. Concerning of water pollution problem, intensified by anthropogenic factors, the negative impact of urbanization on the possible effects of autopurification of polluted water, should be emphasized. Namely, due to the reduced infiltration caused by the impervious surfaces of the urban environment, the polluted water does not pass through the soil, so the effects of water purification by filtering through the porous medium of the soil are also reduced.

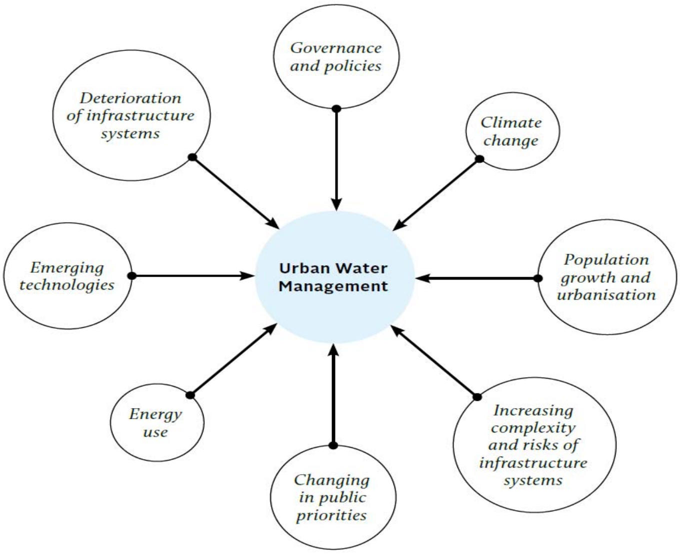

Figure 1.6 - Impacts - Issues and Future Challenges on Water Management (Howe et al, 2012)

Stormwater from roofs typically contains low concentrations of pollutants, which are mainly derived from atmospheric sediment and the discharge or decomposition of building materials. In contrast, stormwater from roads, parking lots, vehicle repair shops, etc. often contain high concentrations of various chemical contaminants.

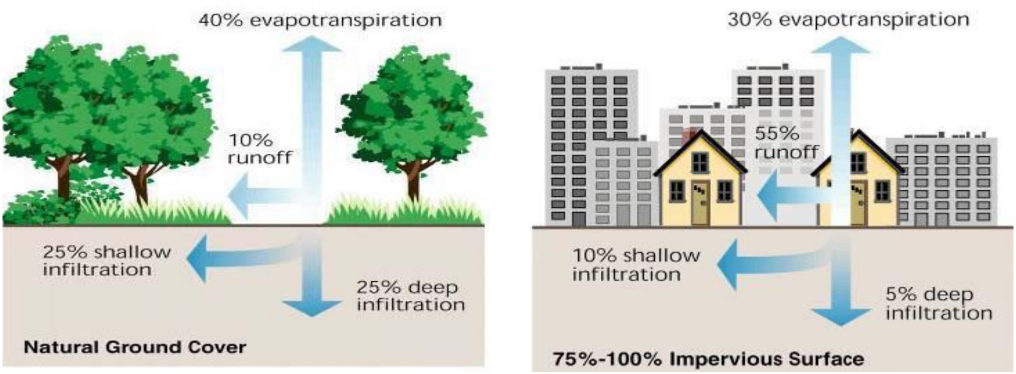

Figure 1.7 - Changes in runoff on natural (left) and urbanized (right) catchment areas (Jotte et al, 2017)

Apropriate water management implies knowledge of rainfall and runoff regimes, but also prediction of the impacts, i.e. consequences of urbanization and climate change. Water resources engineers have the increasingly complex tasks of planning, designing, constructing, operating and maintaining hydrotechnical structures and stormwater drainage systems by which they seek to mitigate the negative effects of urbanization and climate change.

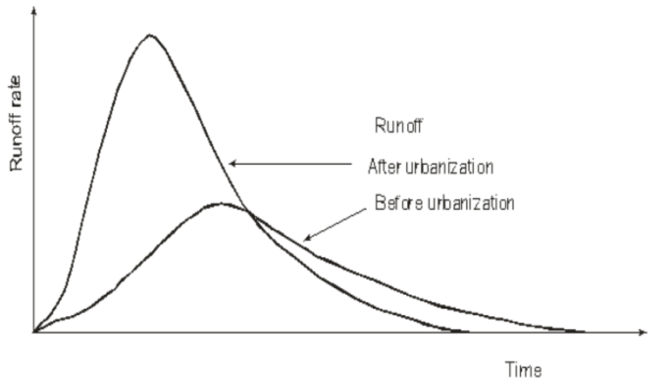

Figure 1.8 - Consequences of urbanization on runoff hydrogram (Despotović, 2009)

A classic approach to urban stormwater management

The classic approach of stormwater drainage systems includes measures and facilities for directing, intaking and conducting of surface runoff. These objects are gutters, rigs, sinkholes, audit shafts, cascades, overflows, pipes, manifolds, drains, retentions (Figure 1.9), etc. These elements are related to natural elements, receiver, slope, depressions, etc. The goal is to prevent local flooding, but also to achieve a sanitary and aesthetic effect (protect health and spills and retain various pollutants). The task of the system is to intake accept surface runoff and introduce it into precipitation collectors, and discharge it into the downstream tube / receiver as soon as possible. The classic concept of stormwater drainage (mixed and / or separable) primarily addresses the issue of precipitation, but these can also have pre-treatment facilities (sediment deposition, separation of oil / grease from contaminated areas), especially in protected aquifers.

Existing sewage systems are often outdated and do not have sufficient capacity to safely intake and conduct increased rainfall, primarily as a result of urbanization (reduction of water permeability areas) and climate change (more frequent rainfall). This results in more frequent floods in urban areas and very often rockfalls and landslides. Different-purpose surfaces in urban areas also have a significant impact on the deterioration of stormwater runoff.

This is an additional negative impact of urbanization, which should also be taken into account when managing storm water. In short, urbanization increases the amount and speed of runoff, while at the same time reducing the quality of stormwater and compromising the sanitary aspect, especially when using a mixed system. The application of a classic stormwater drainage system in urban areas will not result in the development of a healthy and sustainable urban space, nor will it be able to respond in the long term to the challenges posed by the negative effects of climate change and intensive urbanization.

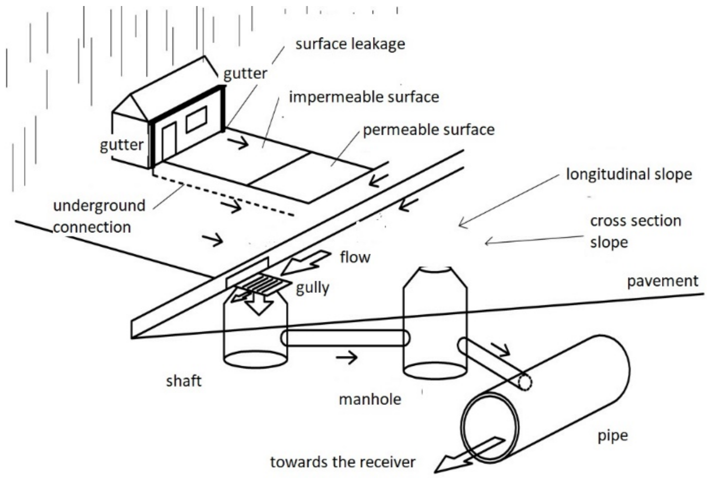

Figure 1.9 - Basic elements of a classic drainage system (Despotovic, 2009)

A new approach to water management - contribution to better management

Modern concepts of stormwater drainage and management provide solutions to previously set goals and contribute to better and more efficient water management. Changes in rainfall and runoff regimes, as well as deterioration in quality, impose a need to change the approach to stormwater management, that is, drainage and treatment. New approaches to stormwater management include measures, facilities and systems that store, retain, purify and discharge urban waters in order to mitigate the effects of an altered hydrological cycle and deteriorated water quality.

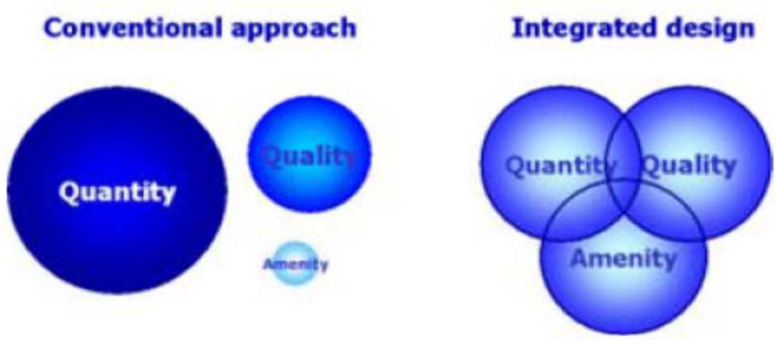

Figure 1.10 - A more sustainable water management approach (Jotte et al, 2017)

For the new approach to stormwater management, in addition to quantities, the pollution of stormwater and the consequences of their discharge into nature are analyzed. New approaches and techniques integrate the control of stormwater quality and quantity, but also the need for comfort in terms of achieving good ecological status (Figure 1.10).

In developed countries, in recent years, new approaches of stormwater management techniques, such as Low Impact Development (LID), Sustainable Urban Drainage Systems (SUDS), Water-Sensitive Urban Design (WSUD), Sponge City, best practices of management (BMP) and other similar approaches, have been applied. In these a new stormwater management systems, facilities are used to mitigate the maximum of urban runnof and to extend the runoff concentration of direct runoff hydrograms (Figure 1.11), but at the same time they are also facilities for treatment of stormwater pollution. Therefore, these approaches allow for control and quantity and quality of water at source and locally.

The main objective of new trends in stormwater management is to use facilities / elements that serve to slow down and treat surface runoff at the source, i.e. before it reaches the sewer system. The goal is to keep stormwater out of the sewer system to reduce overflows and the amount of untreated stormwater discharged into surface water. This is an innovative approach that relies on ecological principles to plan and design drainage according to the natural runoff at source, using evenly distributed decentralized micro drainage and treatment systems (green roofs, tiled rigs, ditches, permeable paving, and asphalt, etc.).

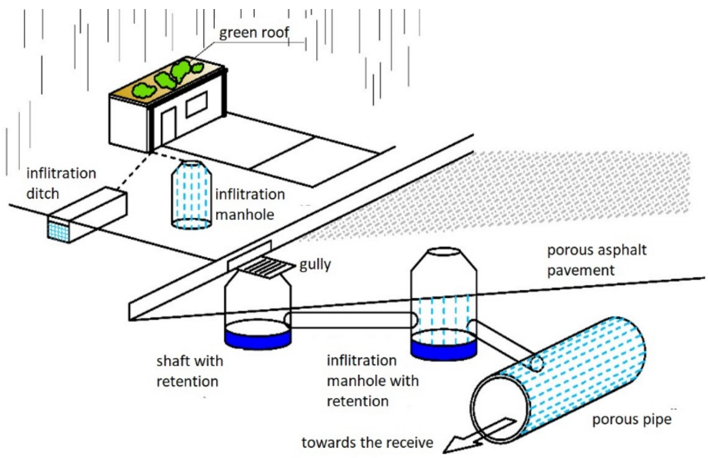

Figure 1.11 - Basic elements of modern stormwater management system in urban areas (Despotović, 2009)

These systems provide mechanical and biological mechanisms for flow control, retention, filtration, infiltration and water treatment. It should be noted that by these systems, which make extensive use of green spaces (grass and corresponding plants, flowers, etc.), also largely achieve an aesthetic effect - amenity environment.

Based on the monitoring of hydrological cycle components, flow and stormwater quality, flooding control is established to convert surface runoff to "gain" in the urban hydrological cycle. The idea is to keep every drop of rain in order not to get dirty and immediately carried out by pipes, thus mitigating the negative effects of climate change and urbanization on the city's microclimate. The condition for adequate reduction of atmospheric water runoff, in addition to storage or retention, is the use of water, for example for later irrigation, which increases evapotranspiration.

The following chapter provides some good experiences, which can serve as a model for adopting the contributions of new approaches to water management.

1.5.2 Sustainable Urban Water Management – Experiences from Europe

The SWICH (Sustainable Water Management Improvements Tomorrows Cities Helth) project, funded by the EC (European Commission), has incorporated new approaches into the area of sustainable water management in the cities where the management challenges are greatest. This management is often referred to as Integrated Urban Water Management (IUWM). This ambitious project (2006-2011 period) aimed precisely at promoting sustainable new water management alternatives (Howe et al, 2012). The platform of this project involves different institutions, i.e. stakeholders, municipalities, utility companies, universities, and sometimes non-governmental organizations, to think, act and learn together, and to provide in an integrated approach solutions that will be put into practice and respond to the challenges of a changed hydrological regime and deteriorated water quality. The institutions of the water sector must adapt to the changes that have emerged, as well as further changes that can be expected in the future (Final Report, SWITCH). New management approaches need to adapt to all the above-mentioned current impacts and the consequences of those impacts, which often cannot be reliably predicted. This uncertainty of consequences requires strategic thinking and strategic and flexible planning and decision making, tailored to the specific circumstances of the space to which new planning approaches need to be applied.

Stormwater management best practices that will contribute to management recommend sustainable solutions. Specifically, the goal is to integrate with existing infrastructure (conventional management approach) and evaluate the effectiveness of new approaches in specific circumstances (circumstances specific to a particular country, city, climate, specific, or current issues related to the control of water runoff conditions and water quality conservation).

The specific circumstances, that is, the priority water issues identified for some European cities through the SWITCH project, are listed in Table 1.1.

Table 1.1 - Priority issues related to water in some European cities (Howe et al, 2012)

City	Average annual precipitation (mm)	Priority problem related to water
Zaragoza (Spain)	318	Water demand management; using water to improve the urban environment
Lodz (Poland)	599	Restoration of polluted and flooded buried rivers as part of revitalization activities; disposal of contaminated sludge from wastewater treatment; flash flood
Birmingham (England)	662	"Future" risks: climate change; increasing of groundwater levels; floods
Hamburg (Germany)	773	Coastal site remodeling (especially Wilhelmsburg Island); flood protection

The municipality of Zaragoza, a city in the north of Spain, has experience of water management improving over 20 years' and in this regard there was no obvious need for major changes in water management. SWITCH was expected to provide additional impetus to processes already in place and to create synergies with specific water-related initiatives being implemented at the same time, such as the Expo and the establishment of the United Nations Office to Support the International Water Decade.

Zaragoza has a lot to show in terms of past and present water management practices. Local stakeholders considered the SWITCH project an important impetus to work on the sectioning and exploration of water demand management measures. Although the actual contribution to the survey results remained limited, SWITCH showed additional motivation for municipal officials to improve the use of survey data in water supply network operations and to plan water demand management measures.

In Lodz, a city in Poland, the focus was on restoring polluted rivers, degraded and even buried as the city developed. Key actors included local government, utilities, the university and a professional research institute. The successful realization of this project is a partially revitalized corridor of a river in the city, which has created a more attractive environment for the population and future development of the city. Through the project activities, management principles have been incorporated into responsible city institutions, which in the future will be responsible for continuing and enhancing the revitalization ("revival" - restoration) of rivers across the city. The idea of linking restored river corridors and other open green spaces to a “blue-green network” has now been recognized as part of the city's planning strategy.

In Birmingham (England), activities focus on future risks, such as climate change, but also the implications of rising groundwater levels. Some partners involved in the project are city council, water management, environmental agency, regulatory agency, consumer association and professional associations - associations. Some of the specific outcomes of the collaboration of the project stakeholders / participants with the development agencies were influences on the plans for remodeling the main site in the city through the widespread use of green and brown roofs.

Hamburg is a city in Germany, with the largest river island in Europe. The SWITCH project has just been focused on improving planning in the area of this river island. The project activities brought together a wide range of participants from the island to develop a water management plan that raised the level of discussions about the future development of the island. Unfortunately, due to delays in activities beyond the scope of SWITCH, the realization of the activities envisaged was impossible.

Berlin is also a city that was part of the SWITCH project. The experiences and achievements from Berlin can be considered as a good model for sustainable water management in urban areas. Specifically, the lessons learned from Berlin can be transferred to other cities, depending on the local context (specific circumstances in them). These experiences relate to: Narrowing the gaps in administration-related governance; Closing the urban water cycle; Realization of integrated water management in reality; Focusing on water demand management.

Narrowing administrative gaps in administration: In Berlin, the administrative structure is an example where the national, federal and local administrative structures are the same. Such a structure can provide an ideal environment for dealing with local situations and problems. In such an arrangement, laws and policies are directly related to the city context, not subnational.

This provides an effective framework for urban water management, respecting local specificities (conditions). At national level, attention should be paid to aligning local and regional strategies.

Closing the Urban Water Cycle: The Berlin case shows that it is possible for a city to be self-sustaining in maintaining its water resources by implementing the necessary technical and policy measures. Depending on the geological and climatic conditions, the closed water cycle can be realized at the urban level. At the same time, it requires the adaptation of certain laws and regulations and a high level of political, technical and financial commitment from city government.

Realization of integrated water management in reality: Berlin has been able to combine several aspects of land use planning, nature conservation as well as water management in an integrated way. While multi-sector integration leads to complexity, it also provides better benefits for the city as a whole - contributing to more efficient water management. Some examples of integrated solutions that could be portable to other cities are: (i) stormwater infiltration, which means enriching groundwater resources (both in quantity and quality); (ii) green roofs and green facades are introduced to improve urban biodiversity and to reduce and control stormwater runoff in the city; (iii) Groundwater storage by coastal filtration with treated wastewater keeping the water resources under control.

Putting demand management into focus: Effective demand management strategies in Berlin have resulted in a 50% reduction in the city's total water consumption over a period of twenty years. These strategies, which can be a model for other cities, focus on four aspects: getting water users to pay the right price for the services offered; launching large public awareness campaigns; temporarily subsidizing water saving equipment and reducing water leaks and losses more efficiently.

3.4.3. Case Study - Climate Change Adaptation of the Transport Infrastructure System

The transport infrastructure that enables traffic as one of the major human activities is directly exposed to the negative impact of high waters. Increasing the resilience of transport infrastructure to climate change as a whole is currently one of the primary goals of many countries in the world. Floods are in most cases the biggest problem facing transport infrastructure. The catastrophic floods that hit Bosnia and Herzegovina, as well as the region in 2014 have raised public awareness of this problem.

The main steps in risk assessment and flood management are hazard identification, risk analysis, risk assessment and risk management.

The World Bank-funded project "Mainstreaming Climate Resilience, Risk in Road Management in Bosnia and Herzegovina" (Reeves et al. 2018), developed a methodology for risk assessment of the main road network in Federation of Bosnia and Herzegovina.

The methodology steps are defined as follows:

1. Identify H, E and V indicators for each type of hazard
2. Establish thresholds for scoring each indicator
3. Consider if weightings should be applied
4. Score the indicators for each road section based on data and expert judgement (1 -10)
5. Normalise scores for H, E and V
6. Multiply H, E and V scores to produce an overall score for risk
7. Map the risk score using the GIS platform – this will enable high scoring road sections for different types of hazard to be easily identified

Risk is defined as the product of hazard (H), the elements at risk (E) and vulnerability (V). For each of them a series of indicators were identified based on the main influencing factors and available data sources. It is suggested that each indictor is scored from 1 to 10 based on data thresholds and expert judgement. The complete analysis is based on a large number of collected datasets on the road network, terrain configuration and watercourse location, geological composition of the soil, previous floods, and weather indicators over a long period (minimum 50 years).

The following indicators for risk assessment were selected:

1. Hazards: number of days in which daily rainfall exceeded 40 mm over the last ten years, average monthly precipitation over the previous 30 years, estimate of future annual rainfall, location of the section within the floodplain, existence of flood defences, road elevation, proximity roads of the river, the existing state of the river bed, the state of culverts.
2. Elements at risk: Assets - culverts, smaller and larger facilities.
3. Vulnerability: average annual daily traffic (AADT), the existence of alternative routes, the strategic importance of the considered section within the entire road network.

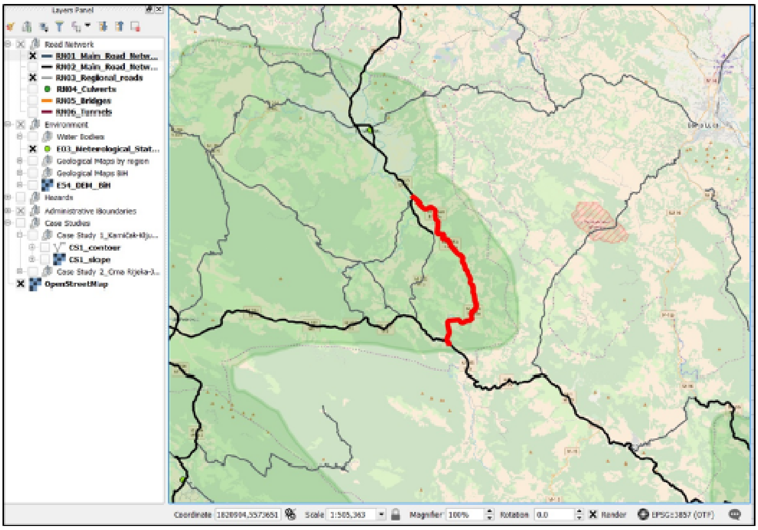

Figure 1.12 - Analysis Area – Road section M15-004 (Bosnia and Herzegovina)

The presented methodology was applied to one of the sections of the main road network in Federation of Bosnia and Herzegovina. All the above indicators were scored based on data collected from the relevant services (road manager, hydro-meteorological institute, geodetic authority, Ministry of Physical Planning, local communities) and an overall flood risk assessment for the specific area obtained.

A semi-quantitative risk analysis approach was applied. Data from different measurements and expert ratings were used to evaluate the indicators. The following figures give an overview of a part of the analysis of the mentioned road section and the relationship of different datasets in the GIS platform.

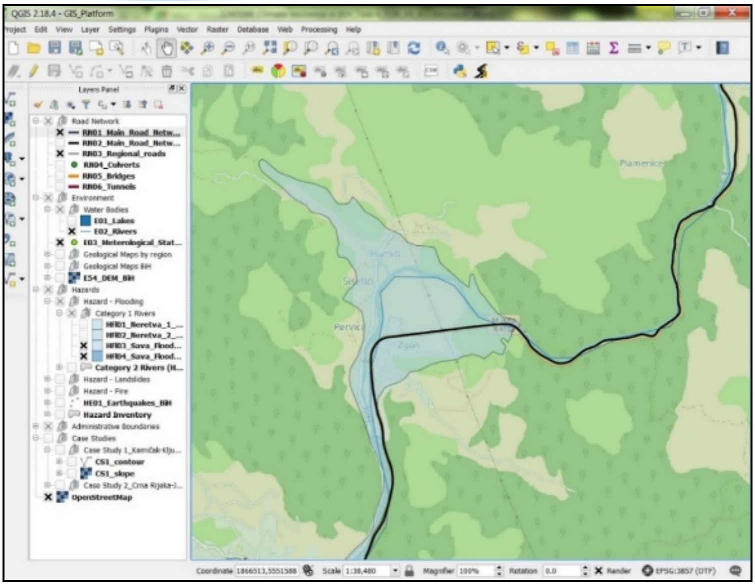

Figure 1.13 - Flood zone and road section M15-004 (Bosnia and Herzegovina)

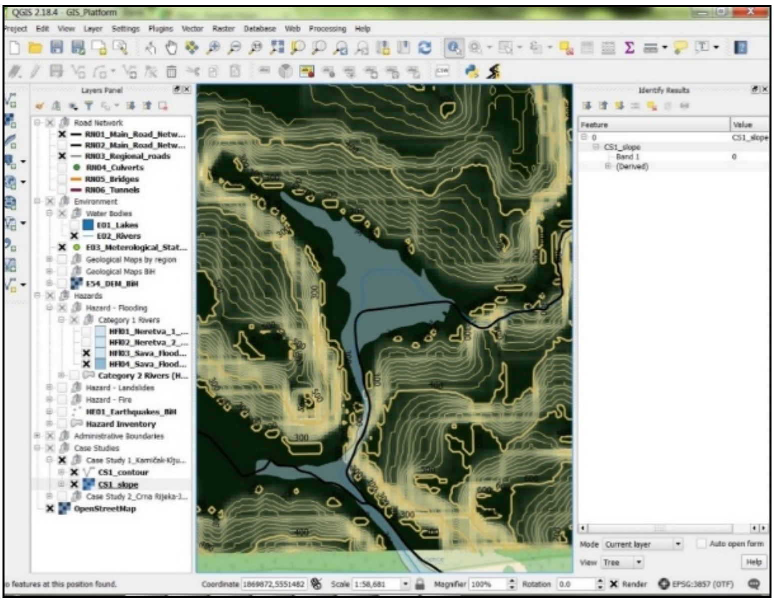

Figure 1.14 - Overview of the relationship between the flood zone and the elevation of the terrain and road section M15-004 (Bosnia and Herzegovina)

The proposed methodology applies to the complete road network. In combination with other hazard assessments (especially landslides, which often accompany the occurrence of floods), it is possible to get an overview of the most endangered sections and react promptly in terms of its protection, regulation and protection of watercourses, finding of alternative routes, etc.

3.5. Conclusion

The importance of studying climate variability poses a challenge that societies, together at the regional level or individually, will need to address to determine their impact primarily on water resources, environmental and human resources. To assess the degree of vulnerability of the society and to determine the strategies and plans for adaptation to the projected climate change, it is necessary to apply sustainable water management already in the full sense of the word.

Climate change is harming the economy and overall social development, especially on vulnerable groups of society. Therefore, it is crucial to implement adaptation measures on time. The cost of investing in climate change adaptation today will undoubtedly reduce the cost of repairing possible damage in the future. Innovative adaptation measures that contribute to climate resilience are of particular interest. Since climate change resilience involves preparing for floods, droughts, and other extreme natural events, managing them effectively when they occur, recovering quickly and learning from them, it is essential to raise people's awareness and change the way we think about such events. New approaches to water management, which include greater adherence to natural laws, that is, returning to the natural hydrological cycle through solutions from nature, can help mitigate the adverse effects of climate change. The integrated approach requires the inclusion of different professions to define the best possible solutions.

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2 WATER – SCARCE RESOURCE

Jelena Đokić, TCASU,
Predrag Stanojevic, TCASU

Abstract

Earth has a finite amount of fresh, usable water. Fortunately, water is naturally recycled (collected, cleansed, and distributed) through the hydrologic cycle. Humans have developed sometechnology to speed this process. However, because of diverse factors (drought, flood, population growth, contamination, etc.) water supplies may not adequately meet a community's needs. Conservation of water can ensure that supplies of fresh water will be available for everyone, today and tomorrow.This chapter presents the level of water scarcity on the global level, in EU and in the Western Balkans Region.The Assessments conducted by the European Commission and the European Environment Agency (EEA) show a number of problems, mostly related to the ecological status of the surface and ground water resources.An increase of more than 10 % in the water withdrawals for irrigation is expected all Western Balkans countries. There is a great impact of urbanization on water resources management, especially in the Western Balkan Region. Water conservation measures are developed in two directions: systemic measures for water saving technology, metering and tariffs use, and leaking control, on one side, and individual measures in changing living habits among the population. Only joint actions will lead to the sustainable management of the scarce water resources.

2.1 Introduction

Water scarcity *and security* has been and will continue to be a key global-scale environmental issue. Water security is defined by the United Nations Water program as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability." Water scarcity is the lack of a sufficient usable water. Clean water and sanitation comprises Goal 6 of the 17 Sustainable Development Goals proposed by the United Nations in 2015.

All countries on Balkan are already trying to align with Sustainable Development goals and started introducing measures from goals 6 and 17 in strategic documents, strategies and plans.

2.2 Water resources in the world, Europe and Western Balkans

2.2.1 World water scarcity

Water scarcity arises in situations where there is insufficient water to simultaneously support both human and ecosystem water needs (White, 2014). Most often this arises as a result of a basic lack of water (i.e., physical water scarcity), but it may also result from a lack of suitable infrastructure to provide access to what might otherwise be considered ample available water resources, which is referred to as economic water scarcity. Physical water scarcity may occur as a result of both natural phenomena (e.g., aridity, drought) as well as from human influences (e.g., desertification, water storage; Pereira et al., 2009; White, 2014), although these influences are often coupled. For example, the process of desertification often commences as a result of water overuse during periods of temporary drought. A key distinction between these various processes is in degree of permanency and reversibility. In the case of drought and water overuse, for example, the impacts may be temporary; however, those arising from aridity and desertification are more likely to be irreversible (Water, 2006). As Pereira et al. (2009) point out, this distinction is often confused when discussing water scarcity and its impacts, but it may be important in understanding both impacts and mitigationoptions.

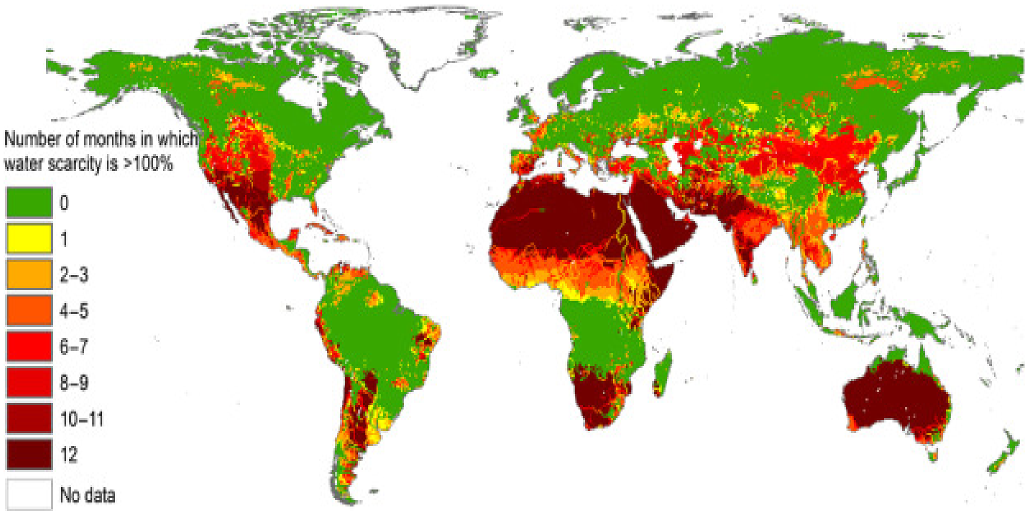

Figure 2.1 - Map showing the global distribution of regions affected by water scarcity. Reprinted from Mekonnen, M.M., Hoekstra, A.Y., 2016. Four billion people facing severe water scarcity. Sci. Adv. 2.

Water scarcity impacts both human populations and natural ecosystems on all continents (Figure 2.1). For example, recent estimates suggest approximately 4 billion people live under conditions of water scarcity for at least one month each year, with roughly 0.5 billion people exposed to severe water scarcity all year round (Mekonnen and Hoekstra, 2016). These figures nearly double previous estimates, in part by considering the flows required to remain in rivers to sustain flow-dependent ecosystems, as well as the goods and services they provide for people. In most, though not all regions, climate change is forecast to exacerbate water scarcity even further (Gosling and Arnell, 2016). These assessments highlight the massive global impacts of water scarcity on human livelihoods and on natural systems, and many global programs such as those of the United Nations focus on improved human access to water within a more sustainable ecosystem footprint. From a global perspective, less attention has in the past been given to the environmental impacts associated with water scarcity (Mekonnen and Hoekstra, 2016), although environmental flow needs are now being incorporated into assessments of water scarcity at both global and catchment scales (Liu et al., 2016; Mekonnen and Hoekstra, 2016).

