Horizon2020 Insurance

Oasis Innovation Hub for Catastrophe and Climate Extremes Risk Assessment

D2.1.3.2 – Report on Novi Sad case study

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Executive summary

As deliverables 2.1.3.1 previously assessed current climate and hydrological conditions, deliverable 2.1.3.2 Support for large scale investments in infrastructure and climate resilience going to analyse the climate vulnerability of the planned Waste Water Treatment Plant (WWTP) in Novi Sad.

The study based on the European Commission official guideline: Making vulnerable investments climate resilient. The process has 8 modules from which we here use now 5 modules comprising: 1. The identification of climate sensitivity of the WWTP, 2. Evaluate exposure to climate hazards 3. Assess vulnerability 4. Assess risks 5. Identify adaptation options. Predictions using the Future Danube model and OASIS Loss Model Framework will be used as support for the precipitation and temperature modelling and subsequent flood risk assessment in the Novi Sad area.

Contents

1. Introduction

Climate change is underway with the effects already felt across Europe. Actions to mitigate greenhouse gas emissions are essential to avoid the worst effects over the longer-term. However, due to the already built-up storage of greenhouse gasses in the ocean and atmosphere and the response of the climate system, there will inevitable consequences over the coming decades regardless of whether the Paris Agreements will be successful or not. Unless the vulnerabilities and risks are managed appropriately, climate change will increasingly affect project performance and the investments made in these projects. There will be changes in average climate conditions and in many places there will be more frequent, more intense extreme climatic events. Extreme events will also occur in new locations that were not previously considered vulnerable. There may also be abrupt, irreversible changes when the climate system crosses so-called 'tipping points', triggering a transition to a new state. As a result, the past may not be a good guide to the future, and decisions based on historic climate data may no longer be robust and uncertainties larger than previously thought. Even small climatic changes can have significant implications.

For the Danube basin, it is expected that the number and intensity of hydro-meteorological events, especially floods, will increase (Hattermann et al. 2018a).

Decision-making under uncertainty

The key aims when undertaking climate vulnerability and risk assessments are to determine the sensitivity of project options to relevant climate-related hazards, identify exposure of the options to current and future hazards in a particular location(s), and identify and prioritise key risks. This information helps to determine options which are robust to current climate variability and also the range of future change. The primary purpose of climate change vulnerability and risk assessments is to inform adaptation planning. Traditionally, this has been achieved through 'top down' or 'scenario-led' methods which focus on deriving fine-scale climate data from coarse scale Global Climate Models (GCMs) through e.g. statistical and/or dynamical downscaling. The resulting local-scale scenarios are fed into impact models or mapped against the locations of project options (or existing assets) in order to determine vulnerability.

Although climate models are constantly being improved, they are inherently uncertain in projecting future climate conditions. Uncertainties in climate variability, future society, the scale of future greenhouse gas emissions, and scientific knowledge on how components of the climate system interact, all lead to uncertainties in the climate projections. Outputs from different climate models can disagree

on both the degree and sign of change in a climate variable, presenting users with a wide range of possible climate futures to deal with (Hattermann et al. 2018b).

A new Waste Water Treat Plant (WWTP) for Novi Sad

The general objective of the WWTP is to facilitate overall improvement of the hygienic conditions in the city of Novi Sad, as well as the environment, and to safeguard the potable water resources and the quality of the environment in the areas located downstream and under the influence of the Danube River. Technical contribution of the WWTP: from Western Balkans Investment Framework (WBIF), Infrastructure Projects Facility Technical Assistance 4 (IPF 4).

The improvement of the wastewater infrastructure and treatment will allow augmentation of Novi Sad social, economic and industrial development. Novi Sad is the largest city in northern Serbia and the second largest city in Serbia with 289 128 inhabitants according to UN city population data centre. The city extends on both sides of the Danube River.

Population Equivalent, (PE) Population equivalent refers to the amount of oxygen-demanding substances (measured in BOD or BOD5) in wastewaters whose oxygen consumption during biodegradation equals the average oxygen demand of the wastewater produced by one person during one day.

The WWTP will be constructed for 400,000 PE, but the proof that upgrade of the WWTP up to 500,000 PE is possible at the same location, in case of population growth in future is required. For the beginning, the capacity of WWTP able to treat 355,000 inhabitants.

The thresholds built into project plan probably reached more frequently in a future because of the changing climate. Changing climate may result in threshold failures once considered exceptional but acceptable. Future projects may have to function within tighter margins between “normal” operation and critical thresholds. This may manifest itself in decreased efficiency of equipment and provide less margin for error before drastic management measures such as reduced operation, throughput etc. need to be addressed.

Climate change will also affect the environmental and social systems around physical assets and their interactions with these systems. For instance, reductions in rainfall may affect the availability and quality of water resources on which industrial assets depend. At the same time, farmers may find they need to irrigate crops for the first time in response to rising temperatures and lower rainfall. Such changes may create competition and could potentially lead to conflict. This highlights the importance of thinking in an integrated, cross-sectoral way about climate risk and resilience.

For instance, availability of water resources may be reduced, operating efficiencies of equipment may be reduced due to higher temperatures, and rising sea levels may increase flood risk and erosion for

coastal assets. As the impacts of climate change intensify, there will be macro-economic consequences in some areas, potential demographic shifts and changing patterns of land use. These, in turn, may affect demand for assets and infrastructure in these areas.

The vulnerability study focuses on climate proofing of the future Waste Water Treatment Plant (WWTP), planned to be built in the city of Novi Sad, Serbia.

2. Methodology

This study is based on the Non-paper Guidelines for Project Managers ‘Making vulnerable investments climate resilient published by the European Commission (COMMISSION). This guide helps to assess the currentand future climate conditions and resilience of projects. The guide sets up a toolbox of eight consecutive modules that can be used to assess risks and determine the necessary adaptation measures. The eight module surveys are performed in two stages and the level of elaboration depends on the size of the project. In Figure 1, the stages in the asset lifecycle are shown in the red boxes, and the main aims of the developer at each stage are shown in grey.

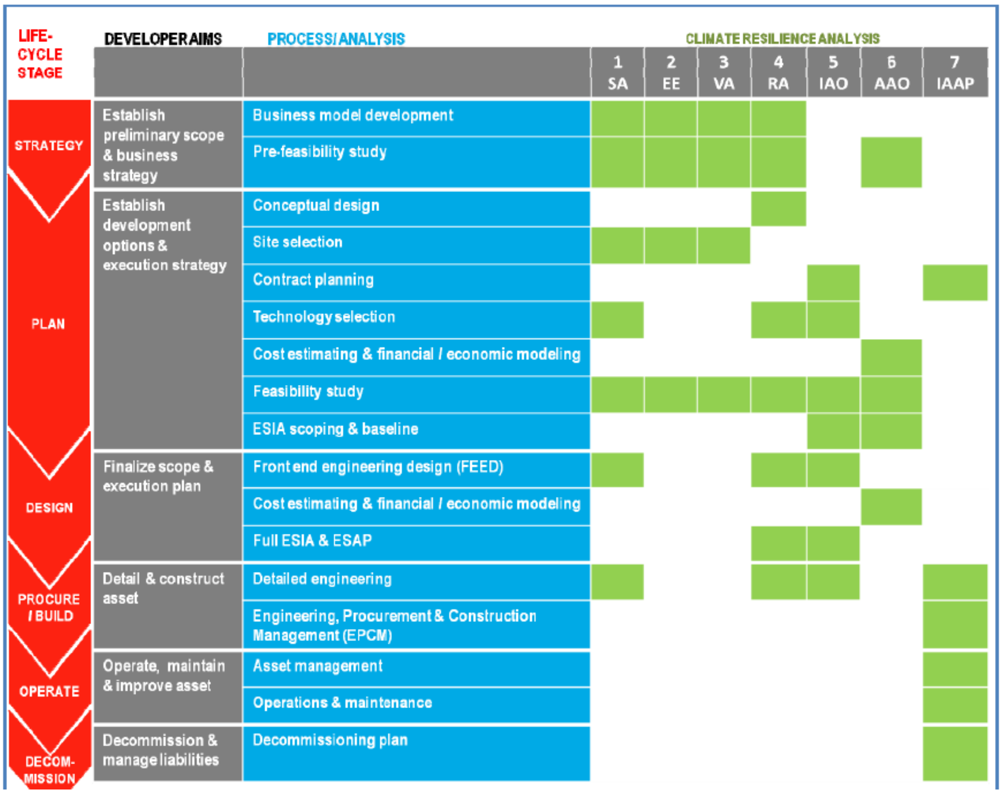

Figure 1. Integration of climate resilience analyses into a conventional asset lifecycle process. (COMMISSION)

3. Modul I. Identify the climate sensitivities of the projected measure

The sensitivity of the project should be determined in relation to a range of climate variables and secondary effects / climate-related hazards. In general, it means to identification of the high-level climate vulnerabilities and risks associated with development options according to the guidelines coves all areas of feasibility:

- project inputs (availability and quality)
- project location and site
- financing
- economic
- operations and management
- legal
- environmental and social

The sensitivity of the project measures to key climate variables and hazards should be systematically assessed through the 'lens' of four key themes encompassing the main components of a value chain as follows:

• On-site assets and processes,

• Inputs (water, energy, others),

• Outputs (products, markets, customer demand),

• Transport links.

A score of 'high', 'medium' or 'no' should be given for each project type and theme across each climate variable. The focus is on determining the sensitivity of project measures to climate variables in relation to each of the four themes. For example, a reduction in average seasonal precipitation could affect the water supply to an asset, but have little impact on important transport links. In cases where sensitivity data are available for the four themes for each project option, these can be used. However, in many cases, the assessment of sensitivity will be subjective. The following descriptions provide guidance on the determination of subjective scores:

• High sensitivity: Climate variable/ hazard may have significant impact on assets and processes, inputs, outputs and transport links.

• Medium sensitivity: Climate variable/ hazard may have slight impact on assets and processes, inputs, outputs and transport links.

• No sensitivity: Climate variable/ hazard has no effect.

The important climate variables and related hazards are those that are deemed high or medium sensitivity across at least one of the four sensitivity themes. These are the ‘essential’ factors against which potential locations for the project should be subsequently systematically mapped using GIS to determine level of exposure and finally vulnerability (see Modules 2 and 3). The assigning of sensitivity scores to project types is best carried out by experts with knowledge of the project. In many cases, projects may not be sensitive to a particular secondary climate variable, for example ‘growing season’. On the other hand, all project types will be sensitive to some hazards such as wildfires or floods. Table 1. shows the results of the abovementioned sensitivity analysis with regards to the planned WWTP in Novi Sad.

