

## 3.2.4 Collection of the available extreme waves risk management plan for the HR test site

---

Final Version

Deliverable Number 3.2.4

<b>Project Acronym</b>	PMO-GATE
<b>Project ID Number</b>	10046122
<b>Project Title</b>	Preventing, Managing and Overcoming natural-hazards risk to mitiGATE economic and social impact
<b>Priority Axis</b>	2: Safety and Resilience
<b>Specific objective</b>	2.2: Increase the safety of the Programme area from natural and man-made disaster
<b>Work Package Number</b>	3
<b>Work Package Title</b>	Assessment of single-Hazard exposure in coastal and urban areas
<b>Activity Number</b>	2
<b>Activity Title</b>	Assessment of meteo-tsunami exposure in coastal areas
<b>Partner in Charge</b>	UNIVERSITY OF SPLIT, FACULTY OF CIVIL ENGINEERING, ARCHITECTURE AND GEODESY
<b>Partners involved</b>	UNIVERSITY OF SPLIT, FACULTY OF CIVIL ENGINEERING, ARCHITECTURE AND GEODESY
<b>Status</b>	Final
<b>Distribution</b>	Public

## Summary

1.	Introduction .....	4
1.1	Brief presentation of Activity 3.2 .....	3
1.2	Description of the test site – Kaštel Kambelovac .....	3
2.	National legislation .....	5
2.1	Water Act (NN 66/2019) .....	5
2.2	Strategy for climate change adaptation for Republic of Croatia .....	7
3.	Regional documents .....	8
3.1	Disaster risk management plan for Split-Dalmatia County.....	8
4.	Local documents .....	9
4.1	City of Kaštela Spatial Plan – Annex for Urban Measures for Natural Disasters and War Protection Plan.....	9
4.2	City of Kaštela Coastal Management Plan .....	9
4.3	Disaster risk management plan for City of Kaštela.....	11
4.4	Emergency Protection and Rescue Plan for City of Kaštela.....	13
	References .....	14

## 1. Introduction

### 1.1 Brief presentation of Activity 3.2

Activity 3.2 within Work Package 3 of PMO-GATE project relates to the assessment of flooding in coastal urban areas due to extreme waves exposure. Significant number of objects along the coastline are potentially exposed to flooding due to the impact of extreme waves on the sea surface generated by severe winds. Within this activity, an extreme waves flooding exposure analysis is performed for the particular test site of Kaštel Kambelovac. Furthermore, this activity addresses the main weak points potentially exposed to extreme waves flooding, which in combination with extreme waves exposure maps are used for flood risk assessment on the particular test site. In addition, existing flood risk management plans are evaluated along with the relevant EU legislation. Finally, a set of actions is defined in order to harmonize local flood risk management plans with EU requirements.

### 1.2 Description of the test site – Kaštel Kambelovac

Along the Croatian coast, flooding endangers many low-lying coastal areas potentially exposing significant number of objects to flood hazard. Many historical buildings and/or areas are located along the coastline, which are potentially endangered by coastal flooding as well and subject to significant consequences and damage. The City of Kaštela area is endangered by sea flooding due to its low-lying topography and significant number of cultural and household objects located near the coastline. The particular test site in PMO-GATE project is Kaštel Kambelovac, one of the seven settlements that form the City of Kaštela. This area covers around 45000 square meters and includes more than 400 objects.

The benefit of the chosen area reflects through diversity of objects considering construction, architecture and material, built from the 15th century until today. According to Marasović [1] the oldest objects in the area date back to 1467. These buildings were made of stone with a wooden floor

construction, and they remained preserved until today with minor modifications over the years. Historical part of the Kaštel Kambelovac is founded in the 16th century around the Tower of Cambi, as well as the church of St. Mihovil and Martin from the 19th century with a bell tower from 1860. This particular area is a mixture of private and public facilities, mostly built as masonry and concrete buildings. Plan view of the selected area is shown in Figure 1, where the green line defines the border of the test site, purple one defines the border of historical part, while the red line shows position of the natural coastline.