2.2.2 EU water scarcity

Water scarcity and drought have become growing problems in many parts of Europe over the last 30 years, costing hundreds of billions of euros. Governments need data and indicators in order to set up efficient early-warning systems. The Commission's Joint Research Centre has launched a European Drought Observatory to monitor developments and publish online forecasts while encouraging Member States to factor drought risk into their River Basin Management Plans, RBMPs.

But water is still under growing pressure from domestic demand, economic activities, urban development and climate change. It is dammed to generate energy, polluted bychemicals, hemmed in by flood protection barriers, and drained off for irrigation andfarmland. Assessments conducted by the European Commission and the European Environment Agency (EEA) show a number of problems:

- Unless stronger action is taken, 47 % of EU surface water will not meet good ecological status (Figure 2.2) by the deadline;
- There is a lot of uncertainty related to the chemical status of surface waters due to information gaps;
- About 25 % of groundwater is still expected to suffer from poor chemical status;
- 60 % of European cities over-exploit their groundwater resources and 50 % of wetlands are endangered.

The Figure 2.2. above shows the ecological water status or potential of allEU member states, ranging from water bodies with High and Good potential (Blue and green in colour) to those of bad or poor status (orange and red in colour).Sixty per cent of the EU's territory lies in transboundary river basins. The hydrological cycles are so interconnected that land use in one country can affect precipitation beyond its borders. Moreover, the European market, EU common policies and Member State policies all have significant impacts on water status. Therefore, action at EU level is needed to face the water challenges of the 21st century.

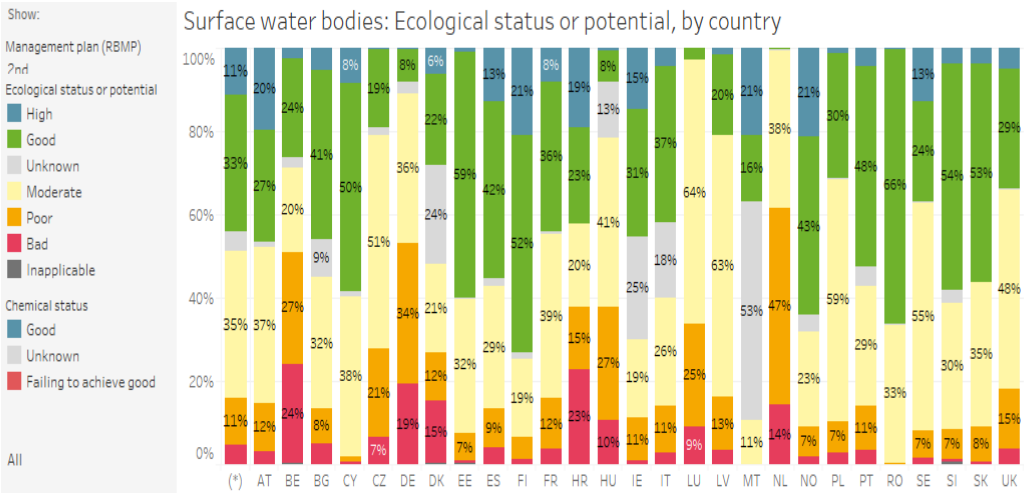

Figure 2.2 - Water status according to the EU Member States' RBMPs, assessed by the Commission – Ecological Status of Surface Water Bodies

In 2007, the Commission adopted a Communication on Water Scarcity & Drought (WS&D)1 . The Communication identified seven policy areas that had to be addressed if Europe was to move towards a water-efficient economy.Consequently, mitigation actions were developed and restrictions were applied in order to restrict water use (FR), irrigation (RO, SE, CY) and shipping (NL) in some of the affected Member States. Six Member States reported that they did not experience drought or water scarcity situations (AT, BE, EE, IE, LU, SK), and the same applied to Switzerland (CH). This information reported by the Member States should be seen in relation to the 2010 State of the Environment report from the European Environmental Agency which states, that "Except in some northern and sparsely-populated countries that possess abundant resources, water scarcity occurs in many areas of Europe, particularly in the south, confronted with a crucial combination of a severe lack of and high demand for water".

2.2.3 Western Balkan Water Scarcity

Water scarcity is a problem, particularly in the summer and in southern parts of the Western Balkans, as well as in coastal zones and on islands. Countries in the region share many river basins and much of their water resources. A brief overlook of the region is next provided.

The EEA has forecast that demand for irrigation water for agriculture will increase in Europe, as countries in this region experience the impacts of climate change, including water scarcity in summer months. A similar trend may be seen in many parts of the Western Balkansand especially in Albania and in the former Yugoslav Republic of Macedonia, which already depend heavily on irrigation.

These forecasts also point toa decline in water use for electricity generation, a trend that may also be seen in the Western Balkans as power stations are modernized. Available projections of water withdrawals for different scenarios are presented in table below.

The Table 2.1 presents the fast track results for Western Balkans countries obtained based on the WaterGAP model and GEO-4 scenarios in the first phase of the SCENES project 'Water Scenarios for Europe and Neighboring States'. Under the Security first scenario an increase of more than 10 % in the water withdrawals for irrigation is expected all Western Balkans countries. The biggest changes (more than 50 %) are expected in domestic sector for Serbia and Montenegro; and in manufacturing and electricity generation for Bosnia and Herzegovina and the Former Yugoslav Republic of Macedonia. Under the sustainability First Scenario a decrease of water withdrawals for more than 50 % is expected for electricity and domestic purposes and smaller decrease for irrigation and manufacturing.

Table 5.7 Percentage change in water withdrawals for the Western Balkans countries as compared to the base year (2000), realised with two different scenarios for 2030

Country	Sector							
	Electricity		Manufacturing		Irrigation		Domestic	
	Security first	Sustainability first	Security first	Sustainability first	Security first	Sustainability first	Security first	Sustainability first
Albania	No or slight changes +/− 10 %	Decrease > 50 %	Increase > 10 %	Decrease > 10 %	Increase > 10 %	No or slight changes +/− 10 %	Increase > 10 %	Decrease > 50 %
Bosnia and Herzegovina	Increase > 50 %	Decrease > 50 %	Increase > 50 %	Increase > 25 %	Increase > 10 %	Increase > 10 %	No or slight changes +/− 10 %	Decrease > 50 %
Croatia	Increase > 10 %	Decrease > 50 %	Increase > 50 %	Increase > 50 %	Increase > 10 %	No or slight changes +/− 10 %	No or slight changes +/− 10 %	Decrease > 50 %
The Former Yugoslav Republic of Macedonia	Increase > 50 %	Decrease > 25 %	Increase > 25 %	Increase > 25 %	Increase > 10 %	No or slight changes +/− 10 %	No or slight changes +/− 10 %	Decrease > 50 %
Serbia and Montenegro	Increase > 25 %	Decrease > 50 % %	Decrease > 50 %	Decrease < 50 %	Increase > 10 %	No or slight changes +/− 10 %	Increase > 50 %	Decrease > 50 %

Source: CESR (2007), SCENES — Water Scenarios for Europe and for Neighboring States. D 3.1. Fast track modeling results, Kassel.

Table 2.1 - Percentage changes in water consumption for the Western Balkan countries, two scenarios for 2030.

European legislation and policy will encourage river basin approaches to water management based on the Water Framework Directive. International frameworks for the Danube and Sava river basins are also promoting this approach. EU and national legislation will establish new requirements for drinking water quality and waste water treatment.

Other policy areas will have an important influence. For example, agricultural policy will affect this sector's demand for water. In several countries, energy policies propose an increase in hydropower, and this will affect freshwater systems.

2.3 Water demand

The growing economies of the region (World Bank, 2017b) are likely to use more resources — both renewable biological resources and non-renewable stocks of minerals, metals and fossil fuels. This is expected to increase pressure on local natural resources and add to the growing volume of imported resources (DG TRADE, 2017) to the region. Increasing dependence on trade and insecure access to regional resources could result in tensions regarding competing claims over resource stocks or indirectly as a result of restricted trade flows.

This implication may be further aggravated by the increasing global population (GMT 1 “Diverging global population trends”) bringing radical changes in consumption patterns and thus demand for resources. Increasing global economic output and global expansion of middle class are expected to contribute to accelerating global resource use/ consumption (GMT 5 “Continued economic growth?”) thus increasing the prospect of insecurity and conflict concerning resources.

As demand grows, there is increasing competition for resources between water, energy, agriculture, livestock, forestry, mining, transport and other sectors with unpredictable impacts for the environment.

Amongst renewable resources, water is perhaps the most strategically important onein the region. Competition for water is expected to increase as demand is likely to rise resulting from implications of climate change (Adelphi, 2013). Water use in agriculture is expected to increase as crops will require more water due to hotter, drier, longer summers (UNDP, 2013, Custovic et al.2012) leading to an increase in the number and the size of irrigated areas.

Over-exploitation of water resources has been identified as significant pressure from the electricity generation sector (JRC, 2014), and such pressures may increase in the near future.

The tables below show the results of the studies on the percentage of water consumption per consumer (Table 2.2) and on the use of drinking water, i.e. how many liters are used, on average, and for what purposes, of drinking water in North Kosovo* (Table 2.3).

Total consumption of drinking water by consumer:	%
Showering	35%
Toilet flushing	21%
Laundry	17%
Hands washing, lave	7%
Dish washing	5%
Apartment cleaning	5%
Water for drinking and cooking	3%
Other	7%

Table 2.2 - Total Consumption of Drinking Water by consumer(Spark)

Water purpose:	Quantity (L/Resident/day)	
	Average	Waterworks "JKP VodovodIbar"
Water for drinking and cooking	2-5	3
Hands washing, lave	5-20	7
Showering	20 - 60	40
Dish washing	5-10	5
Laundry	10-30	20
Apartment cleaning	3-5	10
Toilet flushing	20-50	40
Garden watering		5
Other		20
Total:		150

Table 2.3 - The field study results of water use in the North of Kosovo*(Ibar", 2014)

2.3.1 Fresh water availability

Water scarcity is a function of several interrelated factors. Global water use has increased by a factor of six over the past 100 years and continues to grow steadily at a rate of about 1% per year (United Nations Water, 2018). This is a result of population growth, economic development, and changing consumption patterns. We can anticipate that global water demand will continue to increase in conjunction with continued population growth and economic development. While demand has increased, the quantity of local available fresh water has decreased through global climate change, as illustrated by the recent study cited before. This is exemplified by the severe, long-term droughts affecting several regions of the world. In addition, water pollution has led to reduced water quality for many regions, further reducing the amount of clean freshwater available.

2.3.2 Impact of urbanization on water use and management

Rapidly expanding cities have put strains on social services, including water servicesand since expansion has been unplanned ribbon development it has also encroached on valuable agricultural land, in particular irrigated agricultural land, and cut up rural infrastructure such as irrigation schemes and further complicated service delivery. While service delivery has been able to provide near universal access, the impacts both on urban water management (storm drainage, protection from floods) and rural water management (landscape approaches, contiguous irrigation service areas) are significant.

A large amount of water is used by public water supply companies for drinking water supply, for household and other consumer needs of public water supply companies and sanitation. This supports directly and indirectly all service sectors, and importantly construction, mining, manufacturing and other industry. Agriculture is another large user, currently suppressed in its water usage due to the dilapidated infrastructure and lagging investment in modernization of the agriculture sector. Someof this water use is in rainfed agriculture, which is highly dependent on variableclimate. In the irrigation sector, abstraction and productivity are higher. With intensificationof agriculture, the uptake of irrigation will increase. In the energy sector, there is some water use for hydropower, and an important contribution to thermal powerplant cooling for most of power generated in the country. In industry, water is used for production and cooling the equipment. The quantity of water used in a sector is not correlated to its impact on water security. A very demanding inefficient irrigation scheme may contribute little to overall GDP, and have a large footprint, whereas a highly productive intensive system has major positive impacts on imports, jobs and overall GDP. Hydropower consumes no water but poses large demands on flows in rivers. Optimization of water use requires understanding and optimization of water resources to maximize social, economic and environmental services.

2.3.3 Managing Water Resources

Water scarcity, related to either overextraction of groundwater reserves or pollution of existing surface water resources, promises only to increase as a problem. Currently, agriculture accounts for over 70% of water use. In most countries, production-linked support policies still dominate. This framework encourages overuse and inefficiency and fails to address the environmental damage that results from polluted runoff. As populations increase, competition between uses of water and regulation of wastewater will develop into significant policy concerns. Already, India and China have been faced on numerous occasions with the decisions between providing for water-heavy crops or population settlements. Judicial policy to address multicountry ownership of surface and groundwater resources needs to become a priority before water becomes like oil as a commodity. Improved pricing structures, tradable permits, enforceable government regulations, and more sustainable agricultural water management are necessary to address the crisis of water scarcity. Such initiatives also need to take place on local as well as national levels.

Water scarcity and the need to conserve resources are recognized worldwide as challenges for the near future.

Water conservation and environmentally sustainable use of water will be increasingly implemented to manage the water balance, particularly where water resources are limited and the areas are subjected to droughts. Much emphasis is being placed in Australia, the USA and in the drier parts of south-east England on the adoption of demand constraint measures. In England emphasis is being placed on extending the metering of domestic supplies, installing water saving fittings and on increasing measures to reduce leakage and wastage. In the USA, as required by the Safe Drinking Water Act 1996, US EPA published draft guidelines in 1998 to water suppliers for 'conservation planning', i.e. measures to induce economy in the use of water. The guidelines propose three sequential levels of approach. The first comprises universal metering, loss control (i.e. leakage and wastage reduction) and public education. The second and third levels include such measures as water audits, pressure management, re-use and recycling, and integrated resource management. However, emphasis on demand constraint does not necessarily apply in all countries, where some utilities may be reluctant to curb the demand from metered industrial consumers and from metered households occupied by higher income groups; the payments made by them comprise a major part of the utility's income and are needed to cross-fund supplies given free through standpipes or at below cost to low-income groups. The conditions and position adopted by each utility vary. Where more plentiful supplies exist there may be less incentive to conserve water.

In many countries restricted hours of supply have to be adopted in order to prevent consumption and losses exceeding available supplies. Metering is adopted for the same purpose but it must be efficient to be effective. Intermittent supplies bring many problems. Consumers store water when the supply is on, but throw away the unused balance when the supply next comes on, believing the new supply is 'fresher'. Consumers may leave taps open so as not to miss when the supply comes on again, allowing storage vessels to overflow. Intermittent supplies make leak detection and prevention of consumer wastage very difficult. Typically the hours of supply have to be reduced to at most 4 hours in the morning and 4 hours in the evening, and frequently less, to gain control of consumption. To some extent intermittent supplies are self-defeating: more consumer wastage and more distribution leakage occur because of the difficulty of maintaining the system in a good state; if mains become emptied contaminated groundwater may enter the pipes and endanger the health of consumers. The situation is often exacerbated by loss of income due to difficulties with metering and income collection. Nevertheless, many utilities worldwide have to adopt intermittent supplies.

Water conservation measures that can be effective on 24-hour supplies include:

- imposing temporary bans on the use of water for washing vehicles, on refilling swimming pools and ponds, and on the use of hosepipes and sprinkler equipment for watering gardens during drought or shortage of supplies.
- good publicity can achieve a temporary and short-term reduction in demand, perhaps as much as 10%;
- metering domestic supplies can curb excessive consumption, especially water used for lawns and gardens, provided the tariff structure imposes a financial penalty when consumption exceeds a reasonable amount;
- promoting the use of low water use fittings
- using pressure management control to reduce leakage and to extend the life of the pipes, improves the reliability of network control valves which can operate within their designed range, thereby reducing wastage through the valve malfunctioning;
- keeping operational pressures at the minimum necessary to maintain levels of service reduces water taken unnecessarily;
- flow limiters and throttles on service pipes can curb consumption but are not always effective. If set too low, consumers leave taps open to fill containers which overspill. They can also be bypassed in an attempt to get a better supply.

Commercial and institutional demand can be constrained by metering all consumers: both large and small shops, offices and other business premises. Wastage through plumbing fittings from these non-domestic consumers is frequently high because no one working in the premises is responsible for paying the water charges and the premises are unoccupied outside working hours. Many cases have been reported of night and weekend flows to unoccupied premises being nearly as high as daytime flows when staff are present, especially in government offices in some countries. Manufacturers are also often unaware of the potential financial savings they can achieve by adopting water conservation measures, the lower usage reducing both their water purchase and effluent discharge costs.

Table 2.4. summarizes the opportunities and constraints of water saving technologies, metering and tariffs and leakage reduction, the three primary measures for managing consumption.

Component	Opportunities	Constraints
Water saving technologies	•Low and ultra-low water use efficient appliances •Standards and regulations will achieve greatest savings	•Policing installation and retrofit •Does not stop excessive use •Time to promote and develop •Unlikely to achieve 100% acceptance
Metering and tariffs	•Reduces demand, short and long term •Consumers responsible for their impact on environment •Charge real cost of usage	•To be effective, need both •Ability to pay and need to maintain supplies to low-income and vulnerable consumers •Cost of meter installation and long-term maintenance
Leakage control	•Proactive control can reduce losses down to economic level of leakage (ELL) •Short-term local solution	•Reduction to ELL is one-off win, thereafter marginal impact on resources •Savings depend on maintaining ELL/leakage reduction •Is ELL optimum level?

Table 2.4 - Water conservation measures

Estimating future demands in developed countries can be approached by combining the forecast trends in population and per capita consumption growth with implementing water conservation measures within the forecast period. The trends provide an upper limit to the projections. The conservation measures will produce a range of achievable forecasts provided there is the political and social will to conserve water and adopt a realistic tariff for water and provided the utility manages, and is seen to be managing, system water losses and leakage.

2.3.4 Water conservation measures-individual approach

Water conservation involves changing habits. Since many of these habits have evolved over a lifetime, they can prove difficult to alter. People can become active in conserving water by starting simply, then gradually taking more advanced steps to reduce water consumption. The simplest habits involve turning off water whenever it is not being used. When water is needed for rinsing dishes, it can be held in a sink rather than allowing it to flow unused down the drain

An individual may simply use less water. For example, some people use a hose to “sweep” sidewalks, when a broom works well. People can shorten their shower times or reduce the amount of water they use when bathing.

Other conservation methods may initially require more effort and funds, but in the long run will save money and resources. For example, households can install low-flow showerheads with smaller holes that reduce water flow and increase pressure. A capped bottle weighted with stones takes up space in a toilet tank, reducing the amount of water available to flush down the drain.

Below are the recommendations on actions we can take, on the individual level,in orderto contribute to the conservation of water (Table 2.5.)

1. Use a broom instead of a hose to sweep sidewalks and driveways.
2. When washing the car, use a hose with an on/ off nozzle or use buckets of rinse water.
3. Water lawns in the mornings or evenings when water will not evaporate as quickly. Make sure the water lands on vegetation and not on streets or sidewalks. If possible, save rainwater for watering lawns.
4. If you need to run water before it becomes hot, store the cool running water in a bottle for use in rinsing dishes, and washing vegetables and hands.
5. When washing dishes by hand, use a sink full of rinse water rather than letting the water run.
6. Fix leaks!
7. Install a low-flow showerhead.
8. Turn off the water when it is not in use. Don’t leave it running when brushing teeth. Turn off the water between soaps and rinses when washing hands.
9. Run the dishwasher or washing machine only with a full load.
10. Keep a bottle of cold drinking water in the refrigerator instead of running water until it becomes cool.
11. Limit shower time to 5 minutes or less.
12. Take showers instead of baths.

Table 2.5 - Water conservation measures at the individual level

2.4 Conclusions

Water scarcity and the need to conserve natural resources are recognized worldwide as challenges for the near future. Water conservation and environmentally sustainable use of water will be increasingly implemented to manage the water balance, particularly in the areas with limited water resources or prone to droughts. In the field of management of the water resources, the ‘conservation planning’, i.e.,measures to induce economy in the use of water were included.There are opportunities and constraints related towater saving technologies, such as metering and tariffs and leakage reduction, the three primary measures for managing consumption. Implementing water saving technologies will not stop excessive use, but the metering and tariffs will. The leaks have to be reduced to a minimum. These three measures combined will efficiently contribute to improve the management of scarce water resources. Butthey need to have a consensus within the population to whom they will be applied. However, water conservation starts on the individual level, by changing habits and raising awareness.

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3 FLOOD AND DROUGHT RISK MANAGEMENT

Mladen Milanović, University of Niš, Faculty of Civil Engineering and Architecture
Milan Gocić, University of Niš, Faculty of Civil Engineering and Architecture
Slaviša Trajković, University of Niš, Faculty of Civil Engineering and Architecture

3.1 Introduction

Floods and droughts, as natural disasters, have enormous adverse economic, environmental and social consequences. More recently, these disasters are more frequent with greater and more devastating consequences (Burton et al., 1978). Traditional approaches to flood and drought management have not eradicated these disasters or reduced vulnerability from future occurrences. The enormous damage caused by these disasters clearly indicates the need for a new approach, to manage flood and drought risk (Kundzewicz, 2004).

As both of these natural disasters are closely linked to water, European policies affecting flood management are discussed in the first part. The second section analyzes flood risk management, impacts and adaptation to climate change, and disaster risk reduction. Droughts are among the most costly disasters where the start, end, and boundaries of capture are not easily determined, and consequently the consequences of droughts and water shortages are discussed in section three. Part 4 presents an example of good practice in preventing and managing water scarcity, floods and droughts.

3.2 European policies influencing the management of floods

The European Union attaches great importance to water management and water quality issues. It has therefore adopted a legal framework for the protection and management of water, notably the Water Framework Directive (2000/60/EC) (Directive of the European Parliament and of the Council 2000/60/EC establishing a framework for Community action in the field of water policy, 2000). The Water Framework Directive is a basic document which sets out the establishment of a framework for EU action in the field of water policy. The management of river basin districts under this Directive is carried out on the basis of a Management Plan with a program of measures that integrates environmental, economic and sociological aspects with a view to achieving sustainable development.

The Framework Directive is also the basis for cross-border cooperation between countries within international river basin districts in Europe. According to the Directive, Member States and EU candidates are required to: stop further destruction of water bodies, increase and restore the status of aquatic as well as terrestrial ecosystems and wetlands that are directly dependent on aquatic ecosystems. Also, groundwater pollution needs to be reduced and further pollution prevented, and its implementation should also mitigate the effects of floods and droughts.

All Member States must identify river basins within their own country and designate, for each of them, a river basin district. For rivers flowing through multiple countries, international river basin districts must be established. Also, a River Basin Management Plan for each river basin district must be established under the Directive.

The particular importance of the Directive is reflected in the protection and efficient use of water, as it responds to all challenges related to water resources. The Water Framework Directive is more closely defined and supplemented by other Directives: Directive of the protection of groundwater against pollution and deterioration, Directive of the quality of water intended for human consumption, Directive of the quality of bathing water, Directive of the protection of water against pollution caused by nitrates from agricultural sources, Directive of the urban wastewater treatment, Directive of the environmental quality standards in the field of water policy and the Directive of the assessment and management of flood risks (Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration, 2006; Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, 1998; Council Directive 76/160/EEC of 8 December 1975 considering the quality of bathing water, 1976; Council Directive 91/676/EEC of 12 December 1991 considering the protection of water against pollution caused by nitrates from agricultural sources, 1991; Council Directive 91/271/EEC of 21 May 1991 considering urban wastewater treatment, 1991; Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, 2008; Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007).

As it turned out that full flood protection was impossible, attention shifted from flood protection to flood risk management. Floods, but especially droughts, by their nature, are not regionally restricted occurrences, but often affect more countries, and thus the need for a common risk management framework to increase states' resilience to natural disasters has emerged. It has also been noted that different and inefficient management of disasters, especially in a transboundary context, could jeopardize the long-term objectives of the European Union for sustainable development. The first Floods Directive was adopted in 2007. It is the Directive of the assessment and management of flood risks (2007/60/EC) which aims to promote, by procedural obligations, a minimum common flood management framework for all members of the community (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007). Some European countries already incorporated the flood direccyive in their legal issue.

The Directive establishes a framework for the assessment and management of flood risks, with the aim of reducing the adverse effects on human health, the environment, cultural heritage and economic activity. This Directive provides for the development of Flood Risk Management Plans, which constitute an umbrella act in the fight against flood risk. Adoption of the Plan must be carried out gradually, with the necessary documents and regulations. This approach allows the development of the Plan itself to become a process that is carried out in regular cycles every six years.

The development of a Risk Management Plan in areas with significant flood risk is preceded by a preliminary flood risk assessment, the preparation of flood hazard maps and flood risk maps.

The preparation of a **Preliminary Flood Risk Assessment** is an obligation of each Member for each river basin district or part of an international river basin district in their territory.

The Preliminary Flood Risk Assessment must at least include:

- maps of the river basin district with topography and land use
- a description of historic floods that have had significant adverse impacts
- a description of the floods that may occur in the future and an assessment of the potential adverse effects on human health, the environment, cultural heritage and economic activity.

Based on the Preliminary Flood Risk Assessment, Member States will identify for each river basin district the areas for which significant flood risks are possible.

For these areas, the hazards and the risk of floods are determined in detail, ie:

- flood hazard maps and
- flood risk maps.

Flood Hazard Maps cover areas that can be flooded under different probability scenarios:

- floods with a low probability
- floods with a medium probability
- floods with a high probability, where appropriate.

These maps specify the flood boundaries, water depth, and water velocity or flow rate.

Flood Risk Maps show the potential adverse consequences in a flooded area and contain in particular the number of affected residents and the types of economic activities in potentially vulnerable areas.

The final act is the preparation and development of the Flood Risk Management Plan in accordance with previously adopted documents. The plan is adopted at the level of the river basin district. The plan also includes a program of measures focused on the prevention, protection and early warning systems of floods. The measures promote sustainable land use and the controlled flooding of certain areas in the event of a flood.

It is important to emphasize that the Directive does not set any priorities, but Member States decide which measures and activities to include in their flood risk management plans (Moster and Junier, 2009).

Member States must organize active public participation, ie preliminary risk assessment, flood risk maps, flood risk maps and risk management plans, to make publicly available. The drafting and review of such acts must be in accordance with Directive 2000/60/EC.

3.3 Flood risk management, climate change adaptation and disaster risk reduction

3.3.1 Flood risk management

Flood risk means the likelihood of a flood occurring and possible adverse impacts on people, material goods, the economy and the environment. The principle of flood risk management is based on the concept of taking measures and activities that implement a risk mitigation policy, that is, reducing the possible adverse effects of floods. It is important to emphasize that floods cannot be completely eliminated, but their impacts can be reduced through understanding and managing flood risk.

In order to set up a framework for flood risk management, the EU adopted Directive 2007/60/EC (23 October 2007) (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007). The primary objective of this Directive on the assessment and management of flood risks is to reduce the adverse effects of floods on human health, the environment, infrastructure and economic activity.

According to the recommendation of the European Economic and Social Council (Opinion of the European Economic and Social Committee on the Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Flood risk management – Flood prevention, protection and mitigation, 2005), the following criteria must be observed when selecting flood risk mitigation measures:

- flood protection must not lead to a deterioration of the hydrological situation elsewhere,
- in accordance with the principle of sustainable development, give priority to the action of restoration of river basins and natural measures containing flood water within a specific area without causing damage and
- priority should be given to measures that can offer synergy with other sustainable development goals.

Flood protection in the Republic of Serbia is regulated by the Law on Water (Law on Water, 2018). This Law regulates the management of the risk of harmful effects of water, which includes: preparation of preliminary flood risk assessment, development of flood risk management plans, development of general and operational flood protection plans, implementation of regular and emergency flood protection and erosion protection and flash floods.

Based on the legislation in Serbia, the main objectives of flood risk management are set out:

- avoiding new risks,
- reducing existing risks,
- strengthening the resilience of society to floods,
- increasing flood awareness and
- the principle of solidarity.

Flood risk management is performed by the Flood Risk Management Plan, which is drawn up on the basis of a preliminary risk assessment, hazard maps and flood risk maps. The plan contains management objectives, priorities, necessary measures and how they are implemented.

The flood risk management plan, depending on the circumstances, brings a combination of structural and non-structural measures. The group of structural measures includes water structures built to regulate the water regime, ie those measures that represent the reconstruction and modernization of existing passive defense systems, such as the construction of new embankments, the regulation of watercourses, the construction and maintenance of reservoirs, retention sites, canals (National Disaster Risk Management Program, 2014).

Previous experiences in flood management, with the application of structural engineering solutions, have not made flood vulnerability disappear and have led to the awareness that there is no safe protection, and thus to a paradigm shift from flood control to coexistence and flood management (Kundzewicz, 2004).

Non-structural measures are an addition to structural measures. Measures such as insurance, forecasts, warnings, land planning, wetland restoration can reduce the loss of life and property due to floods (Bonacci, 2008). In recent times, non-structural measures have highlighted measures of green infrastructure that naturally retain and drain water in urban areas.

3.3.2 Climate change adaptation

Climate change means climate change that is directly or indirectly conditioned by human activities that cause changes in the composition of the global atmosphere. Moreover, all human activities (which affect climate) are superimposed on the natural fluctuations of climate and therefore it can be said that climate change is something that is happening now in all regions of the world (Law on Confirmation of the United Nations Framework Convention on Climate Change, with annexes, 1997). Influenced by human-induced climate change, there is supposed to occur an increase in the frequency, intensity, duration and spatial extent of extreme weather events such as extreme rainfall and heat waves. The consequences of such events can be catastrophic floods in given regions and more frequent and prolonged droughts in other ones.

Climate change projections for Europe say that southern and southeastern Europe will be the focus of climate change, as these regions will be most affected by adverse effects (Climate change poses increasingly severe risks for ecosystems, human health and the economy in Europe, 2017). The adverse effects of climate change in Serbia can be seen primarily from the effects of floods and droughts. Water scarcity, which is a vital factor in production, could lead to losses in agriculture (directly reflected by the impact of climate change on the water balance), health, tourism and other water-dependent sectors (High and Dry - Climate Change, Water and the Economy, 2016). In addition to direct damage from extreme climatic events, there are significant impacts on increasing the vulnerability of food production, on natural resources, on soil degradation and desertification.

Climate change management includes mitigation and adaptation measures. According to (Climate Change 2007: Impacts, Adaptation and Vulnerability, 2007), adapting to climate change means: "Adapting the natural or human response of a system to actual or expected climate change or its effects, to minimize damage or to take advantage of new opportunities."

The international community, aware of the responsibilities and dangers of climate change, has adopted several acts that the Republic of Serbia has also verified and accepted the obligations arising from them:

- Law on Confirmation of the United Nations Framework Convention on Climate Change (Law on Confirmation of the United Nations Framework Convention on Climate Change, with annexes, 1997)
- Law on Ratification of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (Law on Ratification of the Kyoto Protocol of the United Nations Framework Convention on Climate Change, 2007)
- Law on Confirmation of the Paris Agreement (Law on Confirmation of the Paris Agreement, 2017).

In fulfilling its obligations under the signed international treaties, the Republic of Serbia has adopted a draft Law on Climate Change, which regulates a system for reducing greenhouse gas emissions and defines a system of adaptation to changed climate change (Draft Law on Climate Change, 2019). This Law provides for the development of the Program for Adaptation to Changed Climate Conditions, which, among other things, provides a special reference to (Draft Law on Climate Change, 2019):

- analysis of climate change observations,
- review of expected climate change,
- analysis of the impact of climate change on sectors and systems and
- measures proposal for the adaptation to changed climatic conditions.