1. Table The elements of the first module: sensitivity of the WWTP

Project type	**Waste Water Treatment Plant**			
sensitivity theme	A (on-site assets and processes)	B inputs (water, energy, others)	C outputs (products and markets)	D (transport links)
incremental air temperature increase				
extreme temperature increase				
incremental rainfall change				
extreme rainfall change				
pluvial flooding				
fluvial flooding				
average wind speed				
maximum wind speed				
humidity				
solar radiation				
relative sea water level rise				
seawater temperature				
water availability				
storms				
soil erosion				
soil salinity				
ocean PH				
dust storms				
coastal erosion				
wild fire				
air quality				
ground instability/landslides				
urban heat islands				
increase in the average fluctuation of air temperature				

increased occurance of inland inundation				
groundwater				
growing season				

SENSITIVITY	NO	MEDIUM	HIGH

As indicated above the operation of the WWTP has high sensitivity to a number of climate related natural event can affect negatively the operation both in the short and long term. The increasing temperatures intensifies the hydrological cycle over the entire catchment, which results in changed precipitation patterns, and which results in an increased risk of heavy to extreme rainfall. These changes will for example lead to increased inflow of rainwater and to an increased risk of flash floods (pluvial floods) and fluvial floods, as well as to increased (decreased) water levels of the Danube owing to increased amounts of large-scale precipitations (drought).

Increasing rainfall intensities is one of the most common impacts of climate change on wastewater reclamation. Although some cities have separated sewerage networks, most urban areas in Europe and North America still employ their original combined systems to convey both municipal wastewater and storm-water together. Such systems were particularly sensitive to increased rainfall intensities (Kessler, 2011; NACWA, 2009). The intensified rainfall regime may for example increase the sewage flow in the conveyance system by infiltration through cracks, improperly-constructed manholes or even direct inflow (O'Neill, 2010). Sewerage overloading scenarios with regards to climate change provisions are generally studied via hydraulic models (Mark et al., 2008; Semadeni-Davies et al., 2008). (Tram Vo et al., 2014)

Higher temperatures can also affect the operation of the wastewater treatment plants directly. These impacts are often categorised into four instances:

Affect I.: changing the sludge structure

The sludge deflocculating increases and the flocculation physicochemical properties deteriorate under increasing temperatures. The sludge settling characteristic has poorer sludge compressibility and settleability. Furthermore, concentrations of the effluent suspended solids increase. This process however requires really high temperatures, towards to 40°C, so it's not a big a hazard. (Manassra, 2006)

(Wastewater Connect, 2019)

Affect II.: lower oxygen solubility

The concentration of the dissolved oxygen is highly temperature-dependent. At cooler temperatures, water has a higher capacity for holding dissolved oxygen. The opposite is true at warmer temperatures;

water at higher temperatures has a lower capacity for holding dissolved oxygen, so plants will need to increase their oxygen delivery.

At higher temperatures, the sludge retention time (SRT, also known as sludge age) must be shorter, so the enhancement of the nitrification is needed. This is another reason to increase the aeration capacity of the system (Instruments, 2019).

Affect III.: Reduced total nitrogen (TN) removal

Biological wastewater treatment plants are generally designed on the basis of SRT, that represents the mean residence time of microorganisms in the biological reactor. SRT is the key control parameter for the process responsible for maintaining “healthiness” of microorganisms.

It can be observed that when the SRT was dropped down to 5 days for the high temperature range of 25–30 °C, the plant treatment performance was improved in terms of BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solids), TOC (Total Organic Carbon) and TP (Total Phosphorus) when considering both removal efficiency and mean effluent concentration. However, in terms of TN, the plant treatment performance was reduced. This would be as expected, since reduced SRTs lead to less simultaneous nitrification and denitrification (SND) occurring in the structure of the aggregated sludge flocs leading to overall reduced TN removal. As the environmental temperature decrease further this TN removal rate slightly deteriorated as well.

It was found that in order to maintain the optimal performance of a full scale activated sludge plant, the SRT should be changed with temperature in a “dynamic” way. Thus, after an increase in bacterial activity in summer, the SRT should be decreased in order to maintain acceptable treatment plant performance. However, as the wastewater temperature drops, and subsequent bacterial activity decreases, the SRT should be raised to maintain the same treatment performance. In conclusion, a stable pollutant removal performance and effluent quality while minimizing energy requirements can be obtained by applying a temperature dependent dynamic SRT control strategy (Moazzam Shahzad 1, 2015).

Affect IV.: Changing natural reservoir

Because of climate change, not only will the temperature of the wastewater increase in summer, but also that of the natural reservoir. The watercourses will evaporate more and their self-cleaning ability will decrease. This phenomenon enhanced the need for more efficient wastewater treatment plants. Thus, emission limit values are likely to be stricter in the future (Bakos Vince, 2017).

4. Modul II. Evaluate exposure to climate hazards of the Wastewater Treatment Plant

Once the sensitivities of a project type have been identified, the next step is to evaluate the exposure of the project and its assets to climate hazards in the location(s) where the project will be implemented.

Different geographical locations can be exposed to different climate hazards as well as different frequencies and intensities. It is useful to understand how the exposure of different geographic areas within Europe will change as a result of changing climate hazards. Understanding what the exposed areas are, and how they will be affected, is important, as it is at these locations where the benefits of proactive adaptation will be greatest. Exposure data should be gathered for climate variables and related hazards to which assets have high or medium sensitivity (from Module I).

Thanks to the Future Danube Model and the OASIS framework, updated and fully probabilistic information on precipitation, temperature and flood risk is readily available for Novi Sad (Hattermann et al. 2018a). Using this information and based on the results of the first module (sensitivity) we analysed here to what extent the project’s planned location in Novi Sad is exposed. Only climate parameters found to lead to medium or high sensitivity is considered sensitivity.

Figure 2. Location: Rokov Potok - Novi Sad, North of Serbia (Source: Publuc Utility Company Water Works and sewerage WWTP NOvi Sad PPT – Radioca Stefanovič)

The Pannonian Plain covers the northern third of the country while the easternmost tip of Serbia extends into the Wallachian Plain. Almost all of Serbia's rivers drain to the Black Sea, by way of the Danube river. The Danube, the second largest European river, passes through Serbia with 588 kilometres (21%

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of its overall length) and represents the major source of fresh water. It is joined by its biggest tributaries, the Great Morava (longest river entirely in Serbia with 493 km of length), Sava and Tisza rivers.

Figure 3. The chosen location of the planed WWTP in Rokov Potok on Google map https://www.google.hu/maps/place/%C3%9Ajvid%C3%A9k,+Szerbia/@45.2508851,19.8811666,15.75z/data=!4m5!3m4!1s0x475b10613de93455:0xb6f7d683724fe28!8m2!3d45.2671352!4d19.8335496?hl=hu&authuser=0

4.1 Assess exposure to baseline/ observed climate

4.1.1 Temperature data analysis

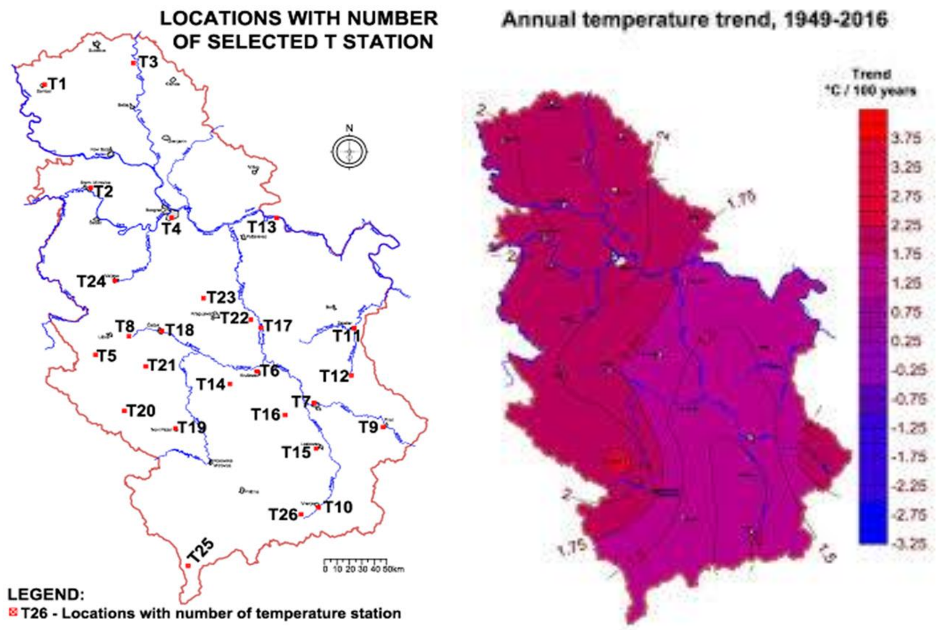
Observations

Most of Serbia has a temperate continental climate. A continental climate prevails in the mountainous areas of over 1,000 metres. The climate in the Serbian southwest borders on the Mediterranean is subtropical and continental. According to measurements made during 1961–1990, the mean annual air temperatures are between 10 and 12°C in the lowlands and Metohija, below 10°C at altitudes higher

than 600 metres, around 6°C at altitudes above 1,000 metres, and around 3°C at altitudes above 1,500 metres. From 1961 to 2010 periods of extremely hot weather last longer and periods of extremely cold weather are shorter. These trends of duration of extreme temperature conditions are most pronounced in summer season (Milanovic-Milicevic et al, 2016).

In the period 1949–2009, there was an increase in mean annual temperatures in almost all parts of Serbia. The rises in temperatures were higher in the northern than in the southern parts of the country. The highest increase of mean annual temperatures was in Belgrade due to the urban heat island effect: 0.20°C/decade in the period 1949–2009. Significant increase of mean annual temperature was found in almost the whole of Serbia during 1989-2010, especially due to warming of the summer season; a negative temperature trend was found for the whole of Serbia for 1961-1989. Daily maximum temperature has also increased over the period 1951-2010.

In 2007 Serbia experienced the most severe heat wave ever recorded in Serbia, with record values of the maximum temperature of 44.9°C (ClimateChangePost, 2019). In agreement with these results, decreasing trends in the frequency of cold waves and increasing trends of heat waves haven been found for the period 1949 to 2012 in Serbia (Unkasevic and Tosic, 2015;
Dimkič (2018) presented the observed climate and hydrologic changes in Serbia between 1946-2016 and what has changed in the last ten years.



a. d.

Figure 4. a. d. The locations of selected temperature (T) stations (a) and the assosiated spatial distribution of the temperatura trends (°C/100 years) for periods 1949–2006; 1959–2016 and 1949–2016

The most significant difference in results of the research presented in his paper, which include data of the last 10 years, in comparison to previous results are related to temperature. An increasing T trend of 1.7 °C/100 years on average was derived from 26 analysed T stations (0.6 °C/100 years in the 1st researching step from the same 26 stations). As in the 1st researching step, a higher trend was noted in western and northern parts of the country. South-eastern Serbia exhibits the lowest trend, what could be explained, maybe, as influence of Aegean Sea through the Axios valley.

