INTERNATIONAL SAVA RIVER BASIN COMMISSION

# PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN

## UPDATE 2021

Supported by

**Prepared by:** International Sava River Basin Commission (ISRBC) in cooperation with the Parties to the Framework Agreement on the Sava River Basin (Bosnia and Herzegovina, Croatia, Serbia and Slovenia) and Montenegro.

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## UPDATE 2021

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# Disclaimer

The Preliminary Flood Risk Assessment in the Sava River Basin (Sava PFRA) – Update 2021 is based on data delivered by the Parties to the Framework Agreement on the Sava River Basin (Bosnia and Herzegovina, Republic of Croatia, Republic of Serbia and Republic of Slovenia) and Montenegro, which joined the activities of the International Sava River Basin Commission based on the Memorandum of Understanding on cooperation between the International Sava River Basin Commission and Montenegro. Some countries were not able to provide all the information needed and these data gaps are noted in the text. Where data has been made available, it has been examined and is presented to the best of available knowledge. Nevertheless, inconsistencies cannot be ruled out.

Given the complexity of all aspects of flood risk management in the Sava River Basin and various legal frameworks, this document is not fully aligned with all national documents, Directive on the Assessment and Management of Flood Risks and other valid documents. For this reason, if there are differences in this document in relation to national valid documents or if there are differences in the interpretation of this document, relevant national documents will be considered valid at that time as well as the interpretations that follow from the valid national documents. For the same reason, for all activities arising out of this document and not foreseen in the applicable national documents, it is necessary to fully align them with national legal frameworks, available flood risk management instruments and to carry out their more detailed elaboration at national and bilateral levels in accordance with the law defined by the national procedure for their acceptance.

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# ABBREVIATIONS

| | |
|---|---|
| APSFR | Area with Potential Significant Flood Risk |
| AMI | Area of Mutual Interest for flood protection in the Sava River Basin |
| EC | European Commission |
| EEA | European Environmental Agency |
| FASRB | Framework Agreement on the Sava River Basin |
| FFWS | Flood Forecasting and Warning System |
| FRMP | Flood Risk Management Plan |
| GIS | Geographic Information System |
| ICPDR | International Commission for the Protection of the Danube River |
| ISRBC | International Sava River Basin Commission |
| PEG FP | Permanent Expert Group for Flood Prevention |
| PFRA | Preliminary Flood Risk Assessment |
| RBMP | River Basin Management Plan |
| UNECE | United Nations Economic Commission for Europe |
| WMO | World Meteorological Organization |

# 1 INTRODUCTION

The *Framework Agreement on the Sava River Basin* (FASRB)[1], which implementation is coordinated by the International Sava River Basin Commission (ISRBC), has established a framework for flood risk management that has set in detail in the *Protocol on Flood Protection to the FASRB* (Protocol)[2]. Althought the Protocol doesn't foresee any timeline or deadlines, the dynamic of preparation of the particular steps is in line with the *Directive 2007/60/EC of the European Parliament and Council on 23 October 2007 on the assessment and management of flood risk* (EU Floods Directive)[3].

Pursuant to the Protocol and based on the national planning documents, the Parties to the FASRB (Slovenia, Croatia, Bosnia and Herzegovina, and Serbia) had prepared the joint report on *Preliminary Flood Risk Assessment in the Sava River Basin* (Sava PFRA)[4] accepted by ISRBC in 2014 and developed the joint *Flood Risk Management Plan in the Sava River Basin* (Sava FRMP)[5] approved by the Parties to the FASRB and Montenegro[6] in 2019.

The initial Sava PFRA, which has been partially aligned to the possible extent with the requirements of the EU Floods Directive, summarized information on the preliminary flood risk assessment of Slovenia, Croatia, Serbia and one part of Bosnia and Herzegovina (Federacija of Bosnia and Herzegovina), while for other parts (Republika Srpska and Brčko District Bosnia and Herzegovina) and Montenegro data were included in the Sava FRMP. The Sava PFRA provided an overview of significant past floods and consequences of potential future floods, designated national Areas with Potentially Significant Flood Risk (APSFRs) with special attention paid to the APSFRs identified along transboundary rivers. The initial Sava PFRA report was a basis for harmonisation of the APSFRs shared by two or more countries, identified as the Areas of Mutual Interest for Flood Protection in the Sava River Basin (AMIs) that were later definded and approved within the Sava FRMP. The joint Sava PFRA report has also addressed the impacts of climate change and provided an overview of transboundary coordination and information exchange.

The EU Floods Directive instructs that the PFRA report shall be reviewed, and if necessary, updated at first after seven years and every six years thereafter. Having in mind that all preparation steps for the first planning cycle covered period from 2014 to 2019, during the second cycle the countries are adviced to have reviewed and updated joint planning steps in the Sava River Basin by 2021 for PFRA, by 2023 for Flood Maps and by 2026 for FRMP.

This Sava PFRA update 2021 included information from the following sources:

- Draft 2nd Sava RBMP (2021)
- National PFRA report of Montenegro (2021)
- 1st Sava FRMP (2019)
- National PFRA report of Serbia (2019)
- Update of national PFRA report of Slovenia (2018)
- Update of national PFRA report of Croatia (2018)
- National PFRA report of Bosnia and Herzegovina (2013, 2015)
- Updated information from the Parties.

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[1] https://www.savacommission.org/UserDocsImages/05_documents_publications/basic_documents/fasrb.pdf

[2] https://www.savacommission.org/UserDocsImages/05_documents_publications/basic_documents/protocol_on_flood_protection_to_the_fasrb.pdf

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=EN

[4] https://www.savacommission.org/UserDocsImages/05_documents_publications/water_management/SavaFRMPlan//preliminary_flood_risk_assessment_in_the_sava_river_basin_20140701.pdf

[5] https://www.savacommission.org/UserDocsImages/05_documents_publications/water_management/SavaFRMPlan//sfrmp_eng_web.pdf

[6] Montenegro, which shares the basin but is not a Party to the FASRB, cooperates in the fields covered by the FASRB on the basis of the Memorandum of Understanding on cooperation between ISRBC and Montenegro, signed on December 9, 2013, in Belgrade: https://www.savacommission.org/UserDocsImages/05_documents_publications/basic_documents/memo_of_understanding_between_isrbc_and_montenegro.pdf

# 2 GENERAL INFORMATION ON THE SAVA RIVER BASIN

The Sava River Basin is the major river basin of South-East Europe, spreading over a total area of about 97,700 km$^2$, sharing among six countries: Slovenia (12,1%), Croatia (26,1%), Bosnia and Herzegovina (39,4%), Serbia (15,6%), Montenegro (6,7%), and Albania (0,2%). The population of the five countries (Albania is not included since only negligible part of the basin area belongs to its territory) of the region is approximately 18 million and half of this number resides in the Sava River Basin.

The Sava River Basin is one of the most important sub-basins of the Danube River Basin, making 12% thereof and contributing to the characteristics of the Danube Basin with its outstanding biological and landscape diversity. It hosts the largest complex of alluvial wetlands in the Danube Basin (Posavina - Central Sava Basin) and large lowland forest complexes.

The Sava River is created from the Sava Dolinka and Sava Bohinjka near Radovljica in Slovenia. From the confluence of these two rivers, the Sava is 945 km long. The Sava River is a unique example of river with some of the floodplains still intact, thus supporting the flood alleviation and biodiversity. The most important tributaries of the Sava River, significant for the flood risk management planning at the Sava River Basin level are listed in Annex 1. Tributaries in the upper basin are characterized by a torrential nature, same as almost all right tributaries in the middle section of the Sava River, particularly in their upper sections. The left tributaries in the middle and lower Sava River Basin drain mostly flat areas and low hills of the Pannonian Basin. Consequently, the slopes and flow velocities are smaller, and the streams are meandering. The most important rivers at the left Sava bank of middle and lower Sava encompass much smaller part of the drainage basin than the right tributaries, thus making the Sava River catchment asymmetric.

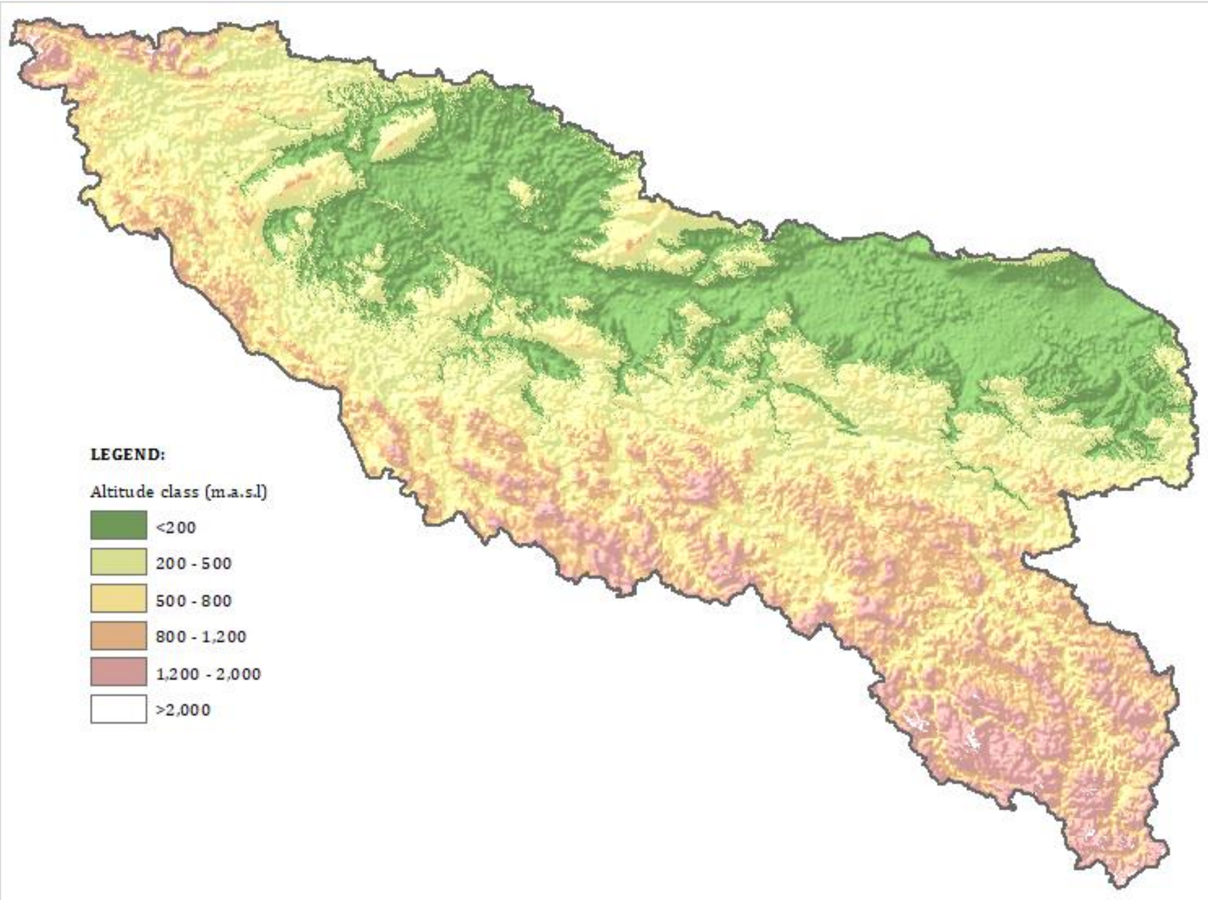



*Figure 1: Relief of the Sava River Basin*

The relief of the Sava River basin is composed of mountainous sections (Alps and Dinaric Alps), dominating in Slovenia, southern part of Croatia, Bosnia and Herzegovina, Serbia, Montenegro and northern Albania (Figure 1). Northern parts of middle and lower Sava River course are characterised by low forests and lowlands. This area is part of Pannonia and Posavina (Croatia, Bosnia and Herzegovina and Serbia), i.e. a lowland agricultural area exposed to flooding. The elevation of the Sava River Basin ranges between 71 m.a.s.l. at the mouth of Sava in Belgrade and 2,864 m.a.s.l. (Triglav, Julian Alps) near of the river source. The average elevation of the basin is approximately 545 m.a.s.l.

Based on the land cover/use data (EEA Corine database) for the period of 2000 – 2018, analysed during the update of Sava RBMP (ISRBC, 2021), the share of artificial surfaces, forests and semi-natural areas and inland waters is slightly increasing, while agricultural lands show a trend of slight decrease (Table 1).

*Table 1: Comparison in main land cover use within the Sava River Basin*

| Land class | Corine 2000 - 2018 | |
|---|---|---|
| | **Change of area (%)** | **Change in basin share (%)** |
| Artificial surfaces | ↗ 22,6 % | ↗ **0,5%** |
| Agricultural areas | ↘ 4,5% | ↘ **1,9%** |
| Forests and semi natural areas | ↗ 2,4% | ↗ **1,4%** |
| Wetlands | ↗ 11,6% | **~0%** |
| Inland waters – water bodies | ↗ 2,9% | ↗ **0,1%** |

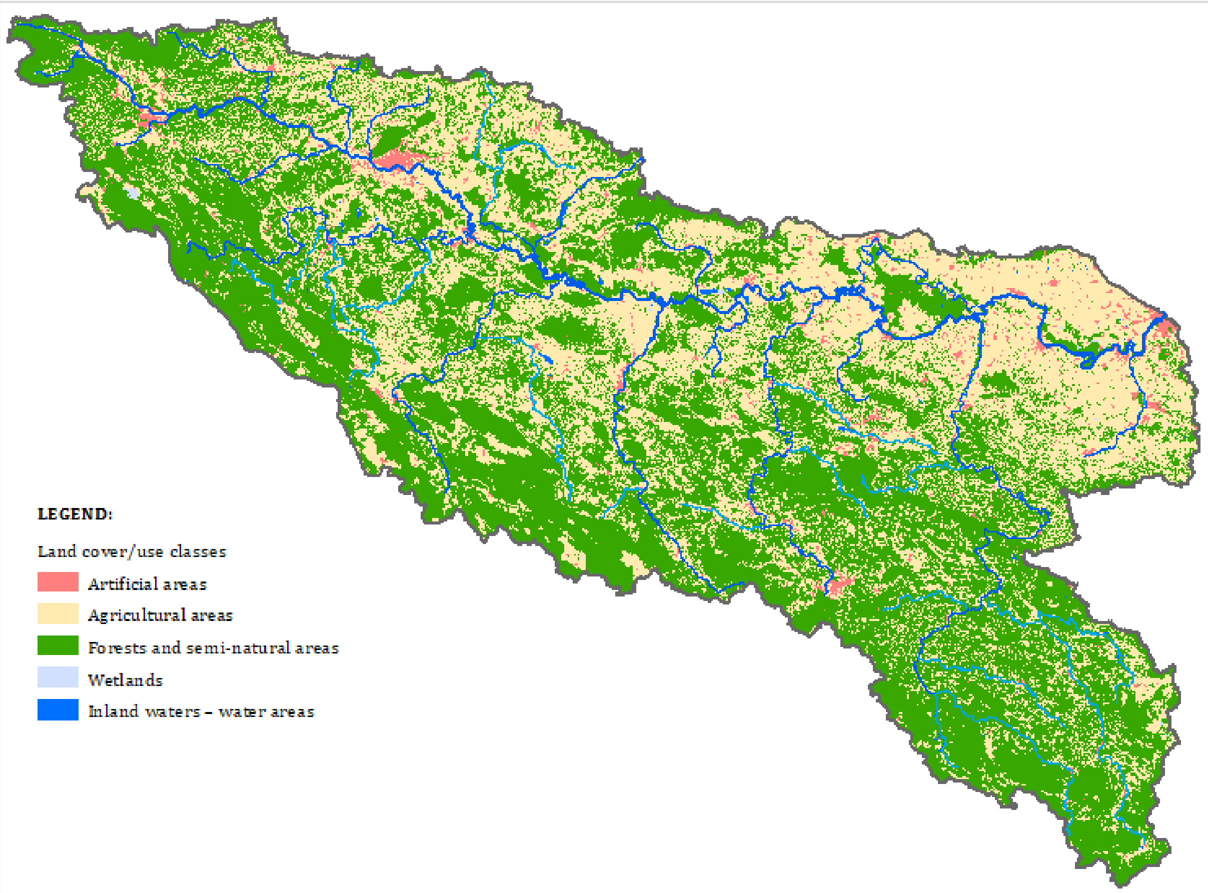



*Figure 2: Land cover/use in the Sava River Basin*

The Sava River Basin is characterized by the dominant moderate climate of the northern hemisphere, modified by the influence of the relief. Alpine climate prevails in the upper Sava Basin in Slovenia, moderate continental climate in the right tributaries' catchment areas within Croatia, Bosnia and Herzegovina, Serbia and Montenegro, while moderate continental, mid-European climate primarily features in the left tributaries' catchments in the Pannonian Plain. Cold and hot seasons are clearly defined. The winters can be severe with abundant snowfalls, while the summers are hot and long.

The precipitation amount and its annual distribution is fairly variable. The largest precipitations take place in far western catchments (Sava Dolinka and Sava Bohinjka Rivers) and at upper parts of catchments of the Kupa, Piva, Tara, Una, Vrbas, Drina and Lim Rivers. Areas with smallest precipitation are found in Slavonia, Srem, Semberija and the Kolubara River catchment.

In general, runoff largely follows pattern of spatial distribution of precipitation. The right tributaries of the Sava River are characterized by much higher water yield. The Drina River, as the largest tributary of the Sava River, has a remarkably high water yield due to high precipitation, the long-term annual average is over 2.000 mm. The left tributaries (Krapina, Lonja and Orljava and Bosut Rivers) gets annually 700 – 1.000 mm of rain but relatively big evapotranspiration reduces unit-area runoff to just a few l/s/km$^2$, which at the hilly regions can rise to 12 l/s/km$^2$.

A long-term average unit-area-runoff for the complete catchment area is of about 18 l/s/km$^2$.

*Table 2: Basic climate and hydrologic characteristics in the Sava River Basin*

| | | |
|---|---|---|
| **Average annual air temperature** | approx. 9,5°C | |
| **Mean monthly water temperature** | lowest January: -1,5°C<br>highest July: 20°C | |
| **Average annual rainfall** | approx. 1.100 mm | |
| **Long-term average annual precipitation** | 600 mm up to 2.300 mm | |
| **Average evapotranspiration** | approx. 530 mm/year | |
| **Spatial distribution of runoff** | 150 mm/year (under 5 l/s/km$^2$) up to 1.200 mm/year (almost 40 l/s/km$^2$) | |
| **Average discharge of the Sava River (mouth)** | approx. 1.700 m$^3$/s | |
| **Average runoff of the Sava tributaries** | Una River | 23 l/s/km$^2$ |
| | Vrbas River | 19 l/s/km$^2$ |
| | Bosna River | 19 l/s/km$^2$ |
| | Ukrina River | 12 l/s/km$^2$ |
| | Tinja River | 12 l/s/km$^2$ |
| | Drina River | up to 50 l/s/km$^2$ |

Occurrence and characteristics of high waters in the Sava River basin are greatly influenced by the basin features and shape, geographic and precipitation distribution season, the ground water level which affect infiltration of river, overflow of high waters into natural inundations and by functioning of the flood protection systems. Taking into account features of the terrain, intensive rainfall and snow melting in the upper parts of the basin, mainly belonging to Slovenia, there are frequent floods with local character, but quite often they impact downstream parts of the middle course of the Sava River.

Flood events caused by high water waves in the Sava River basin usually occur in autumn and spring. The autumn water waves are usually caused by intensive short rains, and can result in extreme high flows. Longer spring flood waves are a result of snow melting, while over the past several years, spring flood events are quite frequent, caused by intensive short and long rains.

A specific problem in the basin includes numerous torrential watercourses, which in the high waters runoff carry huge quantities of material, which is deposited in riverbeds and prevents regular flow. A significant part of the basin surface is under threat of erosion.

# 3 OVERALL APPROACH AND METHODOLOGY

The Protocol on Flood Protection to the FASRB emphasizes the importance of coordination measures, works and activities aimed at decreasing the flood risk throughout the basin, and the implementation of these activities in accordance with the "no harm rule" principle. Therefore, in order to contribute to the decrease of harmful consequences of floods, in particular for human life and health, environment, cultural heritage, economic activities and infrastructure, the countries have agreed to cooperate in the implementation of above activities. The Protocol represents a firm legal foundation for the implementation of all activities agreed by the countries via ISRBC.

With the aim of fulfilling the goals of the Protocol, the countries have undertaken the obligation to cooperate in a flood risk management planning cycle on the Sava River Basin level through reporting on PFRA, preparation of Flood Maps, development of FRMP, starting with preparation of the Program for its development. The Protocol also recognises ISRBC as a body for coordination of the cooperation on activities related to the Flood Forecasting, Warning and Alarm System in the Sava River Basin (Sava FFWS), the exchange of information significant for sustainable flood protection and implementation of all other mutually agreed measures and activities.

The overall work plan with expected outcomes, responsibilities and deadlines in conducting all elements relevant for the flood risk management planning in the Sava River Basin, including development and update of Sava PFRA and accompanying steps is given in Annex 2.

The initial Sava PFRA report and the update 2021 were prepared in accordance with the Article 6 of the Protocol, which states the following:

1. Each Party shall undertake Preliminary Flood Risk Assessment for its part of the Sava River Basin, taking into account the Directive 2007/60/EC.
2. In the process of Preliminary Flood Risk Assessment, the Parties shall exchange all relevant data, in principle, through the Sava Commission or bilaterally, as appropriate.
3. In the case of bilateral exchange of the relevant data from paragraph 2 of this Article, the latter shall also be delivered to the Sava Commission, without delay.
4. Based on the Preliminary Flood Risk Assessment, each Party shall, on the part of the Sava River Basin on its territory, identify those areas for which it concludes that potential significant flood risk exists or might be considered likely to occur.
5. Each Party shall, through the Sava Commission, inform the other Parties on the identified areas from Paragraph 4 of this Article.
6. The Sava Commission shall coordinate the activities on harmonisation of the areas identified pursuant to paragraph 4 of this Article shared by two or more Parties, identified by the Parties as the areas of mutual interest for flood protection.

The countries through ISRBC regularly exchange data relevant on the national PFRAs and inform other countries on the identified and/or updated national APSFRs. The Protocol also gives the mandate to ISRBC to coordinate the activities on harmonisation of APSFRs shared by two or more countries, identified as the Areas of Mutual Interest for Flood Protection (AMIs).

For the purpose of preparation of the Sava PFRA update 2021, the countries have exchanged/updated data and information on areas for which they have concluded that potential significant flood risks exist or might be considered likely to occur. Data and information have been exchanged through a common data sharing platform - the Sava GIS Geoportal described in the Chapter 8.2.

*Table 3: Overview of information on national PFRAs per country*

| | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|
| Defined methodology for PFRA | ✓ | ✓ | ✓ | ✓ | ✓ |
| Considered significant past floods | ✓ | ✓ | ✓ | ✓ | ✓ |
| Considered potential future floods | ✓ | ✓ | ✓ | ✓ | |
| Identified APSFRs | ✓ | ✓ | ✓ | ✓ | ✓ |
| Considered effects of long-term development | ✓ | ✓ | | | |
| Considered effects of climate change | ✓ | ✓ | | | ✓ |
| International coordination | ✓ (i) | ✓ (i) | ✓ (ii) | ✓ (ii) | ✓ (iii) |
| (i) ISRBC, ICPDR, ESPOO Convention<br>(ii) ISRBC, ICPDR<br>(iii) ICPDR, ISRBC | | | | | |

More detailed information is available on the web sites links of responsible national institutions to relevant documents and maps listed in Annex 3 which also further addresses the methodologies and criteria used by the countries.

In addition to a review and update of information on methodologies and criteria used by the countries to identify and assess significant past floods and consequences of potential future floods, the Sava PFRA update 2021 provides an overview of designated and updated APSFRs as well as harmonises APSFRs shared by two or more countries, identified as AMIs.

# 4 SIGNIFICANT PAST AND POTENTIAL FUTURE FLOODS

Occurrence and characteristics of floods in the Sava River Basin are greatly influenced by the basin features and shape, spatial and seasonal distribution of precipitation, the ground water level which affect infiltration of river, overflow of high waters into natural inundations, as well as by functioning of the existing flood protection systems.

Past floods indicate that lowland areas along the Sava River left tributaries in the middle course can also suffer from significant damage. However, greater floods with significant impact affecting the majority of the basin include floodplains in the middle and lower parts of the Sava River. These floods are conditioned by runoff caused by abundant rainfall and/or abrupt snow melting which occur in southern mountainous area of right tributaries (sub-basin of Kupa, and especially of Una, Vrbas, Bosna and Drina). Flood events in the Sava River Basin usually occur in autumn and spring, where the autumn floods are usually caused by intensive short rains, and can result in extreme high flows. Longer spring floods in the Sava River Basin are mainaly result of snow melting, while over the past several years, spring flood events are quite frequent, caused by intensive short and long rains (e.g. event from May 2014).

A specific problem in the basin is the numerous torrents, which in the high waters runoff carry large amount of the river sediment and other material, which is deposited in riverbeds and prevents normal runoff. A significant part of the basin is endangered by erosion.

Floods had occurred in the past and will continue to occur in the future in the Sava River Basin, both along natural river sections and in case of structure overtopping or failure. The countries have assessed the potential adverse consequences of future floods taking into account as far as possible issues such as the topography, the position of watercourses and their general hydrological and geomorphological characteristics, including floodplains as natural retention areas, the effectiveness of existing manmade flood defence infrastructures, the position of populated areas, and areas of economic activity. Important flood prone areas of the Sava River have been identified in the Sava FRMP.The spatial distribution of the past and future flood events in the Sava River Basin is shown in Map 1.

The core of PFRA requirements, in accordance with the EU Floods Directive, is to use information on past significant floods as the basis for identifying where floods may occur in the future. To enable comparison across the Sava River Basin and compilation of the national PFRA, basic information on past floods as well as a modest information on future floods have been collected.