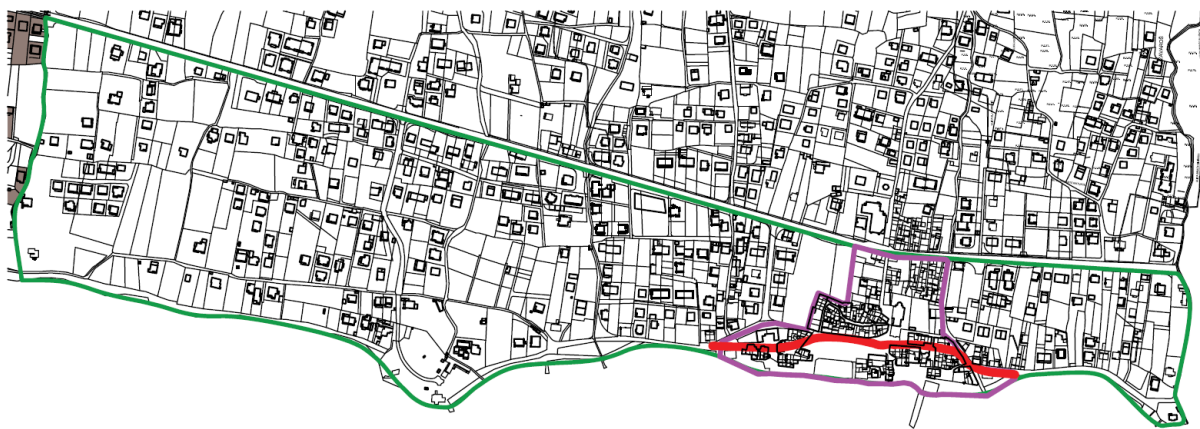


Figure 1. Plan view of the selected area (green line) with the mark of the natural coastline (red line) and the historical part (purple line)

Coastal flooding is considered one of the major threats for coastal urban areas. This is especially related to low-lying coastal areas such as City of Kaštela, where significant part of the city is located near the coastline. High population density in the coastal area of City of Kaštela, together with a large number of buildings and other assets makes this area highly vulnerable. Coastal flooding in the City of Kaštela is becoming more frequent and recent events caused damage to different assets, exposing the weak points within buildings and existing infrastructure.

## 2. National legislation

### 2.1 Water Act (NN 66/2019)

Water Act [2] in Croatia determines the legal status of water in general, including water quality and quantity, water management, institutional framework as well as flood related issues. It is harmonized with the Floods Directive [3] and defines flood as temporary coverage of land by water, caused by rivers, torrents, temporary watercourses, lakes or ice clusters, as well as sea in coastal areas. The definition of flood risk within Water Act is in accordance with the Floods Directive, defining flood risk as a combination of flood probability and potential adverse consequences for people, assets, environment, cultural heritage and economic activity.

Water Act defined a national agency Croatian Waters as a legal entity for water management. Croatian Waters are responsible for water management issues for each particular area, including flood risk management. According to Water Act, flood risk management considers producing preliminary risk assessment, development and implementation of flood risk management plans, including National Flood Defense Plan [4], and water management and regulation, which considers implementation of flood emergency measures.

Based on the available information, which is related to long-term changes especially connected to climate impacts, Croatian Waters are obliged to perform a preliminary flood risk assessment for each endangered area. Based on the preliminary assessment, Croatian Waters will classify particular endangered areas where significant risks might occur. These areas are defined in Water Management Plan [5], and for which a detailed flood hazard and flood risk analysis and mapping should be made.

According to Water Act, for each endangered area a flood risk management plan should be developed as a part of national Water Management Plan, containing specific goals for mitigation of adverse consequences for human health, environment, cultural heritage and economic activities. Actions for fulfilling these goals should focus on non-structural measures and mitigation of flooding probability on an endangered area.



National flood defense plan contains details about: flood risk management goals; flood defense territorial units; particular responsibilities; different flood defense stages and measures, including measures for prevention; flood threat duration in relation to human health and other living environment. It defines details about operational flood defense plans for each area, protection and rescue measures, emergency responders, food and water supply, and warning and communication systems.