These nationwide temperature trends are also reflected in Novi Sad. Annual mean temperature as well as daily minimum and maximum temperatures have increased by about 0.7-1.0°C over the last 50 years.

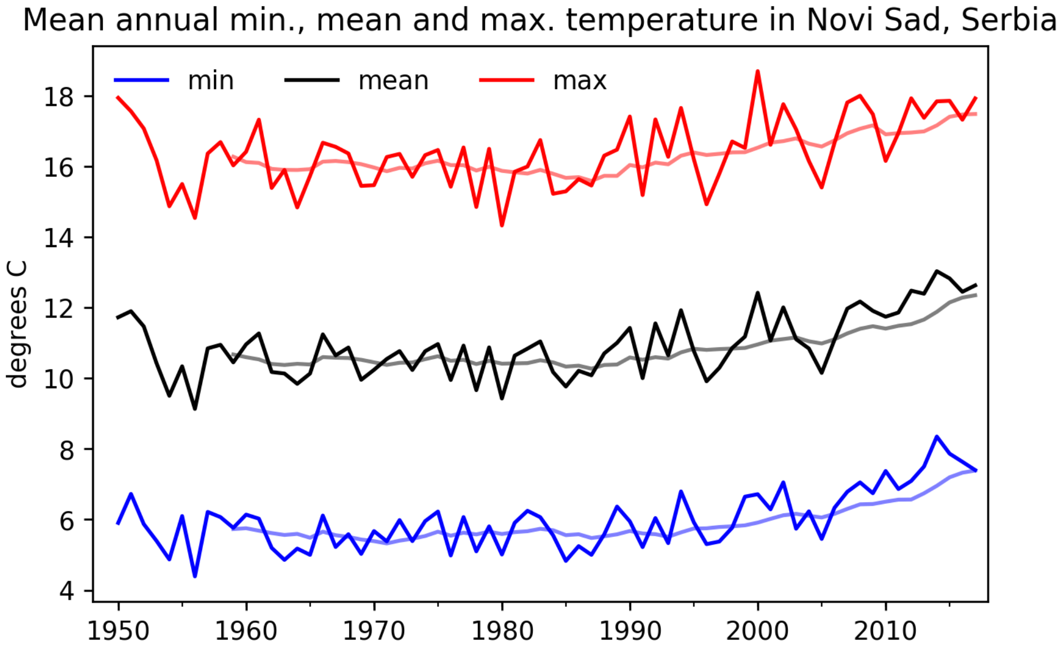


Figure 5: Mean annual minimum, mean and maximum temperature in Novi Sad, Serbia between 1950-2017 from the EOBSv17 daily dataset. Decadal moving averages are given in shaded lines.

4.1.2 Precipitation data analyses

Observations

Observed precipitation changes in (Dimkič, 2018) paper are selected P stations with observed and adjusted trends for periods 1949–2006, 1959–2016 and 1949–2016.

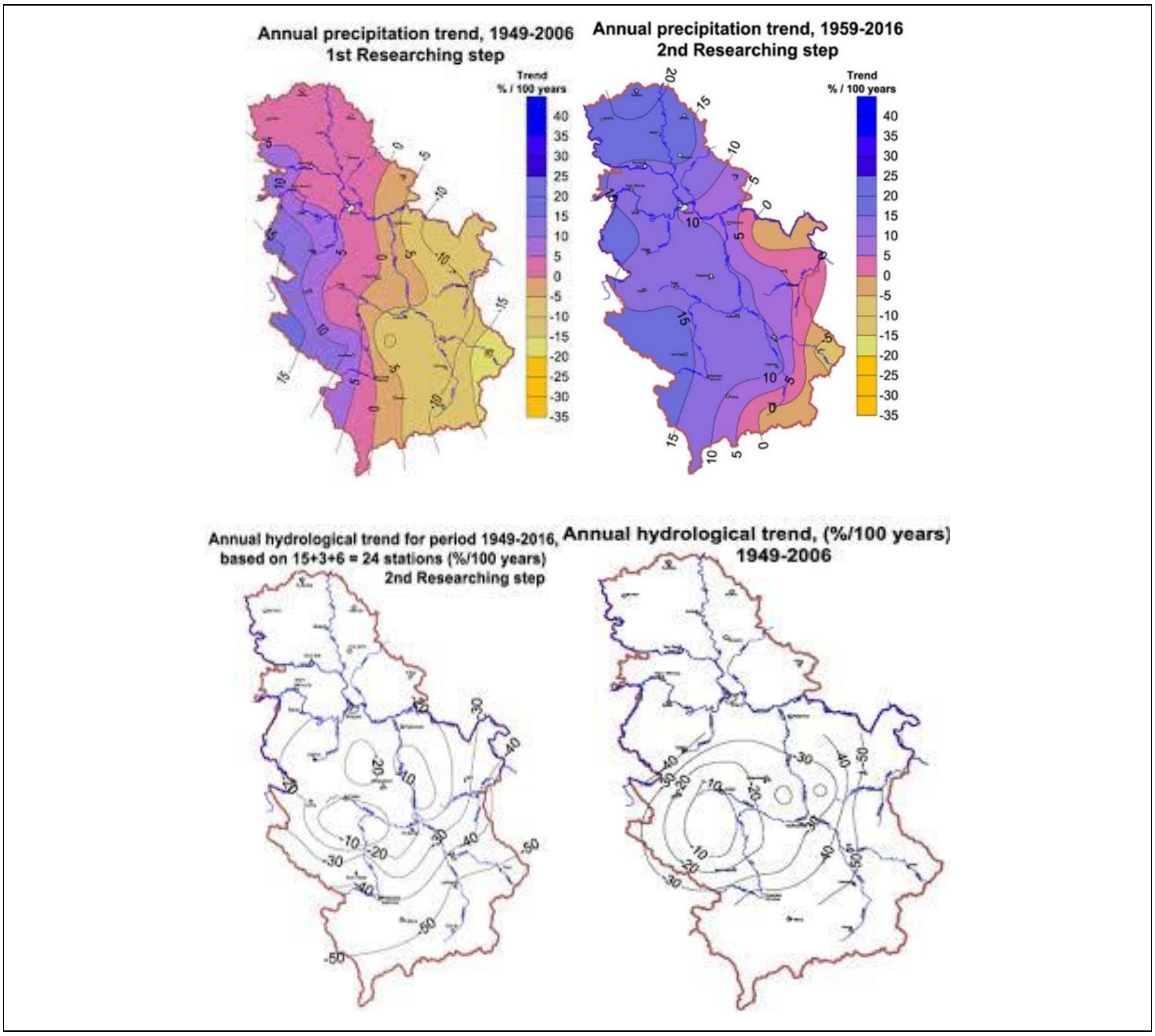


Figure 6. The map of Serbia with orography and position of meteorological stations Source: (Dimkič, 2018)

In order to predict extreme weather events, it is essential to know the thresholds of unfavourable weather phenomena. Many studies have been carried out regarding the impact of these weather phenomena upon different aspects of the environment and human activity within modern climate changes.

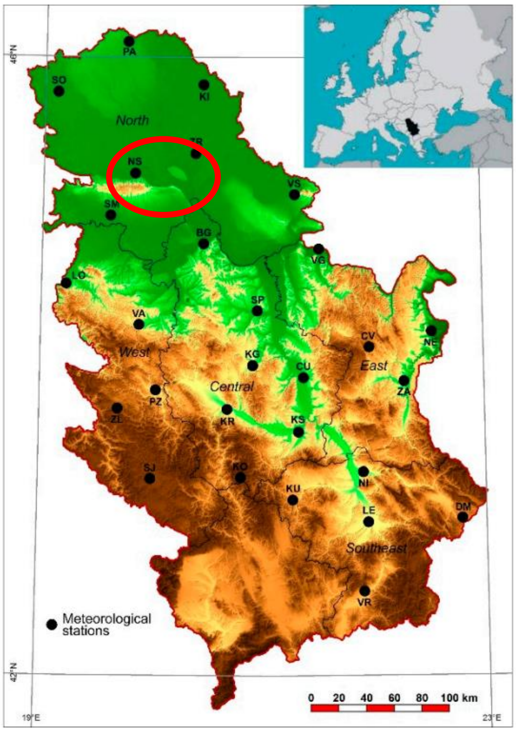


Figure 7(a)

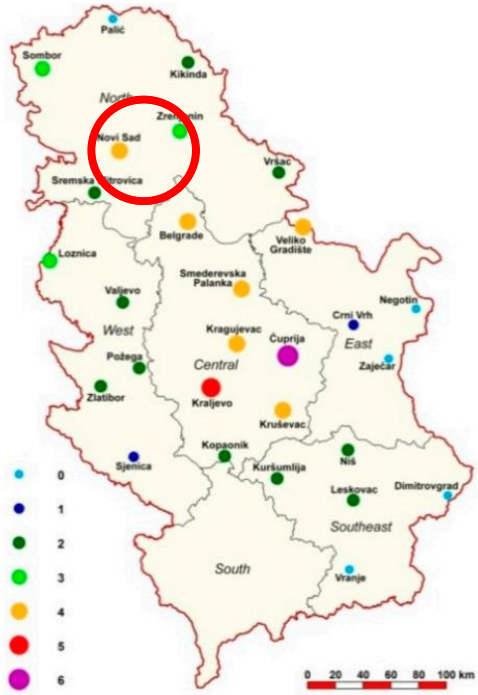


Figure 7 (b)

Figure 7 (a) shows relief map of Serbia with meteorological stations. whereas (b) depits the frequencies of very heavy precipitation events defined by the method of decile at meteorological stations in Serbia and labelled in terms of their f national significance (1961–2015). Source: (Anđelković et al., 2018)

The critical number of stations (namely at least 7 stations) is extraordinarily above normal, since it can cause extremely harmful consequences of national significance in the environment (Figure 7). During the time period in which the largest floods occurred in May 2014, 50% of the meteorological stations in Serbia registered exceedance of the threshold for extreme precipitation. Out of that number, 12 stations were in the area of northern Serbia (covering 33.204 km2 or 42.85% of the territory) which, of all regions, suffered the most from the floods. The consequences of the floods were upsetting: 51 people died, 31,879 people were evacuated, and 1.6 million people were directly or indirectly hurt.