In accordance with the EU Floods Directive, the re-analyse on past floods collected in the previous cycle is not required under the review and update of PFRA. However, having in mind this update of Sava PFRA includes not only the review but also a gap filling of the initial Sava PFRA, past significant floods were elaborated again but in a more structured and analytical form than before.

It should be taken into account that a much more detailed information should be provided for floods that occur in the future during subsequent implementation cycles, and which will be considered as past floods for the review of those cycles.

## 4.1 COMMENCEMENT AND DURATION OF FLOODS

The earliest recorded floods in the Sava River Basin were in Slovenia in 1550, while also three floods in: 1704, 1707, and 1772. Figure 1 shows the percentage of occurrence of a total of 1262 recorded flood events in the Sava River Basin until 2018. During the period until XXI century there was at least one recorded flood each ten years, except in the 1834-1844 period, while in the period after 2000 larger floods were recorder in the basin each year. These statistics are result of the current data availability and a fact that data are mainly available in the recent period.

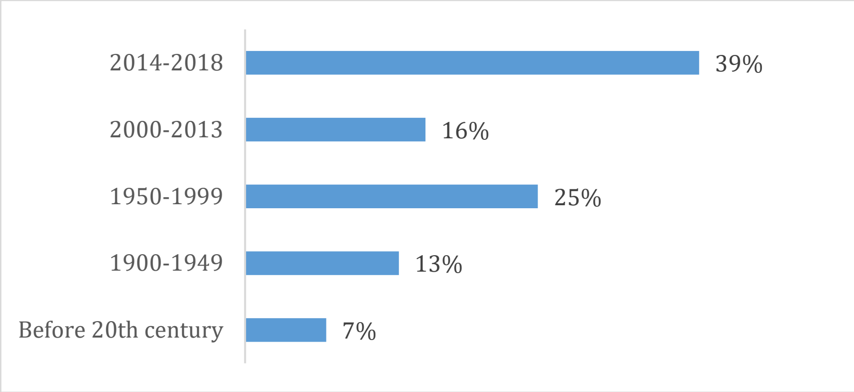



*Figure 3: Occurrence of the recorded flood events (1262 in total) in the Sava River Basin*

In May 2014, the Sava River Basin areas in Croatia, Bosnia and Herzegovina and Serbia, were affected by an unprecedented flood event with a hughe damages and losses suffered.

Details about the most significant past flood events in the Sava River Basin are given in Annex 2.

The number of floods was categorized in terms of their duration based on the Dartmouth Flood Observatory (DFO)[7] classification.

The events are denoted as a short-duration flood if the duration is between 1 and 7 days, moderate-duration flood if the duration is between 8 and 20 days, and as a long-duration flood if the duration is greater than or equal to 21 days. These categories are also consistent with the DFO's flood classification (Brakenridge, 2016): short-, moderate-, and long- duration flood events.

*Table 4: Duration of floods in the Sava River Basin*

| **Flood duration** | **Slovenia** | **Croatia** | **Bosnia and Herzegovina** | **Serbia** | **Montenegro** | **Totals** |
|---|---|---|---|---|---|---|
| Short (1-7 days) | 338 | 273 | 25 | 14 | - | **650** |
| Moderate (8-20 days) | 29 | 54 | 8 | 4 | - | **95** |
| Long (≥ 21 days) | 1 | 17 | 2 | 3 | - | **23** |
| Unknown | 230 | - | - | | - | **230** |
| Not Applicable (future floods) | 1 | - | - | 29 | - | **30** |
| No Data | - | 97 | 245 | 1 | 152 | **495** |

## 4.2 SOURCES, MECHANISMS AND CHARACTERISTICS OF PAST AND POTENTIAL FUTURE FLOODS

Data on the types: sources, mechanisms and characteristics[8] of past (Figure 4) and potential future floods (Figure 5) delivered by countries are aggregated at the Sava Basin level.

By far the most common source of historical flood events is fluvial (51% of events) followed by pluvial (11%). The least common is for artificial water bearing infrastructure (0,1%) and groundwater (2%). The most common mechanism are natural exceedance (51% of events), and defence exceedance (7%). The characteristics of flooding are mainly flash floods (22%), floods with rapid (13%), medium and slow onset (10% each).

[7] http://floodobservatory.colorado.edu/index.html

[8] Definitions are given in Annex 3

It should be also noted that the source of flooding and the mechanism of flooding are not available for over a third of flood events, and the characteristics of flooding for slightly over 40% of flood events.

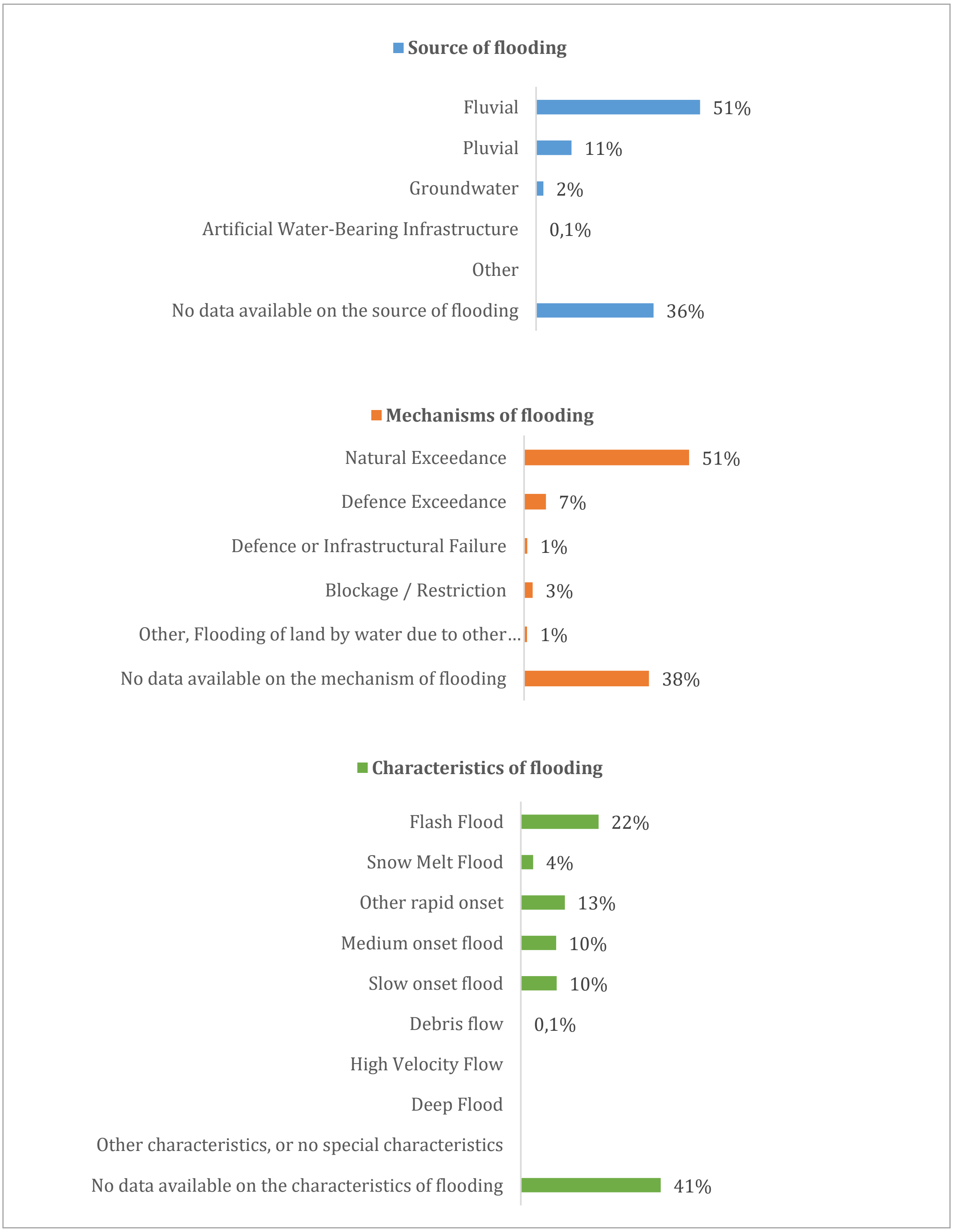



*Figure 4: Types of the past flooding in the Sava River Basin*

As for the future flood events, only Slovenia and Serbia delivered data on 30 potential future flood events, while other countries had not delivered any. In terms of potential future floods, the most common source of flooding is fluvial (97% of events), defence (37%) and natural (29%) exceedances are the most common mechanism, flash flood (63%) and other rapid onset floods (27%) the most common characteristic (Figure 5).

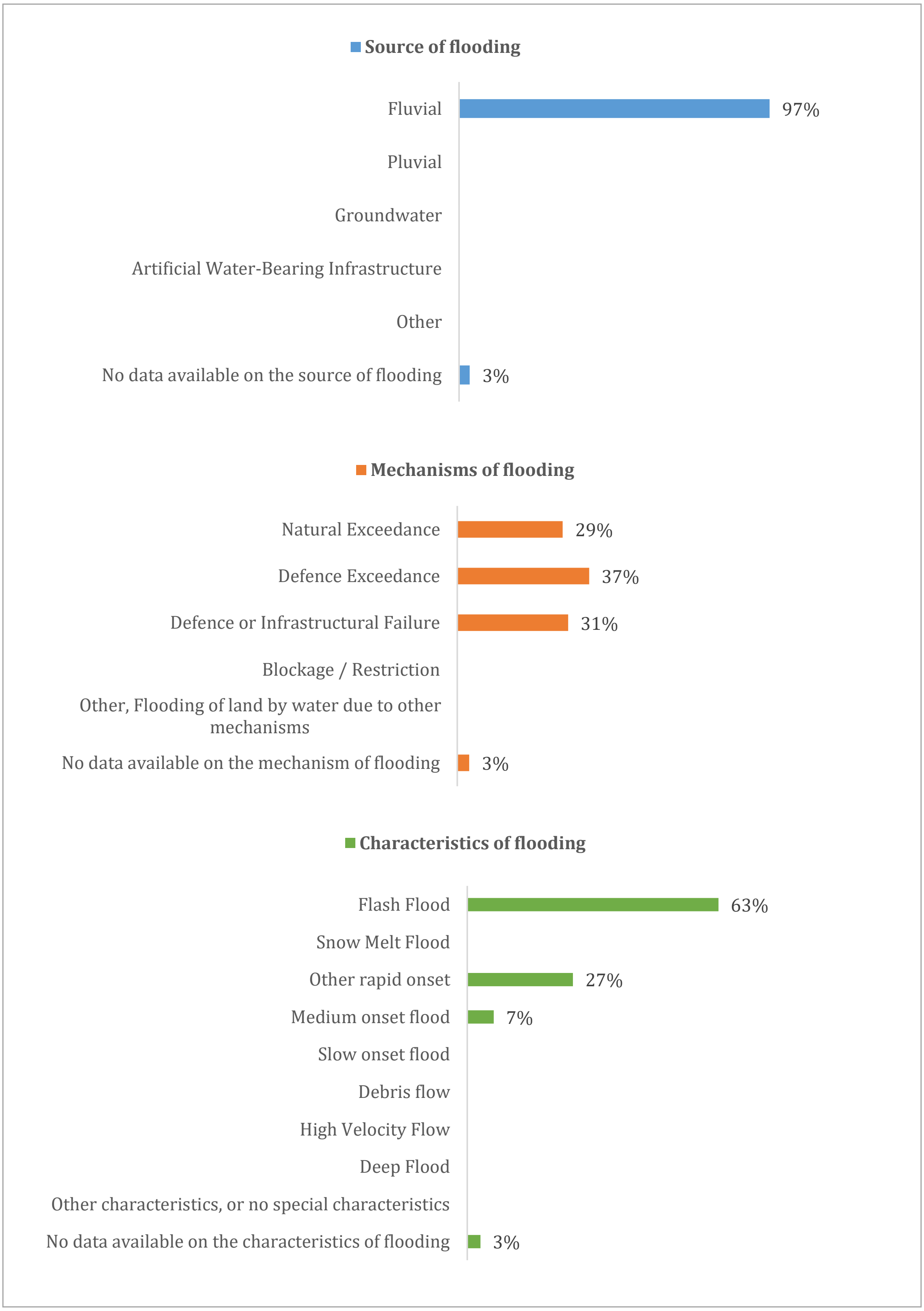



*Figure 5: Types of the potential future flooding in the Sava River Basin*

## 4.3 EXTENT, FREQUENCY/RECURRENCE

Considering features of the terrain in the Sava River Basin, intensive precipitation (rainfall and snow melting) in the upper parts of the basin there are frequent floods with local character, but quite often they impact downstream parts of the middle course of the Sava River. Bearing in mind weather differences between the occurrence of high waters in the main watercourse of the Sava River and its tributaries, historic experience demonstrates that maximum flows during high waters at the mouths of right-hand tributaries reach Sava before the occurrence of maximum flows in the Sava River itself.

The amount of quantitative information on the extent and frequency of past events as well as recurrence of past and future events has slightly improved in the second cycle.

Based on available data on the flood recurrence for Croatia (for 60 past floods), Bosnia and Herzegovina (for 5 past floods), and Serbia (for 5 past and 19 future floods) it was not possible to make any detailed analysis.

The findings of this topic point towards increasing the effort of recording information around flood events in order to prepare better responses in the future, having in mind that an area for improvements is obvious especially for information on the water bodies probably affected by a recurrence of the flood event.

# 5 AREAS WITH POTENTIAL SIGNIFICANT FLOOD RISK

## 5.1 CRITERIA ASSOCIATED WITH APSFRS

In accordance with the national PFRAs, the countries identified those areas for which they concluded that potential significant flood risks exist or might be considered likely to occur. National methodologies for identification of the APSFR are presented in Chapter 3, while for the purpose of Sava PFRA update, countries provided information on criteria for:

- determining significant flood risk
- inclusion of floods risk areas as APSFRs
- how human health, environment, cultural heritage and economic activity have been considered in the identification of APSFRs.

In the following tables, information on criteria are summarized.

*Table 5: Criteria for determining significant flood risk*

| Criteria | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|
| Number of permanent residents affected by the flood extent | ✓ | | ✓ | ✓ | ✓ |
| Number of buildings affected (residential and non-residential) | ✓ | | | | |
| Adverse consequences to infrastructural assets | ✓ | ✓ | | ✓ | ✓ |
| Economic damage | | ✓ | | | |
| Sources of pollution triggered from industrial installations | ✓ | ✓ | ✓ | ✓ | |
| Adverse consequences to rural land use | ✓ | ✓ | | ✓ | |
| Adverse consequences to economic activity (e.g. manufacturing, service and construction industries) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Adverse impacts on cultural assets and cultural landscape | ✓ | ✓ | ✓ | | ✓ |
| Recurrence periods or probability of exceedance | ✓ | ✓ | ✓ | | ✓ |
| Community assets affected | | ✓ | | | |
| Whether floods have occurred in the past | | ✓ | | ✓ | |
| Specific weighting systems defined to assess significance | ✓ | ✓ | | | |
| Expert Judgement | | | ✓ (ii) | | |
| Other | ✓ (i) | | | | |
| Number of past flood events | | ✓ | | | |

(i) for each analytical area, the total number of damage potentials of each area was calculated. New analytical areas are classified according to the criterion of the total number of damage potential
(ii) the basis for determining potential risks were flood polygons for the return period 1/100

*Table 6: Criteria for inclusion of floods risk areas as APSFRs*

| Criteria | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|
| Possible failure of flood defences | | | | ✓ | |
| Frequency of past events | ✓ | | ✓ | | |
| Exceeding thresholds under specific weighting systems defined to assess significance | ✓ | ✓ | | | |

| Criteria | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|
| Expert judgement | | ✓ | | | ✓ |
| High level of damage expected | ✓ | | | | |
| Other | | | ✓ (i) | ✓ (ii) | |
| (i) impact of past and future events<br>(ii) impact of past events | | | | | |

## 5.2 NUMBER OF IDENTIFIED AND UPDATED APSFRS

APSFRs identified by the countries at the Sava River Basin level are shown on Map 2.

*Table 7: Criteria for determining significant flood risk*

| National APSFRs for the Sava River Basin | | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|---|
| Initial (2014/'19) | Number | 42 | 1.688 | 160 | 27 | 9 (i) |
| | Area/Lenght | 82 km² | 14.323 km² | 1.595 km² | 730 km/2.250km² | 40 km² |
| Updated (2021) | Number | 58 | 2.086 | 160 | 28 | 15 |
| | Area/Lenght | 65 km² | 15.570 km² | 1.595 km² | 800 km | 7 km² |
| (i) Definded and approved in Sava FRMP as an indicative information | | | | | | |

**Slovenia** used polygons to roughly mark parts of settlements or objects of economic activities that are identified as APSFR. There are 58 APSFRs covering the area with potential significant flood risk of about 65 km² in the Sava River Basin in Slovenia that can be flooded by a single river or several rivers that confluence within the APSFR, and that is increase of 6 in comparison to the initial report. These areas are threatened by the Sava, Savinja, Sotla/Sutla, Ljubljanica, Krka, and some other first and second order tributaries of the Sava River with smaller catchments. Among the 58 identified, several APSFRs are at the transboundary area of the Sava and Sotla/Sutla rivers while at the Kupa/Kolpa and Bregana rivers there are not national APSFR at the Slovenian side. These areas required coordination with the neighbouring Croatia.

**Croatia** identified 2086 national APSFRs in the part of the Sava River Basin in comparison to 1688 from the initial report. Each of the 2086 areas represent territory of one settlement, as the smallest administrative unit. The APSFRs cover about 15.570 km², which is endangered by: Sava, Sotla/Sutla, Krapina, Lonja and its tributaries Glogovnica and Česma, Ilova, Orljava, Bosut (at the left Sava bank), Kupa/Kolpa and its tributaries Dobra, Korana and Glina, and the Una (at the right Sava bank) as well as other rivers. Large number of settlements is threatened by transboundary rivers – the Sava, Sotla/Sutla, Kupa/Kolpa, Bregana, Una and Bosut.

**Bosnia and Herzegovina** identified 160 APSFRs with total area of about 1.595 km². The largest area is threatened by the Sava River and its first and second order tributaries: Glina, Una, Sana, Vrbas, Bosna, Lašva, Krivaja, Spreča, Tinja, Drina, Prača and Drinjača, but APSFRs are identified in the catchments of smaller rivers as well. As for the transboundary rivers, APSFRs are identified along the Sava, Una, and Drina rivers.

**Serbia** identified 28 APSFRs along 29 rivers in the Sava River basin, which endanger the riparian land along about 800km of rivers length. APSFRs were mapped as lines or as points (where the rivers endanger individual settlements). APSFRs along the rivers relevant at the Sava River Basin level - the Sava River (the entire section in Serbia) and its direct tributaries Bosut, Drina (and its tributary the Lim), Kolubara and Topčiderska reka stretch along 500km of rivers length. APSFRs were identified along four transboundary rivers in the Sava River Basin: Sava, Bosut, Drina and Lim.

**Montenegro** identified 15 APSFR in the Sava River Basin covering about 7 km². APSFRs are located at Lim, Tara, Ćehotina and Piva rivers.

## 5.3 SOURCES, MECHANISMS AND CHARACTERISTICS OF FLOODS IN APSFRS

The types of flood associated with APSFRs slightly follow pattern as for past and potential future floods, what is visible only for the source of flooding where information is sufficiently available.

A source of flooding was identified for all APSFRs with the main source of flooding identified is fluvial (87%). Groundwater floods and floods coming from the artificial water-bearing infrastructure are present in 3% of APSFRs.

Excluding the “no data” category, natural exceedance flooding was the most common mechanism and flash floods the most common characteristic.

Data on the sources, mechanisms and characteristics of floods within the APSFRs are shown in Figure 6.

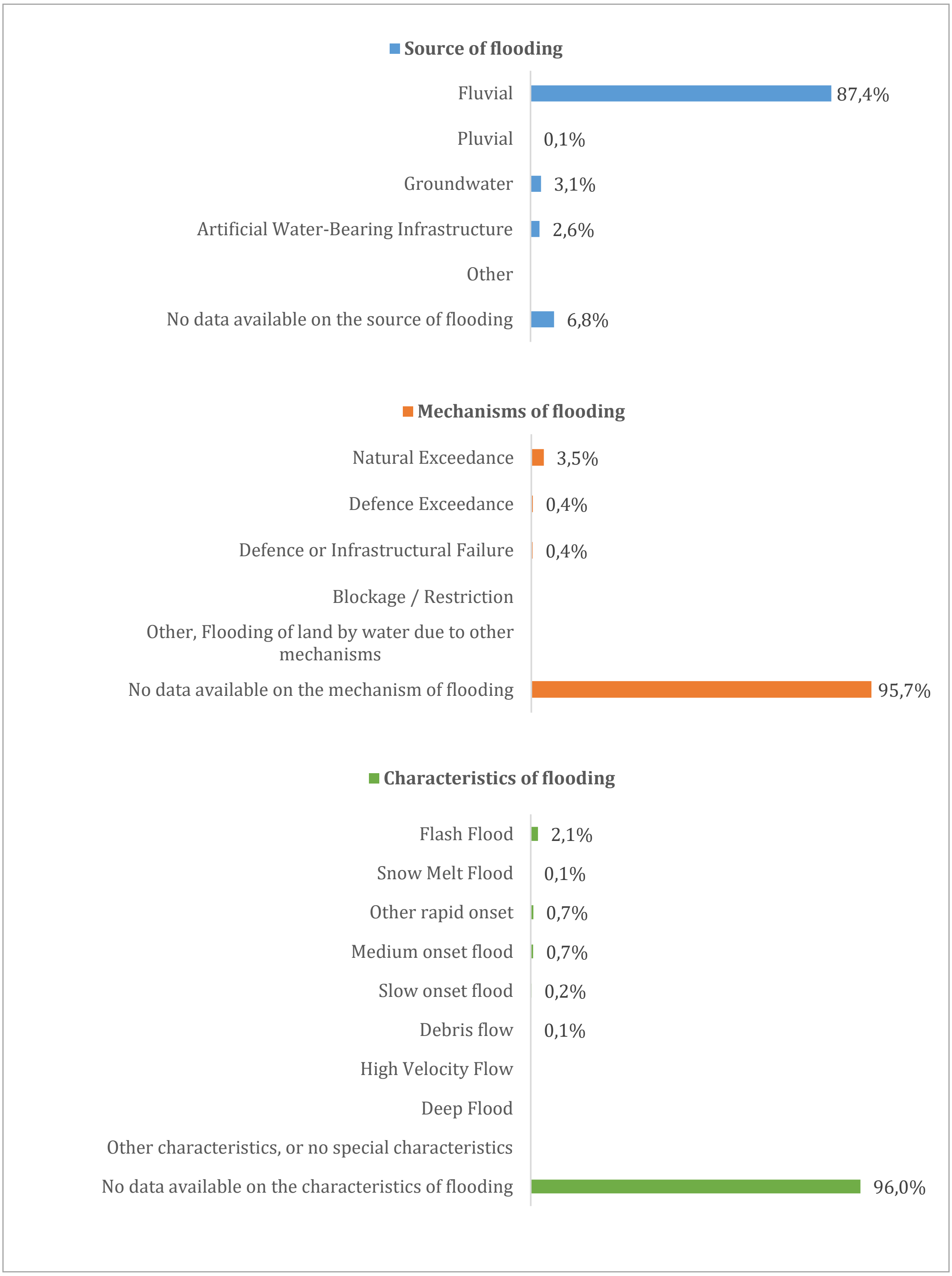



*Figure 6: Types of the flooding in APSFRs*

## 5.4 POTENTIAL ADVERSE CONSEQUENCES ASSOCIATED WITH APSFRS

*Table 8: Data availability on the consideration of consequences associated with APSFRs*

| Consequences | | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|---|
| Human health | Human Health | | ✓ | | ✓ | |
| | Community | | ✓ | | ✓ | ✓ |
| | Other | | | | | |
| | Not applicable | | | ✓ | | ✓ |
| | Unknown | ✓ | | | | |
| Environment | Waterbody Status | | | | | |
| | Protected Areas | | ✓ | | ✓ | |
| | Pollution Sources | | ✓ | | ✓ | |
| | Other | | | | | |
| | Not applicable | | ✓ | ✓ | | ✓ |
| | Unknown | ✓ | | | ✓ | |
| Cultural heritage | Cultural Assets | | ✓ | | ✓ | |
| | Landscape | | ✓ | | | |
| | Other | | | | | |
| | Not applicable | | ✓ | ✓ | | ✓ |
| | Unknown | ✓ | | | ✓ | |
| Economic activity | Property | | ✓ | | ✓ | ✓ |
| | Infrastructure | | ✓ | | ✓ | |
| | Rural Land Use | | ✓ | | ✓ | ✓ |
| | Economic Activity | | ✓ | | ✓ | ✓ |
| | Other | | | | | |
| | Not applicable | | ✓ | ✓ | | ✓ |
| | Unknown | ✓ | | | | |

Based on available data adverse consequences to human health, either as immediate or consequential impacts, such as might arise from pollution or interruption of services related to water supply and treatment (also having environmental implications) and would include fatalities have been identified in 67% of APSFRs, whilst consequences to the community, such as detrimental impacts on local governance and public administration, emergency response, education, health and social work facilities (such as hospitals) have been identified in about 22% of APSFRs and for more almost 8% of data APSFRs were not applicable to consequences to human health.

Adverse consequences to environment, specifically protected areas, or waterbodies such as those designated under the Birds and Habitats Directives, bathing waters, or drinking water abstraction points is in almost than half of APSFRs.

Unlike historic and potential future floods, high proportion of APSFRs were associated with consequences on cultural heritage perhaps reflecting the possibility that this type of consequence was historically not recorded except for the most significant of flood events. Adverse consequences to cultural heritage assets, which could include archaeological sites / monuments, architectural sites, museums, spiritual sites and buildings have been identified in about 72% of APSFRs while to cultural heritage landscape, which represents the combined works of nature and man, such as relics of traditional landscapes, anchor locations or zones, in about 4% of APSFRs.