The Law stipulates that the Program for Adaptation to Changed Climate Conditions shall be implemented by adopting sectoral strategies, plans that specifically include:

- description of specific measures from the priority list,
- areas where the specific measure is planned, with explanations,
- timeframe for implementation of measures,
- cost-benefit analysis of the implementation of the measures and
- the manner and methodology of monitoring and evaluating the implementation of measures.

The Law intends to submit, every four years, to the competent Ministry, a report on the implemented adaptation measures by the bodies and organizations in charge of drafting and implementing sectoral documents.

3.3.3 Disaster risk reduction

Disaster risk reduction involves identifying disaster risks, reducing causation, mitigating consequences and rebuilding after a disaster, as well as improving early warning systems and increasing resilience of the individual and the local community. The principle of disaster risk reduction is, in fact, a system that bases its work (objective) on the analysis and reduction of causative factors of disasters, and therefore on the reduction of damage caused by natural hazards such as floods and droughts.

Disaster risk reduction in the Republic of Serbia is regulated by the Law on Disaster Risk Reduction and Emergency Management (Law on Disaster Risk Reduction and Emergency Management, 2018). This law enables the creation of a single integrated disaster risk reduction system with effective response and disaster relief. At the same time, this system forms part of Serbia's national security system.

The organization of the disaster risk reduction system is defined by the Law, and consists of elements: disaster risk reduction, rights and obligations of citizens and legal entities, while the category of system operation includes emergency management, early warning, notification, excitement, protection and rescue of people and material goods and inspection. Also, the Law stipulates obligations regarding the development of: disaster risk assessment, disaster risk reduction plan and protection and rescue plan.

Disaster Risk Assessment identifies the types and nature of individual disasters, the degree of vulnerability, the factors that cause or increase the degree of possible danger and the consequences that may occur for human and life, the environment, material and cultural goods. Risk assessment can be made by the republic, province, local government, business, health and educational institutions.

Plan for Disaster Risk Reduction contains specific preventive, organizational, technical, financial and other measures that the competent state authorities are obliged to undertake in the future in order to reduce the risk of disasters, based on the assessment of individual risks. Disaster risk reduction plans are adopted for a period of three years.

Plan for Protection and Rescue of the Republic of Serbia contains the following sections: early warning, mobilization and activation, protection and rescue, civil protection measures and use of forces and entities. The protection and rescue plan shall be drawn up on the basis of a risk assessment and adopted no later than 90 days after the adoption of the risk assessment, and shall be regularly updated with changes to the risk assessment. The plan is adopted every third year and updated as necessary. Plans can be made by the republic, province and local government.

It is important to emphasize that the Law enables the introduction of the Disaster Risk Register as an interactive, electronic and geographic-information database for the territory of the Republic of Serbia, which will contain physical-geographical data on the area affected by the risk, on the vulnerability of the population and facilities, on the previous disasters and information on the description and characteristics of the hazard. The law provides that the competent Ministry shall keep such a Register. The Law also provides for the determination of immediate risk zones, ie geographically spatial units in which there is a high degree of certainty that a catastrophe may occur.

Immediate risk zones prohibit activities that may cause new or magnify existing risk factors, such as wild construction in areas where there is a risk of disasters.

3.4 Challenge from water scarcity and droughts

Water maintains life, ecosystems, regulates the climate and is one of the most important resources that must be saved and managed effectively to achieve sustainable development. Water scarcity occurs as a result of natural hydrological variability. Economic policy, water planning and management and the resilience of society to changing supply and demand have a significant impact on water scarcity, i.e. the problem of water scarcity is exacerbated by increased consumption, deterioration of quality and reduced availability of water. Lack of drinking water is the greatest threat facing humanity, resulting in unmet demand, tensions among users, over-abstraction of groundwater and insufficient flow of water into the natural environment.

Climate change projections show a higher incidence of extreme events and rising temperatures. More frequent and severe droughts and floods will have a pronounced impact on water availability, especially in areas with irrigated production (Coping with water scarcity - an action framework for agriculture and food security, 2012). The accelerated urbanization and concentration of cities near the coasts, where fresh water supplies are limited or available at great cost, pose a new challenge for the supply of drinking water and water for other urban needs. Water consumption in the public, industry and agriculture is thought to increase by 16 % by 2030 (Report reveals large water saving potential in Europe, 2007). The agricultural sector is particularly sensitive where water scarcity is of paramount importance. That is why it is important that water in agriculture is effectively managed in order to achieve stability in production.

Seckler et al. (1998) share water scarcity in two groups as (Secker et al., 1998): physical and economic disadvantage. Physical disadvantage is reflected in the lack of water for all water needs, while economically it is caused by insufficient investment in water. As a consequence of these deficiencies, environmental degradation and groundwater levels decrease in the first case, while water infrastructure is underdeveloped in the second.

The Food and Agriculture Organization (FAO) at the United Nations defines water scarcity as excess water consumption relative to water availability (Coping with water scarcity - an action framework for agriculture and food security, 2012). According to FAO recommendations, countries must focus on prevention of the threat of droughts and water scarcity, with particular emphasis on the fact that, if properly identified, many causes of water shortages can be anticipated and mitigated. FAO proposes six basic principles that can be applied in different socio-economic settings and are the starting point for an effective and sustainable strategy for coping with water scarcity (Coping with water scarcity - an action framework for agriculture and food security, 2012):

- All strategies must be based on a clear understanding of the causes and consequences of water scarcity,
- Evaluate the benefits and costs and use systematic and comprehensive criteria for decision making in the watershed,
- Ensure the right level of water management and institutional capacity,
- Adapt water-related responses to local conditions,
- Harmonize policies for water, agriculture and food and
- Predict changes by adaptive management.

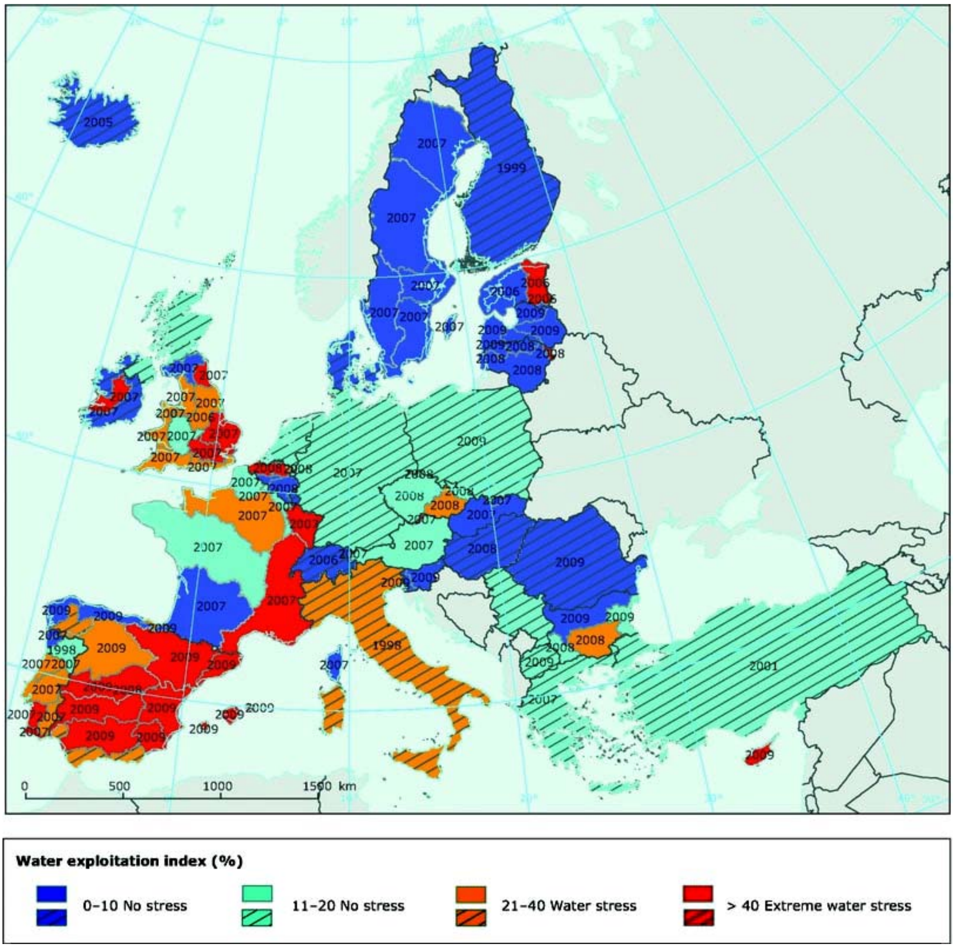

Figure 3.1 - Water Exploitation Index for Europe (Werner and Collins, 2012)

The Water Exploatation Index (WEI), which represents the ratio of the total annual amount of abstracted water and renewable water resources, is an indicator of the availability of water, i.e. of the pressure on the sustainable use of renewable water resources. The affected water resources comprise the total annual volume of surface and groundwater abstracted, while the renewable water resources include the volume of river runoff (rainfall less real evapotranspiration), the change in groundwater volume (internal inflow) and the volume of actual inflow of surface and groundwater from neighboring countries, for at least 20 consecutive years. When analyzing the index, the value of 20 % is considered to be the alert limit.

If the WEI index value is more than 20 %, the water resource is stressed (symptoms of water scarcity or lack) and if the index value is above 40 %, then it is an area with extreme water stress and the index value indicates unsustainable use of the water resource. Figure 3.1 shows the water exploitation index for the member states of the European Environment Agency (Sanz and Gawlik, 2014). Figure 3.1 shows that Serbia is not stressed (WEI = 11 – 20 %), while the index results vary (from stress-free to extreme water stress) in other European countries, leading to the conclusion that EU water distribution is uneven and that it depends primarily on the geography of the terrain and the climate. It is important to emphasize that in some countries the WEI index is calculated and displayed at the level of the river basin district, in the figure it is a space without a hatch, which more precisely identifies areas with water stress, such as in the UK, Spain, Portugal and France.

Moreover, WEI index analysis clearly shows that the deficit (stress due to lack of water) is experienced by different countries and not just the Mediterranean ones. The seriousness of water scarcity is also illustrated by the fact that water scarcity affects at least 11 % of the population and 17 % of EU territory (Sanz and Gawlik, 2014). It is important to emphasize that in addition to the quantities of water, the quality of the water is also important, because it depends on the use and costs of water exploitation.

Drought is a natural feature of climate variability resulting from long-term rainfall deficits. Over the last two decades, droughts have exceeded any other natural disaster in number and frequency of occurrence (Bryant, 2005).

Droughts have affected different parts of the EU with varying intensity and spatial impact. Namely, since 1980, droughts in Europe have become more frequent, with territories engulfing them increasing and the consequences having tripled (Werner and Collins, 2012). Figure 3.2 shows the significant droughts in the last two decades that have occurred in Europe.

In Serbia, the strongest droughts have been recorded over the last two decades. Significant droughts were recorded in 2000, followed by 2003 and 2007. The characteristics of these droughts are the drastic absence of rainfall and the large number of days with extremely high temperatures during the growing season. It is characterized by the 2011 drought, which became extremely severe at the end of the growing season when 39 tropical days were recorded. A severe drought hit Serbia in 2012, when July was the warmest since meteorological data was recorded. In 2012, drought damage was estimated at two billion euros (Petrovic and Grujovic, 2015).

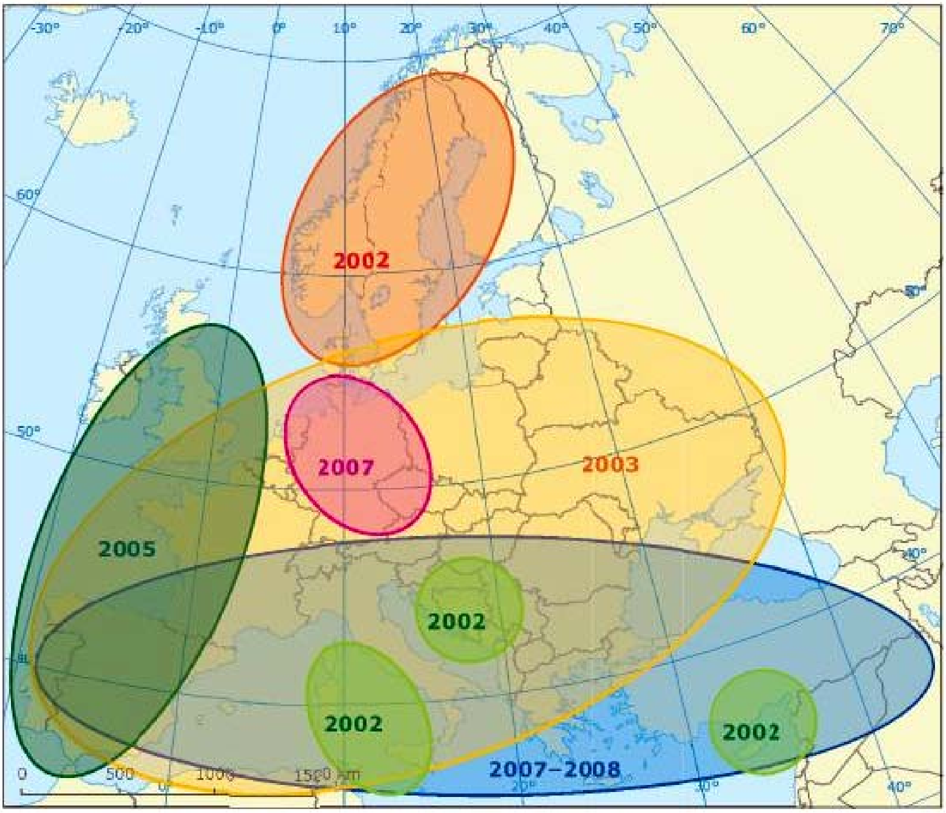

Figure 3.2 - Recent extreme droughts in Europe and affected areas (Tallaksen et al., 2011)

The EU has identified water scarcity and droughts as one of the main priorities of environmental policy (Stein et al., 2016). Accordingly, the EU's drought policy objectives include:

- promotion of drought risk management,
- promotion of drought preparedness and mitigation and planning measures and
- consideration of financial aid tools.

In order to achieve the planned goals, the EU established in 2007 a Communication from the Commission to the European Parliament and the Council, entitled "Addressing the problem of water scarcity and drought in the European Union" (Communication from the Commission to the Council and the European Parliament, 2001). The Communication underlines the importance of analyzing the situation and adapting to climate change. The need to move from drought crisis management to drought risk management is emphasized and an integrated approach to water management is required to successfully address the impact of drought. Specifically, the increasing frequency of droughts and the heavier holdings produced by this natural disaster over the last two decades has motivated the EU to make major improvements from a crisis-oriented approach to the preventive approach, ie., to manage the risk of drought. The Communication identified a number of actions to be taken at EU and national level.

3.5 Good practices and learned lessons across Europe in preventing and managing water scarcity, flood and drought situations

It is clear that there are no universally acceptable environmental risk management practices such as floods or droughts (Environmental aspects of integrated flood management – case studies, 2017). Each country regulates risk management principles according to the local hydro-climatic, topographic and socio-economic environment, all according to its capabilities and priorities.

3.5.1 Sava river basin management

Good practice in flood management and prevention has been taken and discussed is an example of Sava River Basin Management. The management of the Sava River Basin is an example of transboundary cooperation between the countries through which the Sava River flows with the primary goal of sustainably navigating, protecting the ecological system and protecting against the adverse effects of water. Table 3.1 shows an overview of countries' share in the Sava River basin territory.

Table 3.1 – Countries' share in the Sava River basin territory (Flood Risk Management Plan for the Sava River Basin, 2018)

	SL	CR	BA	RS	ME	AL
Total area of the country [km^2]	20.273	56.542	51.129	88.361	13.812	27.398
Share of the country's territory in the Sava River Basin [%]	52.80	45.20	75.80	17.40	49.60	0.59
Area of the country in th Sava River Basin [km^2]	11.734	25.373	38.349	15.147	6.929	179
Share in international Sava River Basin [%]	12.01	25.97	39.25	15.50	7.09	0.18

Recognizing the great importance and value of the Sava River Basin through which the Sava river flows - Bosnia and Herzegovina, Croatia, Slovenia and Serbia signed the Framework Agreement on the Sava River Basin in Ljubljana in 2004 (Law on ratification of the Sava River Basin agreement, Protocol on the navigation regime to the framework agreement on the Sava River Basin and Agreement on the amendments to the framework agreement on the Sava River Basin and the protocol on the navigation regime to the framework agreement on Sava River, 2004). The topography of the Sava river basin is given in Figure 3.3.

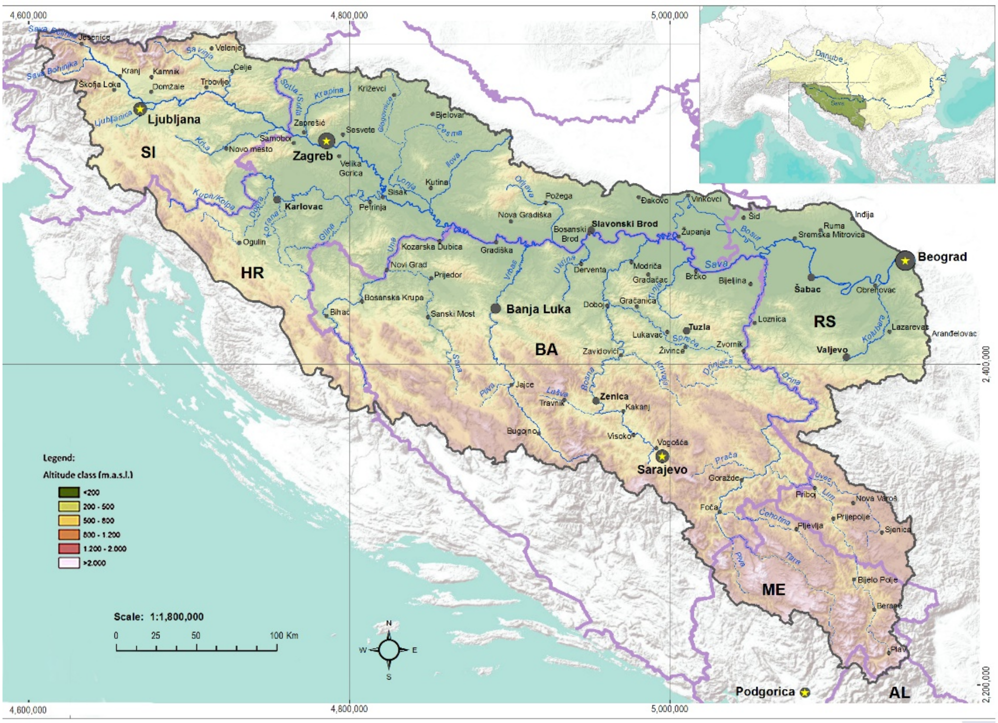

Figure 3.3 - Topography of the Sava River Basin

The main objective of the Agreement is to establish a regime of navigation on the Sava River, sustainable water management and take measures to prevent and reduce the harmful effects of floods, ice and droughts. As the Sava River is part of the Danube River Basin, where several international legal regimes apply in the area of water and environmental law and where EU regulations are in place, the Framework Agreement had to take into account all European Union acts related to the Danube. In order to ensure the implementation of the contract, an international Sava River Basin Commission was established, ie. Sava Commission.

Taking into account Directive 2007/60 / EC, the members have drawn up a single Flood Risk Management Plan in the Sava River Basin (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007). The preparation of the Plan was preceded by the preparation of the Preliminary Flood Risk Assessment, Flood Hazard Maps and Flood Risk Maps. There was tended to national methodologies, in defining these elements.

Based on the Preliminary Flood Risk Assessment, each side identified areas of the Sava River Basin in its territory that it concludes that a potential significant flood risk exists or could be considered likely to occur. The summary results showed that there were 21 areas of common interest for flood protection in the Sava River Basin, for which each party to the Agreement was obliged to prepare flood maps, Figure 3.4.

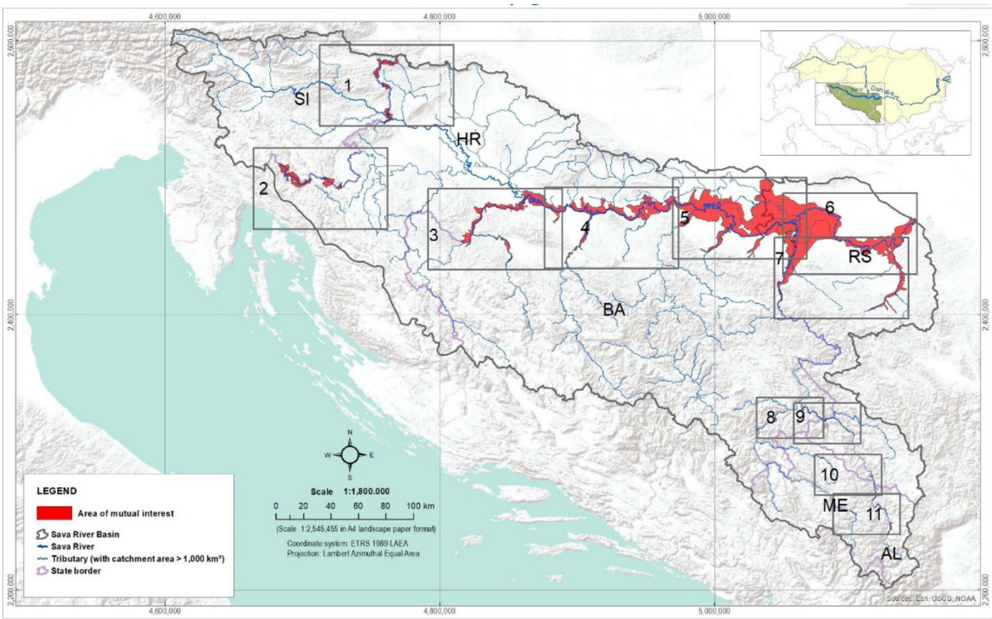

Figure 3.4 - Areas of common interest for flood protection in the Sava River Basin (Flood Risk Management Plan for the Sava River Basin, 2018)

Flood Hazard Maps at the Sava River Basin level have been prepared for the following scenarios:

- floods with medium probability of occurence (100 year return period) and
- floods with low probability of occurrence, corresponding to extreme event scenarios.

Flood Risk Maps have been prepared based on information showing the potential adverse consequences associated with the two flood scenarios mentioned.

It should be emphasized that the key elements of the Flood Risk Maps are:

- a description of the geographical area that could be flooded under different scenarios based on flood hazard maps and
- a description of the potential adverse effects of floods based on the flood hazard maps for the above scenarios for the Sava River Basin.

In making the Flood Risk Management Plan for the Sava River Basin, the signatories to the Agreement, for the sake of uniformity, were required to adhere to the guidelines of the Program for the Development of the Flood Risk Management Plan for the Sava River Basin, adopted in 2017 (Program for development of Flood Risk Management Plan in the Sava River Basin, 2017). The structure of the Plan is given in Figure 3.5.

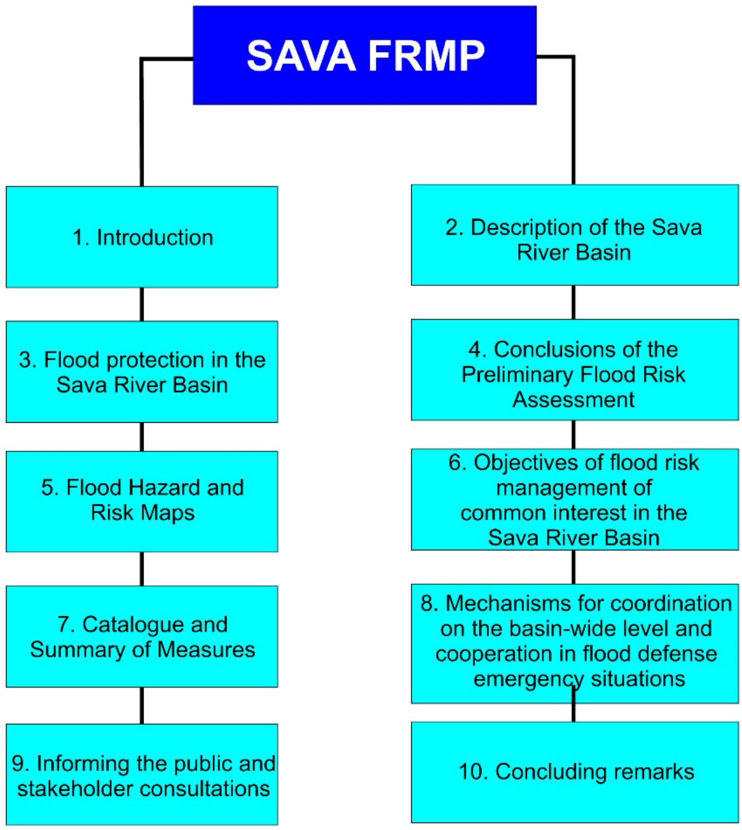

Figure 3.5 - Structure of the Flood Risk Management Plan in the Sava River Basin (Program for development of Flood Risk Management Plan in the Sava River Basin, 2017)

The Risk Management Plan also contains annexes explaining the specific activities in detail:

- Annex 1: List of competent government bodies and institutions for Protocol implementation
- Annex 2: List of multilateral and bilateral agreements in the Sava River Basin
- Annex 3: Proposals of elements of a Joint methodology for preparation of flood hazard and risk maps, and a Simplified methodology for cost-benefit analysis for implementation of measures

- Annex 4: Overview of elements used for preparing flood hazard maps according to national methodologies
- Annex 5: Summary of Measures
- Annex 6: Maps
- Annex 7: Literature

The Flood Risk Management Plan defines the objectives of the flood risk management of common interest at the Sava River Basin level (Flood Risk Management Plan for the Sava River Basin, 2018). The objectives of the Flood Risk Management Plan, of common interest for the Sava River Basin, are aligned with the objectives of the Danube Flood Risk Management Plan and are:

- avoiding new flood risks,
- reducing the existing flood risks during and after the floods,
- strengthening resilience,
- awareness raising about the flood risks and
- applying the solidarity principle.

The Plan also contains measures to achieve the set objectives, a way of coordination at the basin level and a way of joint action of the parties in emergency situations of flood defense.

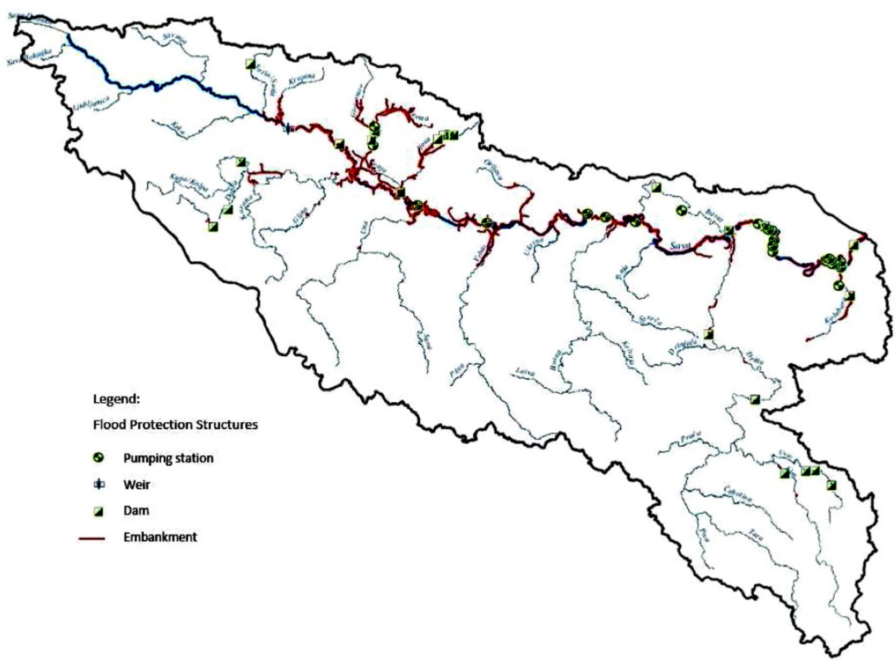

Figure 3.6 - Flood protection measures in the Sava River Basin (Flood Risk Management Plan for the Sava River Basin, 2018)

The Flood Risk Management Plan also provides a catalog and overview of measures to reduce the potential adverse effects of floods on human health, the environment, economic activity and an overview of measures to reduce the likelihood of floods occurring, Figure 3.6.

Proposed measures are grouped into 4 groups:

- regulation of land use and spatial planning,
- re-establishing earlier and forming new retention capacities,
- structural flood protection measures and
- non-structural measures.

According to the European Commission guidelines, the measures in the catalog are categorized under 5 aspects: flood prevention, flood protection, preparedness, recovery and review.

Permanent expert groups for the management of the Plan, for the GIS and for hydrological and meteorological issues have been formed to address specific tasks related to flood risk management.

The Management Plan specifies in detail how the proposed measures will be financed.

Raising awareness of exposure and vulnerability to flood risks is a key step in building resilience. Effective solutions to strengthen resilience should strengthen capacity and increase public understanding to make it faster and more flexible in the event of a disaster.

3.5.2 Implementation of the Flood directive in six European countries

The practice of flood risk management in individual countries can be viewed on the basis of the implementation of Directive (2007/60/EC) explicitly chosen by the EU legislator as a legal instrument. The implementation of the principles of adaptive management approach (the regulator adapts to the system being managed and whose parameters change or are initially independent) analyzed the implementation of the Flood Directive at national level in Belgium (Flemish Region), England, France, Netherlands, Poland and Sweden (selected are countries with different flood risks, geographical location and legal system) (Priest et al., 2016).

In the paper (Priest et al., 2016), an analysis of the implementation of the flood Directive (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007) in the legislation of the states in the field of water and in the draft flood risk management plans was carried out, focusing on the answaers to the following issues:

1. What is the objective of EU flood risk policy and how is it designed to fit the EU legal framework?
2. How is the Floods Directive implemented and integrated into the legal and existing approach to flood risk management within each country? What changes in flood risk management have resulted?
3. To what extent has the Floods Directive succeeded in promoting adaptive governance and increased social resilience to floods? What recommendations can be made to improve resilience at national and EU level?

The analysis was supplemented by interviews with professional stakeholders. Furthermore, concrete examples in practice were considered to highlight the good or bad cases of implementation of the Directive.

The overall conclusion of the analysis is that the effect of the implementation of the Directive is variable and even problematic in the part of rivers with international basin. Possibilities and obstacles to more effective impact on flood resilience have been identified. It was pointed out that it is possible to strengthen the implementation of the Directive by closer cooperation and by providing greater power to the competent authorities, especially in international river basins. It is important to emphasize that the Directive has had a positive impact on flood risk management planning and has been particularly influenced by the binding six-year planning cycle.

3.6 Conclusion

Natural disasters such as floods and droughts cannot be prevented and will continue to happen in the future. Although these two phenomena are independent from a hydrological perspective, the way the surface water occurs is their main cause. Understanding the relationship between floods and droughts is important for the effective sustainable conservation of water and therefore for managing flood and drought risk.

Flood and drought management after their occurrence replaces the principle of flood and drought risk management. The paradigm of control the flood and drought as ineffective transitions to new concept coping with disasters and risk management.

According to the legislation, flood risk management is managed by a management plan that ensures the reduction of possible adverse effects on human health, the environment and the economy. Plans are made by authorized legal entities and their quality depends on the quality of the substrates, ie on the preliminary assessment of risk and hazard maps and flood risk maps that systematically consider the risk. Successful drought risk management involves drought forecasting, monitoring, impact assessment and effective response. Risk management involves a series of activities and measures that are carried out at all times, regardless of whether a disaster has occurred.