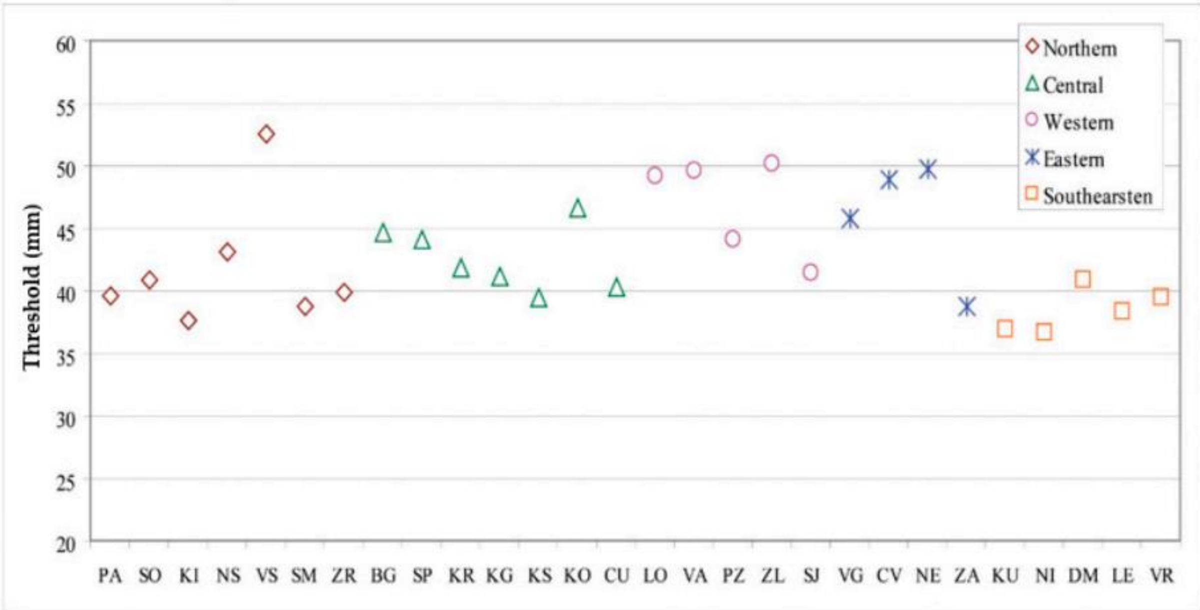


Figure 8. Average value thresholds (mm) for very heavy precipitation events for meteorological stations grouped in five regions for the period 1961–2015 in Serbia Source: (Anđelković et al., 2018)

The threshold for heavy precipitation events, determined by the method of peaks, is in the range of 36.6–52.5 mm per day. (Figure 8) in Serbia. If the daily intensity of precipitation is above the calculated thresholds, it is likely that river discharge and the water level will increase, mechanical water erosion will occur, leading to damage to agricultural areas and settlements.

Table 2. Daily thresholds for heavy precipitation events by region in Serbia (Anđelković et al., 2018)

Region	TH_{av} (mm)	TH_{lv} (mm)	DVI (mm)	Cv	Station of the Minimal Threshold
Northern	42.8	37.6	14.9	11.8	Kikinda
Central	42.6	39.5	7.2	6.2	Kruševac
Western	46.9	41.5	8.7	8.3	Sjenica
Eastern	45.9	38.8	11.0	10.9	Zaječar
South-eastern	38.5	36.6	4.3	4.6	Niš

TH_{av} is the average threshold value; TH_{lv} is the lowest threshold value; DVI is the data variation interval, and Cv is the coefficient of variability.

The results of the research regarding thresholds of extreme precipitation have both local and national significance, and are important for developing readiness strategies which would allow communities to react in situations of crisis. The spatial distribution of very heavy precipitation events has the most significant impact upon the occurrence of dangerous outcomes in the environment.

Precipitation in Novi Sad follows a similar trend than at the national level. While annual precipitation totals have not risen significantly, 24-hour maximum precipitation shows a clear upward trend. The threshold of heavy precipitation proposed by Anđelković et al. (2018) of 42.8mm was exceeded only 3 times in the second half of the 20th century (1950-2000), but was already exceeded 6 times in the 17 years since (2000-2017).

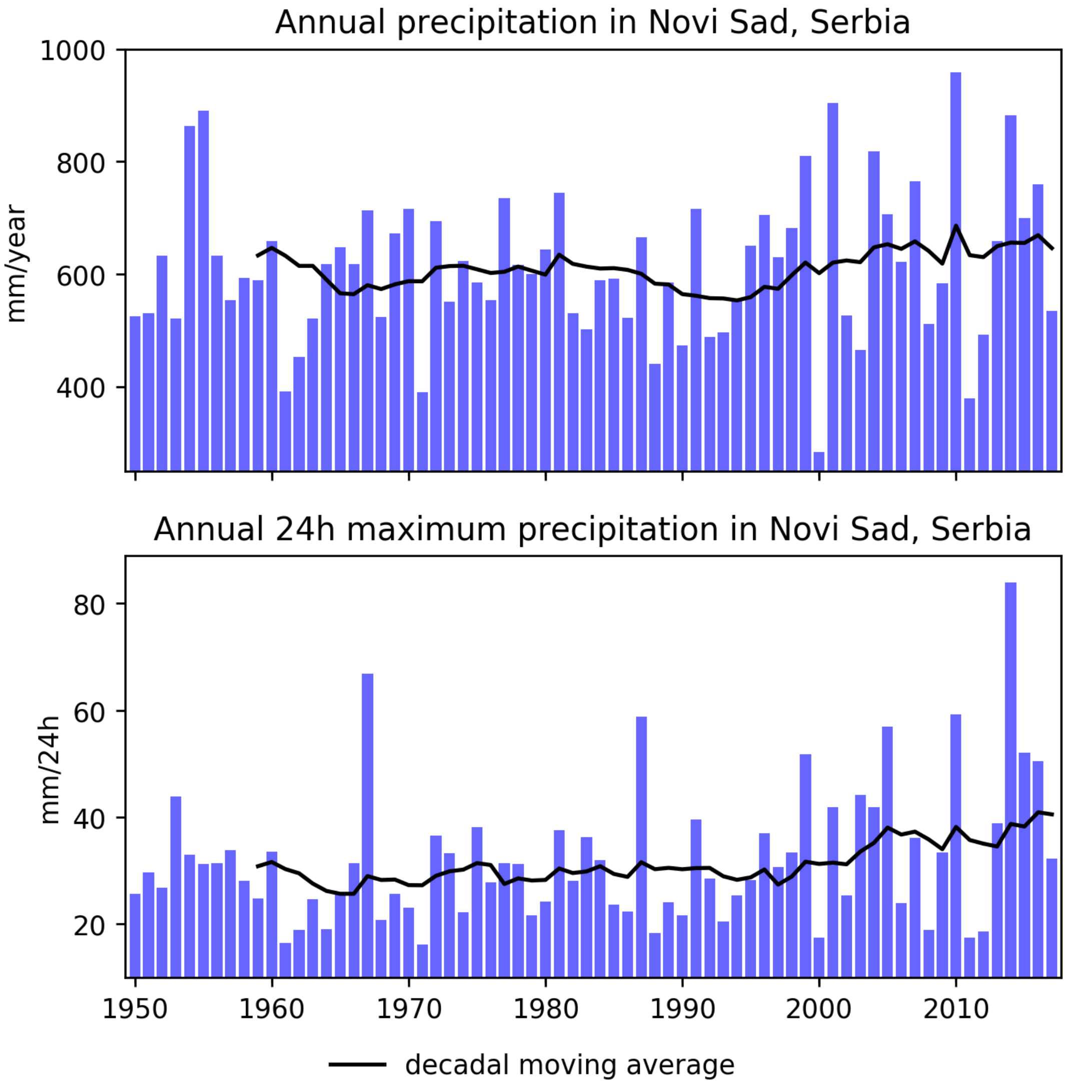


Figure 9: Annual total and maximum temperature in Novi Sad, Serbia between 1050-2017 as given by the EOBv17 daily observational dataset.

4.1.4 Drought

Slide shows the increasing frequency of extreme events and provide historical evidence of the frequency of returns water shortage as much as the water excess.

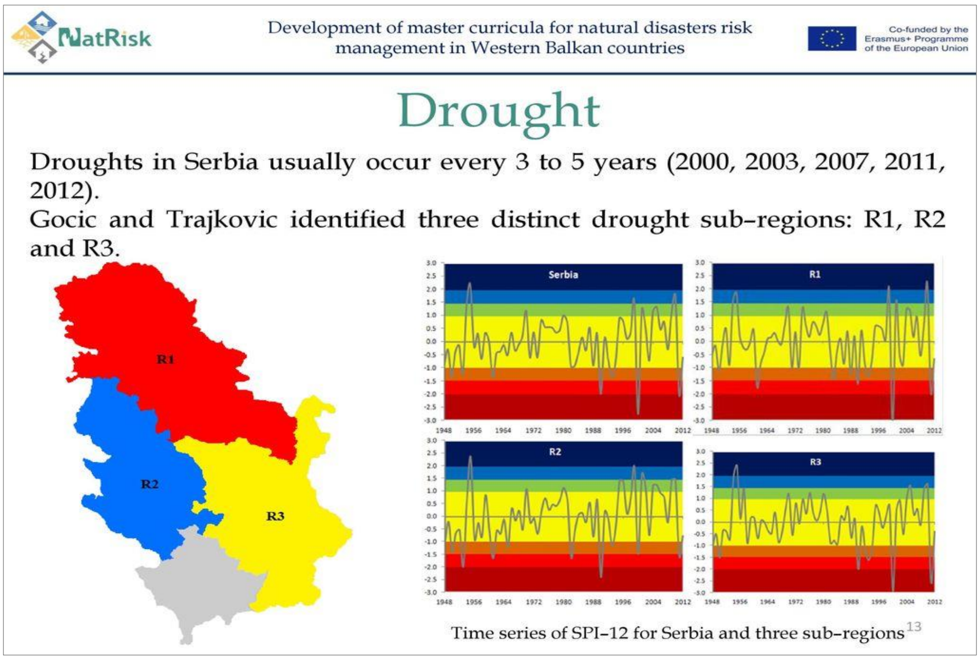
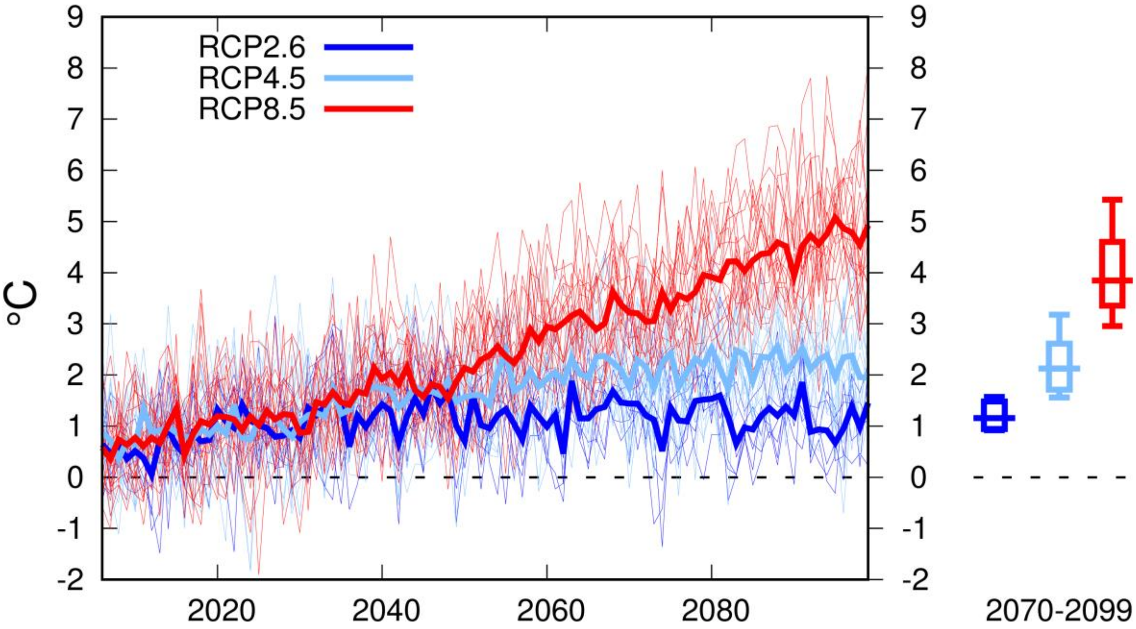


Figure 10. Drought in Serbia according to Gocic and Trajkovic in NatRisk Project

These climate hazards will be definitely determining the future of waste water treatment method and design and operation.