Data also shows that economic consequences were associated with the greatest proportion of APSFRs. Consequences for property (including homes) has been identified in about 35% of APSFRs, consequences for rural land use in 33% of APSFRs and consequences for infrastructure in 9% of APSFRs, while consequences for activities such as manufacturing, construction, retail, services and other sources of employment in 13% of APSFRs.

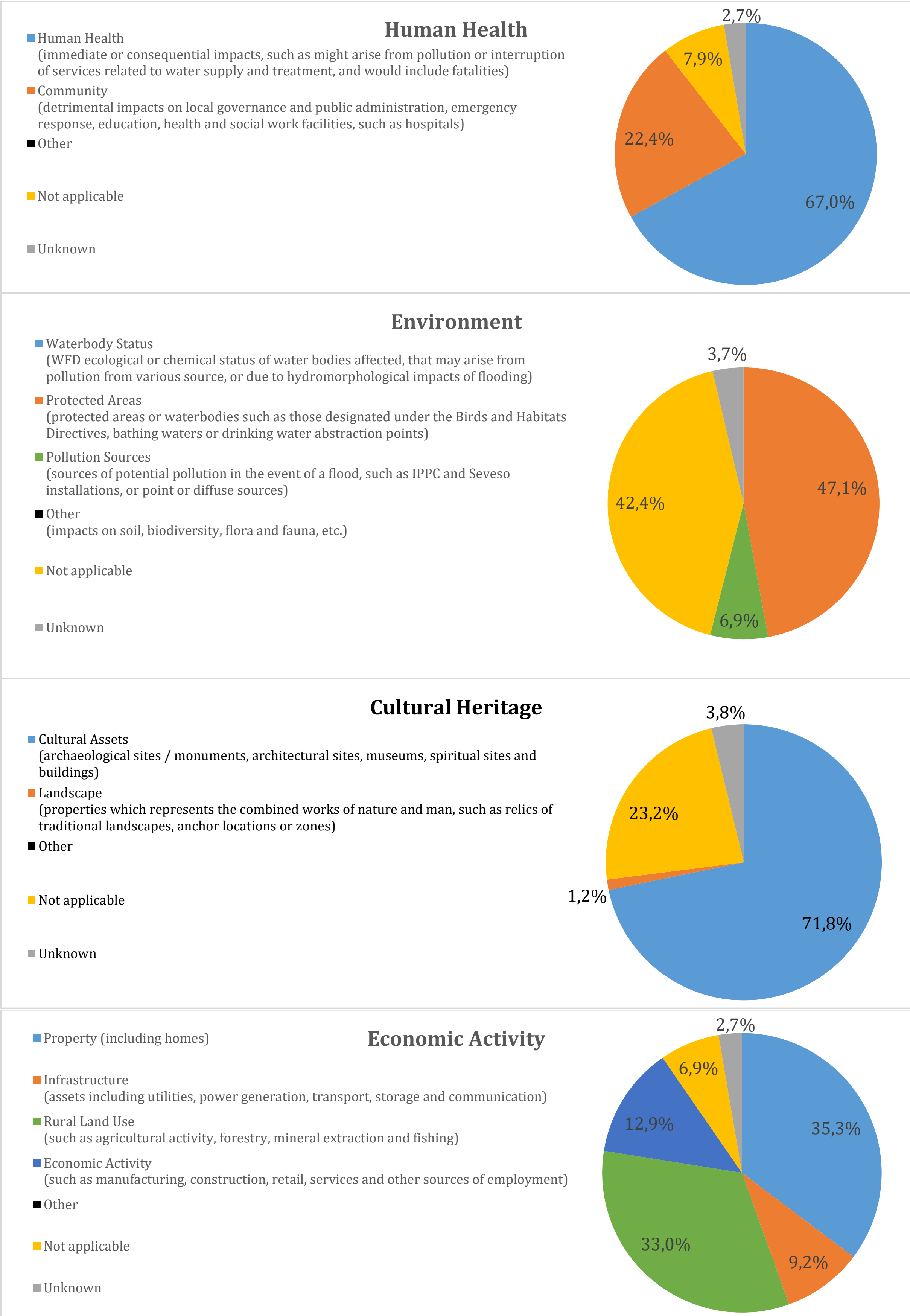



*Figure 7: Potential adverse consequences of floods associated with APSFRs*

# 6 AREAS OF MUTUAL INTEREST FOR FLOOD PROTECTION

Article 6 of the Protocol stipulates that based on national APSFRs, ISRBC coordinates the activites on harmonisation of areas shared by two or more countries, identified by the countries as Areas of Mutual Interest for flood protection in the Sava River Basin (AMIs) that represent basic elements for analysis in the flood risk management planning at the Sava River Basin level.

Within the first flood risk management cycle at the basin level the countries identified 21 AMIs based on the 251 flood prone areas that were approved by Sava FRMP. Total surface of AMIs was about 5.659 km$^2$, which is 5.8% of the total Sava River Basin surface, and home to 1.4 million people.

This is a review and update of AMIs that will be basis for the analysis within update of the flood maps.

## 6.1 REVISIONS AND CHANGES OF AMIS

Taking into account that at the transboundary Sava tributaries in Slovenia (Sotla/Sutla, Kupa/Kolpa and Bregana) the national APSFRs were not defined, AMIs were intialy defined based on the methodology of Croatia, meaning that AMIs in Slovenia represent complete area of a settlement which borders the national APSFRs in Croatia.

Having in mind that during the second national flood risk management planning cycle, at the transboundary Sava tributaries, Slovenia had updated national APSFRs only at the Sotla/Sutla River, AMIs were revised and updated mainly based on the national APSFRs of Croatia.

At next figures changes in AMIs on Sotla/Sutla, Kupa/Kolpa and Bregana rivers between Slovenia and Croatia are shown.

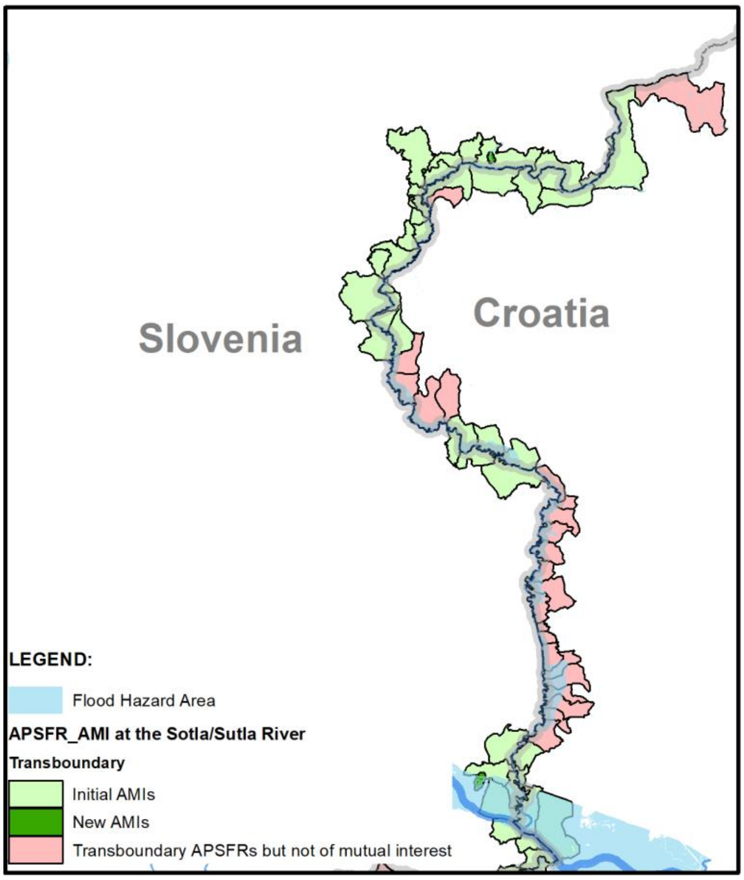



*Figure 8: AMI at the Sotla/Sutla River*

AMIs at the Sotla/Sutla River are almost the same as the initial status with three separate AMIs and three new national APSFRs at the Sotla/Sutla River in Slovenia (Figure 8) that are merged with the initial AMIs (dark green), while national APSFRs in Croatia, with transboundary character (light red), are not included having in mind that are not of interest for Slovenia, are endengered by floods of other rivers or only intersect with the Sotla/Sutla River.

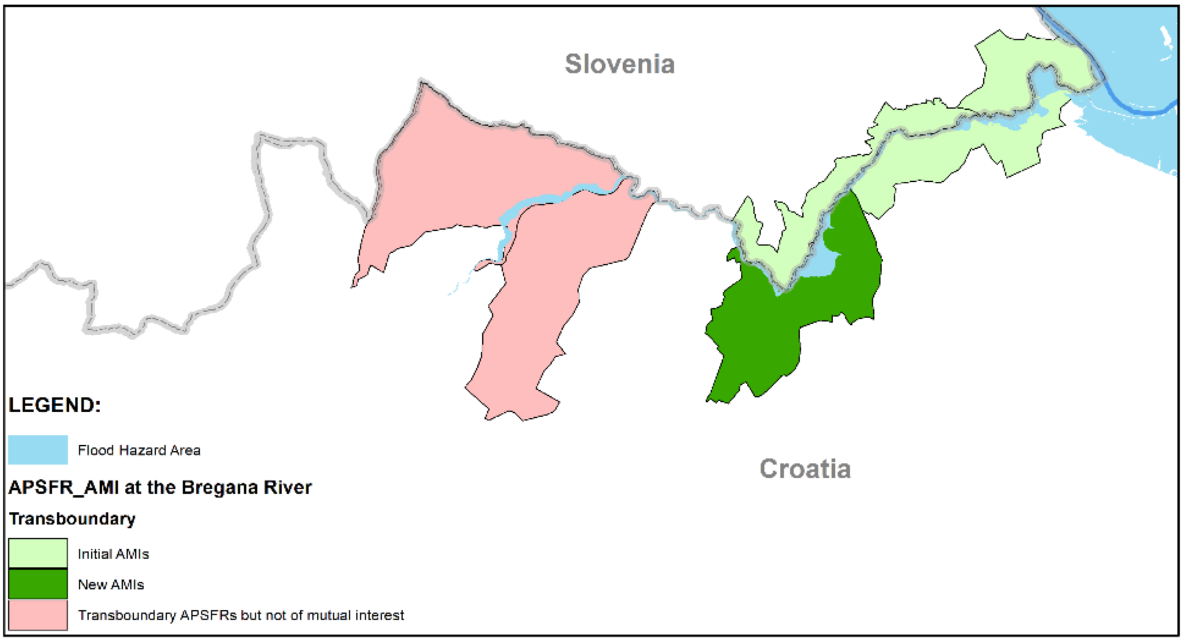



*Figure 9: AMI at the Bregana River*

At the Bregana River (Figure 9) one new APSFR in Croatia (dark green) is included as part of AMI, while two, with transboundary character, are not (light red). Part of AMI in Slovenia remained as initial.

Similar is at the Kupa/Kolpa River where AMIs remained as initial, while several transboundary (light red) APSFRs in Croatia are not included having in mind that are not of interest for Slovenia.

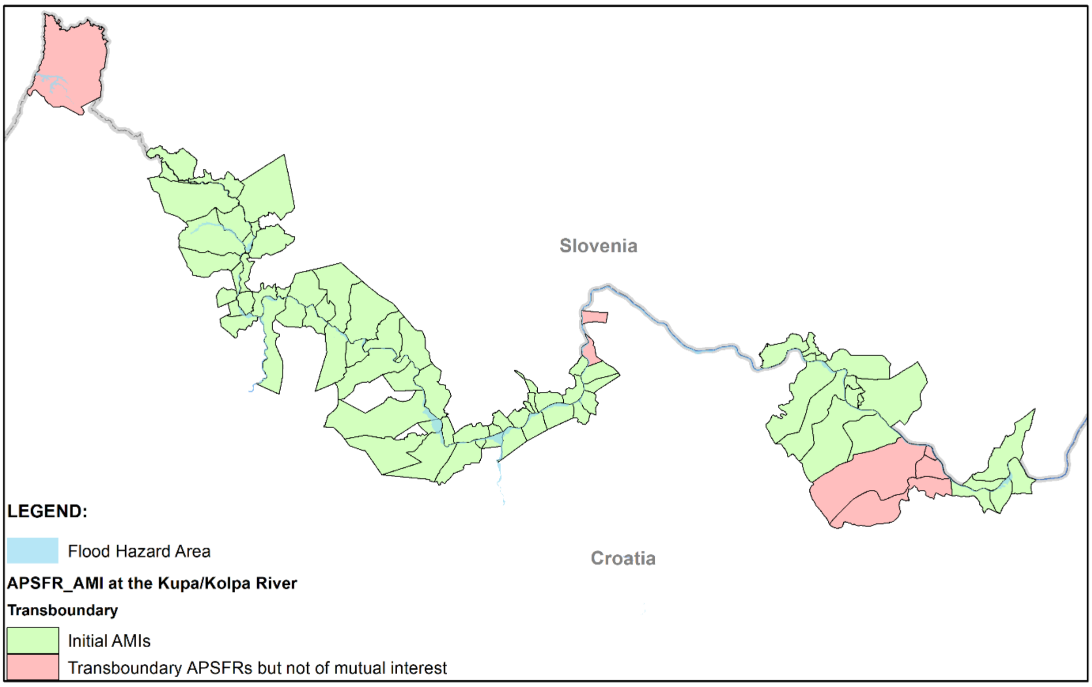



*Figure 10: AMIs at the Kupa/Kolpa River*

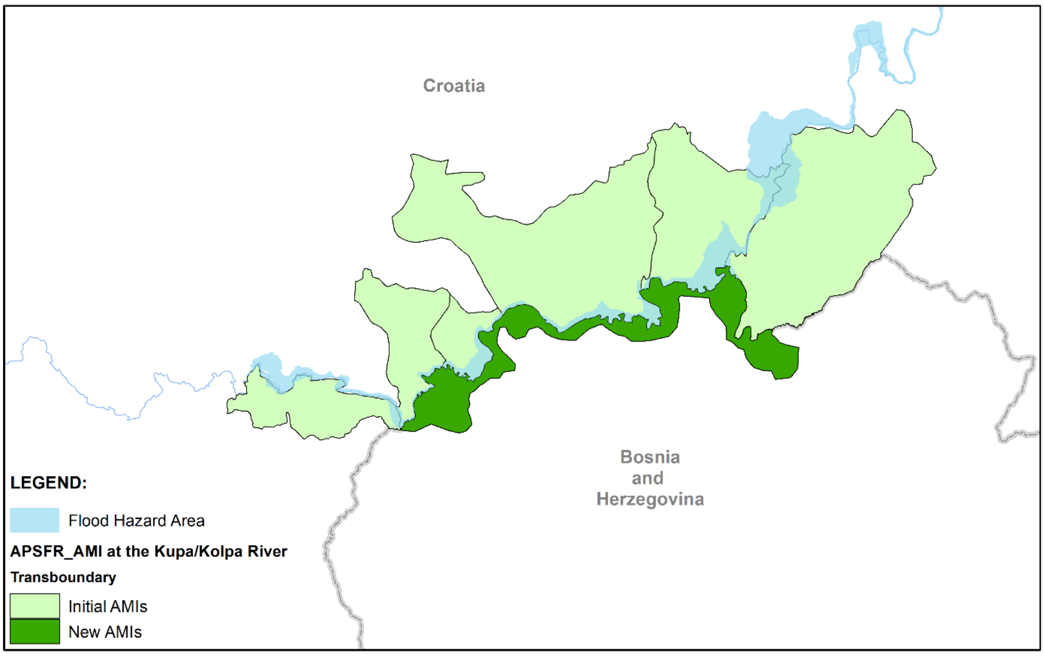



*Figure 11: AMI at the Glina River*

At the Glina River (Figure 11) a new part of AMI in Bosnia and Herzegovina is defined (dark green) having in mind that the flood map in Croatia (left bank) confirmed the flooding character of river which most likely have impact to the right bank as well. Taking into account that the national APSFRs at the Glina River in Bosnia and Herzegovina were not officially defined, the new part of AMI is proposed based on an indicative flooding area.

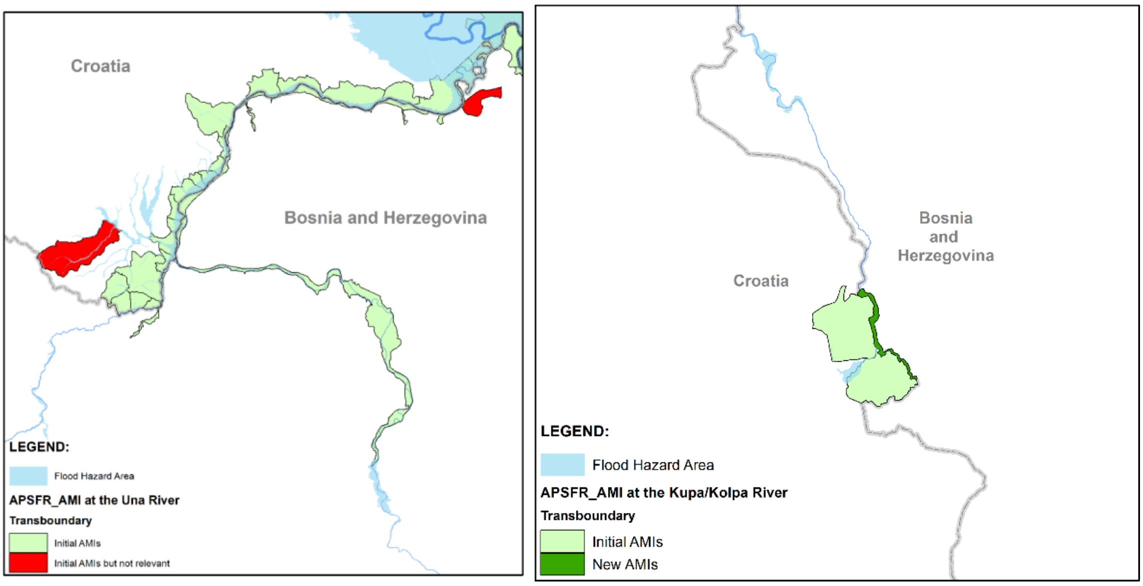



*Figure 12: AMIs at the Una River*

AMI along the Una River at downstream part (Figure 12, left) remained almost the same as initial, only two national APSFRs are revised and defined as not relevant having in mind that APSFR in Croatia is potentially under flood risk from other river and not the Una, while other APSFR in Bosnia and Herzegovina is also potentially under flood risk from the culvert of Sava River and not relevant. As for the upstream AMI at the Una River (Figure 12, right) three national APSFRs in Croatia are defined as not relevant (potentially under flood risk from other river), two remained as initial, and for this AMI part of area in Bosnia and Herzegovina is now also defined considering the flood hazard map in Croatia as well as a fact that area in Bosnia and Herzegovina is within the National Park Una.

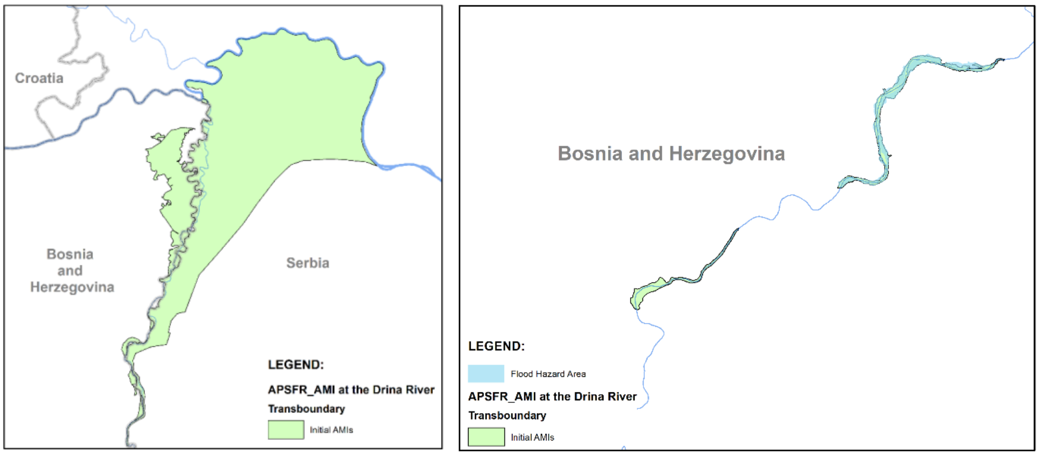



*Figure 13: AMIs at the Drina River*

Both AMIs at the Drina River remain as initially defined (Figure 13). Upstream AMI (Figure 13, right), which is completely in Bosnia and Herzegovina, is of the mutual interest for flood protection due to the potential impact from Montenegro.

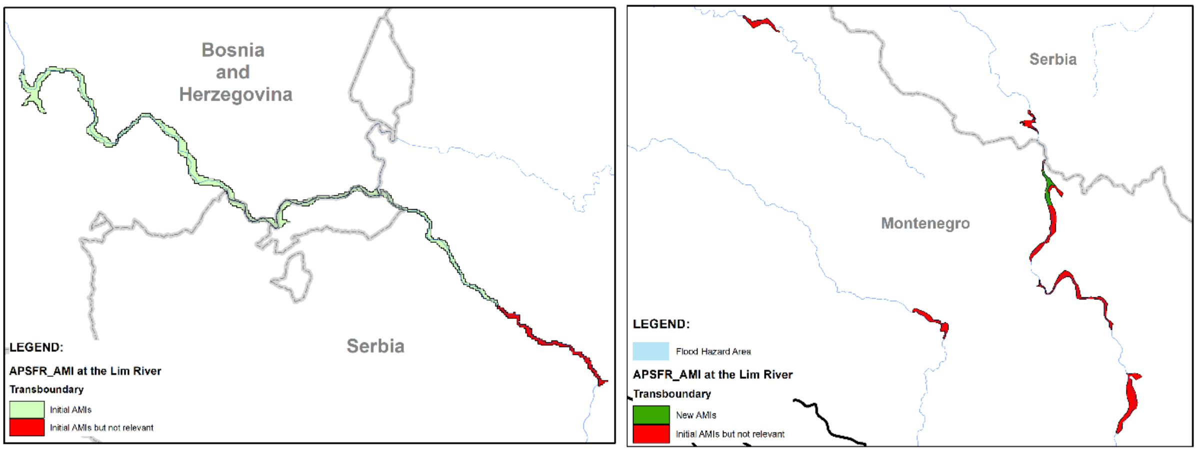



*Figure 14: AMIs at the Lim River*

Downstream AMI at the Lim River, part in Serbia (Figure 14, left) is changed based on the national APSFR and shortened up to the Potpeć dam (dark red). Upstream AMI (Figure 14, right) is also changed based on the national APSFRs of Serbia as well as Montenegro and now only part in Montenegro is represented. Part of area in Serbia is rejected since it was potenital flood areas analysed in Sava FRMP while after an updated of national APSFRs in Serbia this area was not included. However, part of inital AMI in Montenegro is updated (dark green) and confirmed as of mutual interest given that is on the bordering area, so any structural intervention related to the flood protection could increase the flood risk downstream in Serbia. Status of other AMIs in Montenegro, at the Lim, Tara and Ćehotina rivers (dark red) are rejected given that Montenegro has developed national PFRA report including APSFRs determination and therefore potenital flood areas analysed in Sava FRMP are not relevant anymore.

AMI at the Bosut River remain as initially defined (Figure 15).


*Figure 15: AMI at the Bosut River*

As for the upstream AMI at the Sava River, between Croatia and Bosnia and Herzegovina (Figure 16) it remain as initially defined and one that is not relevant anymore is rejected.

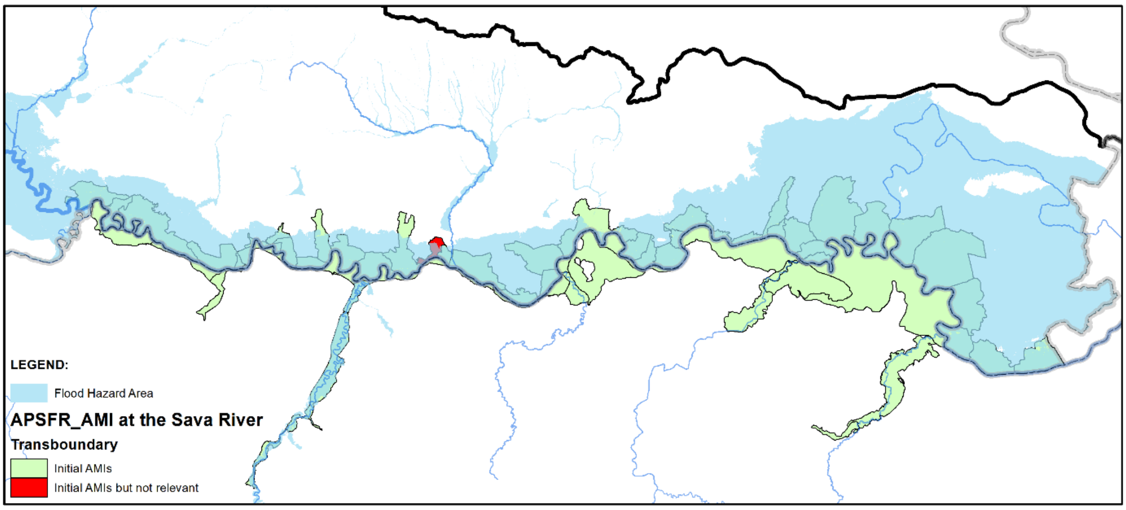



*Figure 16: AMIs at the Sava River (Croatia - Bosnia and Herzegovina)*

The downstream AMI at the Sava River, between Croatia, Bosnia and Herzegovina, Serbia (Figure 17) remain as initially defined with a detail that part in Serbia is now merged into one area.