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4 MANAGING THE QUALITY OF STORMWATERS

Goran Sekulić, University of Montenegro, Faculty of Civil Engineering
Ivana Ćipranić, University of Montenegro, Faculty of Civil Engineering

Abstract

Stormwater systems are compulsory elements during the urban planning of cities. The purpose of these systems is the protection from rain water, and they are designed and constructed mainly for the urban residential area. The literature of the stomwater runoff's quality from urban and suburban basins demonstrates the presence of a wide range of pollution influences that can appear in these waters. Due to big variations in the quality of stomwater runoff among different basins, or due to seasonal variations within a basin itself, there is not a unique approach and legislation regarding protective measures of pollution that is received by stormwater runoff. This report is a review of possible measures and technical solutions that can be adopted to solve the problems of managing the quality of stormwater runoff. The adoption of these measures could secure the preservation of the environmental quality status.

4.1 Introduction

The urban planning affects the hydrological cycle in urban areas, since it increases the surface runoff and decreases the infiltration as well as the evepotranspiration. The increasing of the runoff coincides with higher probability of flooding of urban areas. The implementation of urban planning schemes decreases the water volumes that supply the underground reservoirs as well as deteriorates both the surface and groundwater waters' quality. In order to protect the exising water resources in urban areas and to decrease the risk of damages caused by the water, it is essential to manage city waters in an integrated way. The important component in this process is the management of the stormwater runoff and its quality. Products of burning, substances made out of warned out vehicle parts, industrial pollution products etc. are settling from the atmosphere on urban areas. During rains, these substances are separated from the ground and transported by runoff, which makes runoff quality endangered comparing to its natural condition. The protection of the environment should include the treating of stormwater runoff, including all technical measures thata contribute to it, such as building of cargo overflows in mixed sewage system etc. The ultimate goal of managing the stormwater runoff quality is the decreasing of negative effects of human activities.

This includes applying appropriate measures to control negative effects of unfavorable quality of stormwater runoff, so some limit values are not to be exceeded, which thereafter could endanger survival of receiving bodies of water.

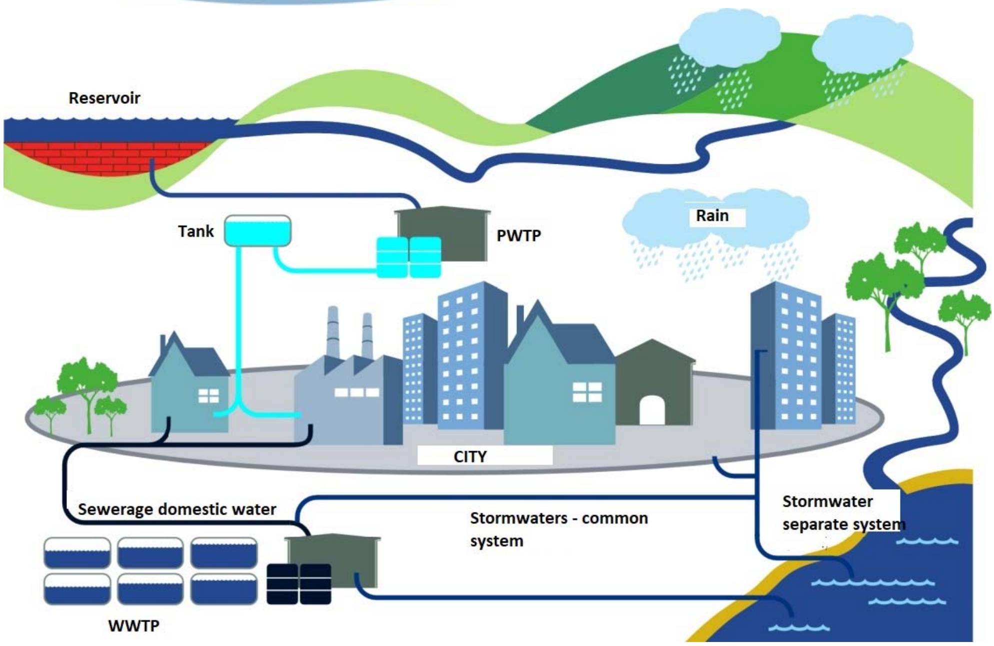

Figure 4.1 - Typical urban water cycle. (Adapted from CM, 2009)

4.1.1 Issue of quality of stormwater runoff

In order to decrease or eliminate negative effects of waste waters on receiving bodies of water and environment in general, it is essential to clean the waste water before discharging it into these receiving bodies. The procedure of cleaning the water aims at separating to some extent the pollutant substances from the waste waters. The extent of cleaning of the waste waters is defined by appropriate administrative measures for protecting the environment, while it is conducted by applying various cleansing procedures. The implementation of these measures is controlled by responsible institutions.

For households waste waters (sanitary waters), as well as sanitary waters from institutions and factories, which are connected to pubic sewage collecting system, there is a clear procedure of controlling their collecting, treatment and discharging it into natural water bodies. The values of maximum allowed concentrations for major pollutants are clearly defined in national legislations. Examples of pollutans that appear in the waste waters are: organic pollution in different forms (expressed by 5-day biochemical oxygen demand – BOD_5 and chemical oxygen demand – COD), suspended substances, nitrogen and phosphorus compounds.

The values of the maximum allowed concentrations that were mentioned cannot be applied to stormwater water outflows. The ifficulties in satisfying the needs regarding the requiring quality of stormwater's runoff before being discharged to a natural water body, originate in the appearance of accidental features in the stormwater, large changes in flows, different pollutants that can appear and big variations of pollution concentration, both in space and time. The main atmospheric water pollution sources are vehicles, air percipitates, as well as the precipitation itself. The other possible sources that appear less frequently are accidental spillings of petrol, oil and lubricants during car accidents. Beside that, the pollution from highways can appear during roads' maintainance, such as spilling sand and salt or use of herbicydes in order to prevent weeds growing. All these pollutions are doubtlessly accidental.

Various basin surfaces act differnetly regarding the atmospheric runoff from them. With impermeable surfaces, the first runoff (first flush) releases the most pollution, because the rain washes the impurities on impermeable surface first (highway, pedestrian zones, roofs, etc). Rain intensity cannot affect the quantity of rain pollution significantly. Typical pollutions in such cases are suspended substances, heavy metals and oils (occasionally), while contents of BOD_5 and nutrients is usually relatively low. Most permeable surfaces (lawns, soil) do not show signs of initail highly polluted runoff, yet the quantity of pollution primarily depends on intensity and duration of rain. Typical pollutions are suspended substances, BOD_5 and nutrients.

Table 4.1 - Typical annual pollution loads from areas of various purposes, expressed in kg/ha annually (Hvitved-Jacobsen and co, 2010)

Parameters	Area type – Land use						
	Commercial	Habitation			Industry	Roads	Parking lots
		High density	Medium density	Low density			
TSS	1100	450	270	10	550	1000	450
TP	1,7	1,1	0,4	0,05	1,5	1,0	0,8
TKN	7,5	4,7	2,8	0,3	3,7	8,9	5,7
BOD_5	70	30	15	1	-	-	53
COD	470	190	60	10	230	-	300
Pb	3,0	0,9	0,06	0,01	0,2	5,0	0,9
Zn	2,3	0,8	0,1	0,05	0,4	2,3	0,9
Cu	0,4	0,03	0,03	0,01	0,1	0,4	0,07

The research on the stormwater runoff quality from urban and suburban basins performed so far indicates the presence of the following pollutions most frequently:

- Ogranic pollutions, expressed as BOD_5, are present in lower concentrations at urban basins and highway runoffs, but their concentration can be higher in cases of runoffs from rural soils (green areas, fields);
- Suspended substances are considered to be major pollutants of stormwater runoff because they are present in significant concentrations, which depends on using the basin soils and rain features (intensity, duration);

- Heavy metals, such as copper, cadmium, nickel, chrome and zink are present in stormwater runoff in wide concentrtions' extent and their concentration shows a good correlation with concentration of suspended substances, which primarily depends on way of using the basin soils (where high concentrations usually appear in highway runoffs);
- Oils and lubricants are only temporarily present in stormwater runoff and their presence indicates accidental pollutions (oil and petrol leakages from motor vehicles, oil rainwash from factories' surfaces where uncontrolled oil outflowing happened);
- Nitrogen and phosphorus compounds are present in runoff if there is a higher quantity of rinsing from green areas.

Table 4.2 - Degree of concentration of certain pollution parameters in stormwater runoff from urban basins according to results of examinations in USA (Metcalf and Eddy, 2002).

Parameter	Concentration
Total of suspended substances (mg/l)	67-101
BOD5 (mg/l)	8-10
HOD (mg/l)	40-73
Coliform bacteria (number/100 ml)	10000-100000
Total Kjeldahl nitrogen (mgN/l)	0,43-1,00
Nitrates (mgN/l)	0,48-0,91
Total phosphorus (mgP/l)	0,7-1,66
Copper (mg/l)	0,027-0,033
Lead (mg/l)	0,030-0,144
Zink (mg/l)	0,135-0,226

Examining the quality of stormwater runoff includes gripping and laboratory analyses of a series of samples of stormwater runoff during rain and runoff periods. Beside this, it is required to measure the rain intensity on sample basin as well as stormwater runoff on that specific place. As the result of examinations, certain diagrams can be formed, showing temporal dependance of following features: flows (runoff hydrogram), concentration of certain pollutions and mass pollution flow (pollutograms). Such appropriate analyses and result interpretation require knowledge of consiered basin parameters (soil use, types of soils, etc). The researches focusing on the quality of rain's discharge show that there is a high results' dissipation depending on the location. Relatively high results' dissipation of certain pollution can be explained with presence of factories in areas where measuring takes place, using anti-freeze means during winter season as well as the range of other factors. The example of measured parameters of stormwater runoff quality from urban basins according to examonations in USA is given in Table 4.2.

Due to huge differences in quality of stormwater runoff in basins, or within one basin during various seasons, there is still no adopted unique approach and legal regulation which would clearly regulate requirements considering measures to preserve receiving body of water from stormwater runoff pollution. This field is the subject of intensive examinations based on range of experimental and urban basins worldwide, and results so far prove following things:

- Quality of stormwater runoff primarily depends on way of using the grounds and types of basin soils;
- Concentration of pollution in stormwater runoff is often the highest at its beginning (so-called „first flush“), although there are results which prove this is not always a case;
- Concentration and mass pollution release from one basin primarily depends on rain intensity (larger rain intensity – more intensive wash – higher mass pollution release);
- Having in mind that great part of pollution is rainwashed by runoff from the terrain and it originates from particles from the air, which precipitate on the surface of terrain, the examinations point that the quality of stormwater runoff can depend on time between two rainy episodes, or total time without rains during the period considered.

It is important to mention that pollution transported by stormwater runoff originates from diffused pollution sources. Therefore, it is clear that decreasing of stormwater runoff pollution emission can be achieved only by combining various measures which must include measures for decreasing it at the place of its origin, or, in other words: managing the basin areas, decreasing soil erosion, decreasing the emission of atmosphere pollution made by motor vehicles and other sources, as well as other measures. Also, some devices for treating rainwater before its runoff into receiving bodies of water can be applied, but their effect would be complete only if the appropriate examination of water runoff quality is performed, current and long-term (cummulative) pollution effects from the stormwater runoff on receiving bodies of water are determined, and cleansing device is accustomed to pecularities of the runoff and protection of receiving bodies of water’ requirements on specific considered basin.

When affecting the quality of atmospheric water into receiving bodies of water is considered, toxicity to living world in receiving bodies of water and appearing of algaes flowering in still waters have particularly negative effects, due to increased inflow of nutritients present in atmospheric waters.

During 1990-ies, a large number of national programmes for controlling atmosphere pollution sources of nature were launched, which resulted in introducing a range of new technical measures which secure higher level of protecting from negative effects of highways' atmospheric inflows.

These experiences need to be transferred to our ambinence, so that some parts of them would be considered as law regulations, and other parts would be considered as parts of planning, urban designing and highway constructing' processes.

4.2 Protection strategy

If protecting the surface and underground waters from stormwaters' pollutions is the aim, the very first thing which needs to be done is establishing their exact origin. The next required step is to estimate the type and the range of other possible sudden basin pollutions (spilling of poisonous agricultural substances but also the ones from factories and households, etc.). For each of possible pollution, it is required to determine the possibility of its appearing and make the estimation of its possible influence. With basis in such analyses, it is possible to estimate the importance of certain pollution type, in other words, the total of probability of basin pollution appearing.

If the probabilty of accident by technical measures is to be reduced, then reconsidering measures for accidents having the highest probability of appearing is to be done at the first place. If the problem is to be solved according to principles of cost-benefit analyses, then the protective measures which can contribute most to the safety can be projected for the known amount of money.

If subject is the highway, then it matters if it is urban, suburban, rural or so-called highway in „untouched nature". The first three cases' share of sudden pollution of whole basin from the highway could be lower or higher, and the forth one's share is only partial. What emanates from this is that the increasing of security from sudden pollution from the highway in first three cases can contribute less to total security than the fourth case.

If there is a chance that each project is reconsidered integrally, and if certain investments' sums could be spent to incrase security according to cost-benefit analyses, (it is also possible for some other potential pollution source), then the best results could be achieved in terms of protection. Having in mind that such way of financing is not a routine and that there are no data basis or familiar methodology which could be definied as cost-benefit analyses, what is left is to define minimum technical requirements regarding safety from highways' sudden pollution by certain criteria. These minimum requirements should be the consequence of increasing safety comparing to price analyses.

4.3 Stomwaters' treatment

Due to nature of stormwater to appear occasionally, mostly in large quantities compared to other kinds of waste waters, it is hard to apply familiar classic cleansing procedures. It is especially hard when it is about polluted stormwater from the highways outside the residential places.

In urban areas, it is possible to clean stormwater on city devices for treatment the waste waters, usualy combined with structures for inflow regulation, independently from applied sewage system. Almost every technology of primary, secondary and tertial treatment can be applied. In accordance with required standards and criteria of final discharge of waste waters into natural receiving bodies, a share of the total of rainfalls that require cleaning on the device is determined. The rule has it that cleaning discharges so-called first flush, the most loaded stormwaters' inflow, while the other part is to be diverted past the device and it is conducted into the receiving bodies without any treatment. The usual factories' routine is that through each treatment phase implements the stormwater which is usually equal to so-called dry weather flow, and also larger inflows can be mechanically cleaned. The main reason for this routine are, above all, treatment costs, because additional hydraulic factory load significatly arises the expenses of its constructing and maintenance. The constructing of rain retension basins in front of the cleaning factory was common practice, which enabled that treatment system include the amounts of the first flush, the most polluted stormwaterflush.

Stormwater from the grounds, which are located outside of residential areas (mostly highways), are not attached to city sewage systems by the rule, nor they are attached to any water treatment devices. The constructing of classical devices, which include all phases of treatment, would be hardly applicable due to discontinuity of water inflow onto them, impossibility of maintaining biological processes and their evident economical unprofitability above all. That is why the stormwaters' treatment outside the residential areas require actions which are adoptable to accidental appearing of falls by different climate and hydrological terrain conditions yet efficient, reliable and cheap in terms of constructing, running and maintaining.

4.4 Methods for controlling quality and quantity of stormwater runoff

Control of quality of stormwater runoff includes the measures which refer to previous control of runoff quality, as well as important measures for controlling the quality of overall process. The control of stormwater runoff quality includes fllowing (Woods-Ballard and co, 2007):

1. Infiltration – water percolation through the soil as a measure of decreasing water runoff on the ground. This solution is highly acceptable when the level of underground water is not too high and when there is no risk from its pollution. The efficiency of infiltration depends on granulometric terrain components into which the water is being overwhelmingly infiltrated.
2. Retension – water retension represents receiving or delaying of stormwater runoff with dry depressions, lakes or specially built underground facilities. These methods decrease the peak of the flood wave, but do not lower the quantity of water runoff.
3. Controlled way of transferring water from one basin into it, or, in other words, from one place to another by ground channels, collectors or trenches.
4. Using of stormwaterfor watering, streets washing or other purposes, depending on local conditions. In this case, what needs to be considered is the possbility of providing space for water retaining, reliability and aspects of water quality.

Table 4.3 - Recommended treatment techniques considering the type of pollution

POLLUTION	TREATMENT MECHANISM
Nutrients, phospohorus, nitrogen	Settling, biodegradation, precipitation, denitrification
Sediments, suspended substances	Settling, filtration
Hydrocarbons	Biodegradation, photolysis, filtration, absorption
Metals, lead, copper, zink, quicksilver, cadmium, chrome, aluminium	Settling, absorption, filtration, percipitation,
Pesticides	Biodegradation, absorption, evaporation
Chlorides	Prevention
Ciyanides	Evaporation, photolysis
Solid waste	Physical removal - regular maintenance
Organic substances	Settling, filtration, biodegradation

Control of quality of water runoff is accomplished by using various methods. Depending on criteria, some methods of treatment should be used before some others, and methods can be combined in multiple ways. The following chart gives the insight of recommended techniques of cleansing regarding the type of pollutant which can appear in atmospheric runoff.

The methods that are used most commonly and which are applicable are shown in the continuing part this report.

1. Percipitation is one of the primarily ways for cleansing the rain waters. The most of the pollution in runoff is connected to suspended substances, so their percipitation can significantly decrease the quantity of pollutants in the runoff.

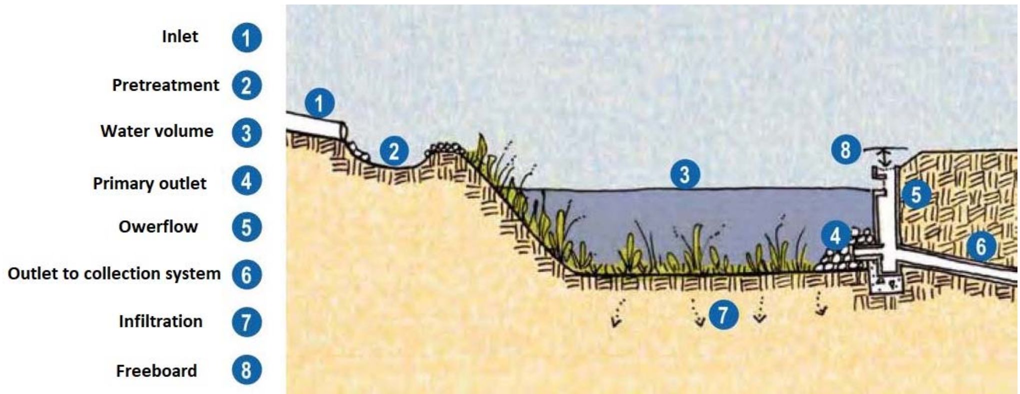

Figure 4.2 - Sediment basin for receiving atmospheric runoff – Keeps the largest sediments, applicable for basins larger than 5 ha, pollution is kept in sedimet and it can be restarted

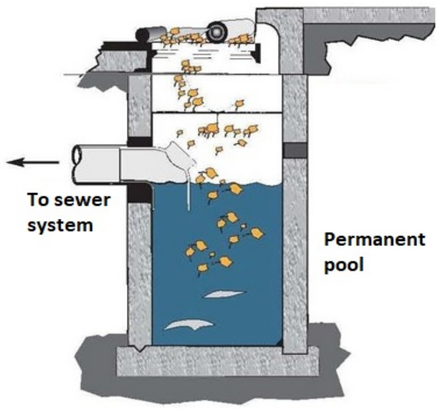

Figure 4.3 - Depositor in atmospheric sewage system shaft – Used on highways, for basins less than 1-2 ha, appropriate for urban areas

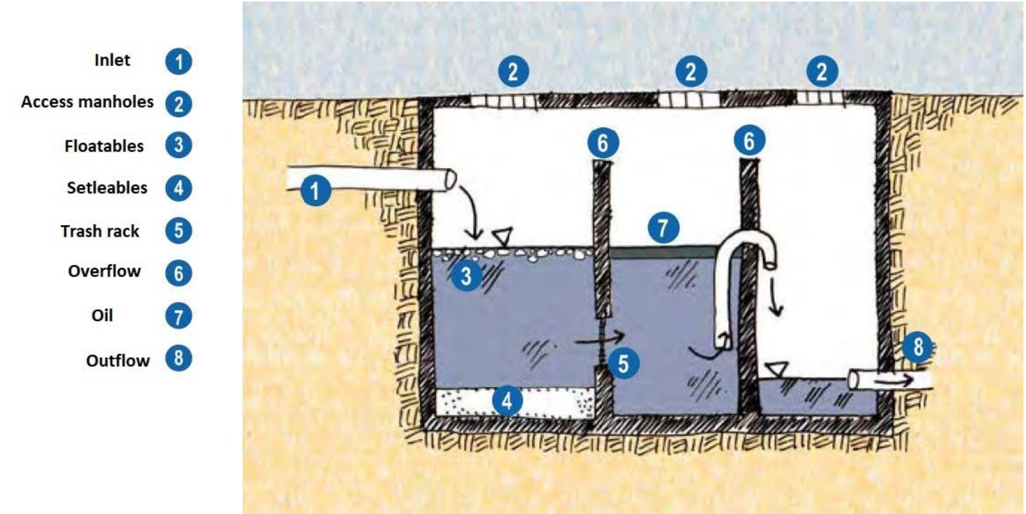

Figure 4.4 - Separator of oils and fats - appropriate for treatment of heavily polluted stormwater (pollutats from highways or any other area where petroleum products can be spilled on). Applicable for smaller basins up to 2.5 ha

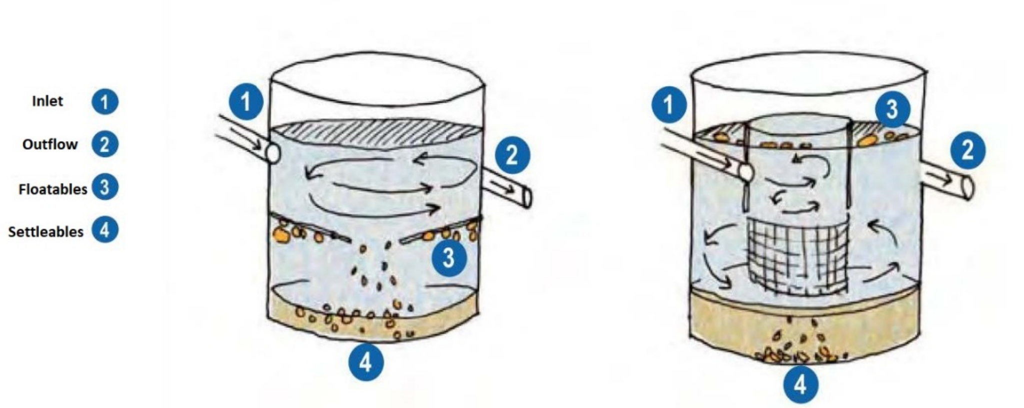

Figure 4.5 - Hydrodynamic separators (SFPUC, 2009).

2. **Filtration and biofiltration** through the soil, generator or artificial substances (geotextile) removes polluted substances by filtration. Also, biochemical processes can take place in filtering material and remove organic substances and nutrients.

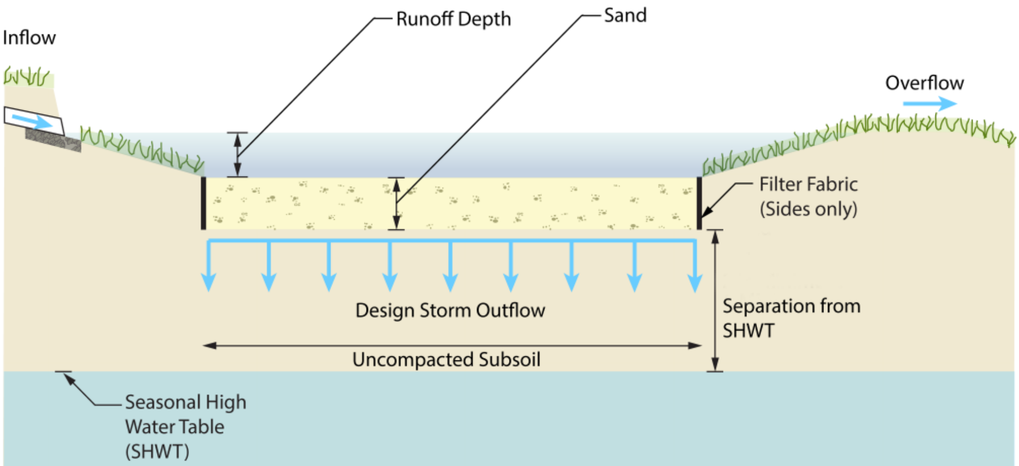

Figure 4.6 - Infiltration basin, appropriate for removing of certain dissolved pollutants, for medium permeable areas, for urban areas smaller than 5 ha

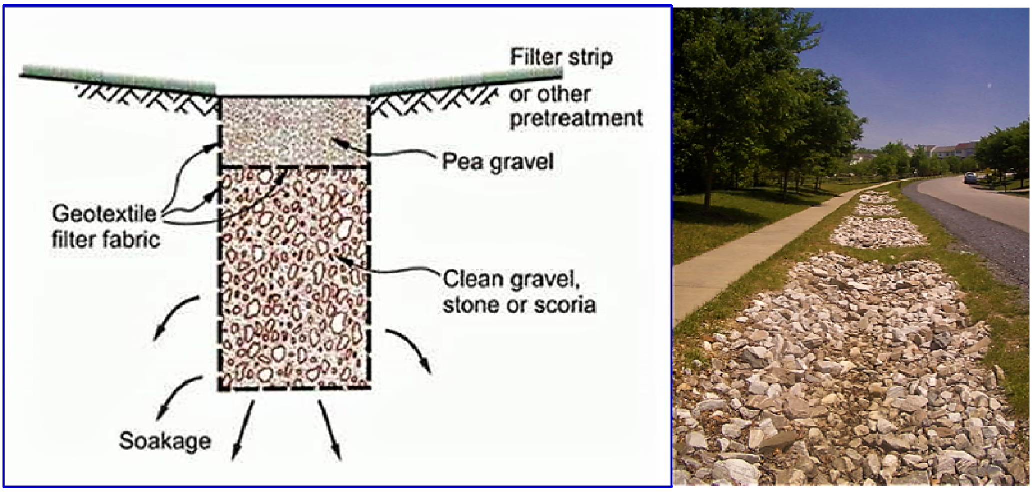

Figure 4.7 - Infiltration through sand and gravel – appropriate for medium permeable areas, removes smaller substances and some dissolved pollutants. It is applicable for urban areas, appropriate for water inflows from the roof tops for areas smaller than 2 ha

3. Absorption represents linking the pollution for solid substances surfaces. The polluted waters are running through certain substances, which can become saturated by the time and end the absorption process. There are various mechanisms against absorption (Woods-Ballard & co, 2007)

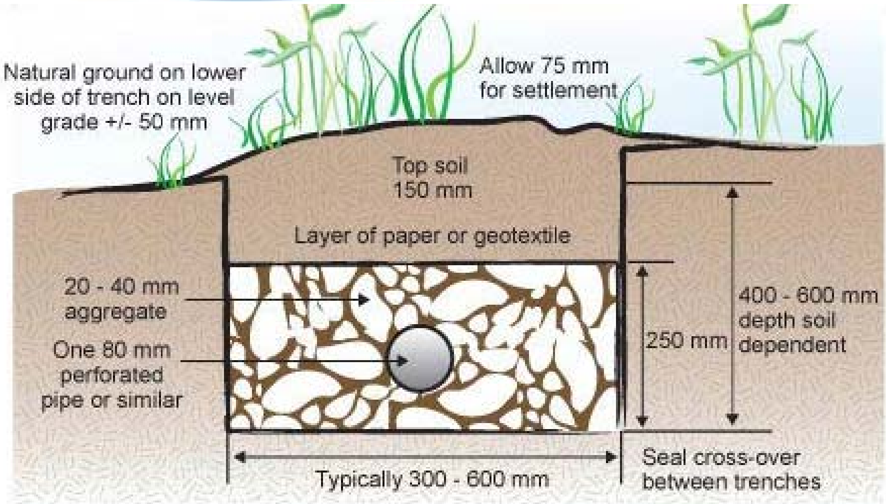

Figure 4.8 - Absorption trench – appropriate for stormwaterwith increased level of organic load, for basins smaller than 2 ha.

4. **Biodegradation** represents a biological process, where microbiological communities form biodegradable organic substances (oils, fats, etc) within ground area and use the oxygen and nutrients from infiltrated water.

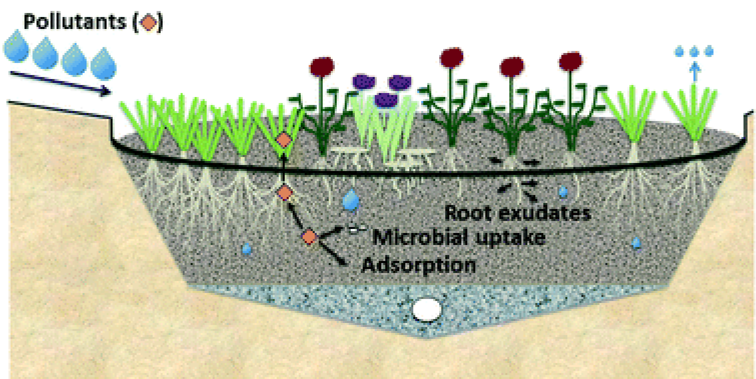

Figure 4.9 - Process of biodegradation of substances which are realised with atmospheric waters

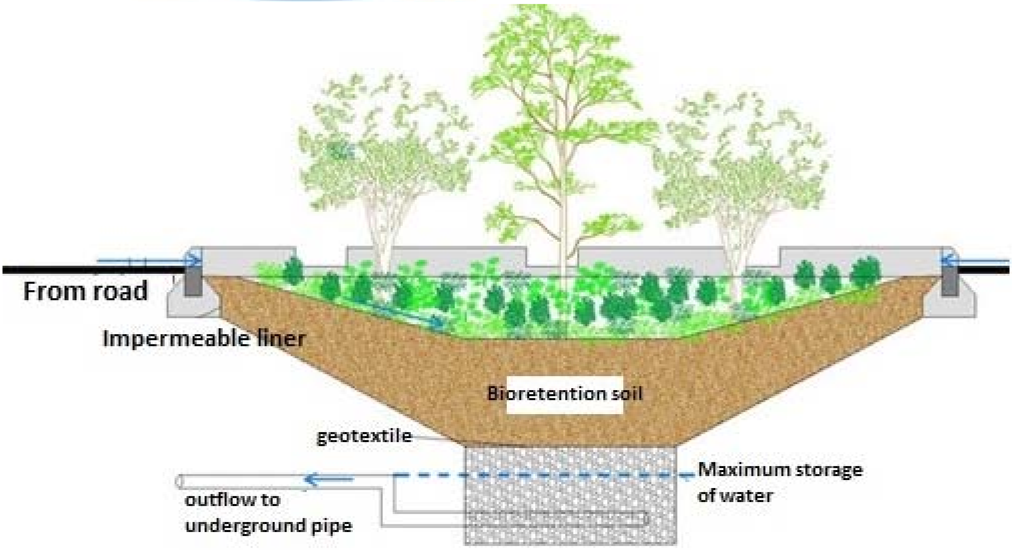

Figure 4.10 - Bioretension inlet with system basics - it performs physical, chemical and biological treatment of atmospheric water, appropriate for urban spaces and basins up to 5 ha in size

5. Plants' absorption – plants in lakes and puddles use certain compounds from the water in process of photosynthesis. This way, phosphorus and nitrogen compounds are extracted and built in into biomass, with absorbing of the other substances as well (sulphates, heavy metals). It is classiefied as tertial degree of treatments loaded by stormwaters.