Flood hazard and flood risk maps have been recently amended in Croatia [6], consisting of scenarios with high, moderate and low probability with estimation of adverse consequences for people, economic activity and assets. Considering coastal flooding, climate change impact on sea level rise has been taken into consideration during flood modelling. Due to large affected area the flood modelling results are presented on a relatively coarse scale (Figure 2), implying that further activities are required in the future in order to obtain more detailed results.

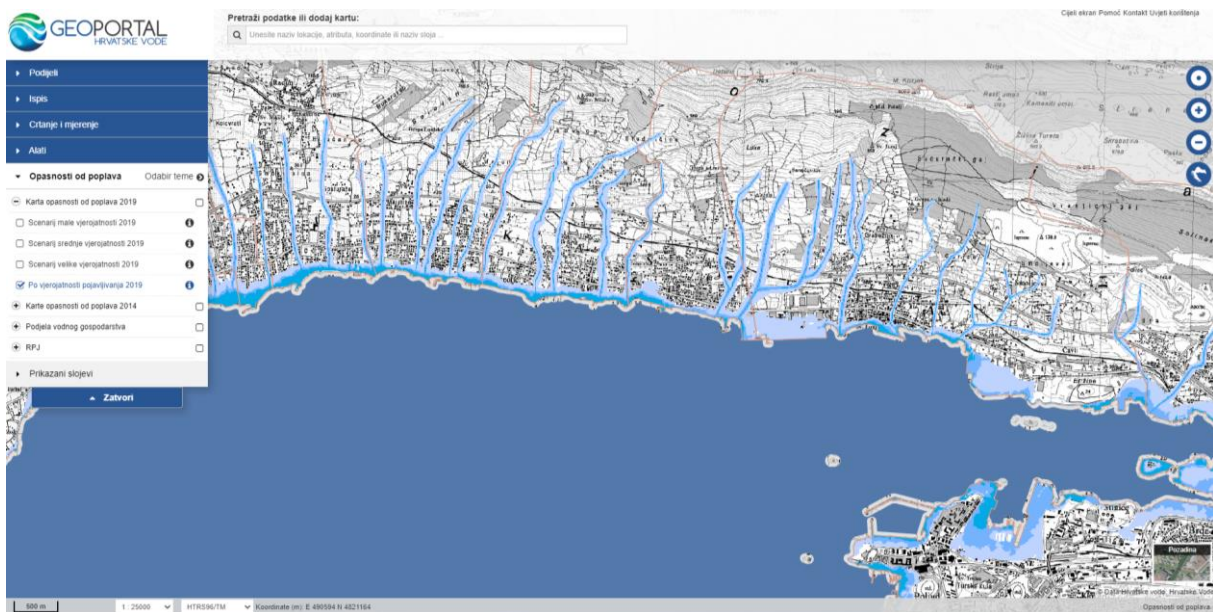


Figure 2. Flood hazard maps for the City of Kaštela area [7]

## 2.2 Strategy for climate change adaptation for Republic of Croatia

Republic of Croatia developed a Strategy for Climate Change Adaptation [8], where one of the major threats is sea level rise due to climate change. Climate changes represent a significant threat as well as strong challenge for humankind due to their impact on environment, economy and sustainable development. Climate change influence frequency and intensity of extreme natural hazards. It is considered that vulnerability to climate changes in Croatia will rise, followed by the strong impact on the environment, biodiversity, economic activities, infrastructure and other assets. According to Intergovernmental panel on Climate Change RCP4.5 Report, which is implemented in Strategy, it is expected that the global mean sea level will rise between 19 and 33 cm in the period 2046. - 2065., and 32 - 63 cm in the period 2081. - 2100. Considering Republic of Croatia, it is assumed that mean sea level could rise between 32 and 65 cm in the upcoming period. However, uncertainty about these results should be taken into consideration.

Expected mean sea level rise will certainly have a significant impact on the coastal infrastructure and other assets, where areas with low-lying coast will face most of the consequences. One of the major goals in defining measures for mitigation of climate change impact is related to strengthening of existing coastal infrastructure as well as implementation of additional measures. Furthermore, Strategy for Climate Change Adaptation defines priority measures for adaptation in order to sustainable development, include those related to mitigation of sea level rise impact.