4.2. Assess exposure to future climate change

Where a project is classified as sensitive (Module 1) OR exposed (Module 2a) (with a score of medium or high) to a climate variable or hazard, an assessment should be made of how this may evolve in the future.



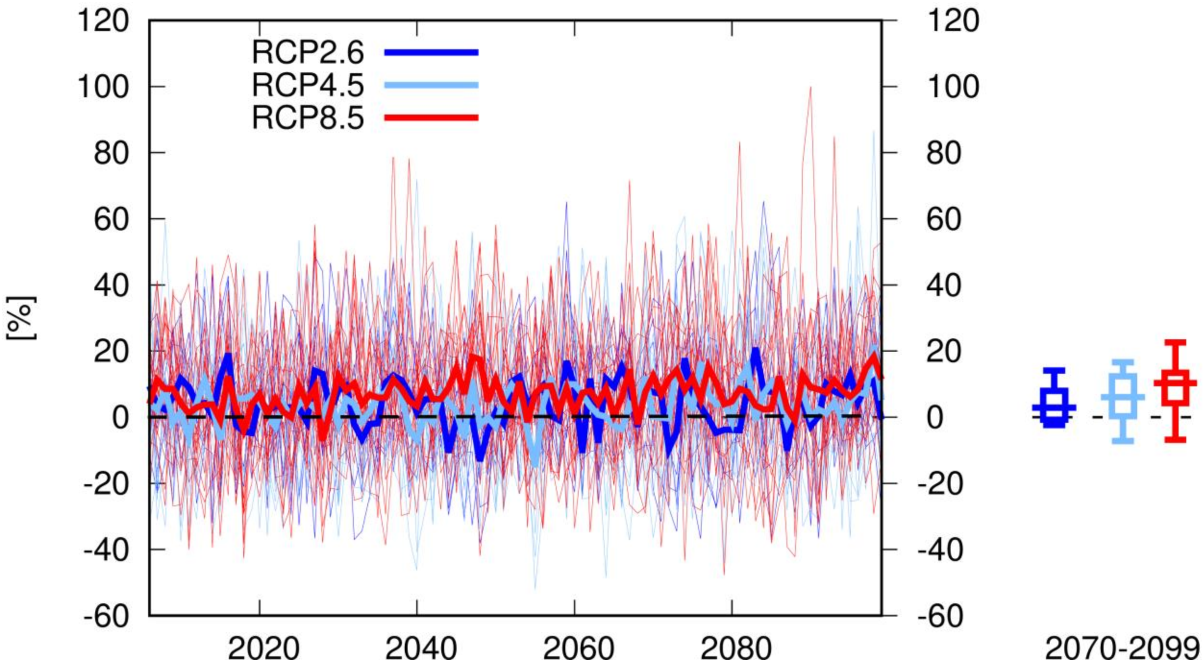


Figure 11: Projected annual mean temperature change (top) and precipitation change (bottom) of Novi Sad, Serbia over the 21st century compared to the reference period 1971-2000. Three climate change scenarios (RCP-2.6, 4.5, 8.5) from the EURO-CORDEX model ensemble are shown with multi-model mean values in bold lines. End-of-century (2070-2099) mean signals of change are indicated on the right.

4.2.1 Temperature extremes

With rising average temperatures in the future, the probabilities of extreme temperature events occurring increases too. The Future Danube Model stochastic meteorological event set was used to show the occurrence of years with extreme temperatures. The number of days the 90th percentile of long-term temperature data is a common heatwave index and is computed for the minimum and maximum temperature and recurrence intervals from 2 to 10’000 years. Values are given for the reference period (1971-2000), the climate period centred around the 2020 representing the current climate and two future climate periods.

Vertical upward shifts in the curves indicate an increase in the number of days the 90th percentile threshold is exceeded is increasing at all recurrence intervals. While the 100-year extreme temperature year in the reference period was defined by about 100 exceedance days per year (both min. T and max. T). Such a year is projected to reoccur every 20-30 years in the current climate period, every 10-20 years towards the middle of the century and every 5-10 years at the end of the century under the medium RCP-4.5 scenario. Inversely, this means that the probabilities are increasing by factors of 3-10 and a future 100-year event would be characterised by 120-160 exceedance days.

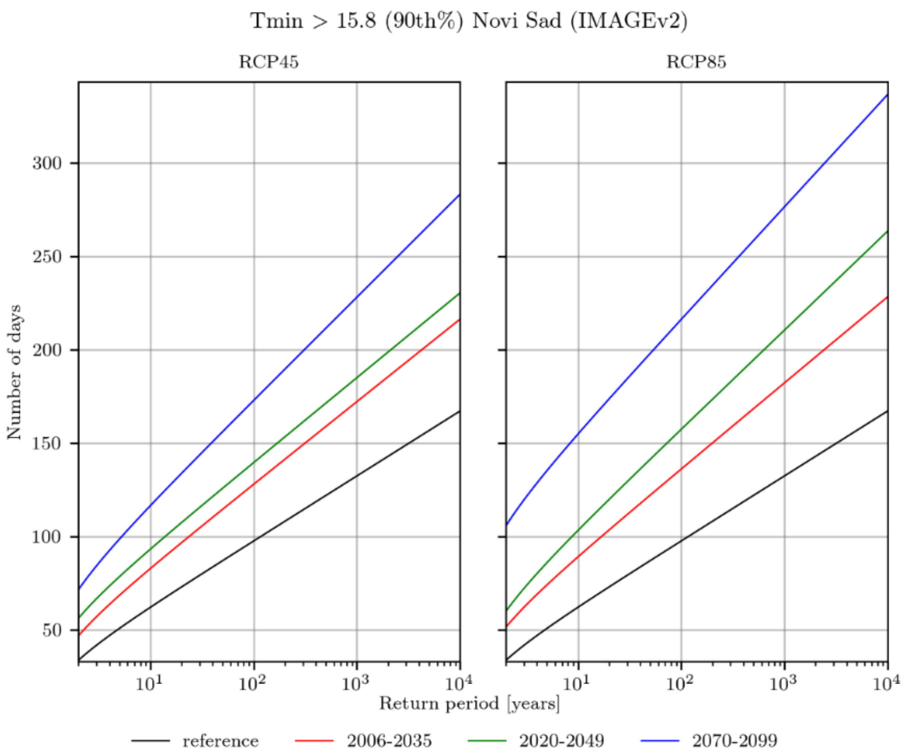


Figure 12: Number of days per year when the minimum temperature exceeds the 90th percentile of the reference period (1971-2000, i.e. 15.8°C). An extreme value distribution (Gumbel) is fitted to the stochastic meteorological event set of the Future Danube Model (IMAGEv2).

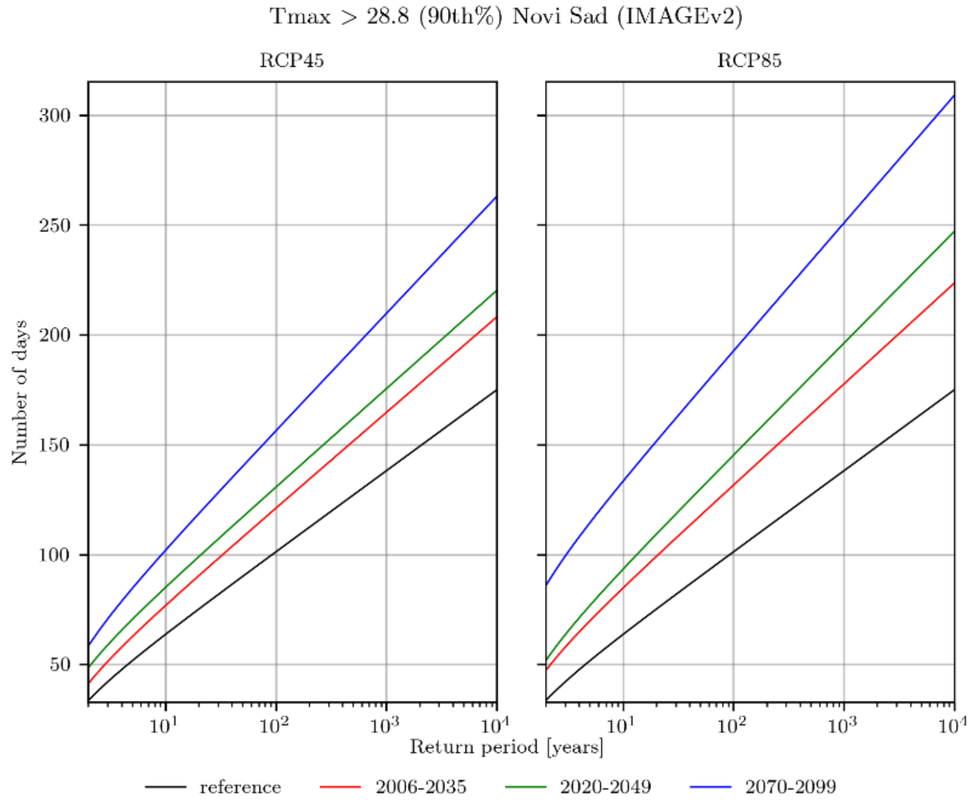


Figure 13: Number of days per year when the maximum temperature exceeds the 90th percentile of the reference period (1971-2000, i.e. 15.8°C). An extreme value distribution (Gumbel) is fitted to the stochastic meteorological event set of the Future Danube Model (IMAGEv2).

4.2.2 Precipitation

With annual precipitation changes of 5-15% towards the end of the century (Figure bottom), extreme precipitation events may worsen too, especially because of the rises in extreme temperatures that enable more water to be taken up and released in extreme rain events lasting minutes to hours leading to short-lived flash flooding (pluvial flooding). But changes in the regional and global climate circulation patterns can lead to changes in regional extreme precipitation events of several days that can lead to longer river flooding (fluvial flooding).