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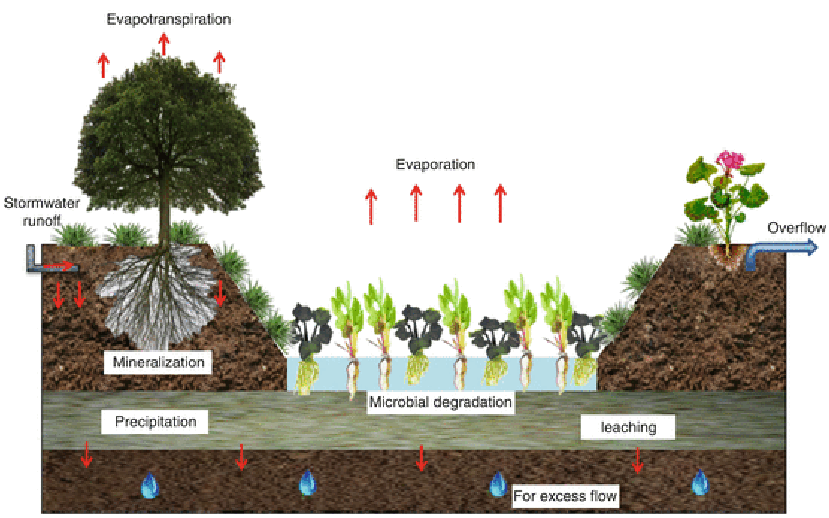

Figure 4.11 - Stormwatercleaning during the plants' cleansing process

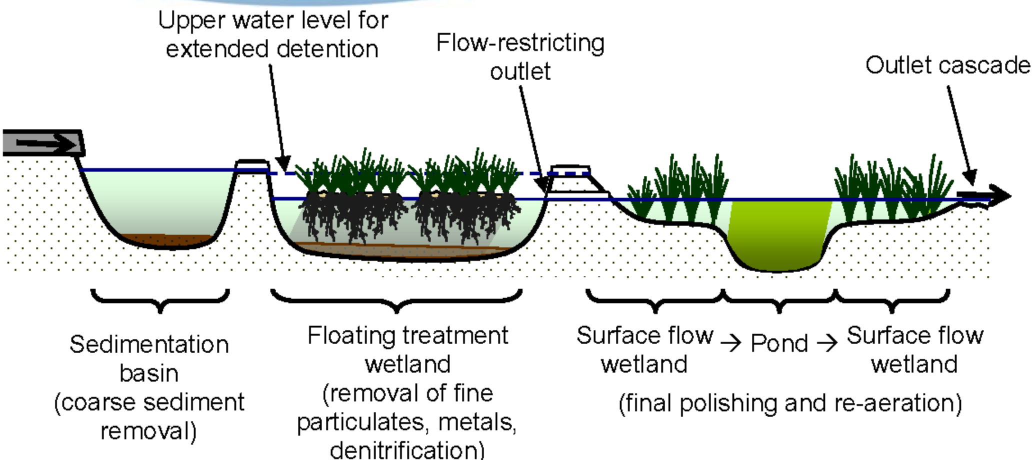

Figure 4.12 - System of artificial swamps which includes multiple phases of processing of stormwaterdischarge (into it). They keep the smaller sediments and nutritients, have a high level of efficiency in preserving different inflow quantities, possible valorization as a new type of habitat of different plants' and animals' species, help retention of flood wave. Generally applicable for basins 5-10ha in size.

6. **Nitrification** is the process where amoniac and aluminium ions form nitrates by biochemical oxidation, in presence of certain bacteria.

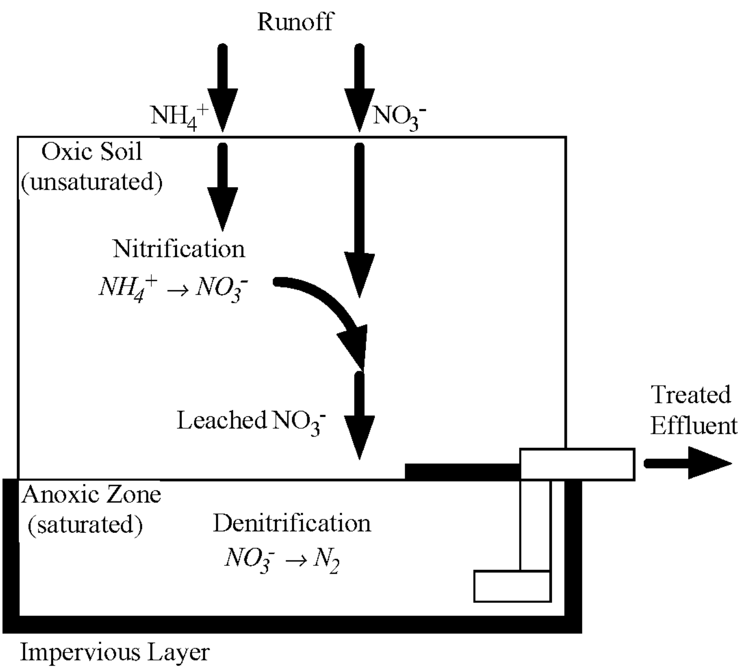

Figure 4.13 - Diagram of Modified Bioretention for Denitrification.

What becomes more present worldwide is inovative approach to managing atmspheric waters, which relies on principles of designing that would be as similar to the natural runoff conditions as possible. This approach has the starting point in principle of equal division of atmospheric runoff by its redirecting to decentralized drainage micro-systems, using the techniques which predict water retention in retensions, infiltration into the underground, evaporation, filtration etc. This approach is used to achieve the best and the fastest possible integration of stormwateraround natural enviroment, urban areas and wider. As the basis of this approach, green areas which make the inseparable part of drainage systems are treated since they can contribute to decreasing of ground stormwaterrunoff by increasing the infiltration and delaying the inflow peak into atmospheric channels for receiving bodies. Beside the effect on discharge quantity of atmosphere waters on green areas, they also have a significant effect on cleansing these waters. Some researches show that following effects can be present on them: suspended substances 97%, phosphorus 35-65%, nitrogen 33-66%, copper 36-93%, lead 24-99%, zink 1-99%, oils and fats 99%, bacteria 70%.

Green areas can be placed in the areas of highways and parking spaces, in parks and open spaces, so every open space within the range of free green areas to arranged parks and every other free space level provides the opportunity for taking care of ground waters.

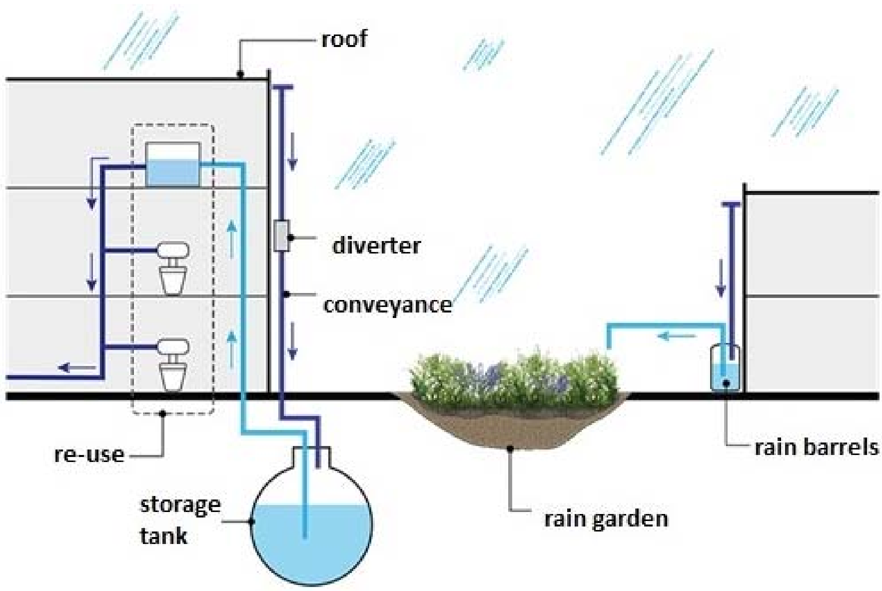

Figure 4.14 - System for collecting rain water from roof tops, cleaned by biofiltration and stores it for watering greenery or gardens, decreases the use of drinking water, but also decreases atmospheric water quantity which is released into sewage system, what makes it suitable for locations where water infiltration is not appropriate.

The idea of using stormwaterfor households' requirements should be promoted to the people everywhere (toilets rinsing, lawns and gardens watering). In area, wherever possible, the solutions of rain water drainage from the roof tops and gardens, without a drainage system or with reduced drainage system outside the estate should be potentiated. That way, the system of atmospheric sewage load would be decreased and their quality would be improved. Techniques and technologies which could be applied for this purpose are best applicable in towns with individual buildings and gardens. Some of these are rain gardens, underground retentions, green walls, green roofs, etc. It would be perfect if their applied technique would be required at urban planning and building of new towns.

4.5 Conclusion

Accelerated and uncontrolled urbanization of towns imposes the need for controlling stormwaterquantity and quality. Quality control of stormwater can be achieved by various methods which solve this problem more or less efficiently. The quantity of pollution flushed from stormwater runoff depends on surface features, existing of pollutant (highways, industry etc), as well as numerous hydrological and meteorological factors. Depending on the criteria, some methods of cleansing should be used primarily (compared to some others) and these methods could be combined on multiple levels. Large spatial and temporal applicability of every parameter of ground runoff, as well as the fact that pollution which could be flushed originates from dispersed pollution sources, represents the issue in establishing simple rules and requirements regarding controlling and pollution decreasing appearing with atmospheric waters.

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5 WASTEWATER TREATMENT AND REUSE OF TREATED WASTEWATER

Srđan Kovačević, University of Novi Sad, Faculty of Technical Sciences,
Maja Petrović, University of Novi Sad, Faculty of Technical Sciences,
Dejan Ubavin, University of Novi Sad, Faculty of Technical Sciences,
Nemanja Stanisavljević, University of Novi Sad, Faculty of Technical Sciences,
Igor Peško, University of Novi Sad, Faculty of Technical Sciences,

Abstract

The primary objective of wastewater treatment is to enable the removal of organic matter and pollutants especially nitrogen and phosphorus, without danger to human health and pollution of the environment. Treated wastewater provides an alternative source of water, particularly in areas where water is scarce. From irrigation to industrial uses to potable supply, treated wastewater can replenish water supplies and reduce the availability gap. The ultimate goal when managing resources in water scarce areas is to reach a balance among demand and availability of those resources. The circular economy offers a new way of looking at the relationships between markets, customers and natural resources, promoting sustainable and resource-efficient policies and practices. This paper provides an overview of the Wastewater Treatment and Reuse experiences and current issues.

5.1 Introduction

There are two main purposes when treating wastewater. The first and the most common is the sanitation of settlements, and the consequent need of safe disposal of treated wastewater into the environment, complying with the regulations. In terms of environmental protection, in most arid and semi-arid areas, river water could itself be treated, especially in the lower part of the river basin.

The second purpose is the wastewater reuse in its modern form, which is a relatively new concept in many communities of the world, even though it has been practiced in an empiric way for more than 5000 years and is a *de facto* phenomenon in nature and along river basins throughout the world [1,2].

The total volume of domestic wastewater generated in the world every day is estimated to be between 680 and 960 million m³ [1], but small percent of globally produced wastewater is treated and even smaller percent of wastewater is reused.

In 2017 the United Nations Global Water Report remarked that wastewater reuse is still an "untapped" source to face both water availability and its pollution. Furthermore, the World Economic Forum has listed the water crisis (availability/scarcity/management) as the global risk with the most devastating impact. Implementation of water reclamation and reuse is a key factor to pursue the sustainable water resource management. Wastewater reuse can satisfy different needs: irrigation requests, industrial purposes, potable demands, and civil uses.

It can be indicated that reuse of treated/reclaimed wastewater as technology-based practice appeared during the 20th century, after the implementation of wastewater treatment at a big scale all over the developed world, and following also the increase of population living in cities. There are right now large amounts of treated wastewater available for reuse, which is expected to increase in the future [3].

Rapidly declining surface water and groundwater quality and quantity has become a global issue with the grow of human population, expand of industrial and agricultural activities, and climate change which threatens to cause major alterations to the hydrological cycle [4]. There is no doubt that reclamation of wastewater will be an important component of sustainable water resource management [5].

In 2015 the volume of reused water in the Europe union (EU) was estimated at 1,100 million m^3/y, accounting for about 2.4% of treated urban wastewater and <0.5% of annual EU freshwater withdrawals [6].

This evidence of reuse in Europe and in the Mediterranean area [7] clearly confirms that while uncontrolled, wastewater is already present in practically all water sources used for any purpose. As a consequence, the establishment of planned and controlled water reuse systems is needed in order to guaranty a safe use of reclaimed water. Water reuse for irrigation or industrial purposes is considered to potentially have a lower environmental impact and lower costs, but it is only used to a limited extent in the Europe.

5.2 Wastewater Processes

Wastewater treatment systems tend to copy natural processes, biological, physical and chemical. The differences between facilities are based on the type of technology used and its intensity, as well as on the possible combinations of technologies. Then, quite all processes can be defined in terms of physico-chemistry, biochemistry (including microbiology) and process speed.

The processes can also be classified in terms of the type of microbiological culture: suspended or fixed. Fixed technologies (i.e. the culture is growing over a solid material) are usually more efficient than suspended ones. The suspended technologies require more energy to maintain the contact between the microorganisms and the nutrients. Extensive "soft" systems use biochemical reactions at a comparative low speed and the efficiency rate is usually improved by increasing the hydraulic residence time and occupying great surfaces. On the contrary, intensive systems reach high biochemical reaction speeds by forcing reactions with the addition of oxygen, reactive or applying agitation (mechanical or by air/oxygen under pressure), and one of its main advantages is a good relationship efficiency/space occupied.

There are three main types of reclamation treatment considered:

1. Secondary treatments capable of obtaining water suitable for reuse,
2. Tertiary treatments without disinfection, with an end-product allowing reuse,
3. Full tertiary treatments, including pre-treatment for disinfection and disinfection;

In all cases, reclamation and reuse must follow the standards or recommendations issued at different administrative levels, but new preventive approaches are appearing, based on risk assessment.

5.2.1 Conventional secondary treatment

Conventional activated sludge (CAS) plants are widely used for large communities and represent the "standard technology" for treatment of municipal wastewater. CAS systems consist of preliminary treatment, primary sedimentation, activated-sludge reactor and secondary sedimentation with recycling sludge. A treatment train that includes a combination of thickening, digestion, and dewatering processes is used to treat the excess sludge. CAS is designed to remove mainly the organic matter and nutrients (nitrogen and phosphorus), to some extent. CAS is also followed by a disinfection process in order to inactivate pathogens. The treatment performance of CAS varies with the organic load, ranging from 85 to 97% (BOD5 removal). Other high-rate secondary biological processes include trickling filters or biofilters, oxidation ditches, and rotating biological contactors [8, 9].

Innovative biological processes that include membrane biological reactor (MBR), biological aerated filters (BAF), moving bed biological reactor (MBBR), and granular sludge reactor have been developed. These technologies are already implemented in full scale wastewater treatment plants to replace CAS, and can allow the reduction of both plant footprint and excess sludge, while producing high water quality. Finally, engineered natural treatment processes such as constructed wetlands and stabilization ponds can be used as an alternative to CAS especially for small communities [10].

The selection of the wastewater treatment technology relies on a lot of circumstances. High-tech facilities are more adequate for great cities, and systems relying on natural technologies are more adequate for villages and small towns. Decision support system (DSS) considers several aspects of the area where the wastewater treatment plant should be implemented as well as the technologies that could be employed (Table 5.1).

DSS suggests a few useful treatment technologies to be applied, gathering all the relevant available information, originated from experts and past experiences.

Table 5.1 - Usual reclamation technologies for advanced treatment of secondary wastewater (not exhaustive) before disinfection [3]

Type	Technology	Comments
Physical	Additional settling	Maturation lagoons, settlers…
	Coagulation–flocculation	Reactive should be added. Stirring is necessary for a good mixing. Needs a settling step
	Filtration	Membrane technologies (nano and ultrafiltration, reverse osmosis), extensive systems with filtering materials (sand, organic matter, coal, multilayer filters…)
	Desalination	Usually membrane technologies (reverse osmosis, electrodialysis reversal)
Chemical (not disinfection)	Coagulation–flocculation	Reactive should be added. Stirring is necessary. Needs a settling step
	Fixed biofilms technologies (e.g. wetlands, infiltration-percolation)	Transformation of nutrients (mainly N forms), chemicals and organic matter (depending on the redox conditions)
Microbiological	Maturation lagoons	Settling, algae can grow at big pace
	Extensive systems (apart from lagooning)	Surface and in depth filtration in systems with sand, soil, substrate… Active role of fixed biofilms. Transformation of N forms depending on the aerobic, anoxic, or anaerobic conditions
Combined systems	MBR (Membrane Biological Reactors)	Combines a classical activated sludge (biological reactor) and in the same tank a membrane to separate activated sludge flocs)

The programme/model is always improved with new information recovered along the time and with the results generated from the new wastewater treatment plants. Depending on the initial concentration levels of several components in wastewater, the treatment processes generate variable amounts of by-products. Part of these by-products can originate in the coagulation/flocculation processes and are denominated chemical sludge, or can be formed when applying microbiological treatment technologies (activated sludge and similar). Both types of sludge are separated from water by using settlers of by filtration. Both of them contain organic matter from wastewater of different origins (urban wastewater, cattle wastewater, several industries) and chemical pollutants as well as reagents used for the processes.

Table 5.2 - Conditions to consider in a Decision Support System (DSS) for wastewater treatment [11].

Conditions to consider/comments and explanations		Remarks
Wastewater characteristics	Depends on the origin: urban, industrial, agriculture, mixtures as well as on the sewerage system	The pollutant loads/variations influence the final decision of the treatment to be applied
Amount of water to be treated	Depends on the domestic and industry water use, economy in the user's society	Usually quantified as equivalent inhabitants (e.i.). The flows have circadian, weekly, monthly and yearly patterns in relation with the activities of the population and the climate
Current rules and regulations	European Directive for wastewater or individual countries inside or outside EU, national and local rules and regulations. Reclamation and reuse has not a common EU law, but some countries' ones	Defines the final quality of treated water (to be disposed) and reclaimed water (to be reused)
Technology available	Depends on the technological and economic capacity. Best Available Technology (BAT) systems to be applied	The administrations use to be conservative in terms of technology
Landscape integration	Depends on the technology (hard or soft), the specific location of the facility and its management	Natural systems are better suited for landscape integration. Sensibility of the users/authorities is important
Economy	Capacity for adequately operating and maintaining the systems. Financial capacity limits/governs the selection	Theoretically all costs should be included in the price of water. In some places this approach is impossible
Social Acceptance	Depends on the location and characteristics of the facility and education of people	Affected by the communication policies and the end-markets demands and requirements
Centralization/decentralization	Several towns share a single WWTP/each one has its own facility	Can depend on engineering theories at the building time
Effluent quality	Depends on wastewater treatment and reuse guidelines, which can	It is necessary to perform great number of analysis, but SSP and

	define legally accepted technologies and on the activities of the population	HACCP approaches can reduce this number
Nutrient management	If water is to be disposed of in sensible areas or used for recharge, reduction of nutrient contents could be necessary	In intensive systems, nutrient reduction can be expensive in terms of energy consumption
Reuse possibilities	The end-quality necessary is fixed by the legislation. The amount of resources available (other than reclaimed water) govern the success of reuse	There are several possible uses, with defined qualities for each one. Agriculture, industry and groundwater recharge are the most demanded uses
Recycling: industries, big buildings, other structures	Marked by intended internal uses (e.g. in industry) and needed quality for each purpose	Can be successive uses inside the facility or external from the process/es: cooling, garden irrigation, boiler feeding
Available surface	Technology adapted to the site of the facility. Surface demanding technologies cannot be implemented where the land is expensive	The location of the facility site exerts an influence on the selection of the treatment (e.g. coastal urbanized areas where the facility is inside a building)

5.2.2 Advanced tertiary treatment processes

In order to reuse wastewater, advanced treatments are designed to remove contaminants still present downstream primary and secondary treatments [12-17]. However, when reclaimed water of high quality is required, it is also important to improve primary and secondary treatments (e.g. via coagulant or flocculant aid addition, increase solids retention times and nutrient removal). On the basis of numerous technologies available for the tertiary treatment, different treatment processes are available nowadays. The combination of these processes guarantees the fulfilling of high water quality standards even for direct wastewater reuse. The most implemented tertiary treatment processes are reported in Table 5.3.

Nutrient removal can be accomplished by biological processes (nitrification and denitrification). Biological phosphorus removal requires an anaerobic reactor as the first biological reactor in the treatment train, which leads to the growth of phosphorus accumulating organisms (PAO). Chemical phosphorus removal is based on the precipitation process by using aluminum or iron based coagulants and can achieve high removal (95%), but results in higher sludge production and related disposal costs [9]. TSS can be efficiently removed by granular media filtration (often sand filtration) or by coagulation (usually includes flocculation, settling and sand filtration).

Membrane based processes (mircofiltration/ultrafiltration, MF/UF, MBR) are very effective as well (nanofiltration/ reverse osmosis e NF/RO are more selective than MF/UF and are used to treat water with very low turbidity level). Among advanced oxidation processes (AOPs), ozonation is the most efficient, while UV based processes are not effective to treat water with high TSS level. The only process that can remove TDS efficiently is NF/RO [8].

Pathogens are removed to some extent by several processes, but for reuse application the physico-chemical processes (chlorination, chloramination, ozonation, AOPs) are required, even though either membrane processes or engineered natural systems (soil aquifer treatment e SAT, riverbank filtration, constructed wetlands) may play a relevant role [11,18,19]. Also, metals may be partially removed in several processes but the highest removal is achieved by coagulation/ precipitation or NF/RO [8,9]. Removal of Contaminants of Emerging Concern (CEC) is very challenging due to their polarity and occurrence at trace level. Many treatment processes show limited removal of CEC. Other processes such as granular activated carbon (GAC) or powered activated carbon (PAC) adsorption, AOPs, RO are very effective [13]. Furthermore, other treatment processes concentrate the target contaminant in a residual such as sludge, exhausted GAC/PAC, concentrate/brine. As a result, the choice of the treatment process can impact the treatment cost [13] and the product water may contain toxic by-products [20].

5.3 Advances on wastewater treatment and reclamation

The real use of reclaimed water is relying on other types of advances not related to technological approaches; i.e., the health, socio-economical and legal aspects as well as the use of new control tools and big number of data available from the compulsory analysis performed during nearly a century of wastewater reuse.

In southern Europe, water is reused predominantly for agricultural irrigation and for urban or environmental applications, while in northern Europe water is reused mainly for urban, environmental or industrial applications [21] .

An important part of the new research items is the implementation of risk assessment and management systems, namely HACCP (Hazard Analysis and Critical Control Points) and SSP (Sanitation Safety Practices). Other new approaches to wastewater reclamation and reuse include [3]:

- The nexus water-energy for wastewater treatment and especially for reclamation procedures;
- The third level nexus water-energy-food, since the most developed reuse practice nowadays is agricultural irrigation;

- The management of nutrients in the irrigation with reclaimed water, avoiding a waste of energy and efforts in the nutrients management (elimination and afterwards fertigation);
- Variations of the classical treatment approaches, like changes in lagooning design (rock filters, reduction of dead zones), the combination of wetland techniques (vertical plus horizontal in series) with sand filters (infiltration-percolation) and the changes of water distribution in reactors (upwards);
- Implementation of changes in disinfection procedures.

Several approaches to the control of reclamation are necessary to indicate if the effluent complies with the qualities established by the standards and if could be reused with an acceptable risk. One of the main problems in terms of control is the availability of the data in relation with time: usually, the analytical results reach the facility operator several days after the sample has been taken, except in the case of the data generated "in situ". It means that analytical data are mainly useful for establishing a history of the treatment plant performances instead of managing it adequately and timely.

Table 5.3 - Main types of reclaimed water reuse, characteristics, problems and other [3]

Use for	Subtype	Additional definition	Type of application	Subtype	Comments
Irrigation	Agricultural	The type of culture can also govern the practice (e.g. trees, lettuces, fodder…)	Localized irrigation	Subsurface drip, exudative pipes	Problems related with the -Salinity of the irrigation water -With sprinklers: emission of aerosols -Toxicity of reclaimed water undesirable components (e.g. toxic micropollutants) & accumulation of toxics in the environmental matrices -Soil/subsoil permeability -Runoff
				Onsurface drip, exudative pipes	
			Surface irrigation	Flood, ridge and furrows	
				Sprinklers, emitters	
	Urban (non-drinking)	Uses not requiring tap water quality	Parks & gardens (public and private), street cleaning, car washing…		-Presence of groups of risk is usual -Contact with people of all ages and conditions is expected (no exclusions)
	Leisure		Golf courses, swimming pools, theme	Mainly irrigated with	Contact with the end-user (sunbathing, children playing and

			parks…	sprinklers	pica, aerosols…) Irrigation staff present “Education” of players
			Sports' grass	Contact with skin Without contact with skin	-The risk depends on the contact with the end-users and the type of sport (see also type of irrigation) -Artificial grass/synthetic turf is also irrigated
Landscaping	Irrigation of green areas	Out of town	All kinds of irrigation systems	n.a.	-Can include firefighting -Cemeteries, median strips of highways -Woodlands, prairies…
	Urban water bodies	Sightseeing Rowing	n..	n.a.	-Can become urban ecosystems (amphibians, fish, birds, pets…) sometimes well studied
Water bodies recovery	Rivers (streams)	Flowing water	Discharge	n.a.	-Dilution/inversed dilution (more water in the environment than the reused) -Can be used for urban drainage
	Stagnant waters	Wetlands, lakes and lagoons	Discharge (direct or indirect)	n.a.	-Mainly used for maintaining/recovering the water level
	Aquifers	n.a.	n.a.	n.a.	-See groundwater recharge for details
Groundwater recharge	Direct (into the aquifer)	Recharge in general Against seawater intrusion Storage	Injection into the aquifer	Pumping Injection wells	-The risk greatly depends on the uses of the aquifer
	Indirect (surface)		Surface infiltration	Lagoons, excess irrigation…	-The risk greatly depends on the uses of the aquifer
	Indirect water bodies)		Relationships water bodies – aquifers	Permeability can be increased through management	-Strictly, cannot be considered reuse; although is included in several rules
Drinking water supply	Effluent to influent	Treatment trains combination	n.a.	The barriers concept is applied	-Increasingly practiced in case of extreme droughts (temporal or structural) -Part of the supply is reclaimed water
	From water bodies	All over the world	n.a.	n.a.	-Strictly, cannot be considered reuse; although is included in

					several rules
Industry	Cooling	Open air or closed	Steam transfer	Several types of towers	-Legionella is a main theoretical concern
	Process	Water can enter the produce	In the reactors or other	n.a.	-Water can be part of the end –product
	Cleaning	–	Cleaning machinery	–	-Careful disinfection is required

n.a. = not applicable; n.r. = not relevant

Table 5.4 - Main reclaimed wastewater usage and main related problems - not exhaustive [3]

Type	Problem	In relation with	End uses/Comments
Agriculture	Salinity	Soils, Plants	Expensive to be reduced Scarce standards
	Plant illnesses	Plant pathogens	Can affect crops
	Toxicity	Accumulation of toxics in matrices	Transmission to the consumers
Urban uses (not for drinking)	Environment pollution (urban)	Aerosols, runoff, animal health,	Mainly irrigation, but also cleaning and industrial uses
Industry	Salinity	Scaling	For cooling, cleaning, processes, …
	Human health	Aerosols, pathogens	
Leisure	Human health	Aerosols, ingestion	Irrigation (golf courses, theme parks, …), swimming pools
Recovery of water bodies	Environment pollution	Pathogens, toxics, nutrients	Increase the amount of water in the neighbouring bodies
Groundwater recharge	Pollution	Chemicals, physical pollution, microorganisms	Water for several uses
Potable	Pollution of groundwater	Drinking water safety	Direct reuse, Drinking water

5.4 Objectives and requirements of wastewater reuse regulations

In terms of rules and regulations on reuse, there are several aspects to be considered. First of all is who is issuing the document (rule) and where it would be applied. Apart from compulsory rules, like South Africa, Namibia, Tunisia, Algeria, Israel, Jordan, Greece, Italy, France, Spain, Portugal, there are several national and international organisations which published recommendations, mainly used as reference, such as World Health Organisation (WHO), Food and Agricultural Organisation (FAO), World

Bank and International Organisation for Standardization (ISO) and Environmental Protection Agency (EPA).

The European Commission proposed on May 2018 new rules to stimulate and facilitate water reuse in the EU for agricultural irrigation. Key documents:

- Proposal for a regulation on minimum requirements for water reuse and annexes;
- Impact assessment - summary and analytical models used in preparing the impact assessment;
- Assessment of impacts on Research and Innovation;
- Territorial impact assessment report;
- JRC report on minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge.

As indicated, the main concern when wastewater is reused or is returned to the environment after treatment is safety. To guarantee that safety degree is achieved there are several options, but the main one still is the application of the existing laws on wastewater treatment, which mark the quality of the treated water allowed to be disposed of in the environment or in the sewerage systems, while laws on reuse establish the different qualities of the reclaimed water to be used for different purposes from the legal point of view.

By far, the main number of reuse facilities are for irrigation (including agriculture). It justifies that quite all countries where reuse is practiced ruled water quality used for irrigation, mainly for agricultural irrigation but not uniquely [22, 23].

The effectiveness of treatments is measured by the final water quality or by comparing the initial quality with the final one, considering several, defined, parameters which are mainly related to biological quality, without forgetting "emerging" contaminants and other chemicals. This is known by "validation" of treatments, and sometimes appears in the rules, as in the draft issued by the Joint Research Centre (JRC) [24] to prepare the EU regulations on reuse.

Many cities are running out of options, and they are realizing that high grade urban water reuse is much cheaper than the alternatives [25]. Although the water scarcity and water supply demands in arid and semi-arid regions have driven reuse as an alternate water supply; there are still many water reuse programmes, for example in the US, that have been initiated in response to rigorous and costly requirements to remove nutrients (mainly nitrogen and phosphorus) from effluent that could potentially contain emerging contaminants and micropollutants [26]. Environmental concerns over negative impacts from increasing nutrient discharges to coastal waters are resulting in mandatory reductions in the number of ocean discharges in Florida and California but also in numerous sites in the UK and Europe [27].

In Europe, the practice of using wastewater for irrigating crops is growing and is particularly well established in Mediterranean countries such as Spain, Italy, Cyprus and Greece. For islands and coastal regions, water recycling allows extended and thus more efficient use of freshwater by avoiding discharge to the sea. In Gran Canaria, for example, 20% of water used across all sectors is supplied from treated wastewater [7]. In Cyprus, the reuse targets for 2014 equate to about 28% of the agricultural water demand in 2008 [28].