## 3. Regional documents

### 3.1 Disaster risk management plan for Split-Dalmatia County

Disaster risk management plan for Split-Dalmatia County [9] has been recently developed for a wide range of natural disasters and other hazardous events. The plan consist of the following chapters: basic characteristics of the area, identification of known threats, simple risk scenarios describing the event with the worst possible consequences, probability / frequency tables, criteria for assessing the impact of threats on categories of social values to human life and health, economy and social stability and politics, simple risk scenario matrices and for each of the criteria separately, matrices with compared risks in the area of Split-Dalmatia County, i.e. local self-government units, analysis of the civil protection system, risk evaluation and finally risk mapping.

Considering floods, an extensive analysis is performed for river flooding and its impact on critical infrastructure. However, although coastline in Split-Dalmatia County has more than significant length, there are no analyses made considering assessment of coastal flooding and its potential adverse effect on the coastal critical infrastructure or other assets.

## 4. Local documents

### 4.1 City of Kaštela Spatial Plan – Annex for Urban Measures for Natural Disasters and War Protection Plan

Urban Measures for Natural Disasters and War Protection Plan [10], developed as a part of City of Kaštela Spatial Plan recognized coastal flooding as a particular type of flooding that might occur in the City of Kaštela area. Coastal flooding is characterized by wind and storm effect, also known as a storm surge effect caused by influence of atmospheric pressure and wind. For the City of Kaštela area, critical wind direction is defined as south-east (*jugo*), which can cause flooding of the coastal area. However, within this particular document the scenario considering climate-change induced coastal flooding is not considered. City of Kaštela Spatial plan requirements considering coastal flooding are related to the definition of worst-case scenario of coastal flooding, early warning system coverage and emergency measures and evacuation routes implementation withing urban area.

### 4.2 City of Kaštela Coastal Management Plan

City of Kaštela Coastal Management Plan [11] has been developed within Interreg Med project CO-EVOLVE, where various aspects of coastal area of Kaštela are considered. Climate change impact on mean sea level rise is recognized as one of the major threats for City of Kaštela coastal area. Climate change scenarios are taken into consideration, with their impact on sea level changes ranging from 30 cm to 100 cm. According to this Plan, it is expected that coastal flooding will occur more frequently in the future.

Adverse effects on the City of Kaštela coastal area due to coastal flooding in the future are considered to be significant. This is related to coastal infrastructure, water infrastructure, cultural heritage and many other assets present on the affected area along with economic activity. Vulnerability analysis

of coastal area due to flooding and sea level rise is performed for the lowest coastal area considering the terrain elevation.

Coastal area has been classified according to terrain elevation (Figure 3) in order to define flooding hazard zones, where Zone 1 (red) is related to 0 – 1 m.a.s.l. (meters above sea level) terrain, Zone 2 (orange) is related to 1 – 2 m.a.s.l., and Zone 3 is related to 2 – 3 m.a.s.l.. For the particular area of Kaštel Kambelovac (Fig. 6) it is estimated that 3.79 ha of the potentially flooded area applies to Zone 1, 4.30 ha to Zone 2 and 3.99 ha to Zone 3, resulting with 12.09 ha of potentially exposed area.

However, considering the definition of particular coastal flooding scenarios it can be noticed that the scenarios were determined on a qualitative level. Main criteria considering vulnerability classification were selected based on the terrain elevation without any further analyses of potential flood exposure. Since flooding is considered to be induced in future by climate-change sea level rise, the natural causes of coastal flooding natural phenomena should be considered more in detail during the risk assessment of the endangered area.



Figure 3. Classification of Kaštel Kambelovac area exposed to flooding

### 4.3 Disaster risk management plan for City of Kaštela

Disaster risk management plan for the City of Kaštela [12] recognizes floods as inevitable natural phenomenon that causes life loss and damage to different assets and environment. However, by applying a range of different measures corresponding risks can be reduced to an acceptable level.