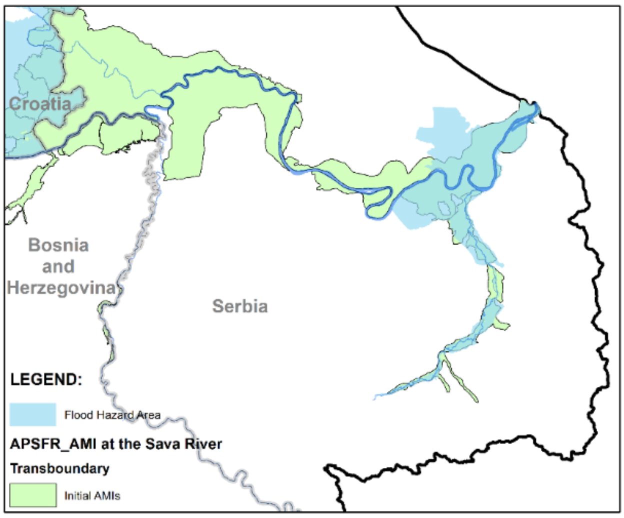



*Figure 17: AMIs at the Sava River (Croatia - Bosnia and Herzegovina - Serbia)*

## 6.2 Number of identified and updated AMIs

Updated AMIs include a total of 255 flood prone areas, identified based mainly on national APSFRs as well as borders of settlements which were not included in national APSFR areas but for which neighbouring countries confirmed that are of mutual interest. AMIs are grouped in 19 areas covering about 5.734,5 km$^2$, respectively 129 km$^2$ in Slovenia, 1.694 km$^2$ in Croatia, 1.099 km$^2$ in Bosnia and Herzegovina, 2.810 km$^2$ in Serbia and 2,5 km$^2$ in Montenegro.

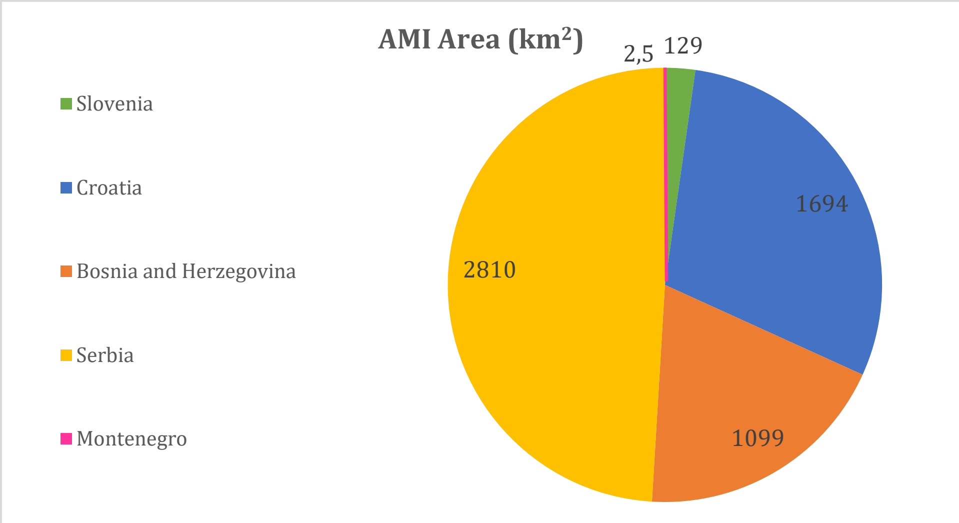



*Figure 18: Distribution of AMIs per countries*

In total, by merging 255 flood areas, 19 AMI areas were identified:

- On Sava River, 4 AMIs were identified, as follows:
  - 1 between Slovenia and Croatia, including the most dowstream parts of tributaries Bregana (right) and Sotla (left) rivers
  - 1 between Croatia and Bosnia and Herzegovina, including the most dowstream parts of tributaries Una, Jablanica, Vrbas, Ukrina, Bosna, Tinja, Lukavac (right) and Trnava and Orljava (left) rivers
  - 1 between Croatia, Bosnia and Herzegovina, and Serbia, including the most dowstream parts of tributaries Drina, Kolubara (right) and Bosut (left) rivers
  - 1 entirely in Serbia, including the most dowstream parts of Kolubara River.
- A total of 15 AMIs were identified on 8 tributaries:
  - 3 on Kupa, 3 on Sutla and 1on Bregana rivers between Slovenia and Croatia
  - 2 on Una and 1 on Glina rivers between Croatia and Bosnia and Herzegovina
  - 1 on Drina River between Bosnia and Herzegovina and Serbia
  - 1 on Drina River entirely in Bosnia and Herzegovina under potential impact of floods from Montenegro
  - 1 on Lim River entirely in Montenegro with potential impact to floods in Serbia
  - 1 on Lim River between Bosnia and Herzegovina and Serbia
  - 1 on Bosut River between Croatia and Serbia.

Table 9 presents the overview of AMIs per river, number and share of potential flood areas within the AMI, as well as share of AMIs in the entire Sava River basin.

The largest area (1.635,72 km$^2$) belongs to AMI (HR_BA_Sava) in transboundary part of the middle Sava which includes 909,48 km$^2$ of area in Croatia, and 726,24 km$^2$ in Bosnia and Herzegovina. The share of this AMI in the entire Sava River basin is 1.67%.

Land cover/use in AMIs is shown at Map 4.

*Table 9: Overview of AMIs*

| No. | AMI code | AMI surface | | Country | Share of potential flood areas in the AMI | |
|---|---|---|---|---|---|---|
| | | km² | % of basin | | km² | % |
| 1 | SI_HR_Sava | 18,87 | 0,019% | Slovenia | 8,54 | 45% |
| | | | | Croatia | 10,33 | 55% |
| 2 | HR_BA_Sava | 1635,72 | 1,674% | Croatia | 909,48 | 56% |
| | | | | Bosnia and Herzegovina | 726,24 | 44% |
| 3 | HR_BA_RS_Sava | 1624,14 | 1,662% | Croatia | 31,14 | 2% |
| | | | | Bosnia and Herzegovina | 166,09 | 10% |
| | | | | Serbia | 1426,91 | 88% |
| 4 | RS_Sava | 155,06 | 0,159% | Serbia | 155,06 | 100% |
| 5 | HR_SI_Sutla_1 (i) | 10,60 | 0,095% | Slovenia | 53,88 | 58% |
| | | | | Croatia | 38,62 | 42% |
| 6 | HR_SI_Sutla_2 (i) | 15,30 | 0,095% | Slovenia | 53,88 | 58% |
| | | | | Croatia | 38,62 | 42% |
| 8 | HR_SI_Sutla_3 (i) | 66,32 | 0,095% | Slovenia | 53,88 | 58% |
| | | | | Croatia | 38,62 | 42% |
| 8 | HR_SI_Bergana (i) | 9,13 | 0,009% | Slovenia | 2,05 | 22% |
| | | | | Croatia | 7,08 | 78% |
| 9 | HR_SI_Kupa_1 (i) | 9,04 | 0,009% | Slovenia | 4,77 | 53% |
| | | | | Croatia | 4,27 | 47% |
| 10 | HR_SI_Kupa_2 (i) | 37,12 | 0,038% | Slovenia | 14,96 | 40% |
| | | | | Croatia | 22,16 | 60% |
| 11 | HR_SI_Kupa_3 (i) | 111,37 | 0,114% | Slovenia | 44,71 | 40% |
| | | | | Croatia | 66,66 | 60% |
| 12 | HR_BA_Glina (ii) | 79,57 | 0,081% | Croatia | 69,51 | 87% |
| | | | | Bosnia and Herzegovina | 10,06 | 13% |
| 13 | HR_BA_Una_1 | 220,59 | 0,226% | Croatia | 157,52 | 71% |
| | | | | Bosnia and Herzegovina | 63,06 | 29% |
| 14 | HR_BA_Una_2 (ii) | 23,47 | 0,024% | Croatia | 21,67 | 92% |
| | | | | Bosnia and Herzegovina | 1,80 | 8% |
| 15 | BA_RS_Drina | 954,66 | 0,977% | Bosnia and Herzegovina | 115,00 | 12% |
| | | | | Serbia | 839,66 | 88% |
| 16 | ME_BA_Drina | 6,02 | 0,006% | Montenegro | - | - |
| | | | | Bosnia and Herzegovina | 6,02 | 100% |
| 17 | ME_RS_Lim | 2,5 | 0,003% | Montenegro | 2,5 | 100% |
| | | | | Serbia | - | - |
| 18 | RS_BA_Lim | 17,79 | 0,018% | Serbia | 7,07 | 40% |
| | | | | Bosnia and Herzegovina | 10,72 | 60% |
| 19 | HR_RS_Bosut | 736,97 | 0,754% | Croatia | 355,47 | 48% |
| | | | | Serbia | 381,50 | 52% |
| | **TOTAL** | **5734,5** | **6%** | | **5734,5** | |

(i) for area in Slovenia complete settlement surface used, since the national APSFRs not defined
(ii) for area in Bosnia and Herzegovina an indicative flooding area is included, since the national APSFRs not defined

## 6.3 Sources, mechanisms and characteristics of floods in AMIs

The types of floods associated with AMIs are based on data related to APSFRs and therefore the main source of flooding identified is fluvial, about 82%. It is very interesting that the defence exceedance and defence or infrastructural failure are the most common mechanism of flooding and medium onset the most common characteristic. Data on the sources, mechanisms and characteristics of floods within AMIs are shown in Figure 19.

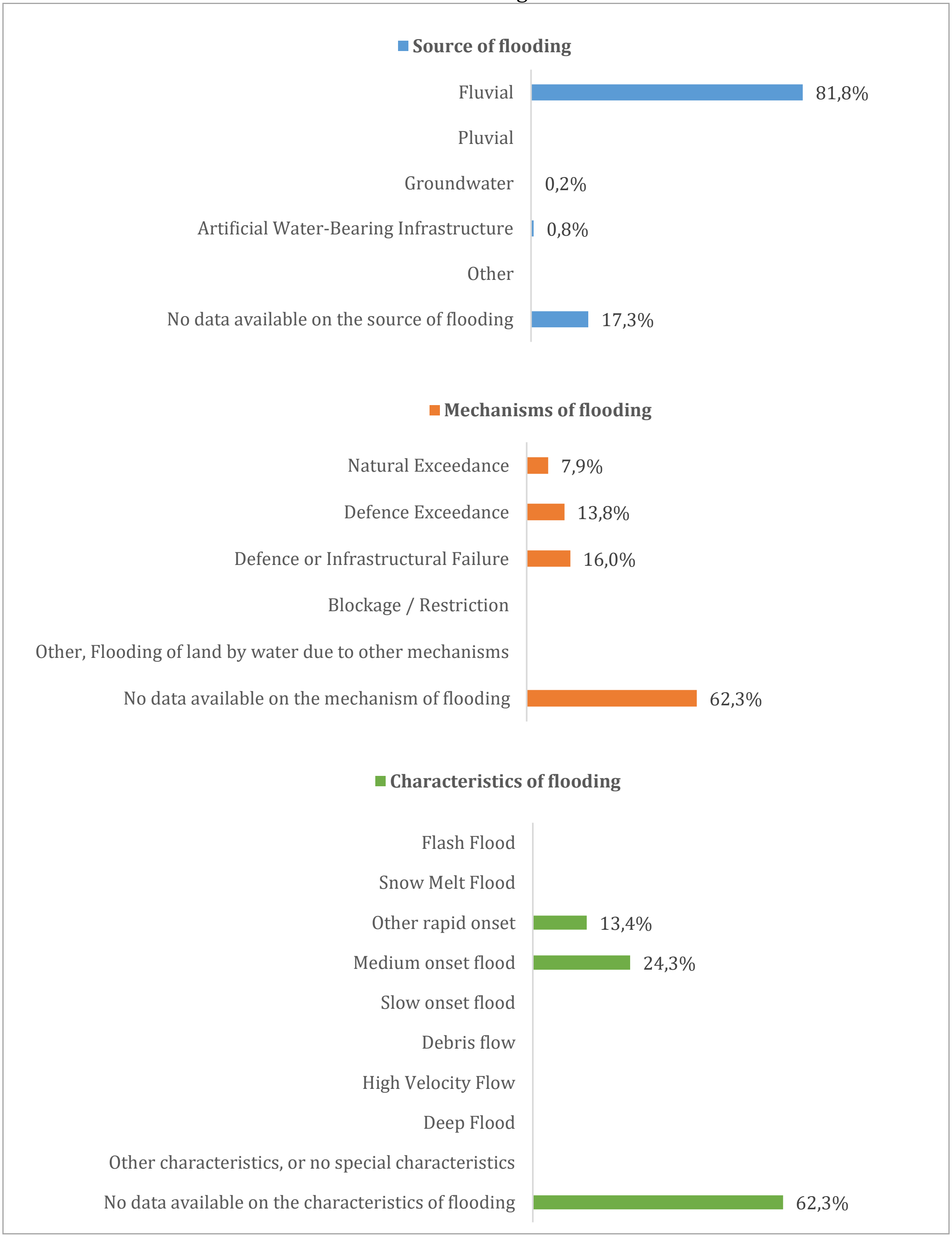



*Figure 19: Types of the flooding in AMIs*

## 6.4 Potential adverse consequences associated with AMIs

### 6.4.1 Human health

Available data on adverse consequences to human health associated with APSFRs, analysed in the Chapter 5.4, served for the purpose of statistical analysis for the AMIs surface.

Potential adverse consequences to human health, either as immediate or consequential impacts, such as might arise from pollution or interruption of services related to water supply and treatment (also having environmental implications) and would include fatalities have been identified in area of 4.506,6 km$^2$, what includes 39% of AMIs.

Consequences to the community, such as detrimental impacts on local governance and public administration, emergency response, education, health and social work facilities (such as hospitals) have been identified in area of 4.022,9 km$^2$, about 28% of AMIs.

For about 373,7 km$^2$ (5% of data), and mainly in Bosnia and Herzegovina (369,5 km$^2$), AMIs were not applicable to consequences to human health, while in Slovenia and Bosnia and Herzegovina at about 28% of the AMIs surface (777,7 km$^2$) data were unknown.

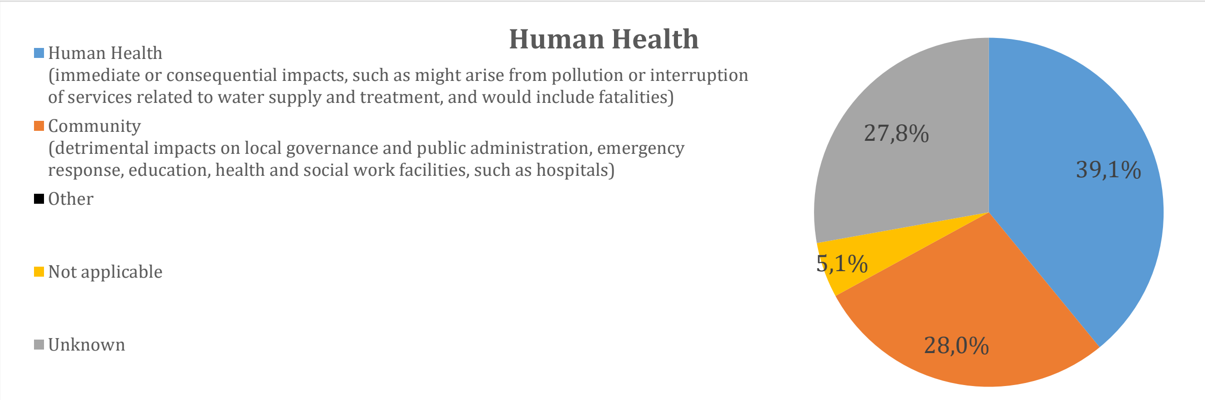



*Figure 20: Potential adverse consequences of floods to human health associated with AMIs*

Spatial distribution of potential adverse consequences of floods to human health associated with AMIs is shown at Map 5.

Having in mind that according to the EU Floods Directive and the Protocol, as well as to the measures of Sava FRMP, among all other receptors attention should be paid to prevention and reduction of potential adverse consequences to human health of flooding in the risk assessment as in the risk management.

For the purpose of further elaboration in the next planning stages it is of utmost importance to operationalize integrated flood and health impact assessments, planning and management on the AMIs level. Therefore a preliminary analysis of the human health issues with focus in the public health burden of floods which can be significant and extends long beyond the direct flood period but it can also be spatially very widespread much more than the direct flood extent. This affects all exposed and sensitive people but especially already vulnerable population groups disproportionately such as young children, elderly, disabled and/or care dependent, lower income groups occupying lower quality housing and/or lacking personal transport capabilities, etc. However many, diverse, types of health effects can occur during one flood event, and therefore an approach is needed to include a variety of potential health effects, in order to protect the population from negative aspects where possible.

Basic elaborations related to the health effects of floods and risk analysis which would be the basis for further planning stages at the AMIs level are given below.

### Health effects of floods

The health effects of floods vary over time. The health impacts of floods vary between affected populations (related to their vulnerability, exposure and capacity to reduce risks and cope with the event), type of flood (slow or fast onset) and the background health situation of the population and their access to health services. Several groups of health risks peak at different moments in time after the onset of a flood and may last a long time (Figure 21). They can be classified as immediate, short-term (days to weeks after a flood), and long-term (months to years after onset of flood) health impacts.

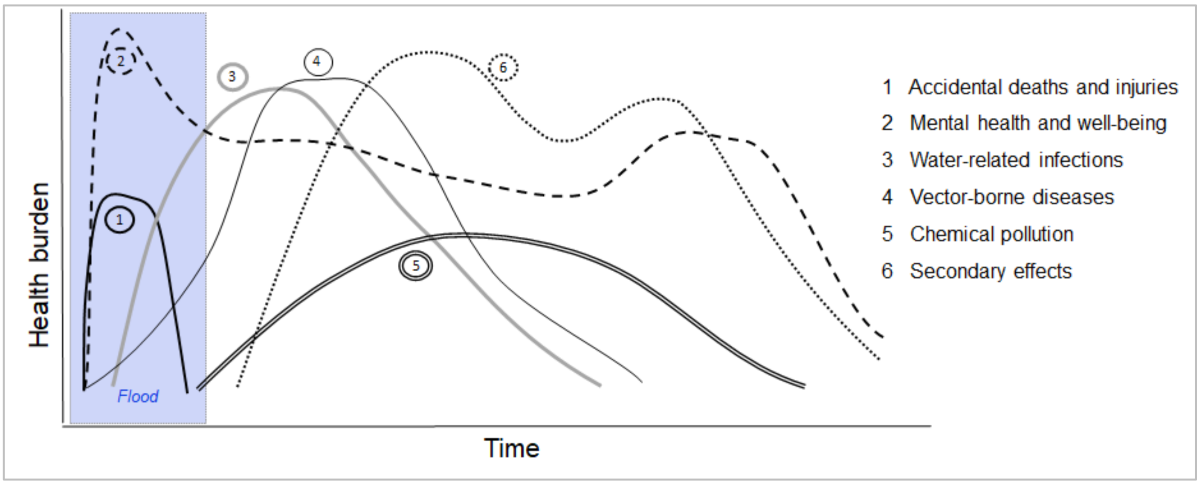



*Figure 21: Potential timelines of the health burden related to flood events (source: Deltares)*

Immediate health impacts of floods occur as the flood spreads and while the land is inundated. These include deaths from drowning and accidents, and injuries. Mental health issues, like fear and anxiety, also affect people from day one.

Short-term health impacts appear within days up to several weeks after the onset of the flood. These include injuries, exposure to toxic substances that might be in the water, and higher risk of outbreaks of waterborne diseases, such aszoonosis (particularly Leptospirosis), hepatitis A (endemic in the countries), cryptosporidiosis, giardiasis, shigellosis and diarrheal diseases. During the flood in 2014 no cases have been reported (analysed) with these diseases.

Floods can also increase the risk of vector-borne diseases through the expansion in number and range of vector habitats. West Nile fever is of most concern in the flooded region, since the conditions after residing of the floodwater are ideal for this mosquito (Culex spp.) and the virus is present in all countries. Aedes albopictus is present in the mid section of the Sava River and could raise the potential for disease transmission upon introduction of arboviruses (e.g. dengue, zika or chikungunya virus via travellers).

Secondary outbreaks of infectious diseases may occur due to overcrowding following population displacement.

Long-term health impacts of floods become apparent many weeks or months after the flood event and may not always be recognized as caused by the disaster. This holds true for most of the non-communicable diseases, the effects of chemical pollution, and mental health issues. Other long-term effects include food insecurity, as harvests may be destroyed by the water or chemically contaminated, machinery is damaged, and decrease in production of farm animals due to stress or illness. Extra pressure on the health system arises due to incidents with displaced landmines and unexploded objects, since warning signs are washed away or the object is displaced with the water or a landslide. In addition, on the wet wall in houses, mold can grow (as well as in the flooded parts of the buildings as other locations due to rising damp). The fungi can cause respiratory infections and breathing problems. Indirect impacts may arise when health facilities are destroyed by floods and services get disrupted, such as vaccination campaigns.

The anticipated mortality and morbidity of these diseases may subsequently be exacerbated by infrastructural losses impacting treatment availability and/or access to alternative sources. For example, broken health care services or damaged hospitals lead directly to an increase in the health burden as the health care becomes limited or lost. Damage or disruption of transport systems threaten the delivery of supply like water, food, medicine and manpower. And damage to water supply and sanitation can (in)directly increase the burden of water-borne diseases. The burden is expected to be the highest in vulnerable population groups.

### FLOOD–HEALTH RISK ANALYSIS

As described, health effects of floods can be manifold, however the actual and potential health risks could vary per country, the current flood situation, as well as the planning and management efforts needed to improve preparedness, protection, responses and recovery.

For the analysis and mapping of risks, health categories are divided in two common dimensions of flood risk analysis, i.e. the hazards and exposure and vulnerability (Figure 22). The hazards and exposure dimension contains the various health effect categories and components. The vulnerability dimension indicates parts of the population that are susceptible, and the healthcare infrastructure that when affected exacerbates local vulnerability during and after floods.

The dimensions of health risks contain components that are quantifiable and mappable to estimate the potential health risks (Figure 22) such as for example chemical factories as potential sources of chemical pollution; farms, sewers, septic tanks, waste water treatment plants as sources of microbial pollution. Less direct health effects, such as "secondary health effects" can be linked to health related infrastructure such as hospital and care centres, access roads to these, electricity supply to these and drinking water supply infrastructure to health care and the general public, estimated housing quality (moulding after floods), etc. Thirdly, the population is not evenly susceptible and some are mostly disproportionately affected. The vulnerable population can be estimated and mapped based on for example age distribution, socio-economic spatial data, remoteness/isolation, transport capabilities, etc. The actual mapping is proposed to be further elaborated in the next planning stages. If desired, an aggregated health risk can be produced to identify areas of risk to hazards and exposure, and/or higher vulnerability.

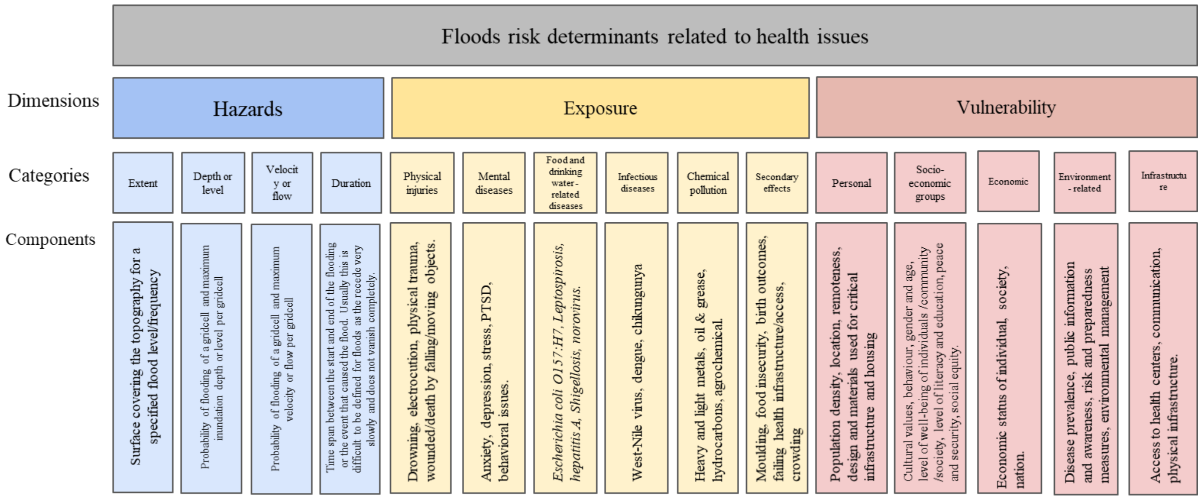



*Figure 22: First overview of determinants of health during and after floods*

The health impact mapping and analysis in the next planning stages should lead to systemic insights and proposed measures in every quadrant of the disaster planning cycle. The analysis feeds into mitigation and preparation phases to target known causes of hazards and exposure, in order to limit these in case a flood happens. Also the (spatially) identified vulnerable population groups can be better prepared, and supporting health infrastructure, linked to its serving area and its supporting infrastructure, be made more resilient to floods. Responses in high risk areas, now with known health effect causes, are more informed about resources needed, and similarly the recovery efforts can be more targeted if the spatial distribution of potential health impacts is known.

By incorporating a health impact analysis into flood management planning, health oriented preparation is not only aimed at improving disaster relief efforts during a flood, but also to lower the actual impacts and efforts needed by more integrated flood management planning.

### 6.4.2 Environment

The Sava River Basin is of specific significance due to its exceptional landscape diversity. The area is characterised by the largest complex of alluvial floodplain wetlands in the Danube basin, and extensive areas are covered by lowland forests.

The Sava River has areas where the floodplains are still intact, especially in the central part of basin which is caracterized with a mosaic of natural floodplains and cultural landscapes formed by traditional land-use patterns. By national legislation of some of the Sava countries the Sava River, its tributaries and wetlands are declared as the ecological corridors of international importance.