Recurrence intervals of 3-day aggregate precipitation events in Novi Sad are given in Figure 4 for the historical, the current and two future climate periods and two climate change scenarios. A 100-year event in the reference period (1971-2000) is characterised by about 105mm of precipitation over 72 hours. This event may occur every 10-20 years in the future periods, while the future 100-year event would have a magnitude of 120-140mm per 72 hours. Under the high-end RCP-8.5 scenario recurrence levels are increasing with every future climate period, while under the medium RCP-4.5 scenario the mid-century period shows the largest increases.

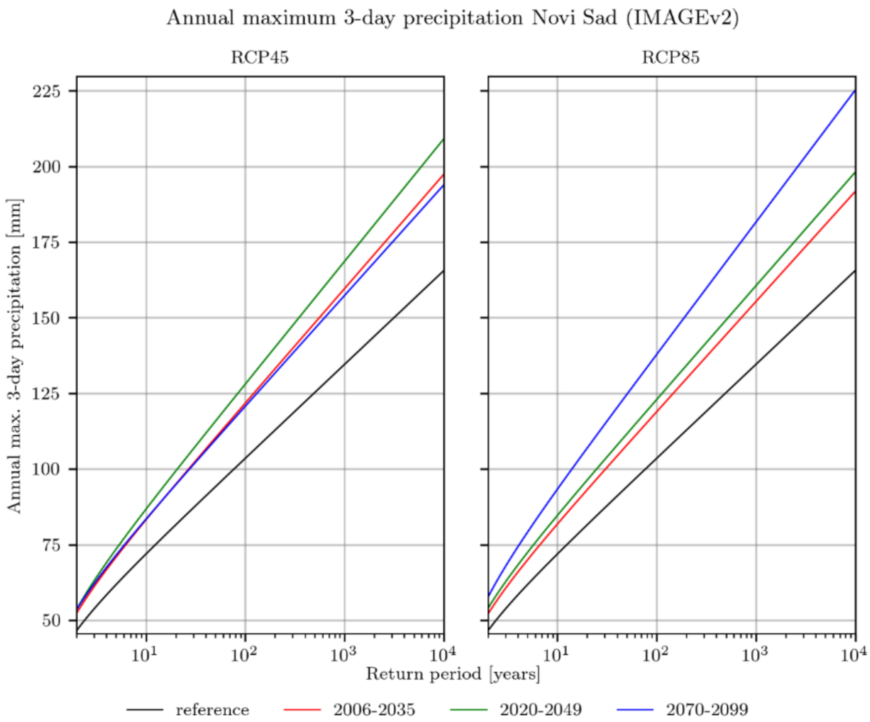


Figure 14: Recurrence of annual maximum 3-day aggregated precipitation in Novi Sad for the reference period (1971-2000), the current and two future climate periods. An extreme value distribution (Gumbel) is fitted to the stochastic meteorological event set of the Future Danube Model (IMAGEv2).

4.2.3. River flooding

The Future Danube Model (FDM) was used to assess the probabilities of flood events of the Danube River that runs through Novi Sad (Hattermann et al. 2018a). The drainage area of the Danube River at Novi Sad is about 257’000km^2. That means that floods may originate in the Alpine headwaters (Germany/Austria) or over much of Hungary and Slovakia. The hydrological module (SWIM) of the

FDM is able to integrate these meteorological events and simulate the resultant discharge at Novi Sad. Since the module is driven by the stochastic meteorological event set of 10’000 years, extreme flood events can be estimated.

Figure 15. gives the flood magnitudes and recurrence intervals of the Danube River at Novi Sad for the reference period (1971-2000) and the current climate period (2006-2035). In the reference period, a 100-year flood would typically have a peak discharge of about 13’000m^{3}s. In the current climate period, this discharge is equalled every 50-70 years, saying that the former 100year event will occur nearly twice as often. This trend is continued in the future periods over the 21st century (Figure15). Depending on the climate change scenario, the 100-year peak discharge is reached every 10-50 years at the end of the century.

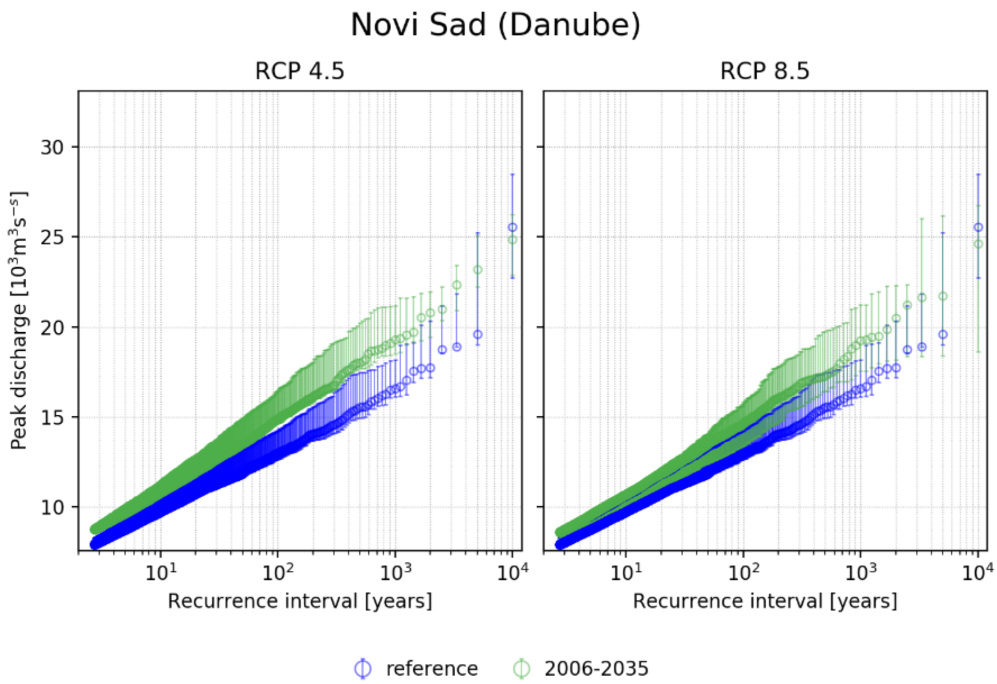


Figure 15: Recurrence of peak discharge in the current climate period (green) in comparison to the reference period (1970–1999, blue) under two climate scenarios. Simulated events driven by four climate model combinations with circles representing the median and error bars denoting the minimum and maximum.

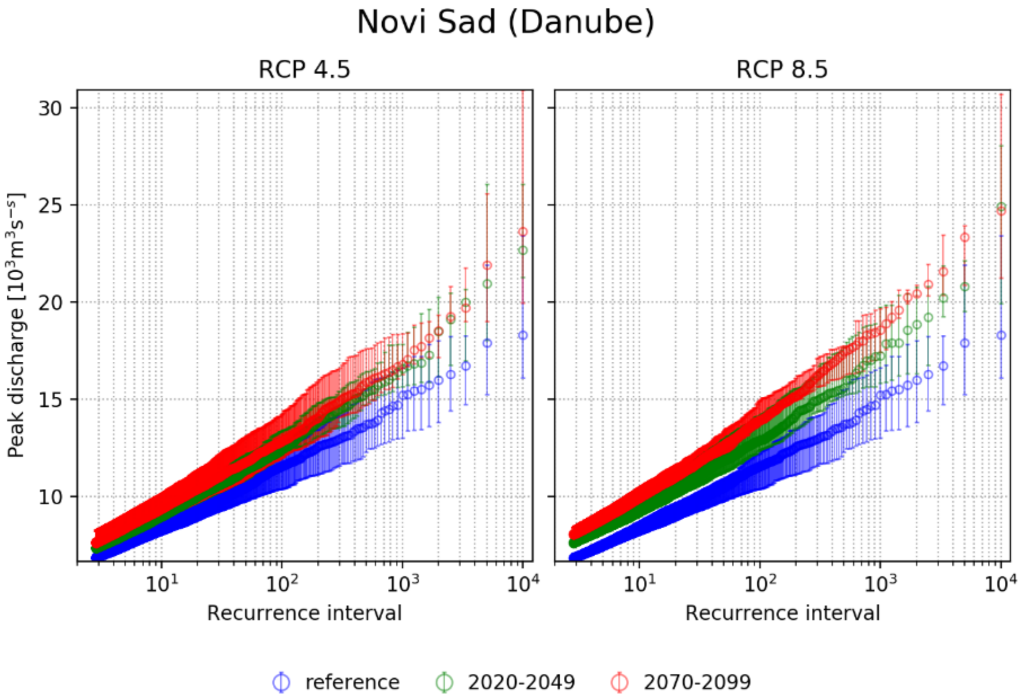


Figure 16: Same as 15. but for two future climate periods of the 21st century in comparison the reference period (1970–1999).

4.2.4. Pluvial flooding

As part of the FDM modelling suite, dedicated floods maps for heavy to extreme precipitation events have been produced for Novi Sad. Figures 18 and 19 illustrates the consequences of a flash flood happening on average once every 20 (Figure 18) and 100 years (Figure 19) under current climate conditions.

The flood maps were produced using a 2D hydrodynamic model based on the EU-DEM v.1.1 (25 m) and quality checked against simulations using a local higher-resolution (5 m) DEM provided by the University of Novi Sad. A simple conceptual representation of the urban drainage system was included as was the effect of infiltration into the soils, taking into account soil types and elevation at a grid point level. A more detailed description of the model may be found in Hattermann et al. (2018a).

Comparing Figures 18 and 19 with Figure 2 and 3 we find that the planned location of the Novi Sad WWTP is in a high-risk area with respect to pluvial flooding. Rainfall falling a higher elevations are thus concentrated and large drained into the Danube around the planned location of the plant.

Flash flood events generally happen at sub-hourly scales. Carrying out a similar analysis to the one shown in Figure 15 for maximum 3-day precipitation for daily, hourly and half-hourly precipitation

(results not shown here) indicate a similar trend for all four climate models and both RCPs scenarios: that the occurrence of what today is a 100-year event will be more frequent in the future. This in turn will put the WWTP at an increasing risk of being flooded, if climate change adaptation measures are incorporated into the plant's design.