Storm surge effect is considered as one of the significant reasons of flooding in the City of Kaštela area. It is caused by a combination of long-lasting wind forcing and significant atmospheric pressure drop, resulting with temporary sea level rise and flooding of the coastal area. Worst case scenario has been analyzed for the City of Kaštela area, although the selection of frequency and severity of this scenario is not clear. It is shown that this particular scenario would cause severe obstacles in everyday living, flooding of households and other exposed objects, as well as damage on cultural heritage.

For the particular area of Kaštel Kambelovac, it is estimated that flooding event would jeopardize 45 households with approximately 135 inhabitants, a port with approximately 30 boats, restaurants and cultural heritage objects (Figure 4).



Figure 4. Estimated flooded area of Kaštel Kambelovac due to extreme storm surge event (blue line)



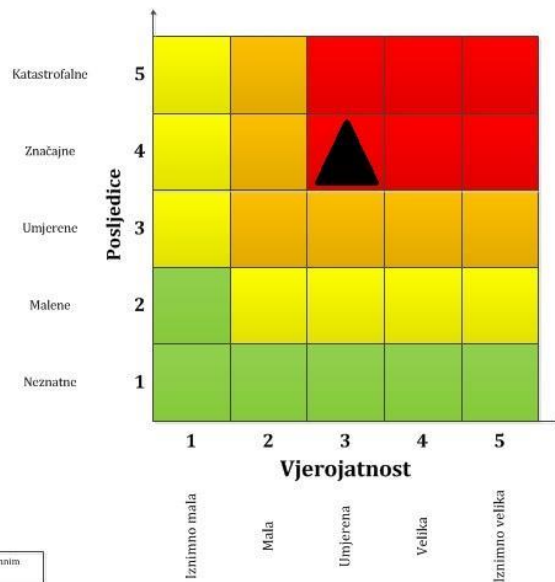
Risk matrix for this particular scenario has been developed for qualitative analysis, and it defined coastal flooding as an event with moderate probability and significant consequences; particularly, low consequences considering potential loss of life, but with significant consequences on economic activity and catastrophic consequences on public buildings and critical infrastructure (Figure 5).

**RIZIK:**

Uspor

**NAZIV SCENARIJA:**

Pojava uspora na području Grada Kaštela



<span style="color: red;">■</span>	Vrlo visok rizik	Rizik se ne može prihvatiti, osim u iznimnim situacijama.
<span style="color: orange;">■</span>	Visok rizik	Rizik se može prihvatiti ukoliko je smanjenje nepraktično ili troškovi uvelike premašuju dobit.
<span style="color: yellow;">■</span>	Umjeren rizik	Rizik se može prihvatiti ukoliko troškovi premašuju dobit.
<span style="color: green;">■</span>	Nizak rizik	Dodatne mjere nisu potrebne, osim uobičajenih.

Događaj s najgorim mogućim posljedicama

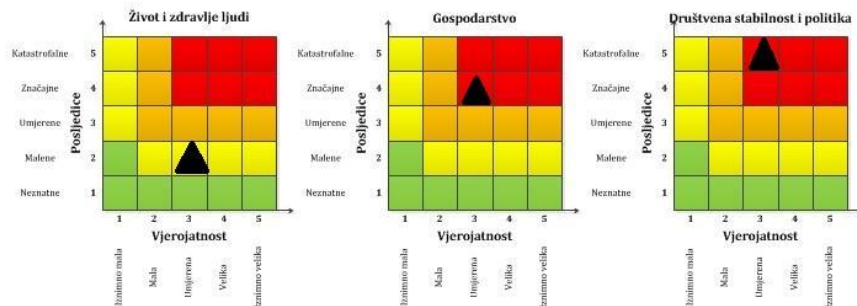


Figure 5. Risk matrix considering coastal flooding due to extreme storm surge event

#### 4.4 Emergency Protection and Rescue Plan for City of Kaštela

Emergency protection and rescue plan for the City of Kaštela [13] is developed to determine the organization, activation and operation of protection and rescue systems. Within this Plan, coastal flooding is considered one of the major threats for the City of Kaštela. This Plan includes tasks and competencies, human forces, necessary material and technical resources, as well as measures and procedures for the implementation of protection and rescue in disasters and major accidents. Protection and Rescue Plan is developed based on the assessment of natural and other hazards that can cause a catastrophe and a major accident. The implementation of the Plan consists of warning, readiness, mobilization (activation) and increase of operational forces, and protection and rescue measures.