Many of this sites are within AMIs and therefore very important for flood risk management on the basin level as well. Related environment issues in AMIs, specifically protected areas, or waterbodies such as those designated under the Birds and Habitats Directives, bathing waters, or drinking water abstraction points are under adverse consequences of flooding at 49% of AMIs (5.266,8 km$^2$). Considering that in a large percent of the protected areas in AMIs also pollution sources exist (16%), such as IPPC and Seveso installations, or point or diffuse sources, these protected areas in the event of a flood are endangered not only from pollution of rivers but also internally.

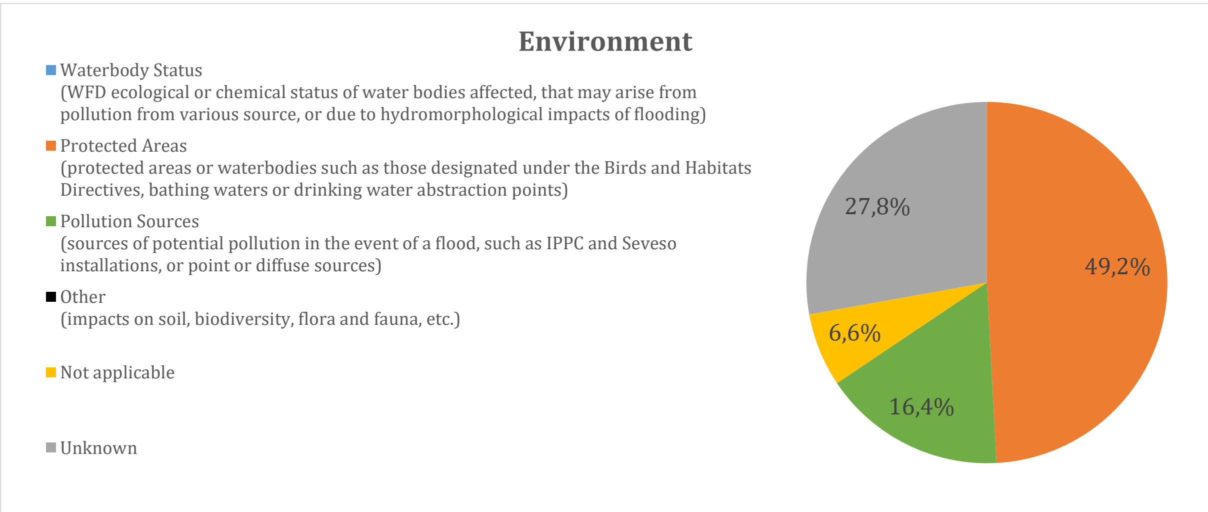



*Figure 23: Potential adverse consequences of floods to environment associated with AMIs*

Spatial distribution of potential adverse consequences of floods to environment associated with AMIs is shown at Map 6.

Flood risk management planning in AMIs have to take into consideration that alluvial forests, along the lowland rivers in the Sava River Basin, as one of the most species-rich habitats in Europe play a crucial role in controlling the structure and function of ecosystems. These habitats which includes large complex of alluvial hardwood forests of oak and ash not only, are one of the most valuable but also one of the most endangered habitat types, laying mainly in the floodplains. Therefore flood protection measures in AMIs where these habitats are present should rely on retention areas and creation of flood control systems capable of storing part of the floods in the natural inundation areas. It is an effective approach that contributes to reducing negative consequences on species and habitat biodiversity of flood control activities.

### 6.4.3 Cultural heritage

Cultural heritage sites are very dense in the Sava River Basin, as areas along the river in history provided good conditions for settlement. Along the river, there are vast fertile areas used for food production and that all led to numerous cultural sites from close history (religious and spiritual sites) to far history (numerous archaeological sites in the region).

Out of the many cultural-historical heritage sites, there are several UNESCO designated sites located in the Sava River Basin spread across five countries: Mehmed Paša Sokolović Bridge in Višegrad (Bosnia and Herzegovina), Plitvice Lakes National Park (Croatia), Stećci Medieval Tombstones Graveyards in Žabljak-Plužine (Montenegro) and Perućac-Rastište-Hrta (Serbia), as well as Prehistoric pile dwellings around the Alps in Ig (Slovenia). Among these UNESCO sites, there are numerous national, regional and local designated cultural heritage objects and locations.

Cultural-historical heritage sites laying in AMIs are mainly placed in floodplains and thus can be affected by the risk of floods.

Based on national data it could concluded that a high proportion of AMIs are associated with consequences on cultural heritage. Adverse consequences to cultural heritage assets, which could include archaeological sites / monuments, architectural sites, museums, spiritual sites and buildings have been identified in about 60% of AMIs, meaning at area of 3.093,45 km2 while to cultural heritage landscape, based on available data, is not represented in AMIs.

Spatial distribution of potential adverse consequences of floods to cultural heritage associated with AMIs is shown at Map 7.

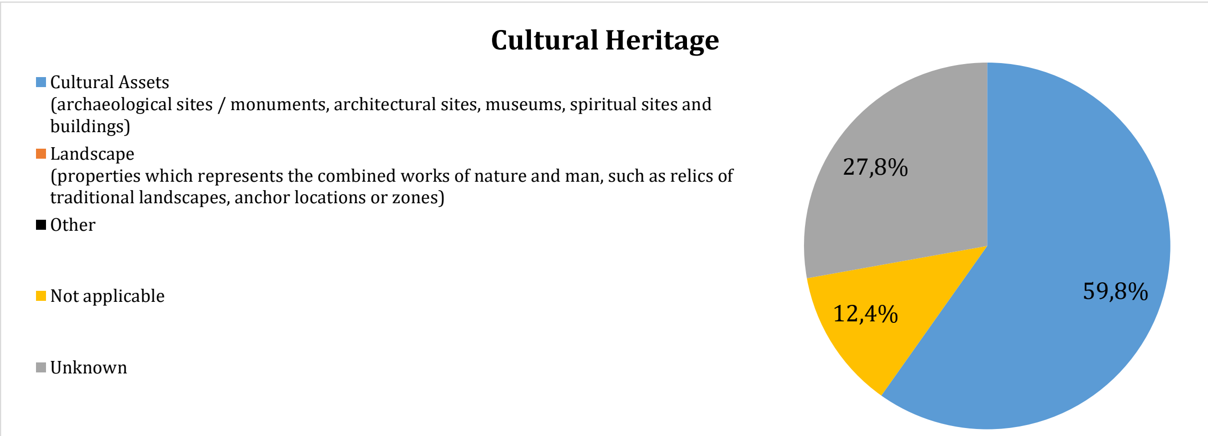
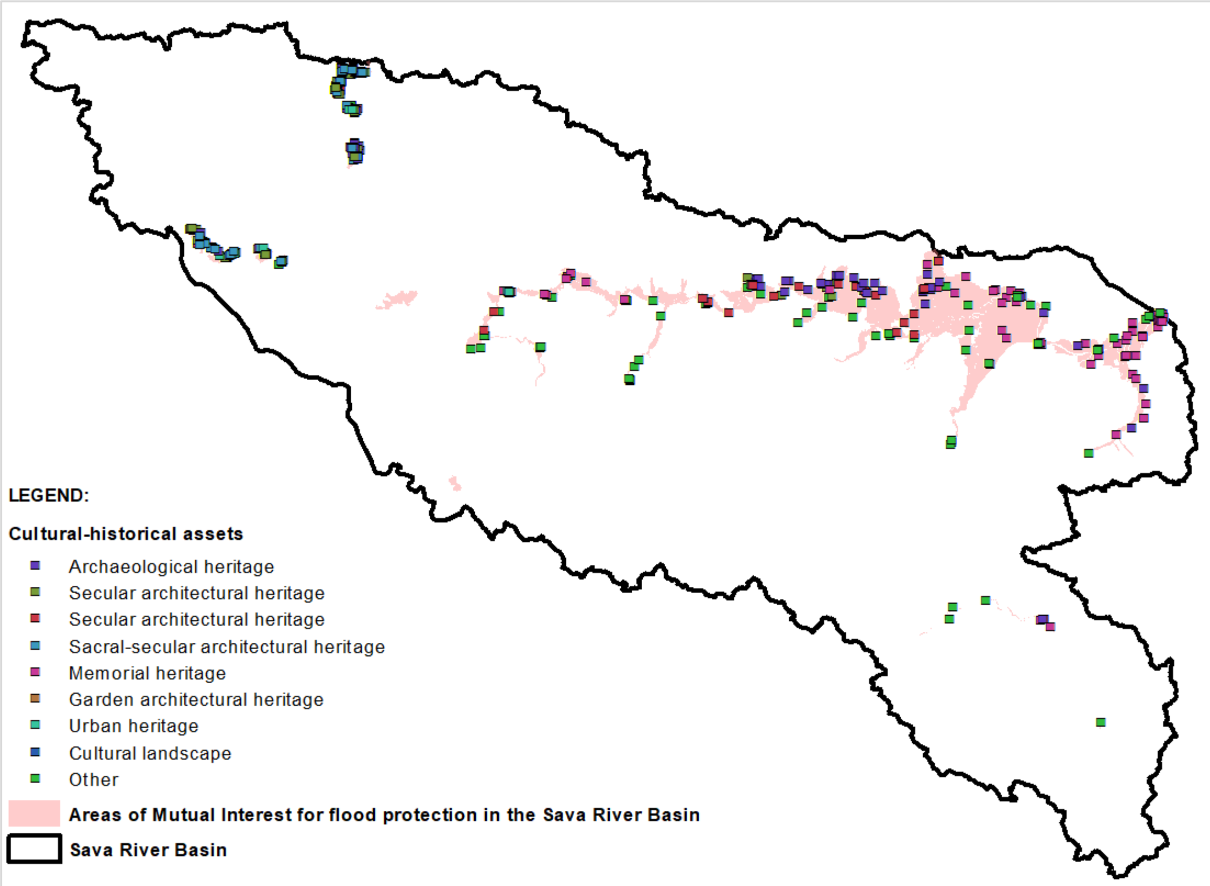



*Figure 24: Potential adverse consequences of floods to cultural heritage associated with AMIs*

Over the last decades, as a consequence of the effects of climate change, the cultural heritage has been impacted by an increasing number of climate related hazards, including floods, posing new challenges to conservators and heritage managers. On other hand a need for more solid data and a spatial layer on cultural-historic heritage in a format compatible to Sava GIS, was recognized within the development of Sava FRMP and therefore countrie through ISRBC supported and joined the project SHELTER - Sustainable Historic Environments hoListic reconstruction through Technological Enhancement and community based Resilience.

The project approved by EU Horizon 2020 aims at developing a data driven and community-based knowledge and operational framework that will bring together the scientific community and heritage managers with the objective of increasing resilience, reducing vulnerability and promoting better and safer reconstruction in historic areas to cope with climate change and natural hazards. All the developments of the project are validating in 5 “open labs” representative of main climatic and environmental challenges in Europe and different heritage’s typologies, including the Sava River Basin. The project also aims to the ISRBC community in development of web services-based data exchange on cultural-historical heritage for the purpose of processing and managing by the Sava GIS Geoportal and for that purpose spatial and attribute data for more than 1.200 heritage sites (archaeological, secular architectural, sacral architectural, memorial, garden architectural, urban, cultural landscape, historical landscape, other) have been collected, harmonized and stored in the central Sava GIS database.




For all assets many data and information are already available or will be delivered by relevant institutions responsible for the management of cultural-historic heritage. These data, will operationally serve the ISRBC cooperating countries and different relevant institutions from water/floods, cultural-historic heritage, and emergency management, to perform the flood impact analysis on cultural-historic heritage in the most vulnerable sites within AMIs. Within the SHELTER representatives of these institutions are currently networking at the Sava River Basin level but also at national level in some of the countries for the first time, through the continuous exchange of knowledge and best practices to raise awareness about the protection of heritage. The results will enable the countries to take the right management decisions and implement operational measures to prevent and mitigate severe flood impacts on the cultural-historic heritage based of reliable data.

### 6.4.4 Economic activity

Based on available data it is clear that economic consequences were most commonly reported in AMIs and also shows that economic consequences were associated with the greatest proportion of AMIs. Consequences for property, including homes and businesses, has been identified in about 32% of AMIs. However, impacts on property in AMIs is mainly in combination with consequences for economic activity, such as manufacturing, construction, retail, services and other sources of employment, then infrastructure assets such as utilities, power generation, transport, storage and communication as well as rural land use, such as agricultural activity, forestry, mineral extraction and fishing.

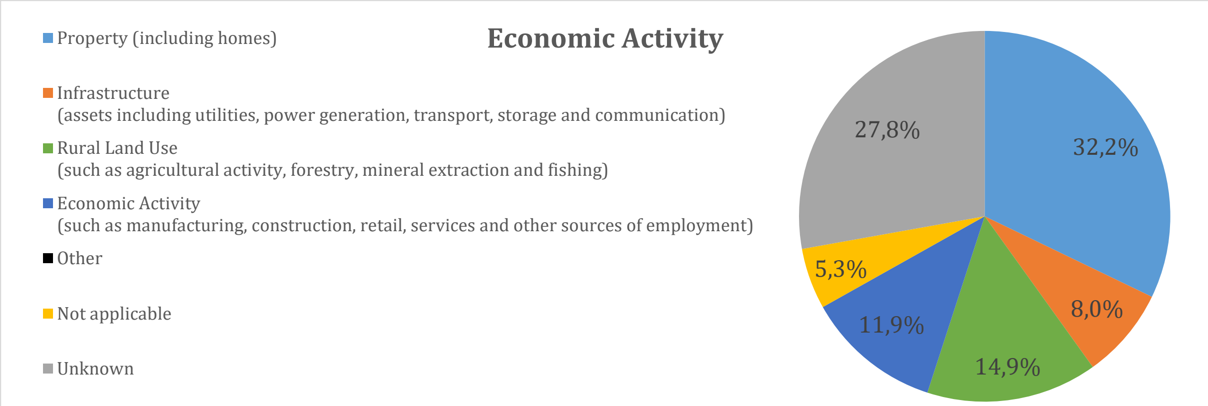



*Figure 25: Potential adverse consequences of floods to economic activities associated with AMIs*

Spatial distribution of potential adverse consequences of floods to economic activities associated with AMIs is shown at Map 7.

## 6.5 WATER CONTROL STRUCTURES WITH POTENTIAL IMPACT TO FLOOD PROTECTION IN AMIS

Map 9 shows existing water (flood) control structures along the Sava River and its tributaries in AMIs, based on available data in the Sava GIS database.

System of levees, including pumping stations, gates, weirs and retention areas along the Sava River and its tributaries, constructed with differently designed protection levels, have positive impact to flood protection in AMIs localy if are within, but also dowstream altought are not in AMIs.

The *Srednje Posavlje* flood protection system, completly within Croatia, with a total surface of about 304.000 ha and the retention capacity of more than 1.800 million m$^3$, planned by the relevant croatian planning documents and currently available capacity of about 1.200 million m$^3$, has an important role in flood protection for the section of the Sava River downstream from Stara Gradiška defined as AMIs. Part of the *Srednje Posavlje* system which includes natural retentions: Lonjsko polje, Mokro polje, Odransko polje, Kupčina, Žutica, Zelenik, Trstik and Opeka, as well as gates: Prevlaka, Palanjek and Trebež, overflow: Jankomir and diversion channels: Sava-Odra, Lonja-Strug, is upstream of AMIs at the Sava River but have a very important positive effect on the flood regime in Croatia, but also in the countries downstream.

On right bank of the Sava River in Bosnia and Herzegovina, in valleys of Posavina and Semberija, levees represent the main flood control structures, which most often provide protection from the high waters of 100-year return period (up to 1,2 m height). Dubica area along the mouth of Una River all the way to Orahovo is protected by levees whose height is not sufficient to protect against the Sava River backwaters of 100-year return period. Levees of variable height (0,6-1,2 m) in relation to high waters of 100-year return period are constructed along the mouth of Vrbas River in Srbačko-Nožičko area and Lijevče polje, but part of levees are not of sufficient height on certain sections. Ivansko polje is protected from flooding by dykes along rivers Sava and Ukrina with the required protection elevation. In area of Odžak-Šamac at the mouth of Bosna River, levees along the Sava River as well as along Bosna River recently were reconstructed to satisfy the height requirements in regards to Sava River high waters of 100-year return period. Srednja Posavina area is protected from Šamac to Brčko by a levee along the Sava River which at certain sections is of unsufficient height for high waters of 100-year return period. In the Semberija area to the mouth of Drina River, a levee was built along the Sava River with the required 1,2 m elevation on most of its length, while areas along the left bank of the mouth of Drina River are protected by a levee of average height of 1.0 m over high waters of 100-year return period.

On the lower Sava River section in Serbia, levees on both banks are not continuous. On the left bank, in the direction from Kupinovo to Sremska Mitrovica, natural floodplains are retained for retention and partial transformation of a flood wave. Levees on the left bank mainly provide protection from the high waters of 100-years return period, with protection elevation of 1,2 meters. In this area is the natural reserve "Obedska Bara", which is a Ramsar site. With its flooding area of almost 12.000 ha and retention capacity of over 250 million m3, it naturaly regulates Sava River high waters. On the right bank of Sava River at Obrenovac a levee was built, which with levees alongside Kolubara River protects Obrenovac and surrounding settlements from the high waters of 100-years return period. On the section of Skela – Šabac, short levees were constructed as protection of agricultural land and small settlements. Protection structures on section Šabac – confluence of Drina have been reconstructed and providing adequate level of protection.

In the flood control syste there are numerous pumping stations, weirs and diversion channels that represent a very important part of the system but also could be "weak links".

A summary of constructed flood protection systems and structures on Sava River and its tributaries is given below, taking into account size and importance of the areas protected by these systems, as well as positive effects of certain systems and structures on flood protection downstream. In addition to levees as longitudinal flood control structures accompaying with retention areas, weirs, pumping stations, in the Sava River Basin exists a number of dams and reservoirs that have or could have impact to the flood protection in AMIs.

The constructed reservoirs mainly have a multi-purpose character (water supply, irrigation, flood protection, hydropower and recreation) while the listed reservoirs (Table 10) have a certain role in flood protection, not only on rivers they are constructed on, but also on the entire downstream basin, although the effects on the flood wave transformation weaken downstream along the watercourse.

*Table 10: Overview of large dams and reservoirs relevant for flood protection in AMIs*

| Country | Sub-basin | River | Dam | | Reservoir | |
|---|---|---|---|---|---|---|
| | | | Name | Dam height (m) | Name | Volume (M m$^3$) |
| Slovenia | Sava direct | Sava | Vrhovo | 24,00 | Vrhovo | 8,65 |
| | | | Boštanj | 7,47 | Boštanj | 8,00 |
| | | | Arto-Blanca | 9,29 | Arto-Blanca | 9,95 |
| | | | Krško | 9,14 | Krško | 6,31 |
| | | | Brežice | 36,50 | Brežice | 3,40 |
| Slovenia/Croatia | Sutla | Sutla | Vonarje | 19,00 | Sutlansko jezero | 12,40 |
| Bosnia and Herzegovina | Vrbas | Pliva/Vrbas | Jajce I | no dam | Plivsko jezero | 23,00 |
| | | Vrbas | Jajce II/Barevo | 26,00 | Barevo | 2,10 |
| | | Vrbas | Bočac | 66,00 | Bočac | 52,70 |
| | Bosna | Spreča | Modrac | 28,00 | Modrac | 88,00 |
| | Drina | Drina | Višegrad | 79,50 | Višegrad | 161,00 |
| Serbia | Drina | Drina | Bajina Bašta | 90,50 | Jezero Perućac | 340,00 |
| | | Lim | Potpeć | 46,00 | Potpeć | 27,50 |
| | | Uvac | Uvac | 110,00 | Sjenica | 200,00 |
| | | Uvac | Radoinja/Bistrica | 42,00 | Radoinja | 7,60 |
| | | Uvac | Kokin Brod | 82,00 | Kokin Brod | 250,00 |
| | | Drina | Zvornik | 42,00 | Zvornik | 47,40 |
| Montenegro | Drina | Piva | HPP Piva | 220,00 | Mratinje | 880,00 |
| | | Ćehotina | Otilovići | 59,00 | Otilovići | 17,00 |

Positive effect of the reservoirs on the flood waves transformations is conditioned upon their characteristics (position, volume, flood control zone, capacities of evacuation structures etc), as well as the manner in which they are managed, both just before and during floods. However, there could also be a negative effect of the reservoirs due to the possible accidental dam failure or burst.

# 7 ADDRESSING THE IMPACTS OF CLIMATE CHANGE

Regarding the climate change, the following projects for the Sava River Basin have already been implemented in coordination or involvement of ISRBC:

- Building the link between flood risk management planning and climate change assessment in the Sava River Basin (UNECE Water Convention, 2013),
- Water – Food – Energy – Ecosystems Nexus Assessment in the Sava River Basin (UNECE Water Convention, 2015),
- Water and Climate Adaptation Plan for the Sava River Basin – WATCAP (World Bank, 2015),
- Danube Water Nexus Project – Sava Case Study (EC Joint Research Center, 2016),
- Climate Change Adaptation Strategy in the Danube River Basin (ICPDR, 2018)
- Overview of Climate Change Adaptation Strategy and Priority Measures in the Sava River Basin (ISRBC, 2018).

However, WATCAP provided the most comprehensive analysis related to the modelling of climate change impact to flood risk management planning at the Sava River Basin level. Based on climatological analysis, in general, temperature is expected to increase over the Sava River Basin area in all seasons (the most pro-nounced increase can be observed for summer and winter). On the other hand, precipitation is expected to decrease in spring, summer and autumn (with the most pronounced decrease in summer), whereas an increase in the winter is expected, especially in north-western part of the basin. Rainfall, which is very variable in the basin and appears to be changing in terms of seasonal distribution, brings uncertainty into hydrological trends within the basin. Therefore, options for reducing the impact pressures associated with rising mean temperatures and variable rainfall should be identified through careful planning and promotion of adaptation measures rather than coping with such changes.

Also, WATCAP concluded that the climate change will increase the peak discharges mainly in the head part of the Sava River Basin. The peak discharges will increase at the end of the 21st century for the 100-year return period i.e. from 3% at Sremska Mitrovica up to 55% at Čatež. The impact of climate change on the water level forecasts with 100-year return period floods is quite high in the head part of the watershed, i.e. more than 2 m. Downstream it initially strongly decreases then it gradually increases up to 1,8 m and finally it drops to 0,1 m at Sremska Mitrovica. There is clear evidence that reforestation has decreased the mean discharges in Slovenia by up to 35% and consequently such actions will decrease flood discharges and mitigate the impact of climate change on floods in the Sava River Basin. By climate change projections made by WATCAP, the flood risk is extremely large for parts of the Sava River Basin where the current 100-year return period floods will become a 10-year return period floods in 2100.

Considering that all this figures were not detailed analysed and confirmed after WATCAP, the need for effective planning of climate change in the Sava River Basin is obvious. The rising mean temperature has very high certainty. Further development of regional climate models is needed, as well as further enhancement of the spatial resolution thereof and development of advanced systems for modelling the atmospheric, oceanic and hydrological systems at regional level. Particular attention needs to be paid to:

- developing adaptation capacity
- ecosystem protection
- cross-border cooperation
- vulnerability assessment
- creating a hazard, risk and flood maps based on the relevant climate scenarios.

These goals should be a guide in ext stages of planning for the mapping of floods which could be caused by climate changes.

# 8 TRANSBOUNDARY COORDINATION AND INFORMATION EXCHANGE

## 8.1 MECHANISMS OF TRANSBOUNDARY COORDINATION AND COOPERATION

The countries in the Sava River Basin, i.e. the Parties of the FASRB, having regard to the need of deepening cooperation and implementation of the jointly agreed activities with the aim to ensure the preconditions for sustainable flood protection in the basin, have prepared the Protocol on Flood Protection to the FASRB which was signed by all the Parties in 2010 and it came into force on November 27, 2015. Along with the FASRB, the Protocol represents a key document for strengthening the cooperation of the Sava River Basin countries in the flood risk management.

ISRBC is a joint body with the international legal authority for coordination of the implementation of the FASRB and the Protocol. ISRBC is also a focal point in identification and coordination of regional projects important for implementation of the FASRB, and a mechanism for strengthening mutual cooperation of Sava River Basin countries in the water management. ISRBC is tasked for coordination of the activities related to the information and data exchange and harmonisation in undertaking the PFRA, preparation of flood maps and of the Sava FRMP, as well as the activities on the establishment of the flood forecasting system. ISRBC also follows up the related activities at the national and bilateral level that might have an influence on the common action at the basin-wide level. In addition to multilateral cooperation maintained by the countries in the Sava River Basin based on the FASRB and other international documents, there are also other forms of bilateral coordination and working groups between individual countries.

Overview of existing mechanisms and actors in the flood management on national and international level is specified in Table 11.

*Table 11: Mechanisms of international coordination at the Sava River Basin level*

| Mechanism | | Slovenia | Croatia | Bosnia and Herzegovina | Serbia | Montenegro |
|---|---|---|---|---|---|---|
| International River Commission (ISRBC) | | ✓ | ✓ | ✓ | ✓ | |
| Bilateral border water commissions* (coordination and working groups) | Slovenia | | ✓ | | | |
| | Croatia | | | ✓ | | |
| | Bosnia and Herzegovina | | ✓ | | | |
| | Serbia | | | | | |
| | Montenegro | | ✓ | | | |
| International coordination and working groups | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Regulations in place to enable exchange of information at international level | | ✓ | ✓ | ✓ | ✓ | ✓ |

Pursuant to the Protocol, countries undertake appropriate measures for establishment and maintenance of preparedness, as well as measures related flood defence emergency situations. This means that in case of emergency flood defence, the affected country(ies) may seek assistance from the other countries, indicating the extent and form of required assistance. Requested countries shall, as soon as practicable, consider such a request and notify the requesting country of their capacity and ability to provide the necessary assistance, as well as the scope and conditions of the assistance. For the purpose of providing effective assistance in the event of flood defence emergency situations, the countries shall agree details of all necessary actions and activities through the flood risk management planning process (Table 12).