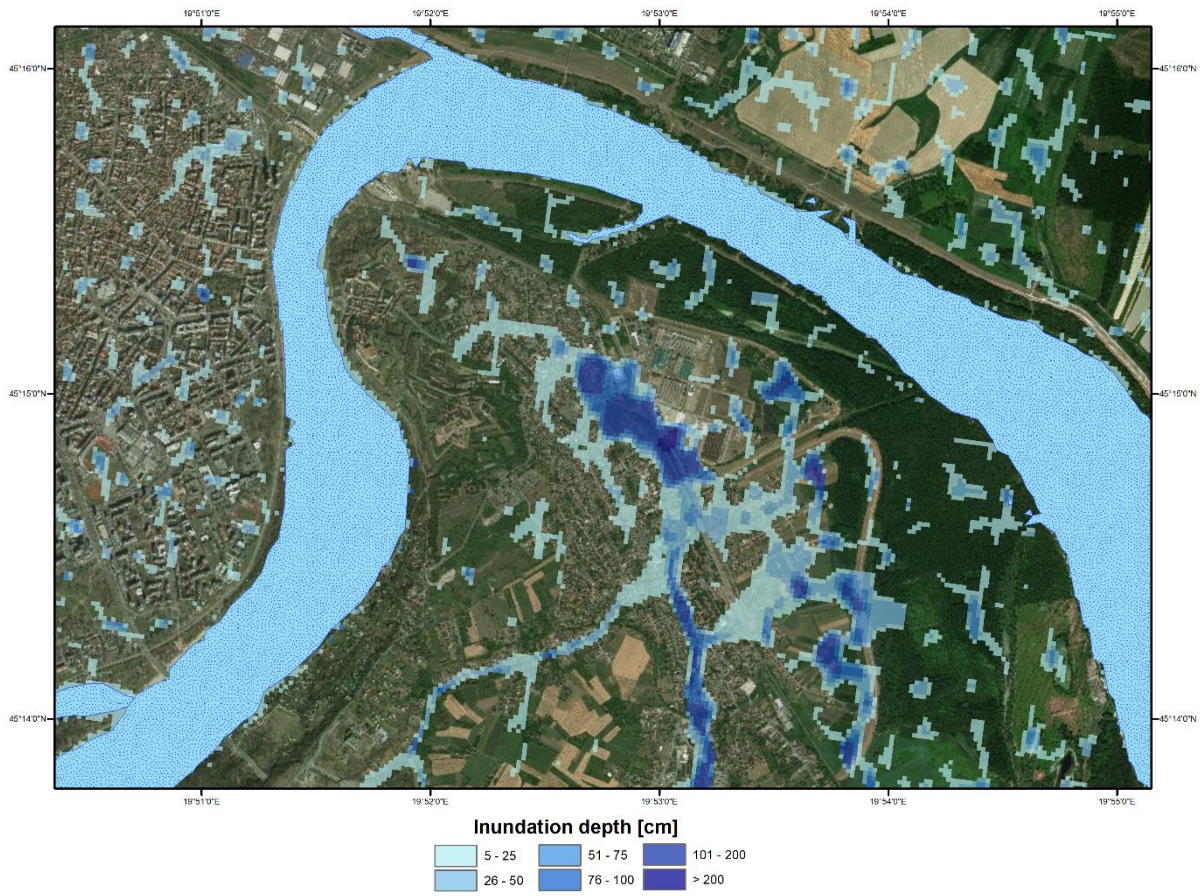


Figure 18: Dynamic estimates of pluvial flooding in Novi Sad caused by high intensity rainfall corresponding to a 20-year return level event (under a present-day climate). The effect of the urban drainage system and of infiltration into soils are included. The varying shades of blue indicate the expected inundation depths. By comparison with Figure 2, it is evident that the planned WWTP in Novi Sad will be located in a very flood-prone area.

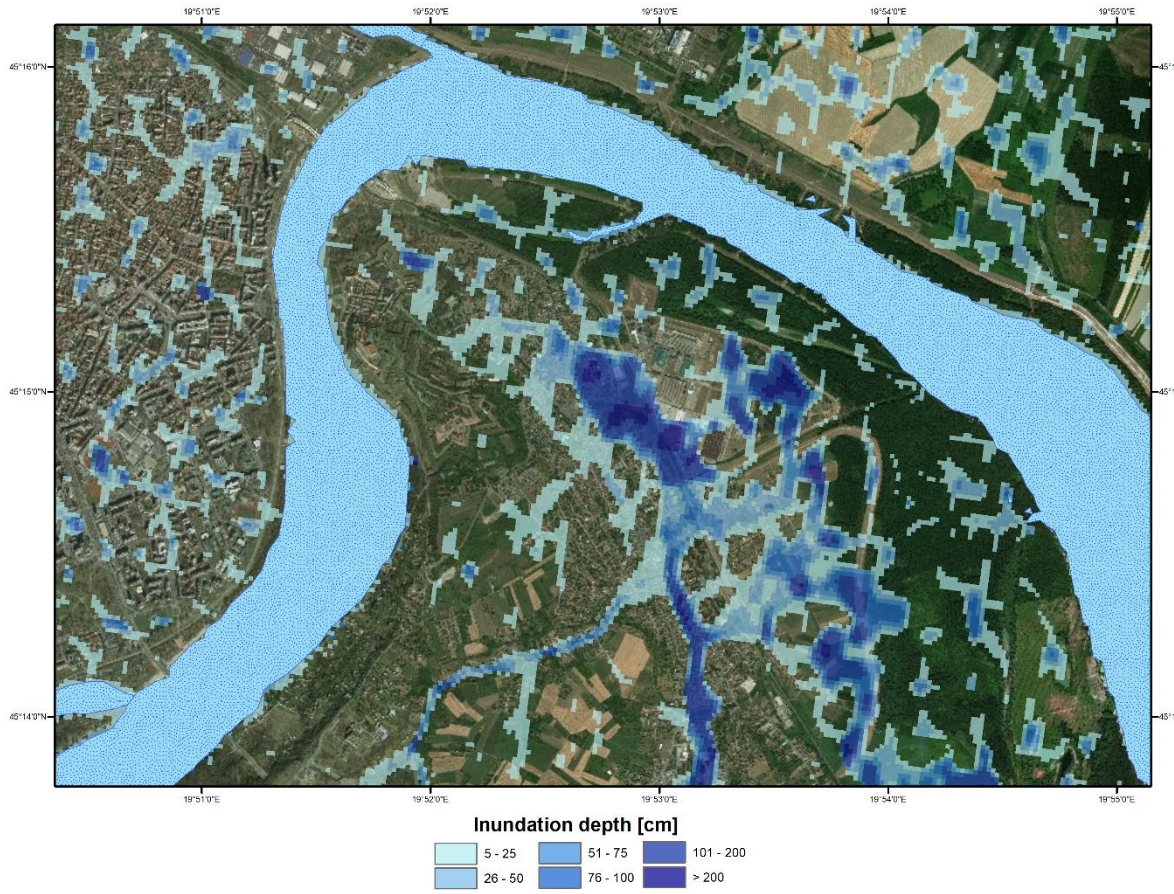


Figure 19: Same as Figure 20 but for an extreme 100-year return level event (under a present climate). Similar to the case of maximum 3-day precipitation (Figure 15) high intensity rainfall events at daily and sub-daily time scales will become more likely under future climatic conditions.

5 Module III. Assess vulnerability

Where a project is considered to have a high or medium sensitivity to a particular climate variable or hazard (Module 1), the project's location and exposure data (Module 2a) will be integrated into GIS in order to assess the vulnerability. Here, for each project site, vulnerability (V) is calculated as follows:

V = S x E

where, [S is the degree of sensitivity the asset has] and [E is exposure to baseline climate conditions / secondary effects]. In this assessment process, the adaptive capacity of each project is assumed to be constant and equal across geographical regions.

Table 3. Impact matrix under current climatic conditions

	Current conditions	Exposure		
		Low	Medium	High
S e n s i t i v i t y	Low			
	Medium		Extreme temperature increasing Increasing extreme rainfall event	
	High			Flash flood Pluvial flood Fluvial flood

LOW	MEDIUM	HIGH

Under current climate circumstances and exposure of the WWTP of Novi Sad it is obviously the vulnerability of the location. First of all, because of the location's low lying. Secondly as the WWTP would be right next to the Danube it has current effect in case of any water related event.

As it can be seen at Modul 1 output the temperature increase can affect the investment, mostly above 40°C but it has to be considered in line with uncertainly of the climate models predicted climate scenarios, it could go to more negative direction.

Table 4. Impact matrix under expected future climatic conditions

	Future Conditions	Exposure		
		Low	Medium	High
S e n s i t	Low			
	Medium			Extreme temperature increase Increased frequency of

Oasis Innovation Hub for Catastrophe and Climate Extremes Risk Assessment Project (H2020_Insurance) is an EU-funded project aiming to innovate a new open source standard for risk assessment, improve climate modelling, damage assessment techniques and accuracy of models as well as operationalise an e-Market for hazard data and climate services: www.oasishub.co. The overarching goal is supporting the understanding of climate risks by the (re) insurance sector and wider society. This will help decrease the gap between insured and uninsured losses caused by climatic hazards.'

i v i t y				heavy rainfall
	High			Flash flood Pluvial flood Fluvial flood

6. Modul IV. Risk assessment

The risk assessment module provides a structured method of analysing climate hazards and their impacts to provide information for decision-making. This process works through assessing the likelihoods and severities of the impacts associated with the hazards identified in Module 2, and assessing the significance of the risk to the success of the project.

In this case the detailed risk assessment will focus on the precipitation data, the return forecast of the heavy rainfalls and the possible amount of water from precipitation. According to the 1-3 modules considering the increasing frequency of heavy rainfalls the capacity of the WWTP is the most vulnerable.

Increasing frequency of heavy rainfall raise the possibility of every kind of flood.

Table 5. Risk assessment of WWTP of Novi Sad

		Catastrophe	High	Medium	Low	No significant
Probability	Almost certain					
	Likely		Increased frequency of flash floods			
	Possible					
	Not likely					
	Rare					
Colours		Extreme	High	Medium	Low	No

Under current climatic conditions, the increase in the intensity of rainfall and the change in seasonal distribution can increase the frequency and intensity of flood waves can already have a highly estimated potential physical impact.