5.4.1 The transition to a circular economy

The circular economy presents the business model that enables the economy to grow, while minimising the amount of virgin resources that are extracted. As many states and corporations are moving away from linear towards circular models of production and consumption, there is ample evidence that shows the need for policy and regulations to enable economies to break away from a polluting economic trajectory and move to a ‘clean’ one. Although water reuse faces numerous barriers, ranging from public perception to pricing and technological, safety and regulatory challenges [29], geographical and sector-wide strategies that underpin the circular economy are emerging, and have the potential to transform some of the main barriers to water reuse. There are also new guidelines on Integrating Water Reuse in to Water Planning and Management in the context of the WFD which is in accordance with An EU action plan for the Circular Economy. The most rapid growth in global water use is in manufacturing. While many industries are still mismanaging water and waste, others have become showcases of a circular economy with promising advances in good water stewardship in the manufacturing chain, not least among small-to-medium size enterprises (SME's). Some industries have demonstrated the ability to recycle and reuse water to achieve zero net water consumption, while others are striving to demonstrate a zero-pollution record.

From a circular economy perspective, water reuse is a win–win option. The full cycle of wastewater management is a critical component of the cycle from source through distribution, collection (sewered and onsite sanitation systems) and treatment to disposal and reuse, including water, nutrients and energy recovery. Circular economy initiatives aim at closing resource loops and extending the lifespan of resources and materials through longer use, reuse and remanufacturing [31].

Water is often free, although increasingly abstraction charges signal the scarcity value of water, reflecting its potential benefits to different users and for different purposes, and the opportunity cost entailed in using it for one purpose (e.g. agriculture) rather than for something else (e.g. urban or hydropower generation). The charge rates can be different between surface and ground water users (e.g. if local rivers were very low, or aquifers falling rapidly), but often apply to both since these two resources are inter-dependent and should be managed in a unified way. Charges also vary by season, depending on the availability of water. The level of abstraction charges depends on hydrological estimates, demand projections, alternative uses, the cost of developing alternative water sources, etc.

Whether water reuse makes sense for a region depends on its cost compared with the costs of other feasible water management alternatives (e.g. new supplies, expanded conservation efforts) and the cost of not pursuing any water management changes. With a wide variety of treatment processes potentially incorporated into a reuse system to meet specific water quality goals for intended uses and to address local site-specific constraints, it is difficult to make general statements about the cost of water reuse.

Substantial portion of irrigation water in Southern Europe and especially Western Balkan Region is abstracted illegally for example from groundwater wells on site. Addressing this short-sighted and not sustainable abstraction practice, likely motivated by economic considerations, is important where planned water reuse programs are being proposed. Planned water reuse does challenge the traditional framework of water allocation, funding structures, deriving water quality standards, regulatory compliance, and institutional mandates. These issues need to be addressed and properly managed [32].

Whether reclaimed water is used for non-potable or potable uses, there are several factors that affect the costs of a water reuse program. These include the location of a reclaimed water source (i.e., the wastewater treatment facility), treatment infrastructure, plant influent water quality, customer use requirements, transmission and pumping, timing and storage needs, energy requirements, concentrate disposal, permitting, and financing costs.

5.5 Conclusions

Over the past decades, increasing attention has been directed towards the need for cheaper, more sustainable and more efficient wastewater treatment technologies that are based on environmental principles and technologies. By eliminating effluent discharges, a municipality or a water company may be able to avoid or reduce the need for costly treatment processes or maintain waste load allocations while expanding capacity. Because of inconsistent national legislation across Europe and a limited public awareness about actual risks and benefits, water reuse tends to be a costly practice subject to distrust from the general public and potential obstacles to the free movement of agricultural products irrigated with reused water are an additional risk deterring investment. Resource recycling and reuse can help close the resources loop, providing a sustainable alternative to extracting virgin resources. However, if resources are cheap, the incentive to run a throw-away society is higher, with no reason for such synergies to take place. A transition to a circular economy will encourage a more-efficient use of water, combined with robust incentives for innovation, can enhance an economy's ability to handle the demands of the growing imbalance between water supply and demand.

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6 IT TOOLS IN THE WATER RESOURCES MANAGEMENT

Đurica Marković, University of Pristina in Kosovska Mitrovica, Faculty of Technical Sciences
Jelena Đokić, University of Pristina in Kosovska Mitrovica, Faculty of Technical Sciences

Abstract

In this chapter the most used software for modeling and simulation in the area of sustaiable water resources management are presented. The authors pointed out some free software available on line. The set of programs developed by the Hydrologic Engineering Center: HEC-HMS(Hydrologic Modeling System) is a program that simulates complete hydrological processes of dendritic water systems; HEC-RAS (River Analysis System) is a program that enables one-dimensional steady-state flow, one-dimensional and two-dimensional unsteady flow calculations, sediment transport calculations and water quality; HEC-SSP (Statistical Software Package) is a program for statistical analysis of hydrological data; and HEC-WAT (Watershed Analysis Tool) is an integral tool that enables multidisciplinary teams to carry out water resource studies. EPANET is a program for hydraulic modelling of the drinking water distribution within pressurized pipe networks, but also to simulate the transport of chemical elements or compounds in distribution networks, or to monitor the quality of water in a water supply network. SWMM (Storm Water Management Model) simulates runoff quantity and quality. In the Hydrologic modeling system, the precipitation is distributed between three recepients: vegetation, land and water body, there is also a software package for simulating water, heat, and solute movement in saturated media. Hydrus program is used for calculation of the soil hydraulic properties, and roots uptake. WEAP is integral water resources management system in terms of its various supply sources (e.g., rivers, creeks, groundwater, reservoirs, and desalination plants); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation.

6.1 Introduction

The huge development of informatics in recent decades has enabled significant use of informatics for economy, science, education, etc., that is, in all spheres of human activities. Water resource management has improved its efficiency by implementing IT tools. This can be noticed from the moment when information relevant to water resources is registered, e.g. rainfall or water level measurement at some measuring point, where at any moment this information is registered and transferred to a central database and thus becomes available.

In addition to the devices that enable the management of water resources, a great importance is given to the appropriate programs that enable their efficient management. There are numerous different programs on the market for different applications in the management and use of water resources. As many of these programs are specialized, meaning that they are very complex (that is also conditioned by the complex nature of water resource management), most of these programs are for sale and often very expensive. However, there are also programs that have been developed for different needs within specific national organizations (eg Environmental Protection Agency, etc.) or science projects (eg. those funded by the EU and thus requiring project participants to be a program after the end of the project) public and accessible without restriction) or warning anyone using such programs that their use is made possible unless used for commercial purposes, thereby enabling their widespread use without copyright infringement. The basic idea of this paper is to show some of the programs that are often used in water resource management and are available for free. Also, our goal is to shortly present the possibilities of using the selected programs, in order for potential future users to decide which program could help them in their professional work. Due to the limited space, this manual will not provide a complete instruction manual for the programs.

6.2 The review of the selected programs

It should be noted that the US Army Corps of Engineers (USACE) has developed a series of programs in the Hydrologic Engineering Center to process and analyze water resource data, and on the basis of those data and defined needs, they further assess the occurrence, availability, possibility of using the water resource, i.e. water resource management. USCAE has developed a number of programs: the HEC-DSS (Data Storage System), which enables the efficient storage and collection of scientific data; The HEC-EFM (Ecosystem Functions Model) is designed to determine ecosystem responses to changes in river or wetland flow regimes; HEC-FDA (Flood Damage Reduction Analysis) is a program that enables the implementation of integrated hydrological engineering and economic analysis during the formulation and evaluation of flood risk management plans; HEC-FIA (Flood Impact Analysis) is a program that helps identify the consequences of a single flooding event; HEC-HMS (Hydrologic Modeling System) is a program that simulates complete hydrological processes of dendritic water systems; HEC-LifeSim is a program that simulates loss of life assessment with the primary intention of simulating population redistribution during an evacuation; HEC-MetVue (Meteorological Visualization Utility Engine) facilitates the viewing and manipulation of meteorological data and performs various calculations and analyzes; HEC-RAS (River Analysis System) is a program that enables one-dimensional steady-state flow, one-dimensional and two-dimensional unsteady flow calculations, sediment transport calculations and water quality; HEC-ResPRM (Prescriptive Reservoir Model Program) enables optimization of management of water distribution from reservoirs, which helps in planning reservoir operation and decision making; HEC-ResSim (Reservoir System Simulation) is used to model the management of water distribution from one or more reservoirs for different operational goals and constraints; HEC-RPT (Regime Prescription Tool) is a program that should make it easy to enter, review and document flow recommendations in real time; HEC-RTS (Real Time Simulation) is a comprehensive data collection and hydrological modeling system to support short-term real-time water management decisions; HEC-SSP (Statistical Software Package) is a program for statistical analysis of hydrological data; The HEC-WAT (Watershed Analysis Tool) is an integral tool that enables multidisciplinary teams to carry out water resource studies.

U.S. Environmental Protection Agency is authorized to protect natural resources: water resources, land and air. The technical support that makes reasonable management of the natural resources easier was developed, giving the answers on how the pollution influences human health and how to prevent or reduce the pollution risks in the future. The most known and used EPA programs are Epanet (Hydraulic modelling of the pressurized pipe network) i SWMM (Storm Water Management Model) run off modelling from the urban areas and channels.

6.2.1 HEC-SSP (Statistical Software package)

Estimates of extreme events of given recurrence interval are used for a host of purposes, such as design of dams, coffer dams, bridges, flood-plain delineation, flood control projects, barrages, and also to determine impact of encroachment of flood plain etc. Frequency analysis, if done manually, is burdensome, tedious, and leaves little maneuvering space if something wrong is noticed at the end of calculation. It often requires calculations all over again. Accordingly, this module attempts at presenting some statistical parameters, its application in flood frequency analysis, and thereafter introduces HEC-SSP software that offers multiple functions to perform frequency analysis speedily and accurately.

6.2.2 HEC-HMS (Hydrologic Modeling System)

The HEC-HMS Hydraulic System Modeling Program is a program from the HEC family of programs that simulates precipitation-runoff processes in dendritic catchments. The program is designed to be implemented in a wide variety of cases: different geographical areas, large and small catchments, natural and urban catchments, so the different types of problems can be solved. The HEC-HMS program provides hydrograms those can be used for studies of water availability in the areas considered, urban drainage, forecasts of watercourses, future impact of urbanization, reduction of flood damage, regulation of watercourses in the floodplain, etc.

The physical representation of a watershed is accomplished with a basin model, that connects hydrologic elements in a dendritic network to simulate runoff processes.

Available elements are: subbasin, reach, junction, reservoir, diversion, source, and sink. Computation proceeds from upstream elements in a downstream direction.

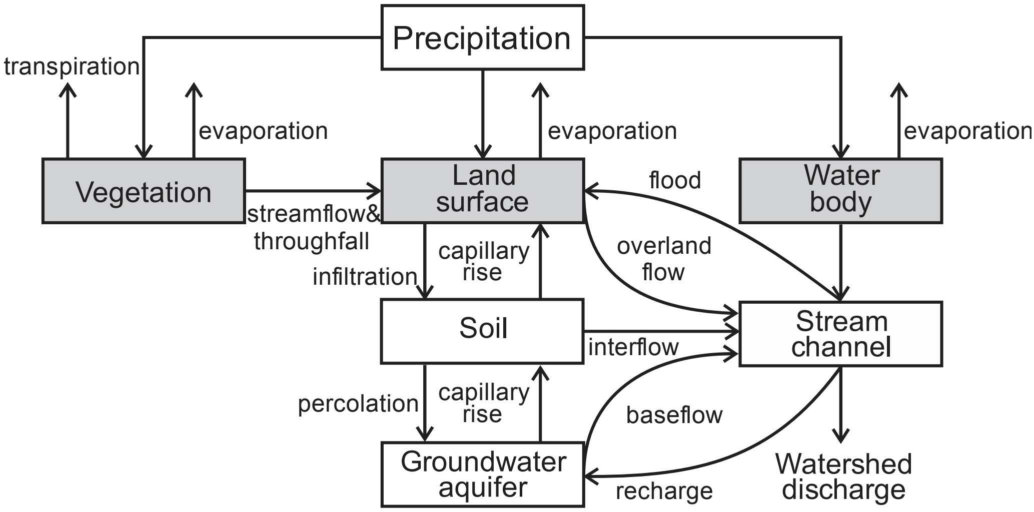

Figure 6.1 - Flow chart of the of a watershed runoff process

In Figure 6.1. there is a schematic diagram of the process Precipitation-watershed discharge as simulated by the HEC-HMS program. Part of the precipitation ends up on the soil surface, water surface (rivers, lakes) and vegetation. One part of the precipitation evaporates from all these surfaces, except in the case of stormy episodes when there is no evaporation. In addition to evaporation, some of the water from the vegetation returns through the leaves to the atmosphere by transpiration. Part of the water that has ended up on the surface goes into the soil and makes the infiltration, and part goes into the surface runoff directly to the watercourses. After the saturation of the soil, there is drainage, partly penetrating deeper into the soil towards the underground aquifers, partly retaining immediately below the soil surface towards the water bodies.

HEC-HMS calculates the runoff volume from a basin by first calculating the volume of water by interception, infiltration, evaporation, transpiration, and soil. Then that volume of water is subtracted from the volume of fallen water on the catchment area. All these processes together make up a volume of water called losses. In a program these losses can be modeled in many ways: as a constant, SCS method, Green Ampt method and moisture calculation method. The runoff can be simulated by the unit hydrogram method.

The recession method gives an exponentially decreasing baseflow : recession method showing exponential decline of the baseflow from a single event or multiple sequential events; the constant monthly method; the linear reservoir method; the nonlinear Boussinesq method which parameters can be estimated from measurable qualities of the watershed.

Simulating flow in open channels can be done by several methods. The traditional Muskingum method is included along with the straddle stagger method for simple approximations of attenuation. The modified Puls method can be used to model a reach as a series of cascading, level pools with a user-specified storage-discharge relationship. Channels with trapezoidal, rectangular, triangular, or circular cross sections can be modeled with the kinematic wave or Muskingum-Cunge methods. The constant loss method can be added to any routing method while the percolation method can be used only with the modified Puls or Muskingum-Cunge methods.Diversion structures can also be represented.

In order not to waste much time with all the data with many hydrological elements of one catchment area being inserted into the program, HEC-HMS has its own GIS module that uses already existing geometry and altitude data. This software module is called Geospatial Hydrologic Modeling Extension, or HEC-GeoHMS. This program is used to prepare model data that will be used in HEC-HMS simulations.

6.2.3 HEC-RAS (River Analysis System)

HEC-RAS is a software designed to perform one dimensional or two dimensional hydraulic calculations for a full network of natural and built channels, overbank or floodplans areas, etc.

River analysis components include: Steady Flow Water Surface Profiles, Unsteady Flow Simulation, and Sediment Transport/ Movable Boundary Computations.

The HEC-RAS is numerical software for hydrology calculations. It is widely used in one-dimensional water surface profile calculations in case of steady and unsteady river flow regimes. In addition, it contains components for one-dimensional sediment transport/movable boundary and river water quality numerical calculations. In this work, the steady flow component and the water quality component were used to perform initial temperature analysis of one short section of the river Ibar. A steady one-dimensional flow model can calculate subcritical, supercritical and mixed flow regime water surface profiles. The HEC-RAS software is used for numerical calculation. This software has long been used for one-dimensional river flow simulations. It is recently enriched with a component for the analysis of river water quality. As professional software, and at the same time simple one-dimensional, the HEC-RAS should serve as a good tool for the hydraulic model setup and the initial parametric analysis of the temperature component of the water quality model. To calculate water surface elevation and energy grade line of two adjacent cross sections the standard step method is applied to energy equation (Kalaba et al. 2014). As an example, the results of the HEC-RAS application in the Analysis of the River Ibar temperature downstream the Gazivode Lake are presented below:

Table 1.Water temperature data between the lake Gazivode and the village Suvi Do

Position	Distance from turbine discharge [km]	Time [h]	The river flow [m^3/s]	Air temperature [°C]	Water temperature [°C]
Lake Gazivode	-0.5	10:45	2	36.6 / 26.2	8.7
Turbine discharge	0	11:00	32	36.7 / 26.2	5.6
Dam Pridvorica	+1.75	11:15	28	37.1 / 26.5	7.3
Dam Trepca	+9.25	11:30	27	38.2 / 32.5	9.3
Suvi Do	+16.75	12:00	27	39.6 / 30.8	14.2

6.2.4 HEC-WAT (Watershed Analysis Tool)

HEC-WAT is a program developed for analysis of the water resources projects, including flood risk management projects, including watersheds as hydrlogic systems. Multi disciplinary process evaluation in the watershed produced inclusion of several HEC programs in one. So, in the HEC-WAT there are the following programs included: HEC-SSP (Statistical Software package), HEC-HMS (Hydrologic Modeling System), HEC-RAS (River analysis system), HEC-ResSim (Accumulation water distribution management), HEC-FIA (Floods impact assessment) i HEC-EFM (Eco systems function analysis). The development of the Flood Risk Analysis (FRA) compute option within HEC-WAT software allows a watershed or study area to be analyzed in a systems context using risk analysis and also supports risk-based analyses and risk-informed decision-making.

The goal of HEC-WAT is to help experts perform overall observation of water resources and their proper management. This was enabled by HEC-WAT through the following steps: load GIS based layers; establish stream networks and schematics; identify locations where models would share information; define the modeling software applications and their sequence order; import and edit existing models; develop new models; organize and develop alternatives, analysis periods, and simulations; run modeling software applications directly; and, view and compare alternative results.

HEC-WAT is designed to enable users:

- Entry of the appropriate data into each of the modeling programs is incorporated into the HEC-WAT framework.
- Trade-off analyses among all study alternatives will eventually be a capability within HEC-WAT through the use of consistent schematics, data, and tools. Results will be easier to compare and contrast making the trade-off analysis easier to perform.

- The definition of alternatives through schematic representations, model identification and sequencing, and tabular formatting.
- The assessment of study status by reviewing HEC-WAT outputs and reports.
- The review of modeling results at all modeled locations without the direct knowledge of how the individual models generate those results. Those attending meetings can view the results system-wide rather than reading the results for a few locations in a hard copy report or poster.

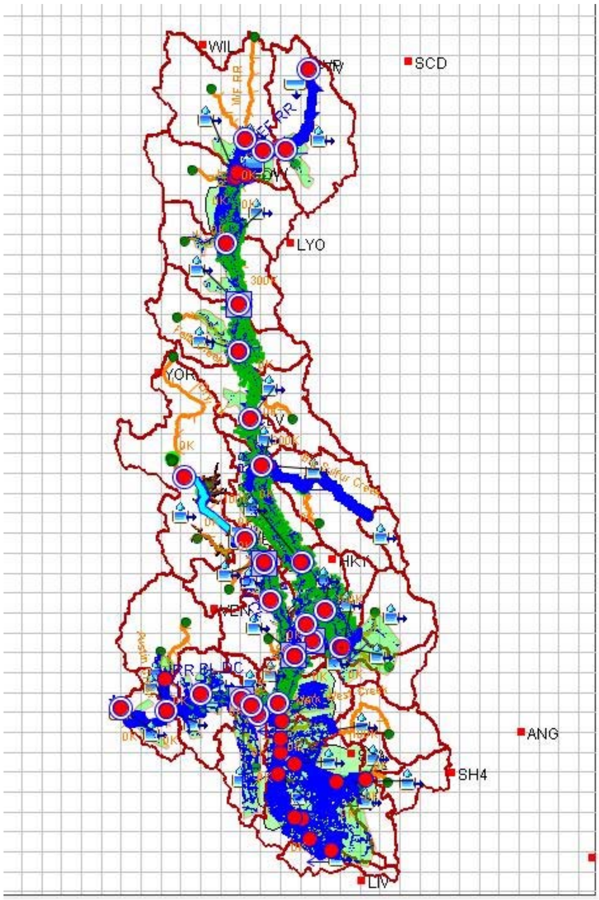

Figure 6.2 - Flow diagram of the Russian river watershed in California with all links of the inlets in the system (inflow, precipitations-run off) and system outlet (different water uses) with critical spots in the catchments considering the flood risk

In the simulation or modelling with HEC-WAT, the first step is to set the watershed boundary and to identify all gage locations (precipitation, flow..) sub-basin delineations, locations where models can share data (common computation points), damage area centers, and location of measures (reservoirs, levees, etc.).

By using the links with GIS program, the geo referencing of all objects defined in the study was done. These water bodies and water objects are presented in the scheme as well as the measures for flood prevention and environmental protection.

During the simulation it is necessary to define the period for analysis. This period can cover one or more events in the life cycle for the flood risk analysis purpose. However, if the simulation is not limited to the life cycle (usually around 50 years and it applies to the objects) neither to the damage estimation, than the analysis can take the assumption of 100 or 500 years period.

Finally, once the water management system in the basin is fully defined, different management decisions can be selected to achieve specific objectives. This method enables decision making process: in case of making larger or smaller reservoirs on the main water flow, then analyze the advantages and disadvantages of one and the other solutions from different aspects: supply of settlements and industry with water, irrigation, use for electricity production, impact of the given solutions on flood prevention, etc.

6.2.5 Hydrus

HYDRUS is a valuable software package for simulating water, heat, and solute movement in saturated media (Šimunek et al., 2008). The software package consists of a computational computer program, and an interactive graphics-based user interface. The HYDRUS program numerically solves the Richards equation for variably saturated water flow and advection-dispersion equations for both heat and solute transport. The flow equation incorporates a sink term to account for water uptake by plant roots. The heat transport equation considers transport due to conduction and convection with flowing water. The solute transport equations consider advective-dispersive transport in the liquid phase, as well as diffusion in the gaseous phase. The transport equations also include provisions for nonlinear nonequilibrium reactions between the solid and liquid phases, linear equilibrium reactions between the liquid and gaseous phases, zero-order production, and two first-order degradation reactions. In addition, physical nonequilibrium solute transport can be accounted for by assuming a two-region, dual-porosity type formulation which partitions the liquid phase into mobile and immobile regions. Attachment/detachment theory, including filtration theory, is additionally included to enable simulations of the transport of viruses, colloids, and/or bacteria.

Soil Hydraulic Properties

Graphs of the unsaturated soil hydraulic functions (various combinations of pressure heads, water contents, hydraulic conductivities, and soil water capacities) for soils in the soil profile are displayed using the command "Soil Hydraulic Properties" of the post-processing section of the HYDRUS-1D GUI (or using the menu command "Results->Soil Hydraulic Properties").

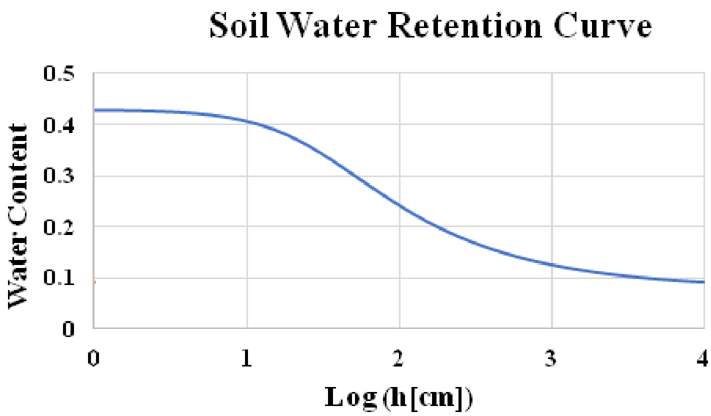

Figure 6.3 - Soil water retention curve

Figure 6.3 shows the water retention curve for the selected "Loam" soil. The horizontal axis is the logarithm of the absolute value of the pressure head, thus representing matric suctions in terms of pF units (one cannot take the logarithm of a negative number). Values of 0, 1, 2, 3, and 4 hence represent pressure heads equal to -1, -10, -100, -1000, and -10,000 cm, respectively). Plots using pF values often provide a better display of the entire soil water retention curve, including values near saturation (such as between -1 and -10 pressure heads in the current example).

The "Soil Hydraulic Properties" command allows users to view the soil water retention and the hydraulic conductivity functions of the soil or soils being studies, among other combinations of soil hydraulic properties (the list boxes of the commend provide many graphing options, including the use of regular of logarithmic scales) HYDRUS may be used to analyze water and solute movement in unsaturated, partially saturated, or fully saturated porous media. Details of the various processes and features included in HYDRUS are provided in the Technical Manual [*Šimůnek et al*., 2008].

6.2.6 Epanet

EPANET is a program for hydraulic modelling of the drinking water distribution within pressurized pipe networks. In addition, it can be used to simulate the transport of chemical elements or compounds in distribution networks, or to monitor the quality of water in a water supply network. The Epanet program helps us to improve our understanding of water movement in the distribution system. It can be used for various presentations in the analysis of hydraulic components of a water supply system, hydraulic model calibration, chlorine residual analysis, etc. Epanet can help us evaluate alternative systems management strategies, such as: when changing the use of water sources in a multi-source system, defining the schedule of filling and discharging tanks throughout the day, targeted cleaning and replacement of pipes, etc. (Epanet 2 Users Manual).

In the simulation of the water supply network the following types of objects are used: pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps.

When the water supply network is properly modeled, at the start of the program analysis, a message is received that all elements of the network are properly modeled, ie. are there any errors in the input data. If there are errors, the program logs them so that the user can track the elements in the network to correct them. When the errors are fixed, you get the message: Run was successful. After that, various analyzes of the water supply network and its elements can be performed, various graphs can be drawn, as well as simulation of the system for a certain period of time (eg 3 days) and a time step (eg 1 hour) can be performed. Different representations of system behavior over time can then be made. This allows us to analyze the water suplly system system in details.

For hydraulic modeling there is no limit on the size of the network that can be analyzed, and the computation is based on · computes friction headloss using the Hazen-Williams, Darcy-Weisbach, or Chezy-Manning formulas including minor head losses for bends, fittings, etc. Based on the pumps characteristics the program can calculate the energy needed for pumping as well as the costs in the variable speed pumps. The program models· models various types of valves including shutoff, check, pressure regulating, and flow control valves, different shapes of the storage tanks (i.e., diameter can vary with height), multiple demand categories at nodes, each with its own pattern of time variation, pressure-dependent flow issuing from emitters (sprinkler heads) and bases system operation on both simple tank level or timer controls and on complex rule-based controls.

In the user manual for the EPANET software the basic characteristics of the model are presented in the water quality modelling:

- models the movement of a non-reactive tracer material through the network over time
- models the movement and fate of a reactive material as it grows (e.g., a disinfection by-product) or decays (e.g., chlorine residual) with time
- models the age of water throughout a network
- models reactions both in the bulk flow and at the pipe wall

- uses n-th order kinetics to model reactions in the bulk flow
- uses zero or first order kinetics to model reactions at the pipe wall
- employs global reaction rate coefficients that can be modified on a pipe-by-pipe basis
- allows wall reaction rate coefficients to be correlated to pipe roughness
- allows for time-varying concentration or mass inputs at any location in the network

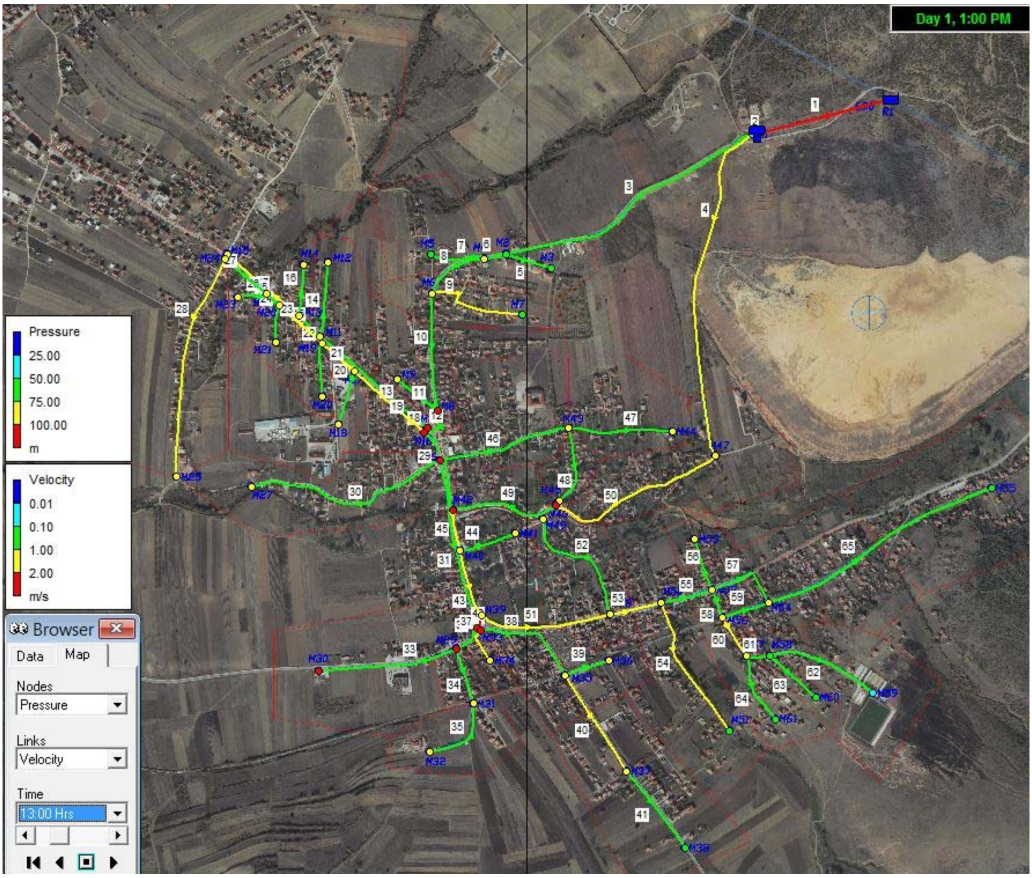

Figure 6.4 - Pressure in the nots and flow velosity in the pipes in one hour interval of time simulation

For this review, the hydraulic model of the water supply network in Gracanica was made. It can be seen in the Figure 6.4. that in the hour of the increased consumption, the velocity in the pipelines are withing the recommnded values range. That indicates well designed water supply network for the determined consumption.

6.2.7 SWMM (Storm Water Management Model)

Storm Water Management Model is a tool that was developed and improved since the first version was made on 1971. SWMM is a physically based rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality. The program is used for runoff simulation primarely from the urban areas, and the following processes are simulated: Surface runoff, infiltration, ground waters, snow melting, hydrogram propagation, surface water retention, pollution propagation.

SWMM has been most frequently used for:

- design and sizing of drainage system components for flood control
- sizing of detention facilities and their appurtenances for flood control and water quality protection
- flood plain mapping of natural channel systems
- designing control strategies for minimizing combined sewer overflows
- evaluating the impact of inflow and infiltration on sanitary sewer overflows
- generating non-point source pollutant loadings for waste load allocation studies
- evaluating the effectiveness of BMPs for reducing wet weather pollutant loadings.

Figure 6.5 - Flow simulation in the main channal in Zvecan during the previously set period of time in one hour interval for the determined loading

Three infiltration calculation models are used in the program (Horton equation, Green-Ampt method and SCS (Soil Conservation Service) method). Flow in a network can be simulated by models of steady-state flow, kinematic and dynamic waves. The concept of the program is such that the catchment areas are divided into sub-basins that gravitate to a particular node (shafts), from where they are further implemented by the channel system. The modeling uses the following objects, which can be divided into: hydrological (rain station, sub-basin, groundwater, snow deposits, unit hydrogram), hydraulic (nodes, collectors, spouts, flow distribution nodes, water tanks, pumps, regulators) flow), water quality (pollutant, land use), water treatment (low impact development control, water treatment function) and finally data objects (curves, time series, timing, control rules).