*Table 12: Existing bilateral agreements in the area of protection and rescue, and provision of support in case of natural or other disasters, between the countries in the Sava River Basin*

| | **Slovenia** | **Croatia** | **Bosnia and Herzegovina** | **Serbia** | **Montenegro** |
|---|---|---|---|---|---|
| **Slovenia** | | ✓ | ✓ | ✓ | ✓ |
| **Croatia** | ✓ | | ✓ | (iii) | ✓ |
| **Bosnia and Herzegovina** | ✓ | ✓ | | ✓ | ✓(i) |
| **Serbia** | ✓ | (iii) | ✓ | | ✓(ii) |
| **Montenegro** | ✓ | ✓ | ✓(i) | ✓(ii) | |

(i) Ministry of Security of Bosnia and Herzegovina and Ministry of Interior of Montenegro have developed and adopted *Standard Operational Procedures* to regulate framework conditions for cooperation in providing cross-border assistance in case of natural and other disasters.

(ii) Ministry of Interior of the Republic of Serbia and Ministry of Interior of Montenegro have developed and adopted *Standard Operational Procedures* to more closely regulate the process of mutual notification about hazards, manner of border crossing, bringing the materials into and out of the country and transport thereof in the activities of protection and rescue, and use of aircrafts for transport of rescue teams and aid.

(iii) No existing bilateral agreement between Croatia and Serbia only *Standard Operational Procedures*.

## 8.2 INFORMATION EXCHANGE

An important basis for flood risk management planning is regular exchange of information on projects and activities related to flood management through the work of Permanent Expert Group for Flood Prevention (PEG FP). In addition to the PEG FP, expert groups participating in solving specific questions and tasks relevant for flood risk management also are: Permanent Expert Group for River Basin Management (PEG RBM), Permanent Expert Group for GIS (PEG GIS), and Permanent Expert Group for Hydrological and Meteorological Issues (PEG HMI).

A comprehensive exchange of information significant for sustainable flood protection was established since April 2016 through the Sava GIS[9] with the main goal to enable the ISRBC community sharing and disseminating of information and knowledge about protection of the water resources and water management activities in the Sava River Basin. Sava GIS is fully functional through the Sava GIS Geoportal - https://savagis.org/ which is scalable and flexible tool for data visualization and management, supports multilingual usage and implements open source technologies as well as open web services. Editing, loading and retrieving data and metadata is also enabled to the registered users. Sava GIS geodatabase model was significantly expanded in order to make it compliant to the EU WFD and EU FD Reporting Guidance and the ICPDR's Danube GIS and currently enables storing of datasets relevant for: river basin management planning and flood risk management planning (management; historical floods; preliminary flood risk assessment; areas with potential significant flood risk; flood hazard and risk maps; measures for reduction of flood risk; flood protection structures).

Through the usage of the Sava Geoportal the interested parties are able to overview available datasets, as well as hydrological and meteorological data with a strong plan to be expanded for all other benefit areas i.e. navigation management, accident pollution prevention and control, sediment management. Further plans related to upgrade of Sava GIS include development of advanced tools for mapping and reporting services and decision support system (DSS).

As integral part of Sava GIS, the system for exchange of hydrological and meteorological data and information Sava HIS[10] has also been established, with the main goal to support the Sava countries

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[9] Sava GIS has been established in line with the Sava GIS Strategy and in accordance with the INSPIRE and other relevant EU Directives and related guidelines

[10] Sava HIS has been established in line with the Policy on the Exchange of Hydrological and Meteorological Data and Information in the Sava River Basin, prepared by ISRBC in close cooperation with the WMO and signed in 2014 by relevant organizations of the FASRB Parties and Montenegro

in sharing and disseminating of hydrologic and meteorological data and to enable an effective common channel for exchanging and viewing data in emergency situations, primarily those related to flood events. Sava HIS is fully functional through the Sava GIS Geoportal and can be also reached through https://savahis.org/.

Sava HIS database model has been designed and structured in accordance to the OGC Water ML 2.0 (the WMO standard), and enables storage of water observations time-series data in a standard format and their sharing and publication via web service for further use. Sava HIS is currently collecting and storing observed data from more than 300 hydrological and 200 meteorological gauges of the following types of real-time and processed data: hourly time series – raw real-time data; daily/monthly/yearly time series – processed data (Hydrological Yearbooks); discharge measurements data; statistical data. The number of stations continuously increase within Sava HIS since its establishment as a result of countries' growing commitment after recognizing efficiency of the system and their own benefits and especially after the integration of Sava HIS within the Sava FFWS forecasting platform.

Flood Forecasting and Warning System in the Sava River Basin (Sava FFWS) was established and put it into operational use in October 2018 as a step in the implementation of the Protocol and one of very important non-structural measures of the Sava FRMP. This effort was also done in close cooperation with the relevant national institutions of the Sava countries. Sava FFWS is a unique forecasting system at the international level, implemented as an open and flexible platform for managing the data handling and forecasting processes, allowing a wide range of external data and models to be integrated. The Sava FFWS concept is particularly important for the five Sava countries, each with its own specifics in terms of organization of the water sector, stage of development of monitoring and forecasting systems, and legal and regulatory framework for flood risk management. Sava FFWS is installed at the hosting sites in the four countries and consists of one primary and three back-up installations in the national institutions, while the archive and web servers are located in the Sava. The system is currently used by 10 organizations – hydrometeorological services and water agencies. In order to ensure the smooth operation of the system and its regular maintenance and performance control of the system, as well as training of engaged personnel, in July 2020 the Sava countries signed the *Memorandum of Understanding on cooperation concerning regular functioning and maintenance of Sava FFWS*[11]. This agreement will ensure the long-term sustainability of Sava FFWS as well as its further developments.

[11] https://www.savacommission.org/UserDocsImages/05_documents_publications/basic_documents/memo_of_understanding_on_savaffws.pdf

# 9 CONCLUSIONS

- The Preliminary Flood Risk Assessment in the Sava River Basin - Update 2021 is prepared in accordance with the Protocol on Flood Protection to the Framework Agreement on the Sava River Basin and the EU Floods Directive based on the national planning documents of the Parties to the FASRB (Slovenia, Croatia, Bosnia and Herzegovina, and Serbia) and Montenegro

- In addition to a review and update of information on methodologies and criteria used by the countries to identify and assess significant past floods and consequences of potential future floods, the Sava PFRA update 2021 provides an overview of designated and updated APSFRs as well as harmonises APSFRs shared by two or more countries, identified as AMIs.

- The Sava PFRA update 2021 will represent a basis for the joint flood maps update 2023 and Sava FRMP update 2026, taking into consideration that the national maps and planning documents will be the main input.

- For the purpose of preparation of the Sava PFRA update 2021, the countries have exchanged/updated relevant data and information through a common data sharing platform - Sava GIS, while part of the information was delivered through the text documents. Taking into account that the initial Sava PFRA report (2014) was prepared before the Protocol on Flood Protection to FASRB was entered into force and the Sava GIS was developed, it was a first time that countries exchanged PFRA and APSFR related GIS datasets through ISRBC.

- The amount of exchanged information has improved in the second cycle of the flood risk management planning at the Sava River Basin level, however quality and consistency of information still should be enchanced. For example, although data were delivered, information on the administrative arrangements, the competent authorities and the units of management relevant for the flood risk management still have to be clarified.

- Types of floods which should be considered are identified, and some of data delivered (e.g. fluvial, natural excedence, slow onset) but whether other types had been considered did not specified at all (e.g. artificial water-bearing infrasructure, defence exceedence, deep flood). It is advised to clearly state if floods, especially for those occurring after completion of the initial national PFRA reports, were not considered because of their relevance, because of the absence of data or if it is to be expected that they will be included in the next reporting cycle. Also, more detailed information should be provided for floods that could occur in the future during subsequent planning cycles.

- Results of the national preliminary flood risk assessments, as well as other data processed during the preparation of this joint report were analysed. Based on analysis of 2.347 areas with potentially significant flood risk defined at the national level, 255 were identified of mutual interest for flood protection in the Sava River Basin,. This is increase of 4 APSFRs of mutual interest in comparision to Sava FRMP.

- 255 areas with potentially significant flood risk defined at the national level are further grouped into 19 AMIs, areas of mutual interest for flood protection in the Sava River Basin.

- Total surface of AMIs is 5.734,5 km$^2$, respectively 129 km$^2$ in Slovenia, 1.694 km$^2$ in Croatia, 1.099 km$^2$ in Bosnia and Herzegovina, 2.810 km$^2$ in Serbia and 2,5 km$^2$ in Montenegro. In these areas the fluvial/river floods that are most frequently registered as a source of significant flooding. The most common mechanism of floods happening in AMIs are defence exceedance and defence or infrastuctural failure and the most common characteristic is medium onset and other rapid onset flooding.
- AMIs, as the basic elements for the flood risk management planning at the Sava River Basin level and a framework for identification of non-structural and national structural measures that may contribute to achieving flood risk management objectives of the common interest, will be used as the main analytical unit in the second cycle of flood risk management planning.

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# APPENDICIES

# ANNEX 1: LIST OF RIVERS SIGNIFICANT FOR THE FLOOD RISK MANAGEMENT PLANNING IN THE SAVA RIVER BASIN

| River | Basin Surface (km$^2$) | River Length (km) | Countries sharing the sub-basin | Tributary class | Sava tributary L-left R-right |
|---|---|---|---|---|---|
| Sava | 97.700 | 945 | SI, HR, BA, RS | - | - |
| Tržiška Bistrica | 146 | 27 | SI | 1 | L |
| Kokra | 222 | 34 | SI | 1 | L |
| Sora | 648 | 52 | SI | 1 | R |
| Kamniška Bistrica | 539 | 33 | SI | 1 | L |
| Ljubljanica | 1.860 | 40 | SI | 1 | R |
| Savinja | 1.849 | 93,6 | SI | 1 | L |
| Krka | 2.247 | 94,7 | SI | 1 | R |
| Sotla/Sutla | 584 | 89,7 | SI, HR | 1 | L |
| Bregana | 92 | 26 | SI, HR | 1 | R |
| Krapina | 1.237 | 66,87 | HR | 1 | L |
| Kupa/Kolpa | 10.226 | 118,3 | SI, HR, BA | 1 | R |
| Lonja | 4.259 | 47,95 | HR | 1 | L |
| Ilova (Trebež) | 1.796 | 104,56 | HR | 1 | L |
| Una | 9.829 | 157,22 | HR, BA | 1 | R |
| Sana | 4.253 | 141,1 | BA | 2 | R |
| Vrbas | 6.274 | 235 | BA | 1 | R |
| Orljava | 1.618 | 93,44 | HR | 1 | L |
| Ukrina | 1.504 | 80,9 | BA | 1 | R |
| Bosna | 10.810 | 272 | BA | 1 | R |
| Lukavac | 462 | 55,8 | BA | 1 | R |
| Tinja | 904 | 88,1 | BA | 1 | R |
| Brka | 231 | 41,3 | BA | 1 | R |
| Drina | 20.320 | 335,67 | ME, BA, RS | 1 | R |
| Piva | 1.784 | 43,5 | ME, BA | 2 | L |
| Tara | 2.006 | 134,2 | ME, BA | 2 | R |
| Ćehotina | 1.237 | 118,66 | ME, BA | 2 | R |
| Lim | 5.968 | 278,5 | AL, ME, RS, BA | 2 | R |
| Uvac | 1.596 | 117,7 | RS, BA | 3 | R |
| Bosut | 2.943 | 132,18 | HR, RS | 1 | L |
| Topčiderska reka | 147 | 29 | RS | 1 | R |
| Kolubara | 3.638 | 86,7 | RS | 1 | R |

# ANNEX 2: WORK PLAN FOR THE 2ND FLOOD RISK MANAGEMENT PLANNING CYCLE

## National activities

| Protocol article | EU FD article | Task | Country / Entity | | Initial | | Review and Update | | Responsibility |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 4, 5 | Preliminary Flood Risk Assessment (and APSFR) | Slovenia | | 22 Dec 2011 | ✓ | Jun 2019 | ✓ | Competent Authorities of the FASRB Parties and Montenegro |
| | | | Croatia | | 22 Dec 2011 | ✓ | 22 Dec 2018 | ✓ | |
| | | | Bosnia and Herzegovina | FBiH<br>RS<br>BD | 2013<br>2015<br>n/a | ✓<br>✓<br>n/a | 2026 | planned | |
| | | | Serbia | | 2019 | ✓ | 2025 | planned | |
| | | | Montenegro | | 2021 | ✓ | 2027 | planned | |
| 7 | 6 | Flood maps | Slovenia | | 22 Dec 2013 | ✓ | 22 Dec 2019 | ✓ | |
| | | | Croatia | | 22 Dec 2013 | ✓ | 22 Dec 2019 | ✓ | |
| | | | Bosnia and Herzegovina | FBiH<br>RS<br>BD | 2020 | ✓ | 2028 | planned | |
| | | | Serbia | | 2022 | underway | 2028 | planned | |
| | | | Montenegro | | 2022 | underway | 2028 | planned | |
| 8 | 7 | Flood Risk Management Plan | Slovenia | | 22 Dec 2015 | ✓ | Sep 2022 | planned | |
| | | | Croatia | | 22 Dec 2015 | ✓ | 22 Dec 2021 | Public consultation | |
| | | | Bosnia and Herzegovina | FBiH<br>RS<br>BD | 2024 | underway | 2030 | planned | |
| | | | Serbia | | 2023 | underway | 2029 | planned | |
| | | | Montenegro | | 2024 | underway | 2030 | planned | |

## Activities by the Protocol

| Protocol article | EFD article | Subject | Outcome | Task | Status | Responsibility |
|---|---|---|---|---|---|---|
| 6 | 4, 5 | Preliminary Flood Risk Assessment | Update of the Report | Undertaking the national PFRA and APSFR identification | ✓ | Competent Authorities of the FASRB Parties and Montenegro |
| | | | | Collection of the national PFRA and APSFR data through Sava GIS | ✓ | ISRBC Secretariat<br>PEG FP<br>PEG GIS |
| | | | | Harmonisation of the shared APSFRs and identification of AMIs | ✓ | ISRBC Secretariat<br>PEG FP |
| 7 | 6 | Flood maps | Update of flood hazard and risk maps | Preparation of national flood maps | ✓<br>(SI, HR, BA)<br>underway<br>(RS, ME) | Competent Authorities of the FASRB Parties and Montenegro |
| | | | | Collection of national flood maps for 2 scenarios (probability: medium and low/extreme event scenario) through Sava GIS | underway<br>(by Q2 2022) | ISRBC Secretariat<br>PEG FP<br>PEG GIS |
| | | | | Informing other countries on national flood maps and preparation of a common maps at the AMIs level based on the national maps<br>Note: Flood maps shall include the assessment of the flood risk along the Sava River, based on a simplified methodology and agreed specification within the Program for development of Sava FRMP for a special case scenario along the Sava River. PEG FP will revise the scenario first. | (Q2 2022 – Q4 2023) | ISRBC Secretariat<br>PEG FP |
| 8 | 7 | Flood Risk Management Plan | Update of the Plan | Review of changes and updates of the previous version of FRMP; an assessment of the progress made towards the achievement of the common objectives; a description of, and an explanation for, any measures foreseen in the previous version of FRMP which were planned to be undertaken and have not been taken forward; a description of any additional measures | (Q2 2024 – Q2 2026) | ISRBC Secretariat<br>PEG FP |
| | n/a | | | Review of mechanisms of coordination on the basin-wide level, mode of joint cooperation in flood defence emergency situations | | |
| 11 | n/a | | | Review of actions and activities related to the assistance of other countries in case of flood defence emergency situations | | Competent Authorities of the FASRB Parties and Montenegro |

# ANNEX 3: KEY ELEMENTS OF NATIONAL METHODOLOGIES FOR PFRA

## Relevant national documents

| Country | Links to document |
|---|---|
| Slovenia | **Report:**<br>https://www.gov.si/assets/ministrstva/MOP/Dokumenti/Voda/NZPO/e56d7a6180/predhodna_ocena_poplavne_ogrozenosti_2019.pdf<br>**Maps:**<br>https://www.gov.si/teme/nacrt-zmanjsevanja-poplavne-ogrozenosti/ |
| Croatia | **Report:**<br>https://www.voda.hr/sites/default/files/dokumenti/prethodna_procjena_rizika_od_poplava_2018_0.pdf<br>**Maps:**<br>https://www.voda.hr/hr/prethodna-procjena-rizika-od-poplava-2018 |
| Bosnia and Herzegovina | **Report:**<br>https://www.voda.ba/udoc/PPPR_Knjiga_1.pdf<br>https://www.voda.ba/uploads/docs/Knjiga_3_PFRA_vodotoci_II_kategorije.pdf<br>http://www.voders.org/index.php/edit-profile/17-vodni-akti/57-izdate-vodne-dozvole-3<br>http://www.voders.org/images/Vode_Srpske/Tabela%20br.17%20-%20AFAs%20podrucja.pdf<br>**Maps:**<br>https://www.voda.ba/udoc/PPPR_Knjiga_2_Vodno%20podrucje%20rijeke%20Save.pdf<br>https://www.voda.ba/uploads/docs/Knjiga_4_PFRA_vodotoci_II_kategorije_Vodno_podrucje_rijeke_Save.pdf<br>http://www.voders.org/images/Vode_Srpske/Karta%203.1%20-%20Predlozena%20AFAs%20podrucja.jpg<br>http://www.voders.org/images/Vode_Srpske/Karta%203.2%20-%20Predlozena%20AFAs%20podrucja.jpg<br>http://www.voders.org/images/Vode_Srpske/Karta%203.3%20-%20Predlozena%20AFAs%20podrucja.jpg |
| Serbia | **Report:**<br>http://www.rdvode.gov.rs/doc/ZPP_2019_tabela.pdf<br>**Maps:**<br>http://www.rdvode.gov.rs/doc/PPRP_ZPP_2019_karta.pdf |
| Montenegro | **Report:**<br>https://www.gov.me/dokumenta/76d31e9f-f454-4316-8fe6-77a3126f5e29 |

## A summary of criteria and approaches used by the countries based on the national methodologies

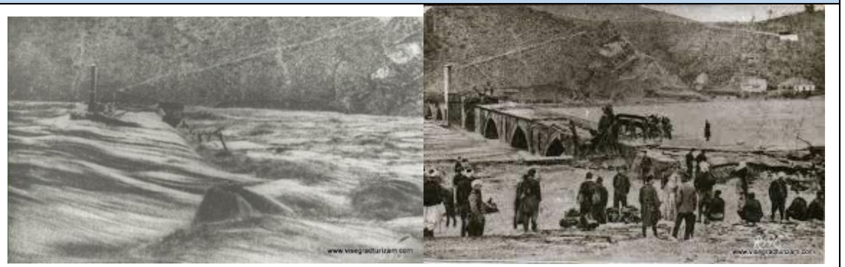
<table>
<tr><th colspan="2">Country</th><th>Significant past flood events</th><th>Potential future floods</th><th>APSFRs</th></tr>
<tr><td colspan="2">Slovenia</td><td>Significant flood events in the past and those that caused:<br>• casualties<br>• damage to property<br>• damage to infrastructure, including cultural heritage</td><td>Potential future flood events were identified based on areas affected by the flood, using:<br>• hydraulic modelling<br>• indicative flood areas.<br>Criteria of significance are possible negative consequences for:<br>1) population (number of permanent and temporary inhabitants);<br>2) economic activities (dimension, vulnerability and value of commercial entities);<br>3) cultural heritage (values for the assessment are vulnerability and unit values of immovable cultural heritage);<br>4) physical environment (SEVESO and IPCC installations and protection areas of Natura 2000, areas for water and bathing water protection which can be polluted from IPPC installations);<br>5) sensitive buildings (schools, kindergartens, hospitals, spas, homes for senior citizens, archives, museums, libraries), public economic infrastructure, emergency services.</td><td>Index of damage from potential floods was defined using GIS methods, taking into account potential harmful consequences for human health, environment, cultural heritage and economic activities.<br>Four types of potential damages are consolidated, re-ranked, and areas with possible potential damages above the selected threshold are denoted as APSFR.</td></tr>
<tr><td colspan="2">Croatia</td><td>Significant flood events in the past identified based on expert judgement of the following elements:<br>• flood duration,<br>• cause,<br>• mechanisms,<br>• consequences,<br>• number of population affected by the flood event</td><td>Methodological approach comprised four steps:<br>• collection, systematization and interpretation, as well as expert revision of the collected data<br>• flood hazard assessment<br>• analysis and assessment of flood sensitivity of an area<br>• flood risk assessment</td><td>APSFR are settlements with:<br>• high flood risk, including commonly flooded settlement areas, large industrial sites (outside the settlement), large infrastructural buildings and waste disposal sites.<br>• moderate flood risk, including defense areas of a settlement, large industrial sites (outside the settlement), large infrastructural buildings, waste disposal sites and commonly flooded agricultural areas;<br>• low flood risk, which concerns defended agricultural areas and other frequently flooded areas (pastures, forests, and the like);<br>• insignificant flood risk, which concerns all other remaining areas.</td></tr>
<tr><td rowspan="2">Bosnia and Herzegovina</td><td>Federacija BiH</td><td rowspan="2">Floods which had significant harmful consequences for human health, environment, cultural heritage and economic activities, which can leave significant harmful consequences for the same, if repeated.<br>If data about the assessment of damages in flood events is not available, significant flood events from the past are those that had at least one of the follofing consequences:<br>• affected more that 100 households or 300 residents,</td><td>Potential floodplains are overlapped with CORINE Land Cover in order to obtain index values, and to enable classification of flood significance.</td><td rowspan="2">APSFR are defined based on the flood risk index.</td></tr>
<tr><td>Republika Srpska</td><td>Potential flood plains are those areas which can be potentially endengered by future floods with lower probability of occurrence, or in case of demolition of flood protection structures or systems.</td></tr>
</table>

| Country | | Significant past flood events | Potential future floods | APSFRs |
|---|---|---|---|---|
| | | • flooded area is larger than 50 km2,<br>• flooded sensitive buildings (buildings attracting more people particularly vulnerable to floods, such as children, elderly and ill people) | | |
| | Brčko Distrikt BiH | The index is obtained by consolidating all negative impacts of floods to human health, environment, cultural heritage and economic activities.<br>Past flood events are classified based on the indexes for the following values:<br>• 0-50 not significant<br>• 50-100 moderately significant<br>• 100-500 significant<br>> 500 excessively significant | Potential flood plains are overlapped with CORINE Land Cover in order to obtain index values, and to enable classification of flood significance. | Based on index values, APSFRs are classified into 4 categories |
| Serbia | | Flood events which caused great damages (damage exceeding 10% of total income of municipality).<br>If data about the assessment of damages in flood events is not available, significant flood events from the past are those that had at least one of the follofing consequences:<br>• they affected more that 100 households or 300 residents,<br>• flooded area is larger than 50 km2,<br>• flooded sensitive buildings (buildings attracting more people particularly vulnerable to floods, such as children, elderly and ill people). | Potential flood plains are undefended areas and areas that can be flooded in case of demolition of flood protection structures, with negative consequences for human health, environment, cultural heritage and economic activity. | APSFRs along river sections or sections exposed to significant flood in the past and/or endangered by future potential floods. |
| Montenegro | | The Rulebook on the Closer Content of the Preliminary Flood Risk Assessment and the Flood Risk Management Plan ("Official Gazette of Montenegro", No. 069/15 of 14.12.2015) specifies the following requirements with respect to the description of past flood and the adverse impacts which could occur with future flooding events:<br>• Description of past flood events which had significant adverse impacts on human health, the environment, cultural heritage, and economic activity, for which it is probable to occur again in the future, considering the severity of flood events, runoff directions and | Assessment of potential harmful impacts of future floods on human health, environment, cultural heritage, and economic activities, considering topography, position of water courses and their hydrological and geo-morphological characteristics, flood plains as natural retentions, efficiency of the existing flood protection facilities, position of settlements, areas of economic activities and long-term development plans, as necessary. Article 3 (5) Rulebook on the Closer Content of the PFRA and the Flood Risk Management Plan ("Official Gazette of Montenegro", No. 069/15 of 14.12.2015). | APSFRs include those areas where flood events can cause potential harmful effects to human health, environment, cultural heritage and economic activity. |

| Country | Significant past flood events | Potential future floods | APSFRs |
|---|---|---|---|
| | assessment of adverse impacts caused by such events (Section 4.4).<br>• Description of floods that occurred in the past in areas where significant adverse impacts can occur in the future due to changed conditions (urban development, proclamation of protected areas). This is also covered in Section 4.4.<br>• The Impact of climate change on occurrence of floods (see Section 5).<br>• Assessment of potential harmful impacts of future floods on human health, environment, cultural heritage, and economic activities, considering topography, position of water courses and their hydrological and geo-morphological characteristics, flood plains as natural retentions, efficiency of the existing flood protection facilities, position of settlements, areas of economic activities and long-term development plans, as necessary (see Section 6). | | |

# ANNEX 4: DETAILS ON THE SIGNIFICANT FLOOD EVENTS

The significant flood events, analysed within the initial Sava PFRA and Sava FRMP, as the largest floods that occurred until 2021.