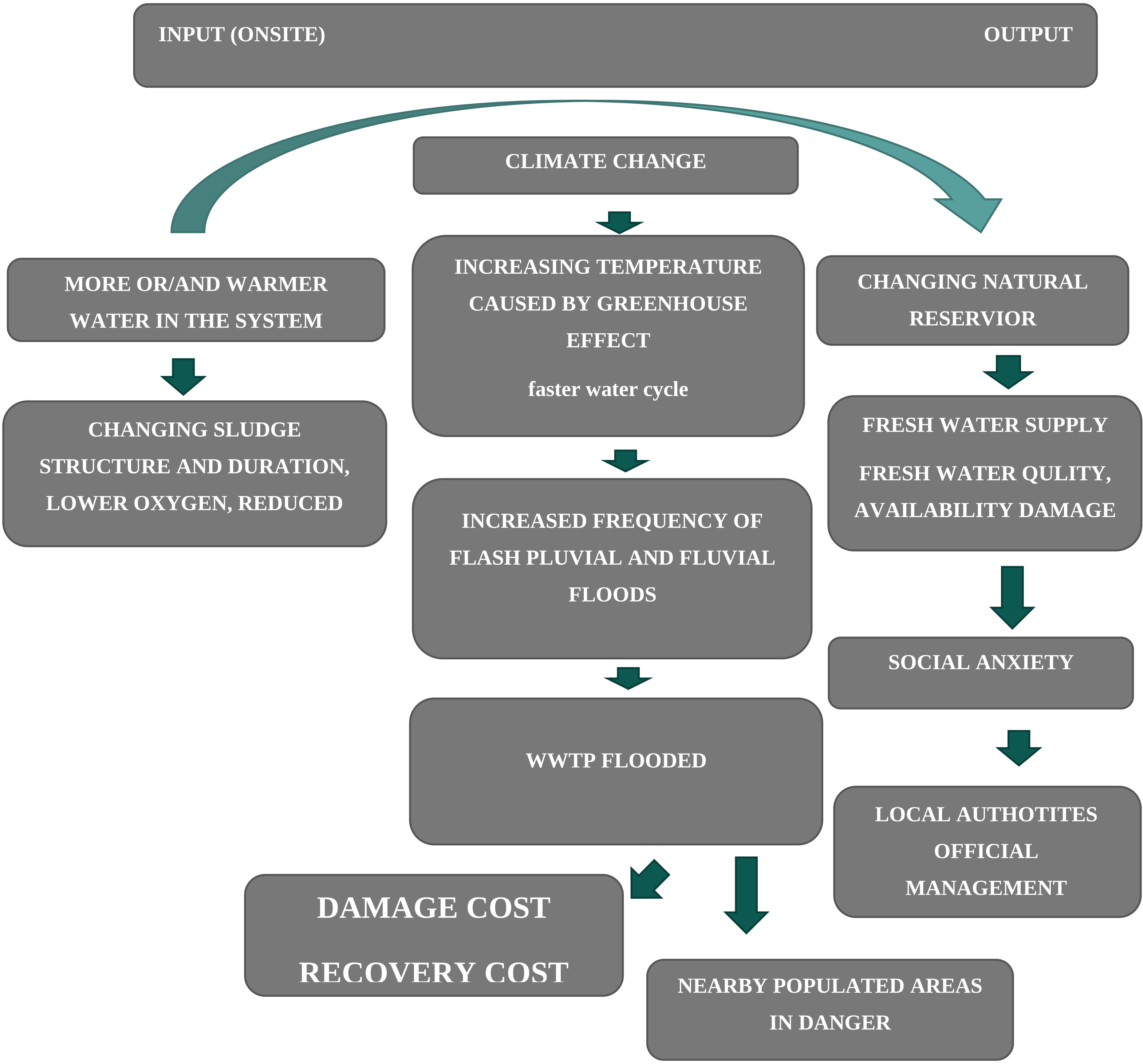
6.1 Risk Identification Workshop - Novi Sad 2019 February

Here participants identified how climate-related risks could affect project performance and ability to achieve the success criteria. We needed to clarify the critical thresholds of the WWTP capacity.

OUTPUTS:

- store capacity on the location compared to the downhill rainwater and rainfall
- critic temperature of the WWTP in type of activated sludge – implemented in Modul I.
- freshwater supply context
- in case of discharge the WWTP can let out extra water 12 per year
- WWTP capacity

6.2 Impact pathway of Waste Water Treatment Plant of Novi Sad



7. Conclusions and recommended adaptation measures

Both the historical data and the climate projections show clear evidence of climate change impacting Novi Sad and that this will have implications for the planned WWTP both in terms of its operation and in terms of increased catastrophic risk to the infrastructure. Investments especially the water related ones have to consider both high flows and low flows and the associated discharges not just locally but at regional level due to natural process and the role of the Danube as an integrator of water

The increased risk of extreme climate event like droughts and flash floods puts the WWTP in high risk, in parts due to its location.

Considering the risk factors, below are the recommendation to the designing process:

1. Building adaptive capacity

The first and strongly recommended climate adaptation option is to make sure that appropriate capacity is built to handle the high-water flows. The total capacity of the WWTP must be updated by the latest baseline data and climate projections. The Future Danube Model provides all the necessary information to do this. The required safety level must be considered and determined, e.g., whether the system should be able to handle, e.g., a 100- and 1000-years fluvial or pluvial flood return level events.

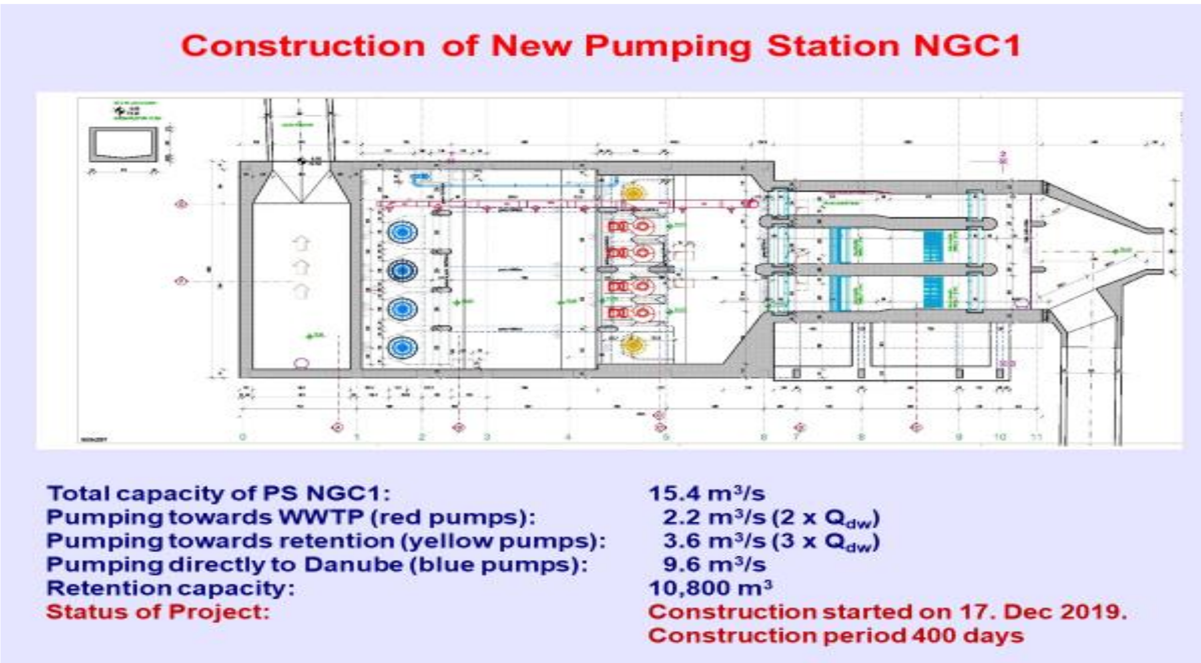


Figure 17. New Pumping Station plan Source: Public utility company Waterworks and Sewerage Novi Sad – Radoica Stefanovič

The plant design must be so that is can operated at extreme low and extreme high-water levels as indicated by climate projections.

2. Flood defences

The investment has to carefully consider the projected risk pluvial flooding from heavy rainfalls. As indicated in this analysis, the WWTP will be located in a location where it is well protected from fluvial floods, but where the risk of flooding is almost the highest in Novi Sad. It is critical that the further planning process consider this weakness point of the WWTP related to the pluvial floods and the suitable adaptation measures are installed.

3. Cooperation with the relevant authorities and water management sector

Besides the basic cooperation it is necessary to discuss the alternatives to hard adaptation options, including also the softer engineering solutions in terms of not only on return on investment but also in term of the direct environmental effects.

4. Recommendations to tackle climate change through WWTP

Waste water treating incurs greenhouse gas emissions that enhances climate change and is in turn also by climate change as described above. Major greenhouse gasses evolved from WWTPs are CO_2, CH_4, & N_20. CH_4 and CO_2 are formed from the anaerobic decomposition of organic matter N_2O is formed in nitrification and denitrification processes that are becoming more prevalent as the industry moves toward more complete nutrient removal.

As climate change is a major concern, alternatives should reduce both greenhouse gas emissions and power consumption, making anaerobic treatment a more attractive component of novel approaches to treatment processes (Kenten Danas, 2012).

8 References

Bakos Vince, G. B. (2017). Investigation of the rheological properties of activated sludge as a function of sludge structure and sedimentation II:. *Hungarian Water Association*.

ClimateChangePost. (2019). Source: https://www.climatechangepost.com/serbia/climate-change/.

COMMISSION, E. (dátum nélk.). Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient.

Dimkič, D. (2018). *Observed Climate and Hydrologic Changes in Serbia—What Has Changed in the Last Ten Years †.* Proceedings of EWaS3 2018.

Floodlist. (2019). Source: Floodlist Serbia: http://floodlist.com/tag/serbia

Goran A, S. J. (2018). Extreme Precipitation Events in Serbia: Defining the Threshold Criteria for Emergency Preparedness. *atmosphere*.

Hattermann, F.F., Wortmann, M., Liersch, S., Toumi, R., Sparks, N., Genillard, C., Schröter, K., Steinhausen, M., Gyalai-Korpos, M., Máté, K., Hayes, B., del Rocío Rivas López, M., Rácz, T., Nielsen, M.R., Kaspersen, P.S., Drews, M. (2018a). Simulation of flood hazard and risk in the Danube basin with the Future Danube Model, Climate Services 12, 14-26.

Hattermann F, Vetter T, Breuer L, Su B, Daggupati P, Donnelly C, Fekete B, Flörke M, et al. (2018b). Sources of uncertainty in hydrological climate impact assessment: a cross-scale study. Environmental Research Letters 13 (1): e015006.

Instruments, H. (2019). *hannainst.com*. Source: https://blog.hannainst.com/5-ways-wastewater-plants-account-for-seasonal-temperature-change-in-their-aeration-tanks/.

Kenten Danas, B. K. (2012). *Climate Change Effects on Waste Water Treatment.* CEE Jordan Group Presentation.

Lalic and Mihailovic (2011) The Ministry of Environment and Spatial Planning of the Republic of Serbia (2010) Lelieveld et al. (2012) Kuglitsch et al. (2010), i. L. (dátum nélk.). *ClimateChangePost*. Source: https://www.climatechangepost.com/serbia/climate-change/.

Manassra, R. I. (2006). Study of temperature effects on activated sludge floc stability. *Master thesis in Applied Environmental Measurement Techniques* .

Moazzam Shahzad 1, S. J. (2015). Influence of Temperature on the Performance of a Full-Scale Activated Sludge Process Operated at Varying Solids Retention. *Water*.

Stojanović, S. (5th April 2017). *Development of master curricula for natural disasters risk management in Western Balkan countries NatRisk project.* Workshop on master curricula best practices in EU partners.

Wastewater Connect. (2019). Source: http://wastewaterconnect.co.za/wastewater-info-hub-entry?id=15.