SWMM takes into consideration various hydrologic processes that produce runoff from urban areas (Mijić 2006):

- time-varying rainfall
- evaporation of standing surface water
- snow accumulation and melting
- rainfall interception from depression storage
- infiltration of rainfall into unsaturated soil layers
- percolation of infiltrated water into groundwater layers
- interflow between groundwater and the drainage system
- nonlinear reservoir routing of overland flow

SWMM also contains a flexible set of hydraulic modeling capabilities to:

- handle networks of unlimited size
- use a wide variety of standard closed and open conduit shapes as well as natural channels
- modeling special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- utilize either kinematic wave or full dynamic wave flow routing methods
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels.

As shown in the Figure 6.5. that in the hour of the increased discharge in Zvecan municipality, the velocity in the pipelines are within the recommnded values range. That indicates well designed sewer network for the determined discharge.

6.2.8 WEAP (Water Evaluation and Planning)

This program is conditionally free of charge. Nonprofit, government, and academic organizations in developing countries may be licensed for the program for 2 years. Other users must pay for the license.

Nowadays, when there is increasing pressure and demand for water resources, their distribution among various users, such as energy, agriculture, population needs for water, tourism, as well as environmental protection requires full integration of all aspects: water availability, need for water, water quality and environmental needs. For this purpose, a program for the evaluation and planning of water use or WEAP has been developed. This program is a practical but robust tool to assist decision makers in integrated water distribution planning. WEAP can handle a wide range of issues, e.g. sectoral analyzes of water demand, conservation of water as a resource, water rights and priorities for water allocation, simulations of flow and groundwater, reservoir management, hydropower generation and energy requirements, pollution monitoring, ecosystem needs and project benefits and cost analysis.

The primary objective of the WEAP is integral water resources management system in terms of its various supply sources (e.g., rivers, creeks, groundwater, reservoirs, and desalination plants); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation. Integrated water resource management means that all problems related to water needs (eg water use schemes, equipment efficiency, water re-use strategies, costs and water allocation scheme) are treated in the same way as water supply problems (eg flow, reservoirs , water transport, groundwater sources). Also, the approach of natural components is integrated with the engineering components of the water management system. This comprehensive approach makes it possible to take into account all factors that can have any impact on the water system when making decisions and managing water systems.

For using WEAP program, The study definition sets up the time frame, spatial boundary, system components and configuration of the problem. The Current Accounts, which can be viewed as a calibration step in the development of an application, provide a snapshot of actual water demand, pollution loads, resources and supplies for the system. Key assumptions may be built into the Current Accounts to represent policies, costs and factors that affect demand, pollution, supply and hydrology. Scenarios build on the Current Accounts and allow one to explore the impact of alternative assumptions or policies on future water availability and use. Finally, the scenarios are evaluated with regard to water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables.

WEAP first creates the existing state of the observed water supply system. Then, based on different economic, demographic, hydrological and technological trends, a reference scenario is defined. Thereafter, one or more policy scenarios can be developed with alternative assumptions about future development. In addition, the user can set water allocation priorities for specific users or for specific water resources.

The scenarios can address a broad range of "what if" questions (Sieber&Purkey 2015), such as: What if population growth and economic development patterns change? What if reservoir operating rules are altered? What if groundwater is more fully exploited? What if water conservation is introduced? What if ecosystem requirements are tightened? What if new sources of water pollution are added? What if a water-recycling program is implemented? What if a more efficient irrigation technique is implemented? What if the mix of agricultural crops changes? What if climate change alters the hydrology? These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

One of the advantages of WEAP is that it is adaptable to all the data available to describe the water resource system, that is, it can use daily, weekly, monthly or annual time steps to describe the available water quantities in the system as well as the stated water needs. This feature means that it can be applied at different spatial and temporal scales and allows analysis of different sets of water management issues for both small and large catchments.

WEAP can be used for solving the following questions (Sieber&Purkey 2015):

- How will water supply and wastewater treatment facilities be affected by the retention and/or diversion of storm waters?
- How will improvements in water collection systems affect water supply and wastewater treatment?
- How will modifications of combined sewer overflow systems affect wastewater treatment?
- How can reclaimed wastewater be used to augment water supply?

Among other things, the program enables the user to consider (Sieber&Purkey 2015):

- Infiltration and Inflow from groundwater to sewage collection systems. These inflows can stress rivers and streams by removing clean water from watersheds and place additional burden on wastewater treatment by taking up valuable plant capacity and limiting future sewer connections.
- Infiltration Basins & Retention Ponds as management practices. These can be used to offset the impacts of urbanization, where water demands increase and potentially threaten water supplies as more rainfall runs off of expanding impervious surfaces, rather than recharging local aquifers. They can also serve to attenuate non-point source pollution.
- Display of User-Defined Performance Measures as Results. This will allow for the output of site-specific performance measures and criteria, which are commonly guided by the objectives of individual studies and systems configuration and local conditions.

- Tiered Water Pricing policies as a means of promoting demand management.
- Combined Sewer Overflows (CSOs) that pose potential risks to public health and aquatic life, because they discharge chemicals and disease-causing pathogens directly into waterways.

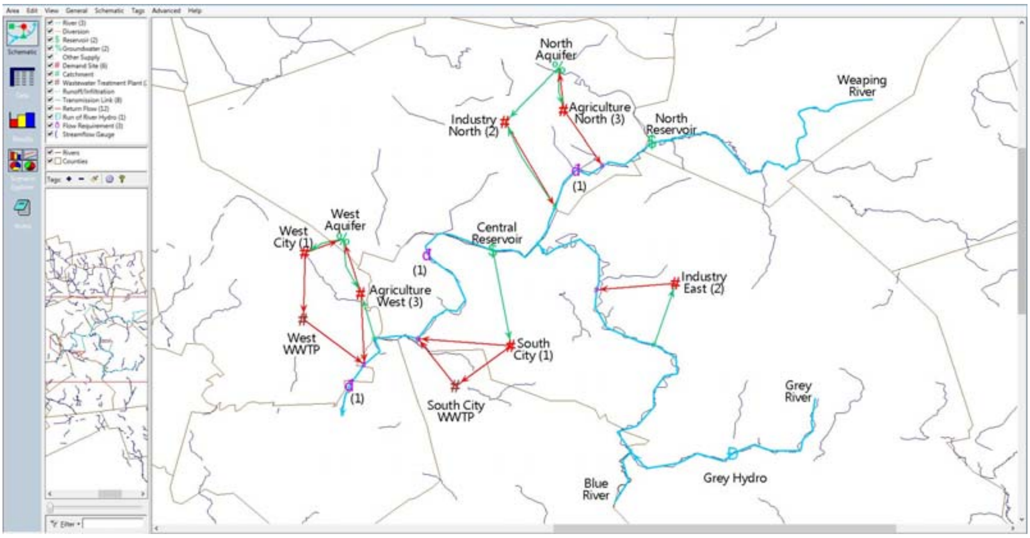

Figure 6.6 - The print screen of the water resources system delivered with WAEP installation

6.3 Conclusion

Using IT in natural resources management has become the necessity in the conditions of constant population growth and climate change. The need for fresh water, drinking water production and transportation, waste water treatment and final discharge, and environmental protection are important not only for scientists and higher level landscape planning experts, but also for professionals in the urban planning, water supply and waste water treatment professionals on the local level. The professionals are introduced with the variety of available programs for estimation, assessment and simulation of the water resources quantity and quality. They can decide to use some of them according to their needs for simulation of floods risks, sustainable water resources usage and drinking water calculation, or for a sewerage capacities in some urban area, and runoff modeling from the urban areas and channels. The comperative review of the programs and their applications was presented in the following table:

Title	Application area	Literatura
HEC-SSP	Statistical data analysis	
HEC-HMS	simulates precipitation-runoff processes in dendritic catchments	Scharffenberg, Bill, Bartles, Mike, Brauer, Tom,

		Fleming, Matt, and Karlovits, Greg 2018; Feldman, Arlen 2000.
HEC-RAS	performs one dimensional or two dimensional hydraulic calculations for a full network of natural and built channels, overbank or floodplans areas, etc	Kalaba et al., 2013
HEC-WAT	analysis of the water resources projects, including flood risk management projects, including watersheds as hydrlogic systems	CEIWR-HEC 2017.
Hydrus	simulating water, heat, and solute movement in saturated media	Šimunek et al. 2008
Epanet	hydraulic modelling of the drinking water distribution within pressurized pipe networks	Rossman, Lewis 2000.
SWMM	rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality	Rossman, Lewis 2010; Rossman, Lewis 2016 I; Rossman, Lewis 2016 II; Mijić, Ana 2006.
WEAP	integral water resources management system in terms of its various supply sources (e.g., rivers, creeks, groundwater, reservoirs, and desalination plants	Sieber, Jack, Purkey, David 2015.

6.4 Reference

Scharffenberg, Bill, Bartles, Mike, Brauer, Tom, Fleming, Matt, and Karlovits, Greg 2018 Hydrologic Modeling System HEC-HMS User's Manual, U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center (CEIWR-HEC), Davis, California, US

Feldman, Arlen (editor) 2000 Hydrologic Modeling System HEC-HMS Technical Reference Manual, U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center (CEIWR-HEC), Davis, California, US

CEIWR-HEC 2017 HEC-WAT Watershed Analysis Tool User's Manual Version 1.0, U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center (CEIWR-HEC), Davis, California, US

Rossman, Lewis 2000 Epanet 2 User's Manual, National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, US.

Rossman, Lewis 2010 Storm Water Management Model User's Manual Version 5.0, National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, US.

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Sieber, Jack, Purkey, David 2015 WEAP Water Evaluation And Planning System User Guide for WEAP 2015, Stockholm Environment Institute, U.S. Center, US.

Šimůnek, J., M. Sejna, M. Sakai, H. Saito, and M. Th. van Genuchten, The HYDRUS-1D software package for simulating the one-dimensional movement of water, heat, and multiple solutes in variably-saturated media, Version 4.0x, *HYDRUS-1D Series 3,* Department of Environmental Sciences, University of California Riverside, Riverside, CA, USA, 2008.

Kalaba D.V., Ivanović, I., Čikara, D., & Milentijević, G. (2014). The Initial analysis of the River Ibar temperature downstream of the lake Gazivode. *Thermal Science* 18(1), 73-80

7 INNOVATION IN THE WATER SECTOR – MODEL OF MANAGING A PROCESS OF WATER SUPPLY NETWORK REPAIR USING FUZZY LOGIC AND FUZZY INFERENCE

Suad Špago, Građevinski fakultet Univerziteta "Džemal Bijedić" u Mostaru

Abstract

The chapter, through the application of fuzzy logic (Mamdani method), develops a model for decision making in the management of the water supply network rehabilitation process. The fundamental assessment attributes – intensity of failure and water loss – are introduced as exact variables in the procedure of logical reasoning in the formation of evaluation criteria such as the "pipes deterioration rate", as well as in "risk criteria" which assess the risk of breakdown and water loss (as events) in the system.

The decision making model, in cases where decision criteria are qualitative, i.e. when their values are defined by linguistic scales, is based on fuzzy sets theory (Bellman-Zadeh) and is extended by the introduction of fuzzy logic to include the quantitative criteria whose previous numerical values were the result of deterministic or stochastic modelling, with use of scarce, imprecise or subjective input variables.

The concept of the model allows its use in similar decision problem classes, such as: which modern pipe reconstruction method to use, or how to choose the optimal water pipe sections when designing and extending the water supply network system.

7.1 Introduction

In order to manage a water supply network repair process, and to keep all relevant factors included in the decision making process, decision makers can include factors that cannot be represented in the form of binary, classic sets, in the process of decision making. In order to use these criteria evenly it is suggested to formulate and represent them as fuzzy sets, and to apply the Bellman – Zadeh method (Bellman & Zadeh, 1970) for decision making in fuzzy environment.

For the criteria such as: remaining life cycle of the section or zone and assumed year of a complete failure of the section or zone, numerical values are determined using a mathematical model as a tool for prognosis (deterministic or probabilistic), which connects relevant factors of the current piping state and makes a prognosis of pipe deterioration dynamics. Based on the insight into methods (models) of current state assessment, by which, according to the current practice and research, prognosis is made for pipe deterioration, it is concluded that these are procedures that imply imprecision and subjectivity. Since in the case of the conclusions from imprecise, close or subjective premises, fuzzy logic becomes a generally accepted concept, and keeping in mind current results of research in the field of assessment of pipes and their condition, suggests application of the Mamdani model (Mamdani, 1977) of fuzzy inference as a frame formalism for pipe assessment. The Mamdani method is applied in assessing conditions of pipes and the risk, based on the failure intensity and water losses, as the two most important indicators of the network, and about which information is available at the lowest cost as compared to all other indicators (TV inspection, laser, radar, ultrasound etc.). The Mamdani inference model is also suggested for assessing alternative values by financial criteria.

This chapter describes a procedure of applying the fuzzy inference model of differently ranked criteria, including the previous application of fuzzy logic inference for single criteria values.

7.2 Algorithm of ranking procedure, key activities

7.2.1 Defining zones (or sections) as an alternative

Alternative forming procedure is not analyzed into details in the available research, but it is generally considered that each water supply system is, for operational management, divided into zones. Zones or pipe sections, parts of the water supply system, defined as separate units by the decision makers, are alternatives for ranking. To define zones or sections as alternatives, the decision maker is led by technical, urban-planning or some other local conditions (quality of data on the network, age, number of connections, reliability parameters etc.), but for the size of an alternative financial aspects are crucial, i.e. available funds. It needs to be mentioned that alternatives do not represent always separate sets, zones or pipe sections, as a whole within an urban water-supply network, as shown in the figure 7.1.b., but they can be defined, as in the figure 7.1.a., in a way that some alternatives can overlap. In any case it is a multi-criteria decision analysis (multi-criteria decision making, where a set of available solutions is discrete, defined in advance and finite.

(a) *(b)*

Figure 7.1 - City zones as alternatives (a) that overlap and (b) completely separate.

In order to make alternatives comparable by some criteria in the ranking procedure, it is necessary to have information on characteristics (quantitative or qualitative) by that criterion.

Selection of criteria depends on the data on the network in the considered parts, alternatives, so forming of criteria, in addition to guidelines and recommendations (CARE-W) (Hertz, Baur, Lipkow & Kropp, 2003), is preceded by the analysis of available data.

7.2.2 Selection of attributes of importance for ranking

In general, decision makers have at their disposal a variety of data on certain alternatives that represent their attributes of differentiation, or comparison. In this step, a decision maker, out of the set of attributes, on alternatives (zones or sections) in line with the ranking goals, choses attributes of importance for the concrete ranking problem.

For the set of *n* alternatives $\{A_i\}_{i=1}^{i=n}$ and a set of *m* characteristics of alternatives, attributes, $\{a_j\}_{j=1}^{j=m}$, from the set of attributes, *k* attributes is selected as of importance for the ranking procedure, in line with the set goals, so the total number of the attributes is considered further is $\{a_j\}_{j=1}^{j=k}$ where $k<m$.

The decision maker choses from the set those attributes that are considered valuable for comparison of the alternatives in the decision-making process, and based on the specific requirements and goals of the model, in this case it is making priorities for repair work within the water supply network.[1]

7.2.3 Selection of attributes and criteria: the Mamdani's method

In the set of attributes, which are used as a basis for comparison and ranking of the alternatives, they can be divided into those that are directly and indirectly used as criteria. In the set of attributes $\{a_j\}_{j=1}^{j=k}$ selection is made of: (1) attributes directly used as variables in the process of modelling which result in indirectly selected inference criteria (e.g. pipe deterioration rate is a criterion resulting from the procedure of inference in which the input variables are the attributes *age* and *failure intensity* or *water losses* or *pipe condition assessment*, based on the application of some of the contemporary assessment methods).

In the models for indirect inference criteria, the values of the attributes as variables, imply certain subjectivity or numerical data is scarce, and because of that deterministic

[1] Procedure is valid for any ranking task, e.g. ranking of surfaces as priorities for afforestization, pavement, roof repair, facdes, fire protection: water needs, etc. or any other type of ranking.

or probabilistic models create the impression of false precision. To overcome this problem, application of fuzzy logic inference is introduced, the Mamdani method.

Fuzzy logic inference which uses attributes as variables, and results in groups of criteria, is used as follows:

Assessment criteria. Assessment of deterioration rate in considered zones or sections (as alternatives of decision making) by applying fuzzy logic is performed based on the available information on failures, losses and pipe conditions, for each zone or section separately. One input variable is selected out of: *failure rate assessment,* or *water loss assessment* or *pipe condition assessment* (based on some of the assessment methods, TV inspection, electromagnetic or laser scanning, sample testing etc.) All these processes are, as indicators of deterioration, actually functions of time, the second input variable for each one is *time*. The output variable *pipe deterioration rate* based on the failure rate, losses or condition assessment, acquired after defuzzification, is a numerical value associated to the criterion of *pipe deterioration rate.*

Financial criteria. Feasibility measure for replacement of some zones is a result of the Mamdani inference method, where the *price* of investment is one input variable. Another input variable is selected out of (based on the available data and decision maker's opinion): *network repair percentage*, *number of the zone connections* etc. The output variable of fuzzy inference is a numerical value of feasibility measure (based on the percentage of network repair, number of connections, water consumption in the zone etc.) as a criterion.

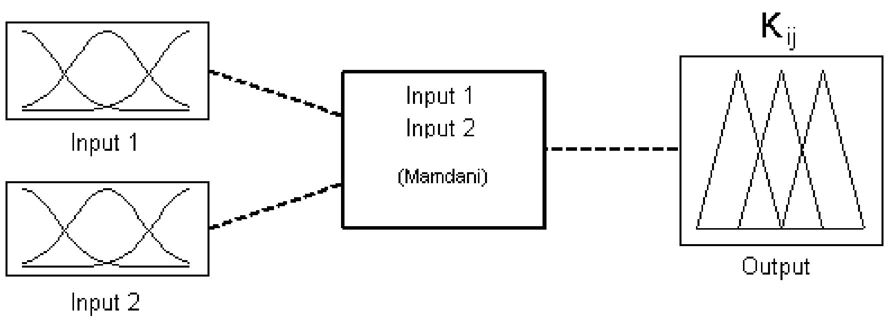

Figure 7.2 - Scheme of the Mamdani fuzzy inference method with two input and one output variable (Mamdani, 1977).

Risk criteria. These criteria include risk of consequences of events such as: water contamination, main infrastructure damage, damage of other underground infrastructure (heating system, gas pipeline, electrical network, telephone and cable network), risk of endangered traffic, interrupted water supply to the users of high sensitivity etc., which can be caused by failures or water losses in the system and its surrounding. One input variable is certainly *event consequence* while the other input variable is either *failure intensity* or *water losses* as the event causes. The output variable is the *risk* of specified event (failure or loss/es), which is a numerical value of the risk criterion. A general procedure scheme is shown in the *figure 7.2.*:

Each of unambiguous numerical values of the output variables acquired from defuzzification, by using the method of center of gravity, is a numerical value that is associated with the criterion individually for each alternative (zone or section).

Attributes selected from the set of attributes and defined as directly used criteria in the ranking process, can be generally divided into quantitative and qualitative. Quantitative criteria are associated with numerical values while for qualitative criteria fuzzy sets are defined whose values of membership function *μ(x)* are calculated and associated with the criteria as numerical values (Bellman-Zadeh method).

Acquired numerical values in the further procedure are elements of the *decision matrix* (performance matrix).

7.2.3.1 Decision matrix; criteria ranking

Each column of the matrix corresponds with one alternative X_i, each row with one criterion K_j, and the element $x_{ij} \in R$ represents rating (performance) alternative X_i as related to the criterion K_j. For *m* of the criteria ($K_1, K_2, ..., K_m$) and *n of* the alternatives ($X_1, X_2,...,X_n$) matrix *R* has the form (2). Relative importance of inference criteria is introduced by assigning of weighting coefficient w_j to the criterion K_j under the condition:

$$\sum_{j=1}^{j=m} w_m = 1 \qquad (1)$$

$$R = \begin{matrix} K_1 \\ K_2 \\ \vdots \\ K_{j-1} \\ K_j \\ K_{j+1} \\ \vdots \\ K_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1i} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2i} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & & \vdots & & \vdots \\ x_{j-1,1} & x_{j-1,2} & x_{j-1,3} & \cdots & x_{j-1,i} & \cdots & x_{j-1,n} \\ x_{j,1} & x_{j,2} & x_{j,3} & \cdots & x_{j,i} & \cdots & x_{j,n} \\ x_{j+1,1} & x_{j+1,2} & x_{j+1,3} & \cdots & x_{j+1,i} & \cdots & x_{j+1,n} \\ \vdots & \vdots & \vdots & & \vdots & & \vdots \\ x_{m,1} & x_{m,2} & x_{m,3} & \cdots & x_{m,i} & \cdots & x_{m,n} \end{bmatrix} \begin{matrix} w_1 \\ w_2 \\ \vdots \\ w_{j-1} \\ w_j \\ w_{j+1} \\ \vdots \\ w_m \end{matrix} \qquad (7)$$

7.2.4 Bellman-Zadeh approach to decision making

Having looked at the decision making matrix *R* in the context of application of the Bellman – Zadeh (Bellman & Zadeh, 1970) approach to decision making, values $\{K_{1,j}\}_{j=1}^{j=m}$ are values of membership functions of individual alternatives $X_i i=1,n$ by the first criterion K_1, i.e. if this is written in the form of fuzzy sets including weights w_j[2], respectively for each criterion up to the m^{th} the result is:

$$K_1 = \frac{\mu_{K_1}^{w_1}(x_{11})}{X_1} + \frac{\mu_{K_1}^{w_1}(x_{12})}{X_2} + \ldots + \frac{\mu_{K_1}^{w_1}(x_{1i})}{X_i} + \ldots + \frac{\mu_{K_1}^{w_1}(x_{1n})}{X_n} = \sum_{i=1}^{n} \frac{\mu_{K_1}^{w_1}(x_{1i})}{X_i}$$

$$K_2 = \frac{\mu_{K_2}^{w_2}(x_{21})}{X_1} + \frac{\mu_{K_2}^{w_2}(x_{22})}{X_2} + \ldots + \frac{\mu_{K_2}^{w_2}(x_{2i})}{X_i} + \ldots + \frac{\mu_{K_2}^{w_2}(x_{2n})}{X_n} = \sum_{i=1}^{n} \frac{\mu_{K_2}^{w_2}(x_{2i})}{X_i} \qquad (3)$$

$$K_m = \frac{\mu_{K_m}^{w_m}(x_{m1})}{X_1} + \frac{\mu_{K_m}^{w_m}(x_{m2})}{X_2} + \ldots + \frac{\mu_{K_m}^{w_m}(x_{mi})}{X_i} + \ldots + \frac{\mu_{K_m}^{w_m}(x_{mn})}{X_n} = \sum_{i=1}^{n} \frac{\mu_{K_m}^{w_m}(x_{mi})}{X_i}$$

Alternatives to the decision by using the Bellman-Zadeh method are given in the expression:

$$D = \bigcap_{j=1}^{m} K_j = \min\left(\min_{j=1,m}\left(\mu_{K_j}^{w_j}(x_{ij})\right)\right) \qquad (4)$$

i.e.:

$$D_1(X_1) = \min\left(\min_{j=1,m}\left(\mu_{K_j}^{w_j}(x_{1n})\right)\right) = \mu_{D1}(\tilde{x}_1)$$

$$D_2(X_2) = \min\left(\min_{j=1,m}\left(\mu_{K_j}^{w_j}(x_{2n})\right)\right) = \mu_{D2}(\tilde{x}_2) \qquad (5)$$

$$D_n(X_n) = \min\left(\min_{j=1,m}\left(\mu_{K_j}^{w_j}(x_{mn})\right)\right) = \mu_{Dn}(\tilde{x}_n)$$

so a fuzzy set of decisions *D* is given with:

$$D = \frac{D_1(X_1)}{X_1} + \frac{D_2(X_2)}{X_2} + \ldots + \frac{D_n(X_n)}{X_n} = \sum_{i=1}^{n} \frac{D_i(X_i)}{X_i} \quad \text{ili}$$

$$D = \frac{\mu D_1(\tilde{x}_1)}{X_1} + \frac{\mu D_2(\tilde{x}_2)}{X_2} + \ldots + \frac{\mu D_n(\tilde{x}_n)}{X_n} = \sum_{i=1}^{n} \frac{\mu D_i(\tilde{x}_i)}{X_i} \qquad (6)$$

The decision is the alternative X^* with the highest values of the membership function to the fuzzy set of decisions *D*, so it can be written (Bellman & Zadeh, 1970; Xing Li & Yen, 1995):

$$D(X^*) = \max\left(D_1(X_1), D_2(X_2), \ldots, D_n(X_n)\right) \quad \text{or}$$

$$\mu D(\tilde{x}^*) = \max\left(\mu D_1(\tilde{x}_1), \mu D_2(\tilde{x}_2), \ldots, \mu D_n(\tilde{x}_n)\right) \qquad (7)$$

Figure 7.3 shows a flow diagram of the procedure of model implementation (Špago & Ćatović, 2009).

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[2]Weight in *w* in exponent in the equation does not define operation of grading, but index, where the function of membership μ is multiplied by the weight *w*.

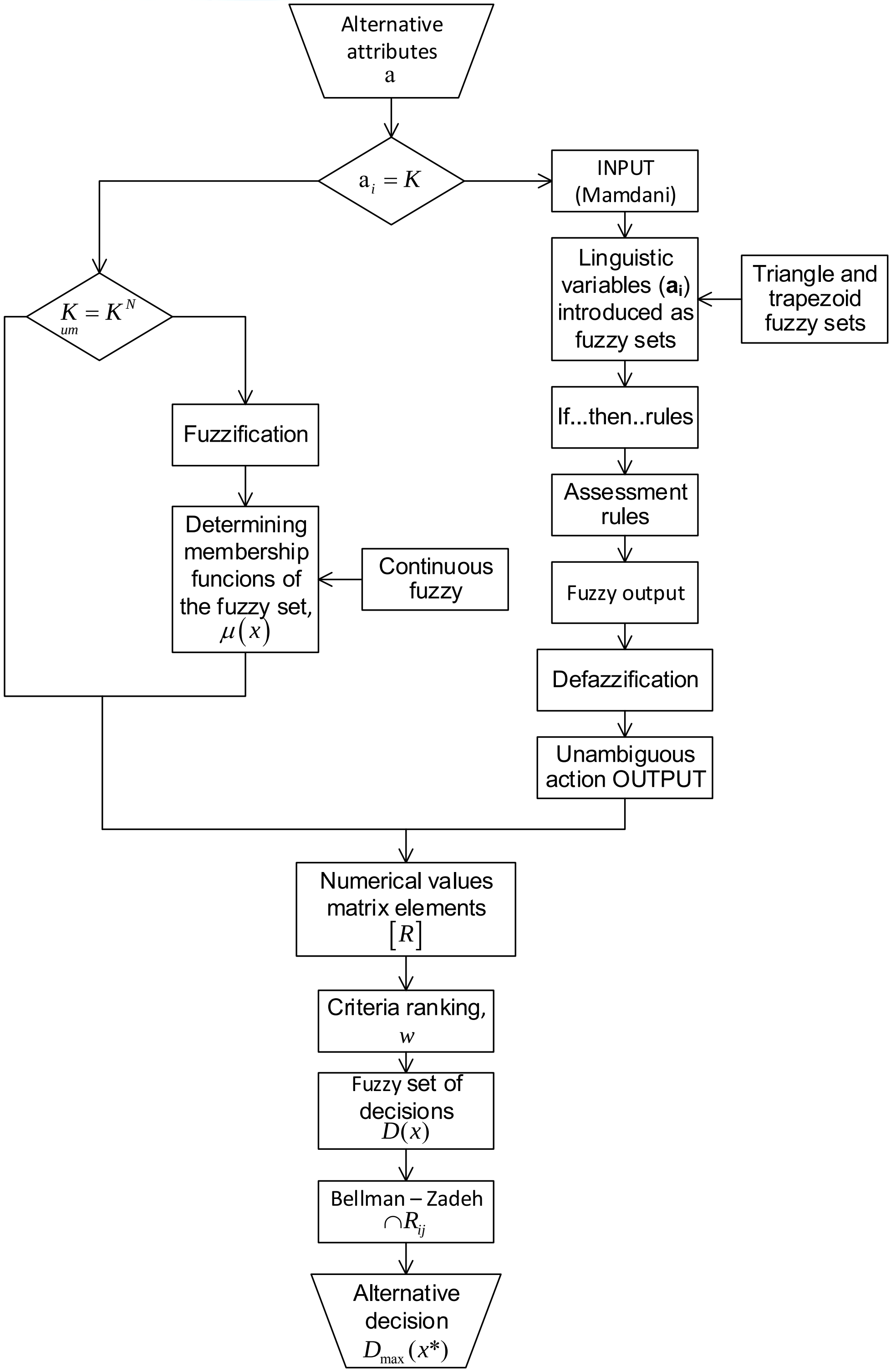

Figure 7.3 - Flow diagram of fuzzy model of repair alternative ranking

7.2.5 Numerical example of application in repair alterative ranking

Hereafter, in an illustrative example, a model application is shown. The example presented in the Report by CARE-W is used (Hertz, Baur, Lipkow & Kropp, 2003), only the number of alternatives is increased from 4 to 7, and the number of criteria from 7 to 10.

First, out of all available attributes, a list of attributes is created of importance for the ranking of alternatives $\{A_i\}_{i=1}^{i=7}$, i.e. ranking of zones as priorities for repair. The set of attributes is $\{a_j\}_{j=1}^{j=12}$ and they are:

a_1: *Cost price* (€).
a_2: *Pipe age* (good/year).
a_3: *Water losses* (m^3/h/km, q_{VR}[3]).
a_4: *Failure intensity* (number of failures/km/year).
a_5: *Network repair percentage* (%).
a_6: *Consequences of main infrastructure damage caused by failure* (linguistic qualification).
a_7: *Consequences of main infrastructure damage caused by losses, leaks* (linguistic qualification).
a_8: *Consequences of other underground infrastructure damage caused by failure (*linguistic qualification).
a_9: *Consequences of other underground infrastructure damage caused by losses, leaks* (linguistic qualification).
a_{10}*: Estimated number of illegal connections* (%).
a_{11}: *Number of citizen complaints* (linguistic qualification).
a_{12}: *Number of users* (#).
Table 7.1 shows numerical values and linguistic qualification of the attributes $\{a_j\}_{j=1}^{j=12}$ for the alternatives $\{A_i\}_{i=1}^{i=7}$.

By using the suggested Mamdani method (Mamdani, 1977) of inference in the following step the attributes $\{a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{12}\}$ are used as input variables, and the attributes $\{a_{10}, a_{11}\}$ are used directly as the criteria in the decision making process. The total number of the criteria, after selection and application of the Mamdani method, is $\{K_k\}_{k=1}^{k=10}$.

[3] DVGW (Deutsche Vereinigung des Gas-und Wasserfaches e.V.)

Table 7.1 - Qualitative and quantitative values of attributes aj for Ai criteria.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
a_1	1.1 mln €	1.15 mln €	1.2 mln €	1.4 mln €	1.6 mln €	2.4 mln €	3.2 mln €
a_2	40	38	40	45	42	45	50
a_3	0,28	0,30	0,32	0,29	0,31	0,34	0,36
a_4	0,11	0,13	0,12	0,14	0,12	0,13	0,145
a_5	1,2%	0,85%	0,5%	0,8 %	0,9%	1,4 %	1,6%
a_6	Medium	Quite severe	Medium	Low	Quite severe	Low	Quite severe
a_7	Quite severe	Low	Medium	Very low	Medium	Very low	Low
a_8	Medium	Low	Quite severe	Medium	Quite severe	Medium	Medium
a_9	Quite severe	Medium	Low	Very severe	Low	Quite severe	Quite severe
a_{10}	5 %	7 %	6 %	8 %	6 %	9 %	10 %
a_{11}	High	Medium	Low	Medium	High	High	Very high
a_{12}	1.500	1.320	1.600	2.100	2.450	3.200	3.800

Figure 7.4 provides a scheme of the application of the Mamdani method of fuzzy inference, where it can be seen which attributes are used as variables for fuzzy logic inference in order to get the criteria for decision making, and which attributes are used directly as the criteria in decision making.