| Date of the flood event | River(s) caused the flood | Description | Photo illustration |
|---|---|---|---|
| 1896 Oct/Nov | Drina | Flood affected the whole Podrinje region with catastrophic consequences even along entire Sava River course in Semberija and Serbia (48,000 ha was flooded in the Mačva region). Settlements Rudo, Višegrad, Skelani, Ljubovija, Francjozefsfeld (today Novo Selo), Bijeljina, Bosanska Rača and Sremska Rača were were seriously affected. Ljubovija and Sremska Rača were displaced to present location, while Bosanska Rača has never been restored. On the Drina in Višegrad water level rose for 17 m, while near Zvornik it was 8.4 m above the average. The discharge was estimated at 9,540 m3/s.<br>*Figure 6: The 1896 Drina flood in Višegrad (Recorded water level of the Drina was 1 m over fence on the famous bridge of Mehmed Paša Sokolović in Višegrad)*<br>By constructing reservoirs of HPP Mratinje, HPP Višegrad, HPP Bajina Bašta and HPP Zvornik, probability of occurrence of such catastrophic flood significantly decreased. |  |
| 1932 Apr | Sava | n/a | n/a |
| 1933 Sep/Oct | Sava | Due to heavy rains on September 23 and 24, 1933, rivers swelled and flooded more than two thirds of Slovenia. A huge amount of water could not drain away, so rivers flooded almost everything. The Sava and the Krka overflowed their banks and flooded fields, roads and villages. The wood brought by the river stuck and accumulated under the bridges. In Krška vas, the locals partially demolished the bridge so that the flood would not completely take it away, but the upper structure of the bridge was still destroyed. Traffic on the road from the Brežice bridge to Kostanjevica na Krki was stopped, as well as traffic across the bridge in Krško. The floods did not spare Kostanjevica na Krki or the villages of Loče, Mihalovec and Mostec, which were completely under water, and traffic there was only by boat. |   |

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| 1939 | Kupa | n/a | n/a |
| 1944 Nov | Sava | n/a | n/a |
| 1964 Oct | Sava | Around 6,000 ha of the immediate urban area of Zagreb were flooded, as well as the settlements of Zaprešić, Samobor, Dugo Selo, and Velika Gorica. The disastrous consequences of the flood accounted 17 fatalities, extensive material damage, 150,000 evacuated, and tens of thousands who lost their homes due to partially constructed, inadequate, inconsistent and vulnerable flood protection system which was not able to withstand a sudden extreme inflow from the upper part of the Sava River Basin in Slovenia |  |
| 1966 Dec | Sava, Kupa | The towns of Karlovac and Sisak, many settlements in between lying in floodplains along the Kupa River, app 5,500 housing units, an area of 15,600 ha at the territory of the then municipality of Karlovac, the Karlovac-Zagreb motorway, and many other roads were flooded. Even if the Sava waters were released into the Lonjsko Polje retention area by breaching the Sava levee near Dubrovčak, due to a coincidence with the high waters of the Kupa River, the Sava spilt over the levee in Sisak, flooding the lowest parts of the town. | n/a |
| 1968 Dec | Bosna | Bosna River flooded Sarajevsko Polje, overflowed the bridge at the gauging station in Reljevo by 30-40 cm, and washed away part of the local road on the right bank in length of about 80 m | n/a |
| 1970 Jan | Sava and Bosut | Due to a great inflow of the Sava's right-bank tributaries middle and lower parts of the Sava River Basin in Croatia the Sava flooded an area of 222,640 ha, inflicting huge damage to agricultural and urbanized areas. Since the high waters of the Sava and Bosut rivers coincided, a large part of the Biđ-Bosutsko Polje was flooded as well. | n/a |

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| 1972 | Kupa | n/a | n/a |
| 1974 Nov | Sava, Krapina, Kupa and Una | The most widespread flooding in the Sava River Basin when 270,000 ha were flooded was caused by a simultaneous and long-lasting heavy inflow from almost the entire basin. The Sava River spilt over and breached its levees on several sections downstream of Zagreb (on 7 locations). Despite that the levees were blown up on 3 locations in order to release excess water into Odransko Polje, Lonjsko Polje and Mokro Polje retention areas, numerous villages at the left and right Sava River banks (from Oborovo to Stara Gradiška) were flooded. Even though the temporary embankments (in some places as high as 120 cm) managed to protect the area beyond the Sava levees on the section from Stara Gradiška to Županja from immediate flooding, intensive rainfall and seepages beneath levees caused great damage to the agricultural areas of Crnac Polje, Jelas Polje and Biđ Polje.<br>In the Krapina River Basin an area of 9,200 ha, Zlatar Bistrica, Pojatno, Bedekovčina and other smaller settlements, the Zagorje highway, and the Zaprešić-Kraljevec railroad, were flooded by the Krapina River and its tributaries<br>In the Kupa river basin, the Kupa River flooded 14,600 ha, parts of Karlovac, Ozalj and 12 smaller settlements, while its tributaries flooded Ogulin, Slunj, Glina, Topusko and numerous smaller settlements.<br>Even though flood protection works had been carried out as far back as 1963 in the Una River-Sava River node and on the section of the course of the Una River towards Hrvatska Dubica, parts of the villages of Tanac and Uštica were flooded. The Una River flooded parts of the town of Dvor | n/a |
| 1989 Jun | Krapina | An area of 5,600 ha, the settlements of Krapina, Donja Stubica, Zabok, Marija Bistrica, Stubičke Toplice, Kupljenovo, Zaprešić, and other smaller settlements, the Zagorje highway and a number of local roads were flooded; roads and rail traffic between Zagreb and Zagorje were closed. | n/a |
| 1990 Oct/Nov | Upper Sava | Flooding event covered 2/3 of the territory of Slovenia (excluding the Mura River Basin and costal area) endangering 240,000 inhabitants, causing 237 relocated inhabitants and, 2600 evacuated. Flooded were 5,231 buildings (190 destroyed) and 398 industrial facilities, 96 bridges demolished and 280 damaged 2,683 km of roads damaged, 20 km of railroads destroyed, and many landslides | n/a |

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| | | initiated. The economy suffered the largest portion (28%) of the total damage. The Savinja – Sotla/Sutla area sustained the largest part of the damage (62%). The height of this wave on the Sava section from Radeče (Slovenia) to Podsused (Croatia) exceeded the disastrous flood wave of 1964, passed through Zagreb and further downstream without any serious damage because the Sava-Odra relief channel was activated. Damage was recorded only on the stretch from the Podsused Bridge to the mouth of the Sutla River, due to lack of flood protection system. | |
| 1996 | Kupa | n/a | n/a |
| 1998 Oct/Nov | Upper Sava | Three flood events covered half of the Slovenia's territory (116 municipalities), excluding the Mura River Basin, costal area and part of the Gorenjska area. The direct damage amounted to 173 million EUR and the Savinja – Sotla/Sutla area suffered the largest share (44%). | n/a |
| 1998 Nov | Kupa | Although the flood protection solution in the Kupa River Basin is integral part of a comprehensive flood protection solution in the Srednja Posavina. providing protection from mere 5-year high water to 50-year high water, due to occurrence of higher water flows, the Kupa River flooded 12,000 ha urbanized and agricultural areas in Croatia | n/a |
| 1999 May | Tamnava, Ub and Gračica | About 6,000 ha and 480 households with about 2,050 inhabitants were flooded | n/a |
| 2001 Jun | Kolubara, Jadar and Ljubovida | Flood caused inundation of 3,800 ha with 110 households and a prison due to a lack of flood protection system in Kolubara middle section.<br>The Jadar River and its tributaries flooded an area of 5,500 ha and 700 households. The Ljubovida River flooded an urban area with 515 households and 2,100 endangered inhabitants (925 of which were evacuated), as well as kindergarten, primary and secondary schools | n/a |
| 2006 Mar | Tamnava, Ub and Gračica | 5,600 ha and 129 households were flooded | n/a |
| 2006 Apr | Sava | The Danube backwater caused flooding of about 60 ha at the right Sava bank, 334 buildings with about 1,455 endangered inhabitants, important economic facilities and infrastructure in Belgrade (Belgrade Fair, railway station, important city roads) | n/a |
| 2007 Sept | Upper Sava | Large long time persisting storms caused extremely large flows of the small and medium-sized rivers. Torrential floods | n/a |

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| | | were recorded in 1/3 of the Slovenia's territory. Direct damage amounted to 200 million EUR, 38% of which in water infrastructure. 83% of the total damage was in the Gorenjska and Savinja – Sotla/Sutla area. 4,329 residential buildings, 979 commercial buildings, 61 public institutions, 192 companies, 347 km of national and 1,591 local roads, 147 bridges, 17 km of water supply network, 7 km of the electrical network and 48 water reservoirs were flooded, 432 landslides were triggered thus endangering 29 buildings. | |
| 2009 Mar | Tamnava, Ub and Gračica | 3,000 ha and 280 households with 1,100 inhabitants were flooded. Larger damages were avoided by retaining water in a fishpond at the Ub River. Frequent flooding of the adjacent land along the Tamnava, Ub and Gračica in the Kolubara River Basin due to a lack of flood protection system initiated reconstruction of the flood protection system along these rivers. | n/a |
| 2009 Dec | Upper Sava | The flood covered 1/3 of the Slovenia's territory, causing damage of 25 million EUR, 72% of which was in water infrastructure. 93% of the total damage was in the area of the Upper Sava and Soča . | n/a |
| 2010 May/Jun | Middle Sava | The catastrophic floods in eastern left-bank tributaries of the Sava River in eastern and central parts of Croatia caused large damages to agriculture, livestock production, infrastructure, personal and local self-government units properties. Since economy of the area, and of the country as a whole, depends on the proceeds from farming, including livestock and fruit production, accounted that hail and thunderstorms destroyed most crops and pastures, it was estimated that financial consequences would be felt more than a year afterwards. 420 houses, cellars and yards were flooded; 524 houses were directly threatened and damaged; 105 families were evacuated, and, where appropriate, also movables and domestic animals (poultry, pigs, cattle). The evacuated population (and animals) were cared for and provided with temporary accommodation. Wells and other water sources were polluted, so potable water had to be delivered by water trucks. Floods blocked road traffic on county and local roads, which impeded the delivery of food and other livelihood products and provision of health service and potable water, as well as public transport. | n/a |

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| 2010 Sep | Middle Sava | Outstanding long-term rainfall caused torrential, river and karst floods in the 3/4 of the Slovenia's territory (170 municipalities). Direct damage amounted to 188 million EUR, 62% in water infrastructure, 35% of which in the Sava floodplains in its upper section. At the Sava section in Croatia upstream of Sisak, the water wave had the occurrence of a 100-year return period. High flows also occurred along the western left-bank Sava tributaries. In total, 900 residential buildings were flooded, 257 people were evacuated from flood-affected areas in Croatia and, where appropriate, movables and domestic animals as well (poultry, pigs, cattle and horses). From the area of the Nature Park "Lonjsko Polje" 600 cattle were evacuated, mostly native horse species. Municipality water wells and other water sources were polluted, so water trucks delivered potable water. Many roads were closed. Since Zagreb is one of the most traffic-heavy nodes in the country, closing down of the roads caused enormous material losses and great reparation costs | n/a |
| 2010 Dec | Drina, Kupa and Una | Flood waves were induced by extreme rainfalls in Montenegro and east Herzegovina, where 100-200 mm of rain fell in 3 days. Flood waves on the Drina tributaries (Piva, Tara, Ćehotina, Lim and Jadar) and the main course were such that hydropower reservoirs could not retain them. A new maximum was recorded on 3 December 2010 at Radalj, the most downstream gauge station on the Drina River. The Drina River flooded about 1,000 households at the right bank, downstream of the Ljubovija settlement causing evacuation of app 1,400 inhabitants. Consequently, flood wave occurred at the downstream section of the Sava River in Serbia, where emergency flood defence was declared at the beginning of December.<br>The Lim River flooded 150 households in the Prijepolje town Discharge peaks with return periods between 10 and 50-year on the Kupa and Una rivers in Croatia caused flooding of many roads at the Karlovac and Sisak-Moslavina counties, and parts of the Nova Drenčina, Lužice-Letovanić, Stari Brod and Žažina settlements and agricultural land along the Kupa River |  |

| | | | |
|---|---|---|---|
| 2014 Feb | Kupa | n/a |  |
| 2014 May | Middle and Lower Sava, Una, Vrbas, Bosna, Drina, Bosut, Kolubara | The devastating floods occurred when in three days a three-months amount of rain fell onto the region. The heaviest rainfall since records began 120 years ago caused an extreme increase of water levels in the rivers, some exceeding ever recorded maximums. The floods have firstly occurred along the rivers with smaller catchments. At the left Sava bank, floods occurred in the Orljava River basin (500 households were flooded in the Pleternica settlement and the surroundings), and in the Ilova River basin (over 100 houses were flooded). Right tributaries of the Sava River – the Bosna, Vrbas and Una caused flooding and great loss in the area with particular devastating impact in the towns and villages along the Bosna River (Zavidović, Maglaj, Doboj, etc.). Additional damage was caused by landslides. The Drina River basin suffered from flooding and landslides causing extreme damage. Several settlements in the Kolubara River basin were flooded, where the town of Obrenovac suffered the most after it was impounded by water several meters deep in the city centre. Enormous inflow from the right-bank tributaries lead to a fast increase of the Sava water levels as of May 15, in the bordering sections between Bosnia and Herzegovina and Croatia and in Serbia. On May 17, the Sava River breached left-bank levee at two locations, flooding several settlements and agricultural land in eastern Croatia. The downstream breach occurred just about 5 km and the upstream breach near the Rajevo Selo 25 km from the state border, so the flood water progressed over flat areas towards lower terrain in Serbia and flooded agricultural areas and the Jamena village there as well. Right-bank levee did not withstand high water pressure of the Sava River either. In period May 17-18 levees burst at several locations in Bosnia and Herzegovina, causing flooding of large areas in the Odžačka Posavina, Srednja |  |

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| | | Posavina and in Semberia. On May 19 the levee breached in Serbia just upstream of Obrenovac, endangering the town once again. The rough estimate based on satellite imagery revealed that the flooded areas were: 266.3 km2 in Bosnia and Herzegovina (Federation B&H 179.5 km2, Republic of Srpska 72 km2 and Brčko District 14.7 km2), 53.5 km2 in Croatia, and 22.4 km2 in Serbia. Additional danger presented flooding of the areas suspected to contain mines in Bosnia and Herzegovina and in Croatia, potential spread and dislocation of mines and unexploded ordnance, risk of water contamination, epidemics and water borne diseases, as well as landslides which continued to pose further risk in hilly areas after the flooding. The report Floods in the May 2014 in the Sava River Basin, jointly prepared by ICPDR and ISRBC is publicly available via the website of ISRBC |  |

# ANNEX 5: DEFINITIONS OF SOURCE, MECHANISMS AND CHARACTERISTICS OF FLOODS

**Sources**

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|---|---|
| **Fluvial** | Flooding of land by waters originating from part of a natural drainage system, including natural or modified drainage channels. This source could include flooding from rivers, streams, drainage channels, mountain torrents and ephemeral watercourses, lakes and floods arising from snow melt. |
| **Pluvial** | Flooding of land directly from rainfall water falling on, or flowing over, the land. This source could include urban storm water, rural overland flow or excess water, or overland floods arising from snowmelt. |
| **Groundwater** | Flooding of land by waters from underground rising to above the land surface. This source could include rising groundwater and underground flow from elevated surface waters. |
| **Artificial Water-Bearing Infrastructure** | Flooding of land by water arising from artificial, water-bearing infrastructure or failure of such infrastructure. This source could include flooding arising from sewerage systems (including storm water, combined and foul sewers), water supply and wastewater treatment systems, artificial navigation canals and impoundments (e.g., dams and reservoirs). |
| **Other** | Flooding of land by water due to other sources, can include other tsunamis. |

**Mechanisms**

| | |
|---|---|
| **Natural Exceedance** | Flooding of land by waters exceeding the capacity of their carrying channel or the level of adjacent lands. |
| **Defence Exceedance** | Flooding of land due to floodwaters overtopping flood defences. |
| **Defence or Infrastructural Failure** | Flooding of land due to the failure of natural or artificial defences or infrastructure. This mechanism of flooding could include the breaching or collapse of a flood defence or retention structure, or the failure in operation of pumping equipment or gates. |
| **Blockage / Restriction** | Flooding of land due to a natural or artificial blockage or restriction of a conveyance channel or system. This mechanism of flooding could include the blockage of sewerage systems or due to restrictive channel structures such as bridges or culverts or arising from ice jams or landslides. |
| **Other** | Flooding of land by water due to other mechanisms, for instance wind setup floods. |

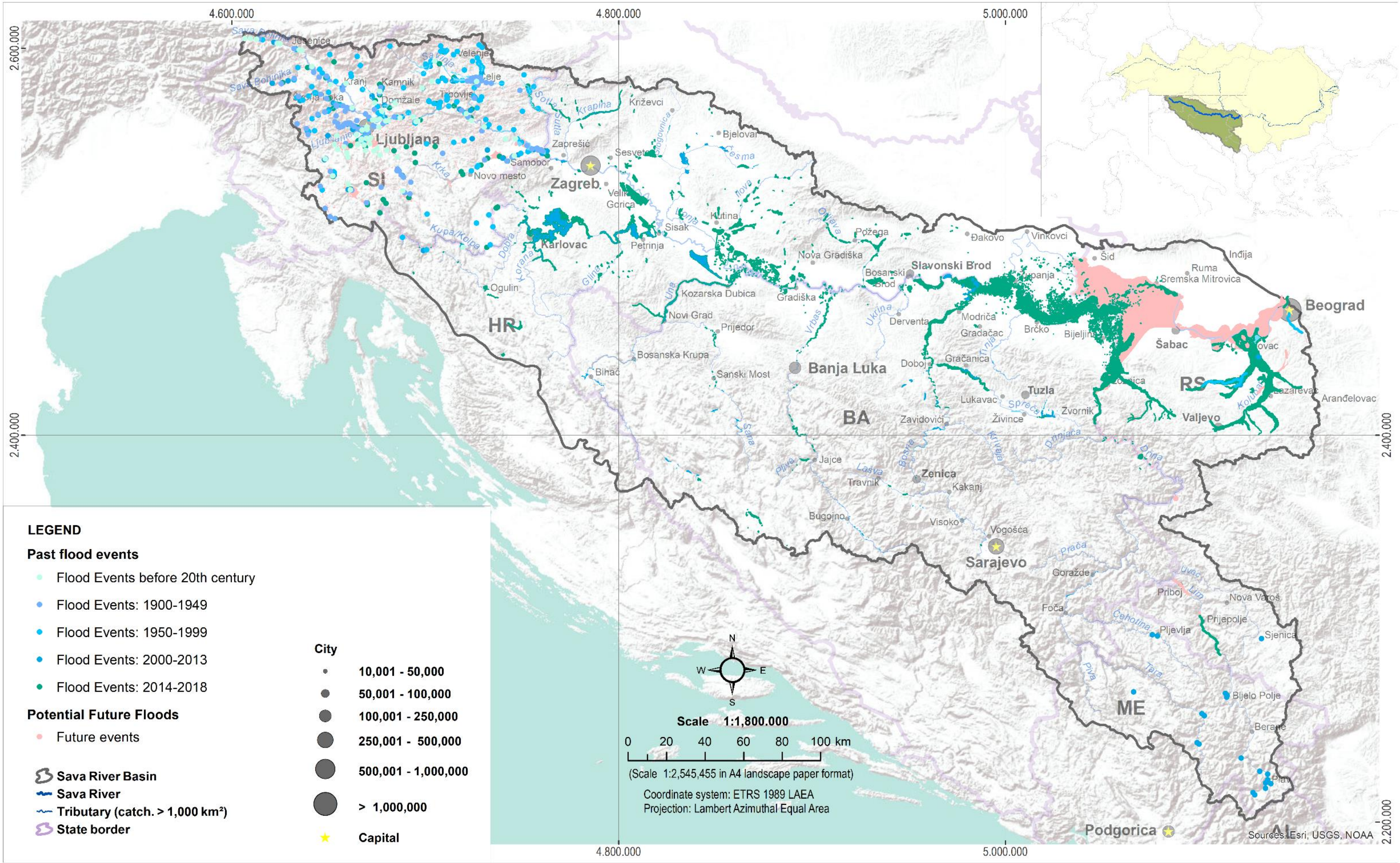
**Characteristics**

| | |
|---|---|
| **Flash Flood** | A flood thatrisesandfalls quiterapidly with littleor noadvance warning, usually the result of intenserainfall over a relatively smallarea. |
| **Snow Melt** | FloodFlooding due to rapid snow melt, possibly in combination withrainfallorblockage due to ice jams. |
| **Other rapid onset** | A flood which develops quickly, other than a flash flood. |
| **Medium onsetflood** | An onset of flooding that occurs at a slower rate than a flashflood. |
| **Slowonset flood** | A flood which takes a longer time to develop. |
| **Debris Flow** | A flood conveying a high degree of debris. |
| **High Velocity Flow** | A flood where the floodwaters are flowing at a high velocity. |
| **Deep Flood** | A flood where the floodwaters are of significant depth. |
| **Other** | Other characteristics, or no special characteristics. |

# MAPS

# Significant past and potential future floods in the Sava River Basin

INTERNATIONAL SAVA RIVER BASIN COMMISSION

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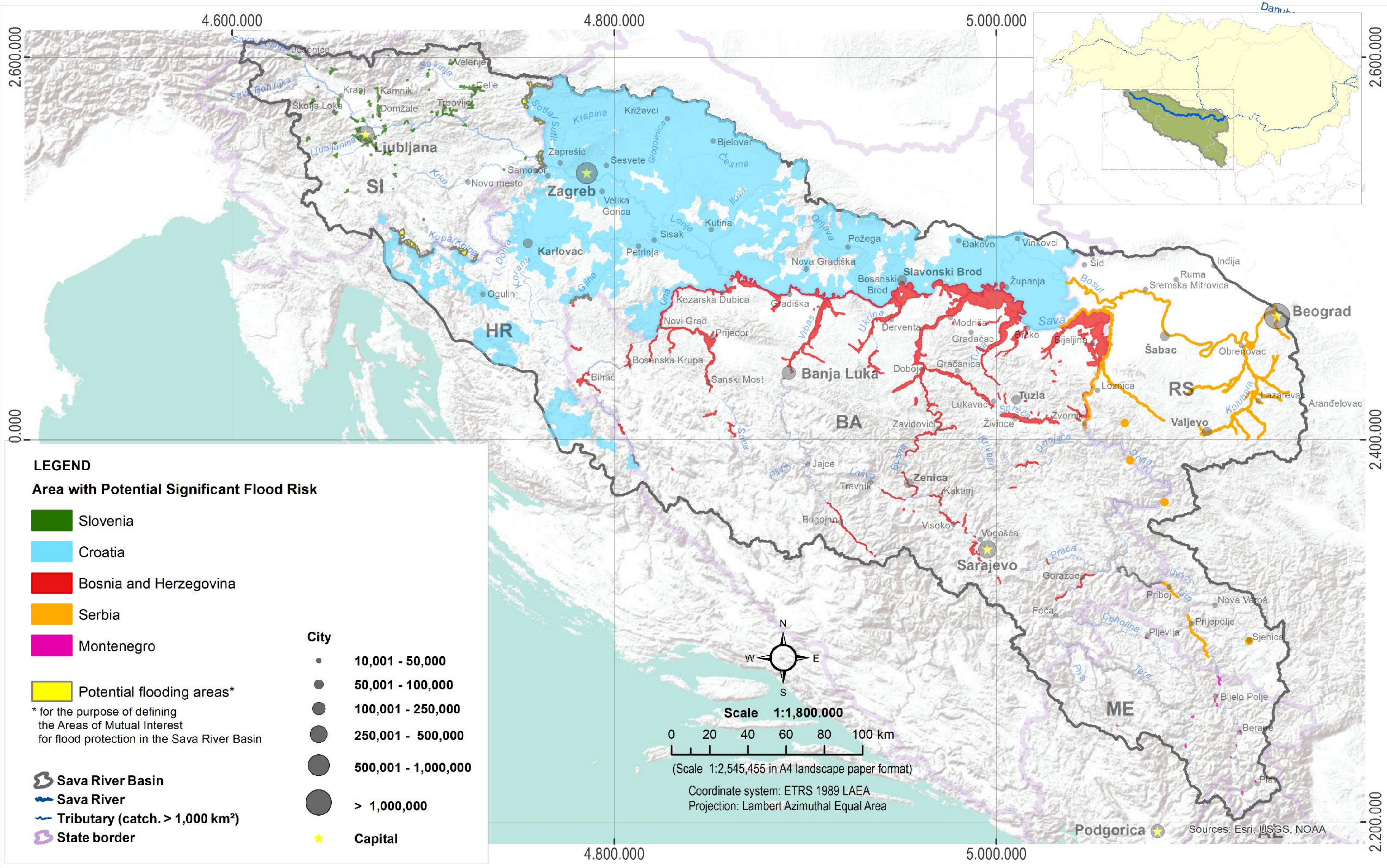
The content and maps do not prejudice the determination or demarcation of the borders in any way.

PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN - UPDATE 2021
Processed and compiled by the Secretariat of the ISRBC, December 2021

INTERNATIONAL SAVA RIVER BASIN COMMISSION

# Areas with Potential Significant Flood Risk

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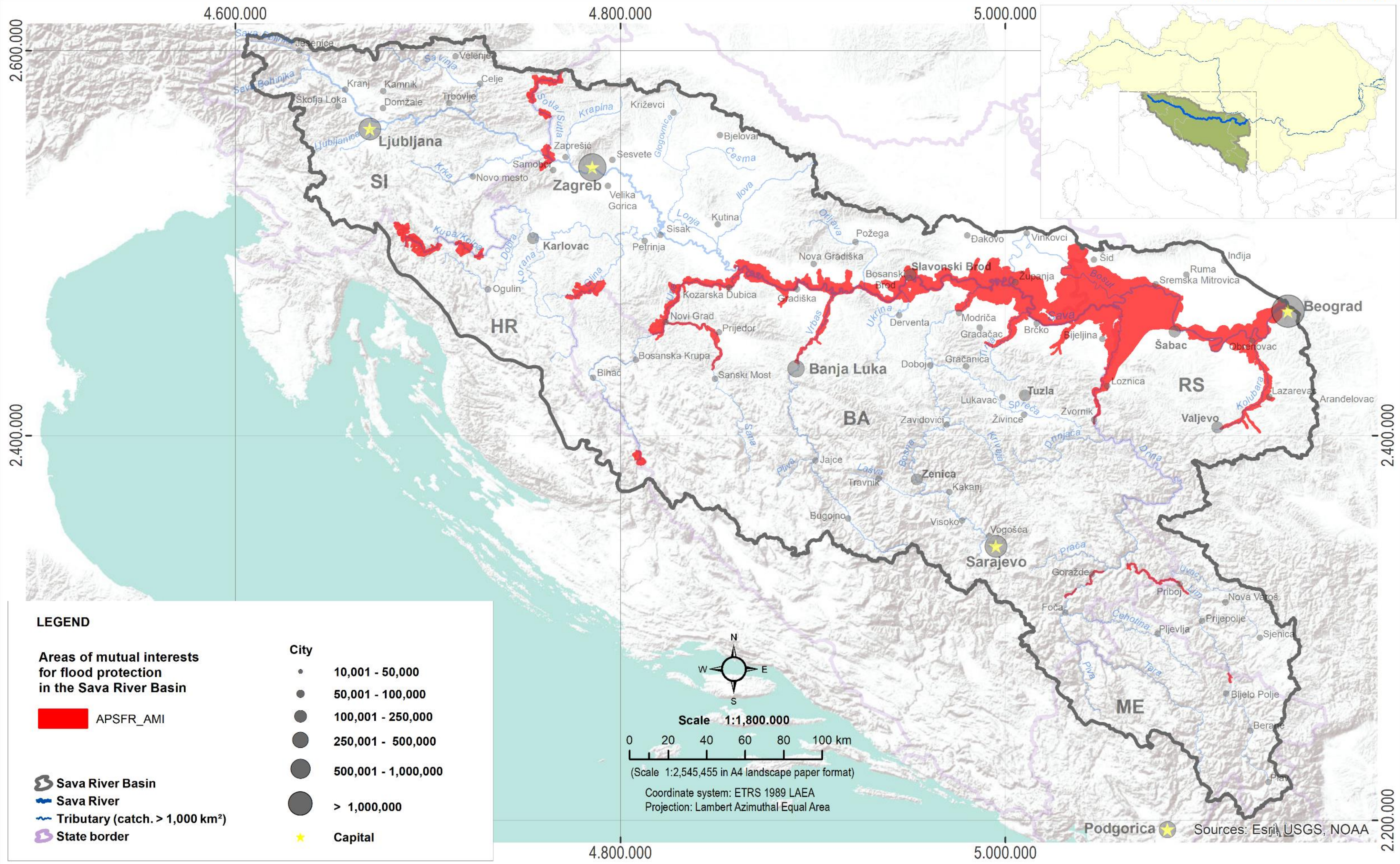
# Areas of Mutual Interest for flood protection

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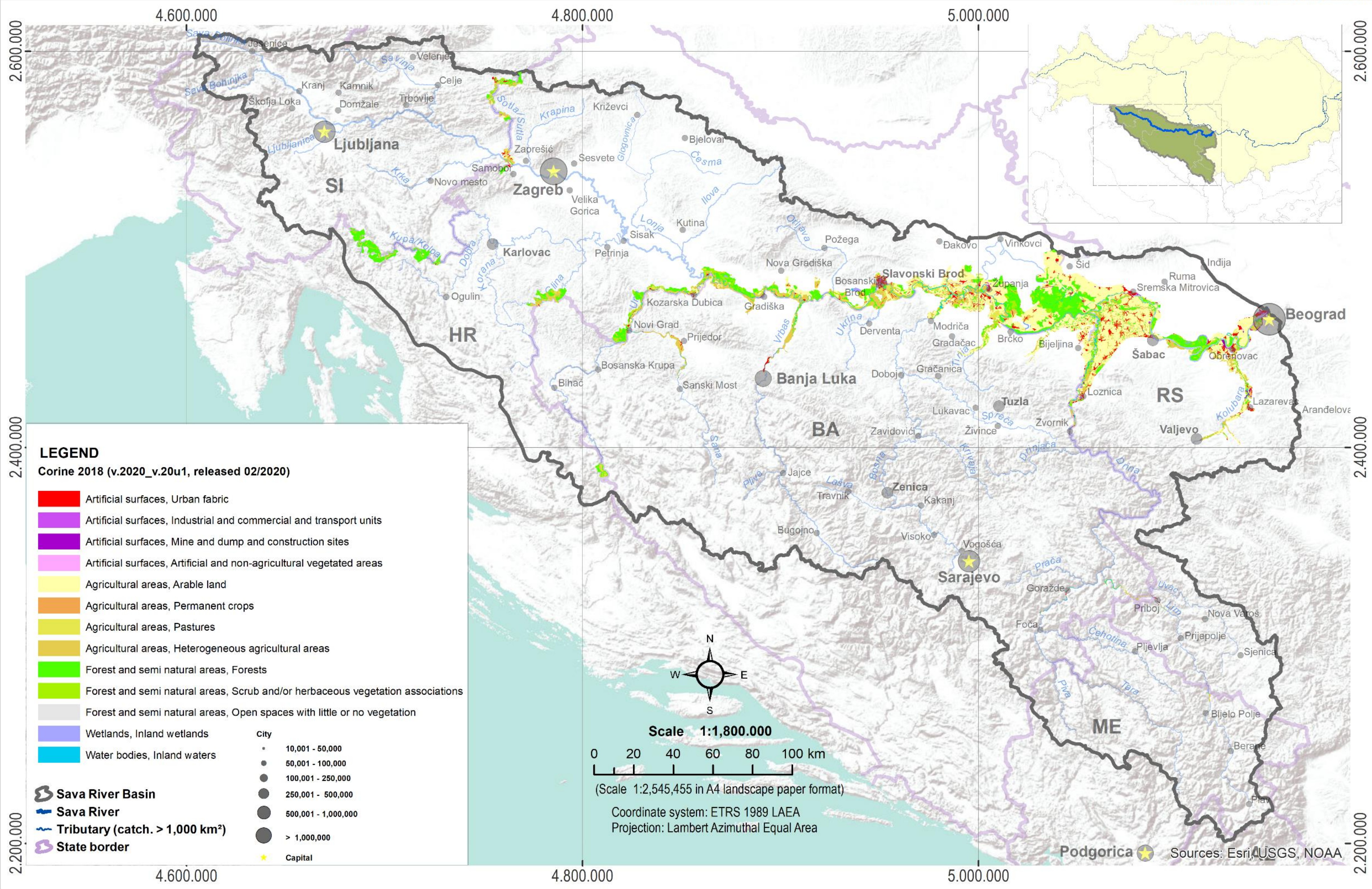
# Land cover / use in Areas of Mutual Interest for flood protection



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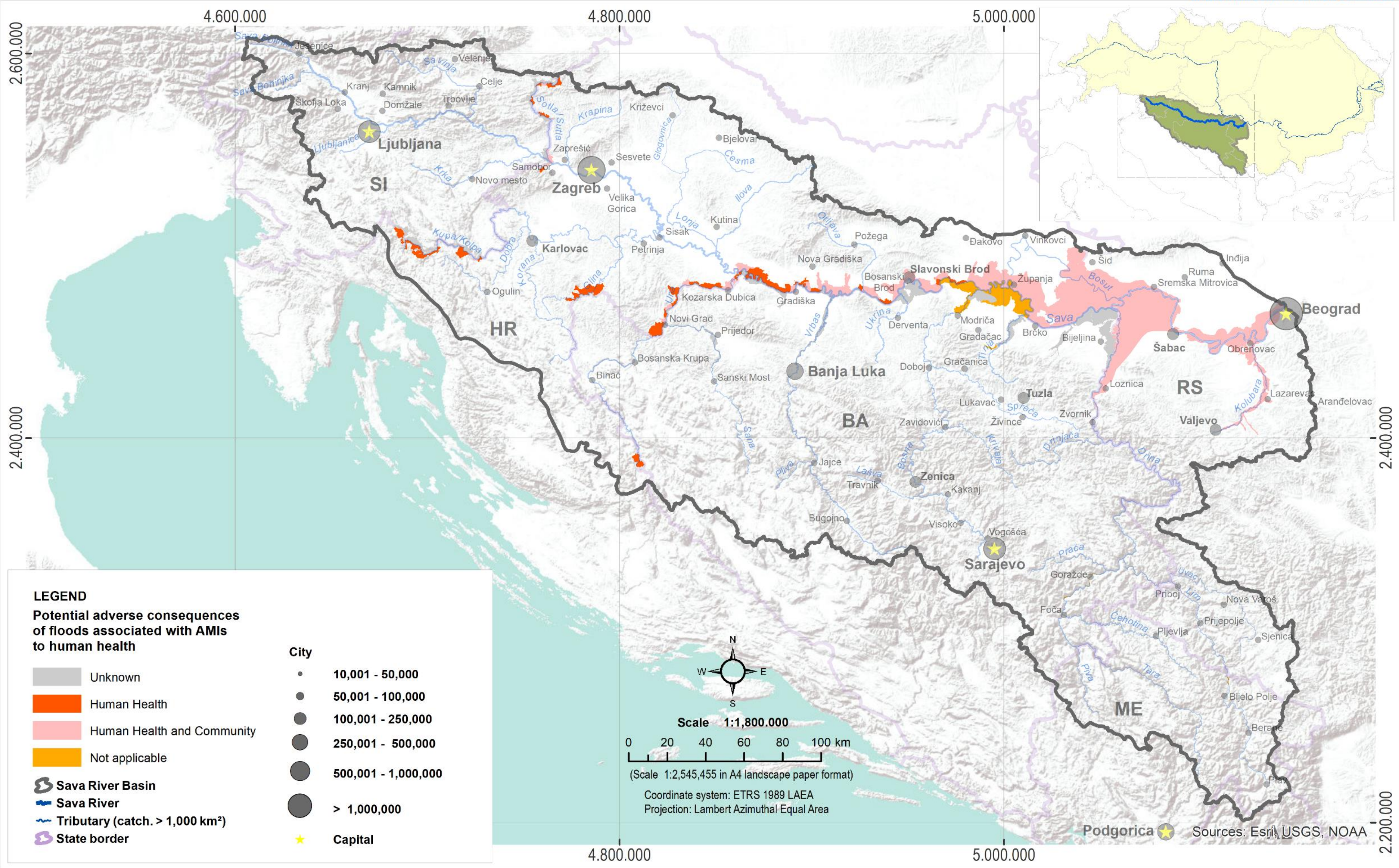
# Potential adverse consequences of floods in AMIs - Human Health

INTERNATIONAL SAVA RIVER BASIN COMMISSION

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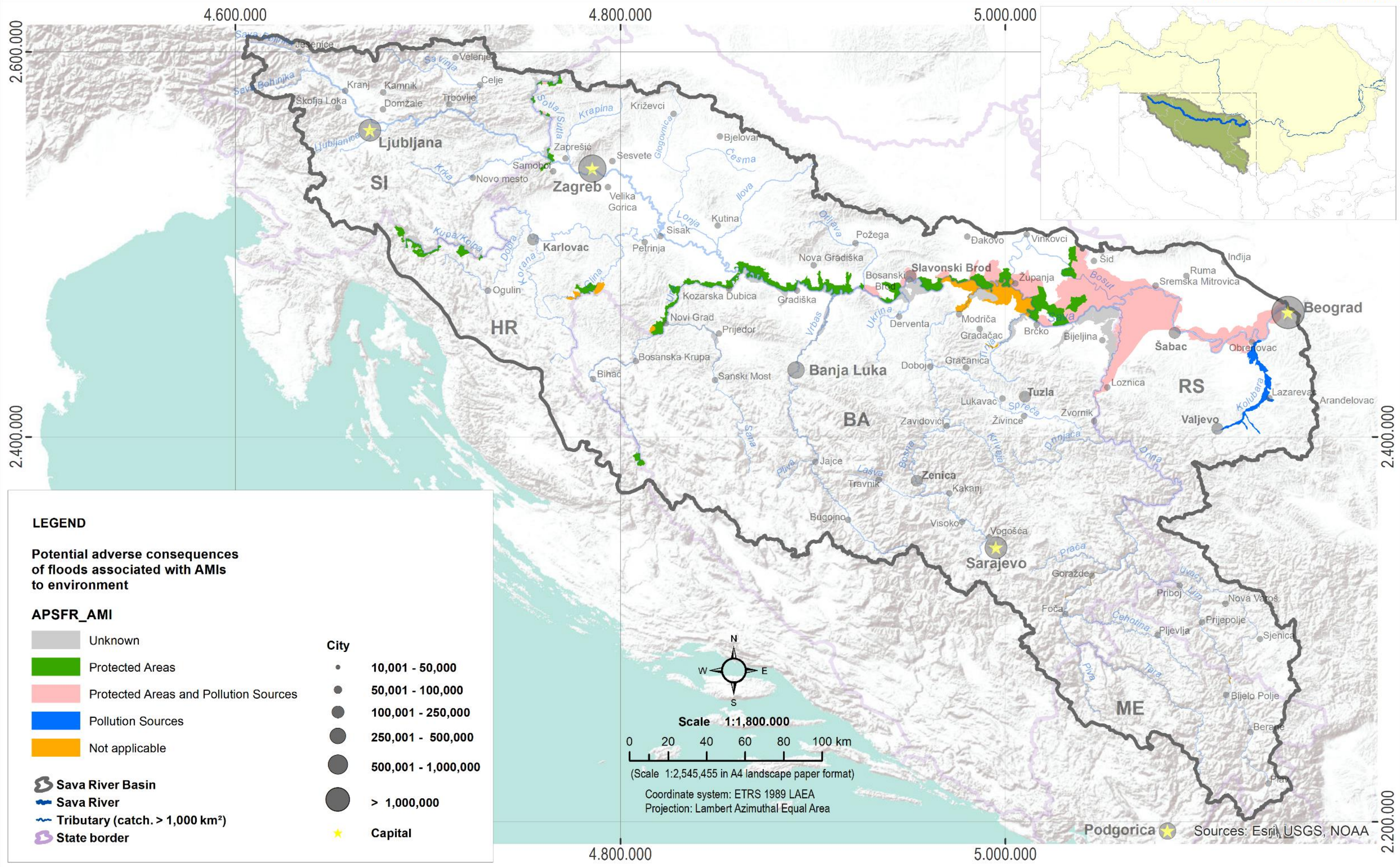
# Potential adverse consequences of floods in AMIs - Environment

INTERNATIONAL SAVA RIVER BASIN COMMISSION

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# Potential adverse consequences of floods in AMIs - Cultural Heritage

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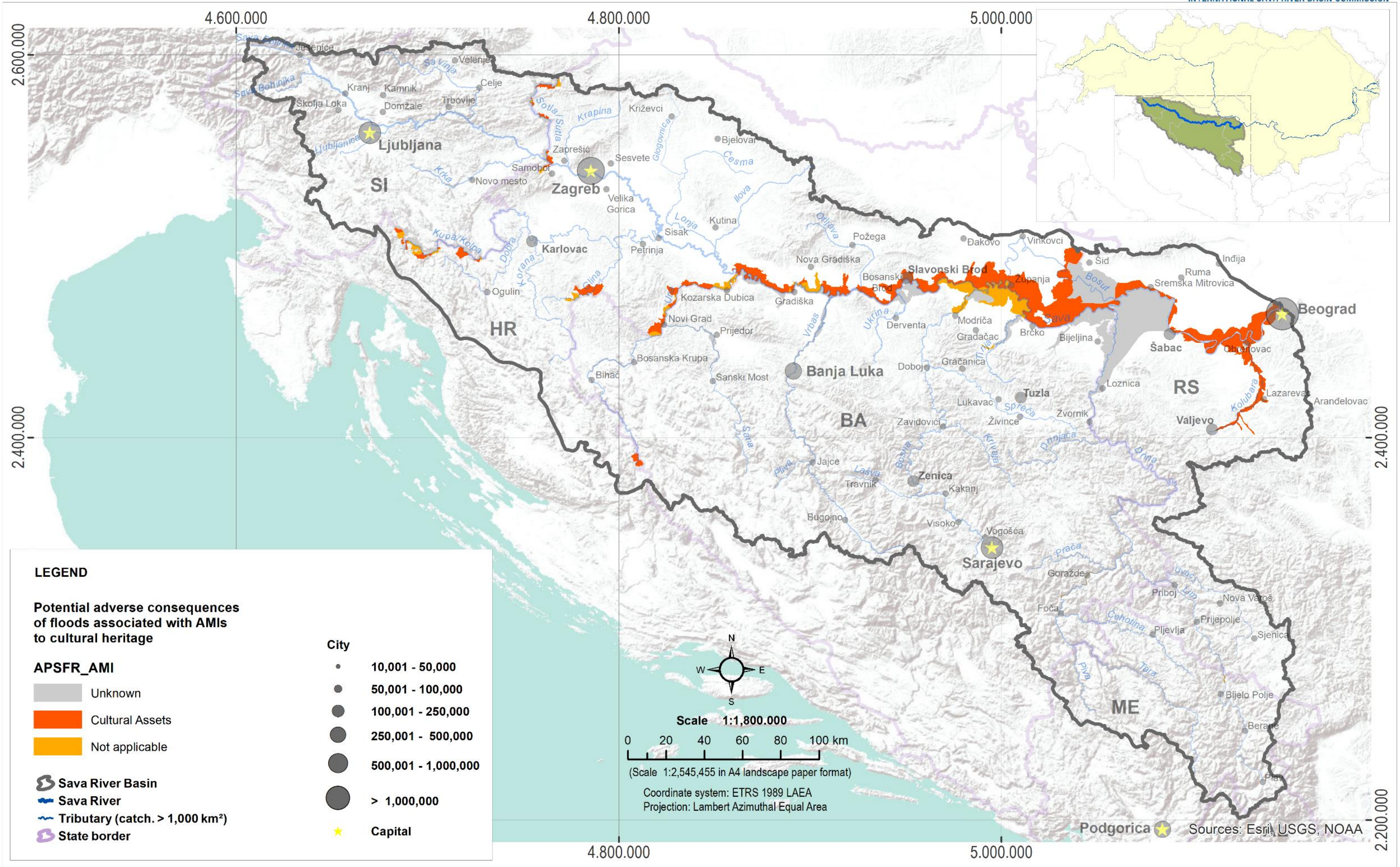


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# Potential adverse consequences of floods in AMIs - Economy

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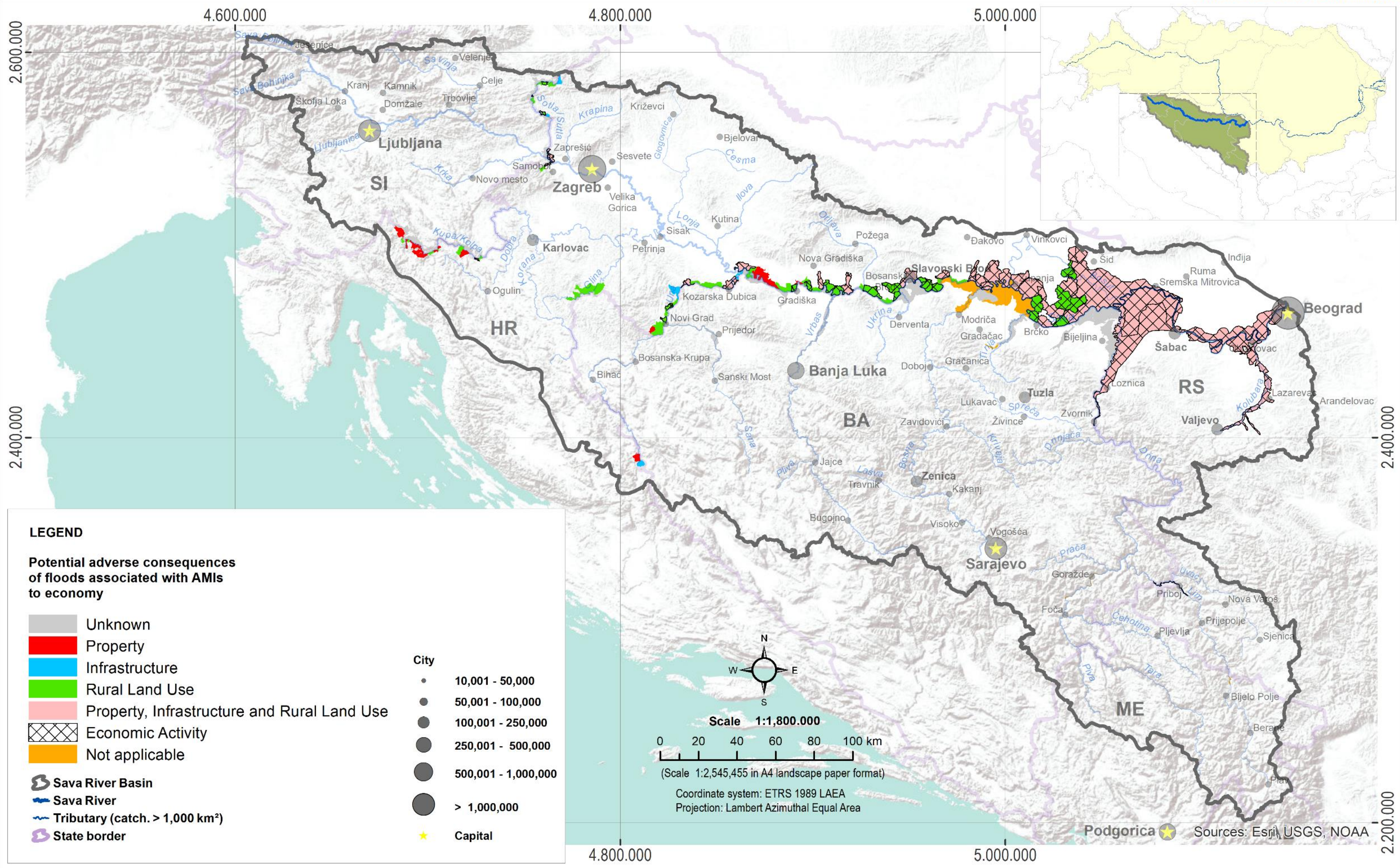


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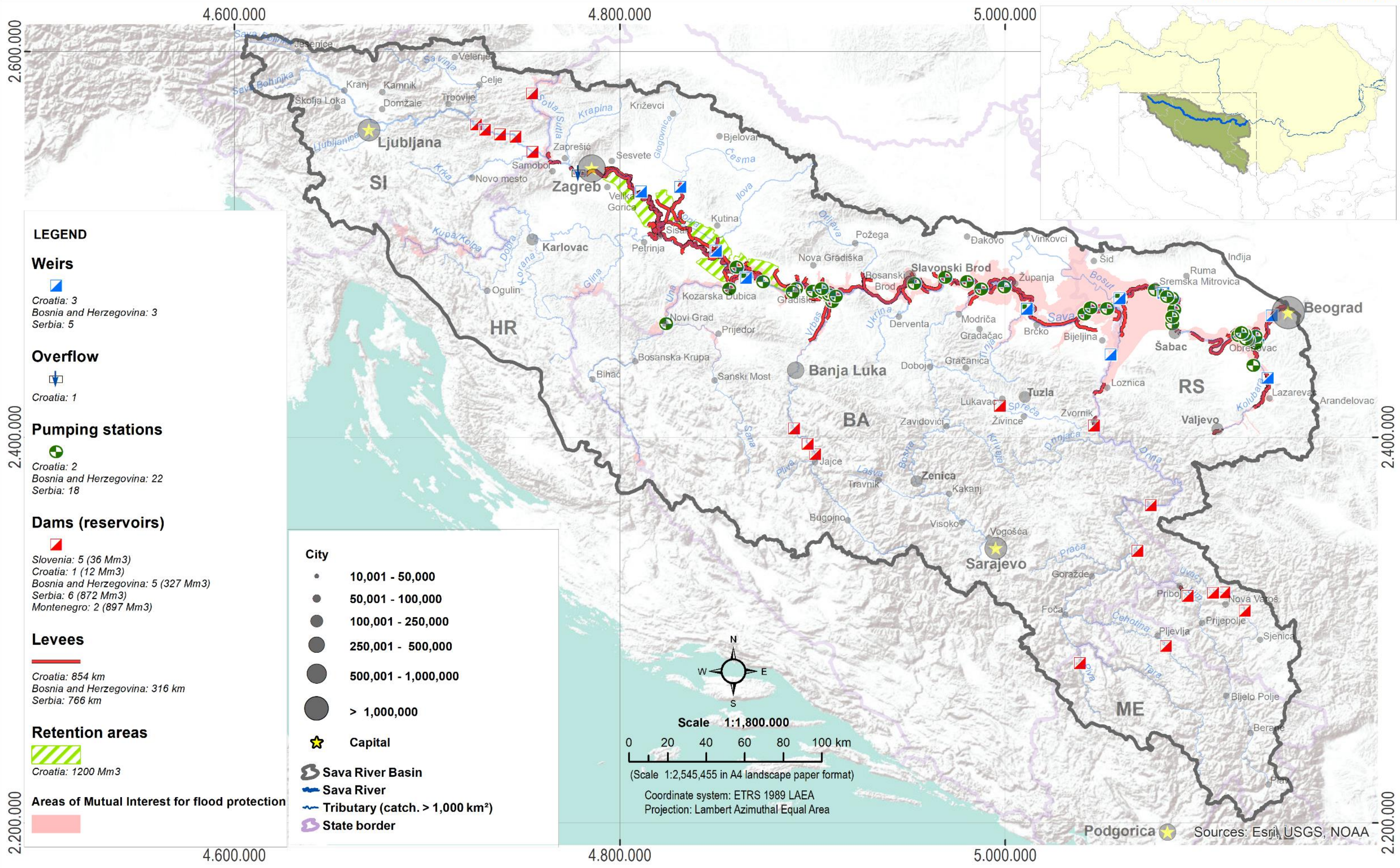
# Major structures for the flood protection in AMIs

INTERNATIONAL SAVA RIVER BASIN COMMISSION

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