Based on the Disaster risk management plan for the City of Kaštela [12], an Action Plan considering response actions of Civil Protection has been developed for the City of Kaštela area [14]. In the case of coastal flooding, key measures are related to warning dissemination about the potential threat, information collection considering adverse consequences and other response measures such as evacuation. The Civil Protection requirements for implementation of response actions are related to warning system coverage, evacuation routes, building of structural measures for protection as well as assessment of existing protection structures.



## References

- [1] Marasović K.; Kaštelanski zbornik, 7, 35-61, 2003.g.
- [2] Water Act (NN 66/2019) [https://narodne-novine.nn.hr/clanci/sluzbeni/2019\\_07\\_66\\_1285.html](https://narodne-novine.nn.hr/clanci/sluzbeni/2019_07_66_1285.html)
- [3] DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy, <https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC1&format=PDF>
- [4] Državni plan obrane od poplava, 2010. (in Croatian) [https://narodne-novine.nn.hr/clanci/sluzbeni/2010\\_07\\_84\\_2389.html](https://narodne-novine.nn.hr/clanci/sluzbeni/2010_07_84_2389.html)
- [5] Plan upravljanja vodnim područjima 2016. – 2021. (in Croatian) [https://www.voda.hr/sites/default/files/plan\\_upravljanja\\_vodnim\\_podrucjima\\_2016.\\_-2021.pdf](https://www.voda.hr/sites/default/files/plan_upravljanja_vodnim_podrucjima_2016._-2021.pdf)
- [6] PLAN UPRAVLJANJA VODNIM PODRUČJIMA 2022. - 2027. - Upravljanje rizicima od poplava, Karte opasnosti od poplava i karte rizika od poplava, 2019., [https://www.voda.hr/sites/default/files/dokumenti/karte\\_opasnosti\\_od\\_poplava\\_i\\_karte\\_rizika\\_od\\_poplava\\_-\\_2019.pdf](https://www.voda.hr/sites/default/files/dokumenti/karte_opasnosti_od_poplava_i_karte_rizika_od_poplava_-_2019.pdf)
- [7] Flood hazard and flood risk maps, 2019. Hrvatske vode [https://preglednik.voda.hr/?lang=hr&topic=Opasnosti%20od%20poplava&bgLayer=hr.raster.tk-crno-bijeli&layers=hr.karta-opasnosti-od-poplava-mala-vjerojatnost2019&catalogNodes=1275&X=4822861.33&Y=489678.40&zoom=6.254282976150767&layers\\_visibility=false](https://preglednik.voda.hr/?lang=hr&topic=Opasnosti%20od%20poplava&bgLayer=hr.raster.tk-crno-bijeli&layers=hr.karta-opasnosti-od-poplava-mala-vjerojatnost2019&catalogNodes=1275&X=4822861.33&Y=489678.40&zoom=6.254282976150767&layers_visibility=false)
- [8] Strategy for climate change adaptation for Republic of Croatia (in Croatian) [https://narodne-novine.nn.hr/clanci/sluzbeni/2020\\_04\\_46\\_921.html](https://narodne-novine.nn.hr/clanci/sluzbeni/2020_04_46_921.html)
- [9] Disaster risk management plan for Split-Dalmatia County, 2021. (in Croatian)
- [10] City of Kaštela Spatial Plan – Annex for Urban Measures for Natural Disasters and War Protection Plan, 2018. (in Croatian)
- [11] City of Kaštela Coastal Management Plan, 2019. (in Croatian)
- [12] Disaster risk management plan for City of Kaštela, 2019. (in Croatian)

[13] Emergency Protection and Rescue Plan for City of Kaštela (in Croatian)

[14] Natural Disasters Response Action Plan for City of Kaštela (in Croatian)