Decision making criteria are:

K_1: Deterioration rate estimated on the basis of losses.
K_2: Deterioration rate estimated on the basis of failure intensity.
K_3: Feasibility measure by repair percentage.
K_4: Feasibility measure by the number of connections.
K_5: Risk of damage of the main infrastructure caused by failure.
K_6: Risk of damage of the main infrastructure caused by losses.
K_7: Risk of damage of other underground infrastructure due to failure.
K_8: Risk of damage of other underground infrastructure due to losses.
K_9: Estimated number of illegal connections. (%)
K_{10}: Number of citizen complaints.

Attribute values $\{A_i\}_{i=1}^{i=7}$ by the decision-making criteria $\{K_k\}_{k=1}^{k=10}$, and the weight values of certain criteria are given (illustratively) in *Table 7.2.*[4]:

[4]Numerical values are calculated using MatLab software, Fuzzy Logic Tools.

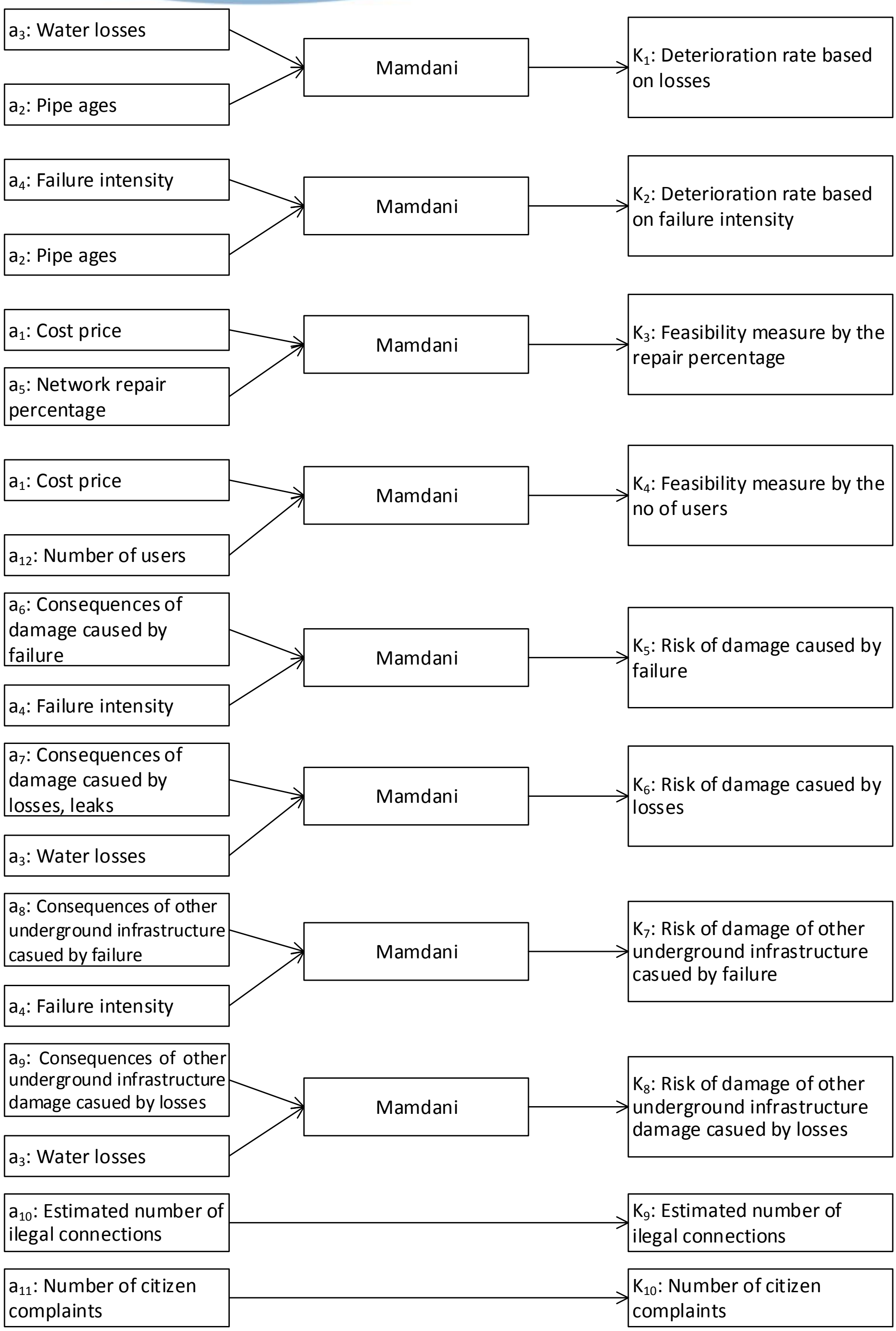

Figure 7.4 - Scheme of Mamdani's method application and getting decision making criteria (Špago & Ćatović, 2009).

Table 7.2 - Qualitative and quantitative criteria values Kk and weight values wk for Ai criteria.

	w	A_1	A_2	A_3	A_4	A_5	A_6	A_7
K_1	0.09	0,741	0,919	0,92	0,715	0,887	0,85	0,809
K_2	0.09	0,75	0,782	0,759	0,747	0,735	0,721	0,712
K_3	0.12	0,75	0,681	0,5	0,586	0,585	0,597	0,48
K_4	0.08	0,547	0,5	0,572	0,619	0,633	0,559	0,473
K_5	0.12	0,75	0,905	0,759	0,678	0,915	0,625	0,919
K_6	0.12	0,84	0,75	0,92	0,467	0,92	0,5	0,75
K_7	0.09	0,75	0,625	0,915	0,827	0,915	0,782	0,864
K_8	0.09	0,84	0,92	0,75	0,919	0,75	0,92	0,92
K_9	0.10	5 %	7 %	6 %	8 %	6 %	9 %	10 %
K_{10}	0.10	High	Medium	Low	Medium	High	High	Very high

The decision-making matrix has the form:

$$R = \begin{matrix} K_1 \\ K_2 \\ K_3 \\ K_4 \\ K_5 \\ K_6 \\ K_7 \\ K_8 \\ K_9 \\ K_{10} \end{matrix} \begin{bmatrix} 0,741 & 0,919 & 0,92 & 0,715 & 0,887 & 0,85 & 0,809 \\ 0,75 & 0,782 & 0,759 & 0,747 & 0,735 & 0,721 & 0,712 \\ 0,75 & 0,681 & 0,5 & 0,586 & 0,585 & 0,597 & 0,48 \\ 0,547 & 0,5 & 0,572 & 0,619 & 0,633 & 0,559 & 0,473 \\ 0,75 & 0,905 & 0,759 & 0,678 & 0,915 & 0,625 & 0,919 \\ 0,84 & 0,75 & 0,92 & 0,467 & 0,92 & 0,5 & 0,75 \\ 0,75 & 0,625 & 0,915 & 0,827 & 0,915 & 0,782 & 0,864 \\ 0,84 & 0,92 & 0,75 & 0,919 & 0,75 & 0,92 & 0,92 \\ 5\% & 7\% & 6\% & 8\% & 6\% & 9\% & 10\% \\ High & Medium & Low & Medium & High & High & VeryHigh \end{bmatrix} \qquad (8)$$

All criteria except K_9 and K_{10} are a result of the Mamdani logic inference, and their numerical values (obtained by defuzzification) range in the interval [0,1]. Having in mind the way numerical values are formed, for all criteria the principle *„more is less"* can be applied, so the membership functions of these criteria $\{K_k\}_{k=1}^{k=8}$ have the form:

$$\mu K_k\left(x_k\right) = x_k \qquad k = 1,\ldots,8 \qquad (9)$$

i.e. the membership function values are equal to the criteria values.

K_9: *Estimated number of illegal connections* (%) is a quantitative criterion whose numerical values are set (cf. *Table 7.2*), and which is fuzzified according to the Bellman-

Zadeh method, by a continuous fuzzy set whose membership function is given in the expression (10) and is shown in *Figure 7.5.*

$$\mu(x_9) = \frac{1}{7}(x_9 - 4) \quad (10)$$

$$K_9 = \frac{0,143}{A_1} + \frac{0,429}{A_2} + \frac{0,286}{A_3} + \frac{0,571}{A_4} + \frac{0,286}{A_5} + \frac{0,714}{A_6} + \frac{0,857}{A_7} \quad (11)$$

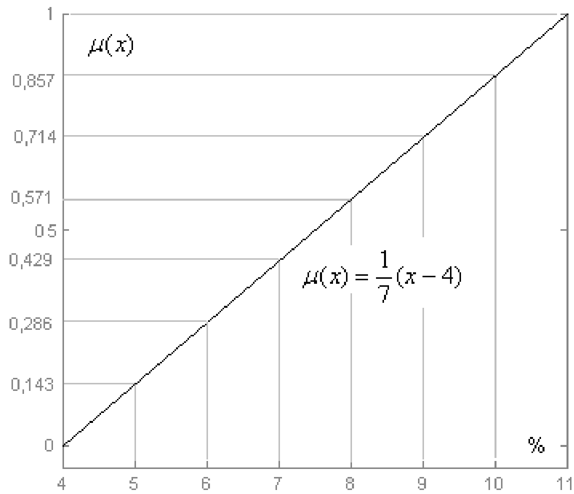

Figure 7.5 - Membership function of the fuzzy set of Estimation of illegal connections.

K_{10}: Number of citizen complaints is a qualitative criterion qualified by a seven-level linguistic value scale: No complaints, Low, Very low, Medium, High, Very high and Extremely high number of complaints. Fuzzification according to the Bellman-Zadeh method, is performed by a continuous fuzzy set (Špago & Ćatović, 2009) shown in *Figure 7.6.*

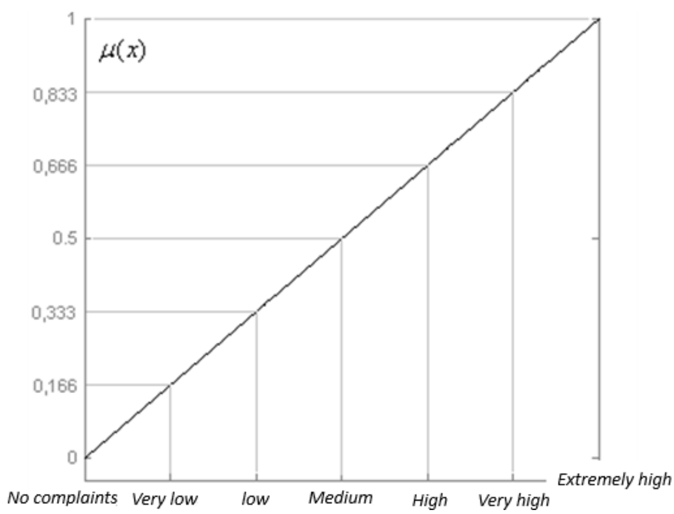

Figure 7.6 - Membership function of the fuzzy set Number of citizen complaints.

$$K_{10} = \frac{\mu_{K_{10}(High)}}{A_1} + \frac{\mu_{K_{10}(Medium)}}{A_2} + \frac{\mu_{K_{10}(Low)}}{A_3} + \frac{\mu_{K_{10}(Medium)}}{A_4} + \frac{\mu_{K_{10}(High)}}{A_5} +$$

$$+ \frac{\mu_{K_{10}(High)}}{A_6} + \frac{\mu_{K_{10}(VeryHigh)}}{A_7}$$

$$K_{10} = \frac{0{,}666}{A_1} + \frac{0{,}5}{A_2} + \frac{0{,}333}{A_3} + \frac{0{,}5}{A_4} + \frac{0{,}333}{A_5} + \frac{0{,}666}{A_6} + \frac{0{,}833}{A_7} \quad (12)$$

A general form of all fuzzy sets according to the Bellman-Zadeh method is given in the expression:

$$K_k = \left\{ \sum_{i=1}^{7} \frac{\mu_{K_k}(x_{ki})}{A_i} \right\}_{k=1}^{k=10} \quad (13)$$

Table 7.3 gives the values of membership functions of all fuzzy sets of criteria by individual alternatives.

Table 7.3 - Numerical values of membership functions of fuzzy sets of the criteria K_k for A_i alternatives.

	W	A_1	A_2	A_3	A_4	A_5	A_6	A_7
		$\mu_1(x)$	$\mu_2(x)$	$\mu_3(x)$	$\mu_4(x)$	$\mu_5(x)$	$\mu_6(x)$	$\mu_7(x)$
K_1	0,09	0,741	0,919	0,920	0,715	0,887	0,850	0,809
K_2	0,09	0,750	0,782	0,759	0,747	0,735	0,721	0,712
K_3	0,12	0,750	0,681	0,500	0,586	0,585	0,597	0,480
K_4	0,08	0,547	0,500	0,572	0,619	0,633	0,559	0,473
K_5	0,12	0,750	0,905	0,759	0,678	0,915	0,625	0,919
K_6	0,12	0,840	0,750	0,920	0,467	0,920	0,500	0,750
K_7	0,09	0,750	0,625	0,915	0,827	0,915	0,782	0,864
K_8	0,09	0,840	0,920	0,750	0,919	0,750	0,920	0,920
K_9	0,10	0,143	0,429	0,286	0,571	0,286	0,714	0,857
K_{10}	0,10	0,666	0,500	0,333	0,500	0,666	0,666	0,833

The decision-making matrix gets the form (14):

$$R = \begin{matrix} K_1 \\ K_2 \\ K_3 \\ K_4 \\ K_5 \\ K_6 \\ K_7 \\ K_8 \\ K_9 \\ K_{10} \end{matrix} \begin{bmatrix} 0{,}741 & 0{,}919 & 0{,}92 & 0{,}715 & 0{,}887 & 0{,}85 & 0{,}809 \\ 0{,}75 & 0{,}782 & 0{,}759 & 0{,}747 & 0{,}735 & 0{,}721 & 0{,}712 \\ 0{,}75 & 0{,}681 & 0{,}5 & 0{,}586 & 0{,}585 & 0{,}597 & 0{,}48 \\ 0{,}547 & 0{,}5 & 0{,}572 & 0{,}619 & 0{,}633 & 0{,}559 & 0{,}473 \\ 0{,}75 & 0{,}905 & 0{,}759 & 0{,}678 & 0{,}915 & 0{,}625 & 0{,}919 \\ 0{,}84 & 0{,}75 & 0{,}92 & 0{,}467 & 0{,}92 & 0{,}5 & 0{,}75 \\ 0{,}75 & 0{,}625 & 0{,}915 & 0{,}827 & 0{,}915 & 0{,}782 & 0{,}864 \\ 0{,}84 & 0{,}92 & 0{,}75 & 0{,}919 & 0{,}75 & 0{,}92 & 0{,}92 \\ 0{,}143 & 0{,}429 & 0{,}286 & 0{,}571 & 0{,}286 & 0{,}714 & 0{,}857 \\ 0{,}666 & 0{,}5 & 0{,}333 & 0{,}5 & 0{,}666 & 0{,}666 & 0{,}833 \end{bmatrix} \quad (14)$$

Ranking of the criteria is formally introduced through weight coefficients $\{w_k\}_{k=1}^{k=10}$, by a classic procedure.[5]

Introducing of weight coefficients into fuzzy sets results in:

$$K_k^{(w)} = \left\{ \sum_{i=1}^{7} \frac{w_k \cdot \mu_{K_k}\left(x_{k,i}\right)}{A_i} \right\}_{k=1}^{k=10} \quad (15)$$

For the sake of clarity, the membership functions of fuzzy sets are given in *Table 7.4*.

Table 7.4 - Values of the product of membership function μi(x) and the weight w_k.

		A_1	A_2	A_3	A_4	A_5	A_6	A_7
	W_k	$w_1\ \mu_1(x)$	$w_1\ \mu_2(x)$	$w_1\ \mu_3(x)$	$w_1\ \mu_4(x)$	$w_1\ \mu_5(x)$	$w_1\ \mu_6(x)$	$w_1\ \mu_7(x)$
$K_1^{(w1)}$	0,09	0,0667	0,0827	0,0828	0,0644	0,0798	0,0765	0,0728
$K_2^{(w2)}$	0,09	0,0675	0,0704	0,0683	0,0672	0,0662	0,0649	0,0641
$K_3^{(w3)}$	0,12	0,0900	0,0817	0,0600	0,0703	0,0702	0,0716	0,0576
$K_4^{(w4)}$	0,08	0,0438	0,0400	0,0458	0,0495	0,0506	0,0447	0,0378
$K_5^{(w5)}$	0,12	0,0900	0,1086	0,0911	0,0814	0,1098	0,0750	0,1103
$K_6^{(w6)}$	0,12	0,1008	0,0900	0,1104	0,0560	0,1104	0,0600	0,0900
$K_7^{(w7)}$	0,09	0,0675	0,0563	0,0824	0,0744	0,0824	0,0704	0,0778
$K_8^{(w8)}$	0,09	0,0756	0,0828	0,0675	0,0827	0,0675	0,0828	0,0828
$K_9^{(w9)}$	0,10	0,0143	0,0429	0,0286	0,0571	0,0286	0,0714	0,0857
$K_{10}^{(w10)}$	0,10	0,0666	0,0500	0,0333	0,0500	0,0666	0,0666	0,0833

[5]In this example pairs are compared by their criteria, where preference is expressed with the Saaty's scale (Saaty, 1999) of relative importance, with 5 levels and 4 inter-levels of verbally described intensities and corresponding numerical values in the range 1-9, taken as an illustrative example.

Since the fuzzy set of decision D according to (4) is:

$$D = \bigcap_{k=1}^{10} K_k^{(w_k)} = \left(\min_{k=1,10} \left(\mu_{K_k}^{w_k} \left(x_{k,i} \right) \right) \right)_{i=1}^{i=7}$$

After values of the membership function for each alternative were defined through the fuzzy set, decision D is:

$$D_1(A_1) = \min_{k=1,10} \left(\mu_{K_k}^{w_k} \left(x_{k,1} \right) \right) = \mu_{D_1}\left(\tilde{x}_1 \right) = 0,0143$$

$$D_2(A_2) = \min_{k=1,10} \left(\mu_{K_k}^{w_k} \left(x_{k,2} \right) \right) = \mu_{D_2}\left(\tilde{x}_2 \right) = 0,0400 \qquad (16)$$

$$D_7(A_7) = \min_{k=1,10} \left(\mu_{K_k}^{w_k} \left(x_{k,7} \right) \right) = \mu_{D_7}\left(\tilde{x}_7 \right) = 0,0378$$

Finally, the fuzzy set of decisions D has the form:

$$D = \frac{\mu_{D_1}(\tilde{x}_1)}{A_1} + \frac{\mu_{D_2}(\tilde{x}_2)}{A_2} + \frac{\mu_{D_3}(\tilde{x}_3)}{A_3} + \frac{\mu_{D_4}(\tilde{x}_4)}{A_4} + \frac{\mu_{D_5}(\tilde{x}_5)}{A_5} + \frac{\mu_{D_6}(\tilde{x}_6)}{A_6} + \frac{\mu_{D_7}(\tilde{x}_7)}{A_7} \qquad (17)$$

$$D = \frac{0,0143}{A_1} + \frac{0,0400}{A_2} + \frac{0,0286}{A_3} + \frac{0,0495}{A_4} + \frac{0,0286}{A_5} + \frac{0,0447}{A_6} + \frac{0,0378}{A_7}$$

The maximum value of the membership function is:

$$D(X^*) = \max\left(D_1(A_1), D_2(A_2), \ldots, D_7(A_7) \right)$$ ili

$$\mu_D(x^*) = \max\left(\mu_{D_1}\left(\tilde{x}_1\right), \mu_{D_2}\left(\tilde{x}_2\right), \ldots, \mu_{D_7}\left(\tilde{x}_7\right) \right)$$

$$\mu_D(x^*) = \mu_{D_4}\left(\tilde{x}_4\right) = 0,0495 \qquad (18)$$

So the highest level of belonging to a fuzzy set of decisions D is associated with the alternative A_4, which is, in this case, an alternative of decision.

7.2.6 Suggested areas for the model application

7.2.6.1 Model application in decision making on repair work manner: classic or unconventional repair methods

Technology of repair work and reconstruction of the water supply network in the last 20 years has been significantly changed. Today, technical procedures of repair and reconstruction work include both conventional (classic) and unconventional (trenchless) methods. Rehabilitation of the pipeline by conventional methods is based on total replacement of the old pipelines and excavation of a trench alongside the entire route. In addition to the classic approach of replacing old pipes with completely new pipelines, in practice different techniques and materials are applied, which are globally increasingly used, and known as *trenchless* methods.[6] Trenchless methods are usually more expensive in comparison to the classic methods when it comes to construction work price only. Practice in B&H is that still, almost in all cases in the process of repairing and replacing of water supply and sewage pipelines, old lines are replaced with new ones, in a classic way. Such a process causes a significant deviation in urban life (system environment) which is, due to damage and indirect costs (interrupted or heavier traffic during construction work days), damage on some of other underground infrastructure, noise and dust etc., a cause of various forms of public protest and complaints. If indirect costs are taken into consideration, i.e. criteria that cannot be expressed in financial terms, and which are in practice usually neglected or skipped, a preference in urban settings is given to the trenchless technology.

This preference is seen in the shortened time of work duration, decreased noise from construction sites (city traffic), avoiding risk of damage of the existing communal installations, less ground works, transport and installment of raw materials, i.e. generally easier work conditions with less possible unexpected traffic jams or other events caused by the classic way of pipe replacement, with trench alongside the entire route.

In this sense, it is necessary to look at the technological reconstruction procedures and water pipeline repair offered on the global market, the most important criteria influencing their selection, their size, or weight, so that the ranking of possible solutions includes all relevant criteria for an optimized decision.

Since in the B&H practice it is common that selection of the water supply network reconstruction method is based exclusively on economic criteria, i.e. the price of the investment which includes mostly construction work, here on the basis of practical experience inclusion of qualitative criteria is suggested into the decision making process on the repair manner.

After the decision about the zone or the section for repair work is made, what follows is the selection of the method to be applied. However, it is possible to include the same zone in the process of decision making about the priorities, but with different repair manner as alternatives. Regardless of the approach that will be accepted by the

[6]Unconventional (trenchless) methods are based on the principle of repair without excavation, i.e. rehabilitation of the pipelines through the existing revision trenches with small excavation at the ends of the treated section. These methods can be divided into several groups: 1. *close-fit-lining* 2. *sliplining* 3. *spray lining* 4. *local repairs and crack grouting* 5. *cured-in-place pipe, CIPP* 6. *on-line replacement* 7. *impact moling and ramming* 8. *directional drilling* 9. *pipejacking and microtunneling*. (CEN, 2000; Piškorić, 2007).

decision maker, the following circumstances in the decision-making process are the criteria generators:

- During classic excavation damage of other underground infrastructure is possible. This circumstance introduces the need for the criterion that can be directly introduced into the model (Bellman-Zadeh) or indirectly (Mamdani) as one input variable, while, depending on the situation, another input variable would be the length of the section with this possibility, or if it is a risk criterion, assessment of damage that can be caused by a risky event (there is a considerable difference in the price of a damaged optical telephone cable in comparison to e.g. damaged connection of the cable TV). By introducing these criteria, a new picture is formed about realistic conditions on the site during the works, which is considered in time, and not, as it is a usual practice – that neglecting these circumstances generates need for additional works so eventually more favorable and cheaper solutions are actually more expensive, regardless of the very price of the construction works.
- Classic excavation will make traffic flow heavier or block it completely. This is one of the unavoidable consequences of ground works that are necessary in classic pipe replacement, and that cause biggest traffic issues in urban city zones, and potentially cause accidents. There emerges a need for introduction of the criteria in a direct manner (Bellman-Zadeh) or indirectly (Mamdani) as one input variable (e.g. five-level linguistic value scale) while the other input variable can be the time of duration of the works, or traffic intensity, or importance of the road in terms of (non)existence of alternative communications etc.
- During the repair works duration of the water supply stoppage needs to be as short as possible and limited to the maximum of „n“ hours. In case there are no alternative lines of water supply (when it is not a ring but branch network shape) or if the main supply pipes are in question, then this circumstance favors classic methods since trenchless methods use sections that cannot be functional during the works. In this sense, possible construction of temporary or permanent bypasses can be considered, so that both methods are included as alternatives or to consider different repair methods for different zones. Duration of water supply stoppage can be introduced as one of the criteria directly (Bellman-Zadeh) or indirectly (Mamdani) as one input variable while the other variable can be the number of users or water consumption.
- Number of connections on the section or zone. A high number of connections in the water pipeline can be an issue for application of trenchless methods. Since each connection needs a connector which implies excavation, so the number of connections decreases advantages of the trenchless method. Here introduction of a number of connections by a unit of length can be suggested as a criterion

which can be directly introduced into the model (Bellman-Zadeh) and that will have an impact on the repair work type selection.

Generally, introduction of attributes that support specific qualities (advantages and disadvantages) of technological solutions of contemporary repair methods and concrete conditions for the works, provides a larger picture about the real process, for optimization of the decision making in selection of technical procedures.

7.2.6.2 Model application in ranking of alternatives for the system upgrade

The system upgrade includes some of the following activities: introduction of new amounts of water into system, expanding the network in line with urban needs, and upgrade of pipe sections within the system area in order to form a ring network for better reliability of water supply. Each of the mentioned activities includes construction of new pipe sections that in some projects need to be installed in segments or completely through private properties. Under such circumstances, there are two problems: during construction there are property issues, and after the construction pipe sections that go through private properties, become attractive to illegal connections, and problematic in terms of later availability and right to compensation for damages caused by failures, losses or repair works.

Due to all of this, the laying of pipes through private property is to be avoided and reduced to the minimum. In that sense, when decision is made about section routes, in addition to standard (hydraulic and financial) parameters, additional ones are to be considered, such as: *length of the section going through private property, number of private properties within the section, distance of the section from the communication roads, length of the section on which the failure or repair works can cause damage etc.,* and as criteria *Sensitivity of the section to illegal connections* and *Maintenance suitability* are to be introduced.

7.3 Conclusions

Assessment of current conditions of the pipe network, on which all prognoses are based, of its future condition, reliability and life cycle, within the required performances, depend on the quality of information about the system. Assessment, or prognosis of the future condition of the pipes or zone is the initial criterion for pipe classification, and from which result all later ranking procedures, and managing actions. In order to perform a high quality assessment, in the last two decades, many techniques and models were developed, such as: TV inspection, laser, ultrasonic or sonic scanning, estimation based on the tested samples of pipe walls, etc.

However, if the pipe deterioration level is so high that failures and losses in the system are common on a daily basis, then the importance of information about the failures and losses is incompatible[7] with their precision, and the measured changes or estimated values in that case have fundamental importance in prognosis of the future system condition. As opposed to this, with such a level of pipe deterioration, information precision about the system provided by contemporary methods of assessment, goes beyond their importance in the context of repair process management. Because of that, the failure intensity and scope of water losses (manifestations of the existence of hidden works), on the water supply pipe network, are today characteristics of the system conditions which are usually in some form (assessment based on experience or measurement) available to those who make decision about priorities for repair and forming of a subjective picture about the network condition.

Interpretation and presentation of the indicators of system failures and losses, as input information in prognostic models, brings subjectivity and imprecision, or data scarcity, which is a limiting factor for reliable application of deterministic or stochastic models.

In a situation when input variables are imprecise or express subjective opinion, introduction of fuzzy set theory, or fuzzy logic has been proved to be a convenient concept and its application (Mamdani method) has been implemented with a detailed procedure with a concrete example.

Water pipe classification based on the assessment of their condition and deterioration rate during exploitation, as well as the very value scales of assessment parameters (losses and failure intensity) are used standardly in the form of classic sets, with marked thresholds between individual classes within assessment scales. Belonging to a certain class, from the categorization, determines further processes and procedures applicable, which causes that the classification directly affects the final result of modelling, i.e. it becomes a limiting factor.

Suggested application of fuzzy sets in an analytical form of value scales introduces step-by-step and gradual description of the characteristics and processes, eliminates rough classification of classic approach of two-value logic and enables its propagation exactly during the entire modelling procedure.

Ba applying fuzzy logic in network condition assessment, fundamental assessment attributes – failure intensity and water losses – are exactly introduced as variables into the logic inference procedure in forming of assessment criteria such as pipe deterioration rate, and in the risk criteria that are also a result of breakdowns and water losses as events in the system.

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[7] „As complexity increases, ability to make precise, and at the same time important expressions about its behavior decreases until it reaches the threshold behind which precision and importance become mutually exclusive characteristics.“ (Zadeh, 1973)

The decision making model, when the decision criteria are given qualitatively, i.e. when their values are qualified by linguistic scales, based on fuzzy set theory (Bellman & Zadeh, 1970), has been expanded by introducing fuzzy logic on the criteria given quantitatively (assessment of pipe life cycle), and whose numerical values used to be a result of deterministic or stochastic modelling with implied usage of scarce, imprecise or subjective input variables.

A suggestion for further research and upgrade of the model, in a wider sense, relates to interpretation of empirical knowledge acquired in the water supply managing process in a convenience form, fuzzy sets, as input variables for fuzzy logic inference, in modelling of processes for operational management and engineering.

Additionally, it is possible to introduce a sensitivity analysis, which belongs to the post-optimum problem analysis, i.e. after defining an alternative decision (Bellman-Zadeh) thresholds for input data are of interest, within which the order of alternatives is not changeable in ranking or at least the top-ranked alternative is not changed.

7.3.1 Critical review of the fuzzy concept

A basic advantage of the assessment procedures that use fuzzy logic (Mamdani), which relies on the production rules, formalized expert knowledge, defined in the form: „If...then...“ is that, in comparison to classic concepts of modelling of a future state of the system, time needed for its comprehension is incomparably smaller than the time needed for learning of classic mathematical areas (differential equations, linear algebra, optimum management theory etc.), because of which the classic concept often endangers a model operational principle. Additionally, simplicity of the application results in establishing a better model-user relation which enables faster adjustment of the model and its development according to the concrete needs.

Weaknesses of the fuzzy concept are in the fact that today there is not enough theoretical explanation of forming of the rules that relate to the selection of the form of fuzzy sets for individual processes and characteristics they describe (triangle, trapezoid, bell-shaped etc.), rules of their overlapping, the number of fuzzy sets etc., where only previous positive experiences are still a basis for recognition (Ross, 2005). This weakness is a result of how dynamically the fuzzy sets entered the engineering application, and which is far ahead of its theoretical foundation.

Regardless of its weaknesses, the fuzzy set theory is one of the paradigms of operability, and its advantages are successfully used in an increasing number of engineering applications and in all technical fields. It is a fact that by replacing classic numbers and sets, as usually applied in practice, with fuzzy numbers and fuzzy sets, each model can be fuzzified and seen in a new light, which indicates the importance of acquiring knowledge on fuzzy sets, but the goal of this acquisition should not be a presumption that the fuzzy concept offers the best solutions for all engineering problems, but simply that it offers another useful model for better description of reality in everyday engineering practice.

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