SOUTH-EAST EUROPEAN MULTI-HAZARD EARLY WARNING ADVISORY SYSTEM

Assessment of capabilities of the South-East European National Meteorological and Hydrological Services in flood forecasting and warning

Final Report

10 October 2019
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Background

In 2016, the World Meteorological Organization (WMO) initiated the development of a South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A) with initial support from the U.S. Agency for International Development (USAID), Office of U.S. Foreign Disaster Assistance. Fully developed SEE-MHEWS-A system will support the National Meteorological and Hydrological Services (NMHSs) in fulfilling their core function: providing timely and accurate forecasts and warnings of hazardous hydrometeorological events in order to reduce loss of lives and other impacts on people, infrastructure and industry.

Developed during the 2016-2017 inception phase, the Implementation Plan for SEE-MHEWS-A (SEE-MHEWS-A Implementation Plan, 2008) provides guidelines for the development of the technical components and activities necessary to establish advisory system operations by mid-2023. World Bank through the Global Facility for Disaster Reduction and Recovery (GFDRR) and Instrument for Pre-Accession Assistance (IPA) of the European Commission is supporting the second phase of the project (February 2018-December 2020), concentrating on implementing a pilot hydrological modelling system connected to a numerical weather prediction system, forming the basis of the comprehensive operational regional advisory system.

During the second phase of the SEE-MHEWS-A project, a pilot hydrological modelling system should be developed for one river basin in the South-East Europe region (SEE). Development of operational flood forecasting and early warning system (flood EWS) at the river basin level requires availability of quality-controlled hydrological and meteorological observational data as well as post-processed high-resolution numerical weather prediction (NWP) model output.

An inventory of the available automatic, real-time reporting weather and hydrological observing station network in SEE should be carried out including, which stations could immediately deliver sufficient quality and representative operational data to SEE-MHEWS-A, and whether National Meteorological and Hydrological Services operating these stations are in agreement to submit these data for the purposes of
the regional advisory system. The inventory should also include the availability of historical meteorological, hydrological observing stations data needed for hydrological model calibration and validation, as well as required ancillary information (e.g. snow data, reservoir operation policies and data, topography, land cover data, bathymetric/cross sectional data, etc.).

The availability of the required data, as well as other considerations should be taken into account in the selection of the river basin from the SEE for setting up the pilot hydrological modelling and forecasting system.

Such assessment of capabilities of SEE NMHSs in end to end process of flood forecasting, including data observations and management activities will be an essential component for the development of pilot operational hydrological modelling and forecasting system for the SEE-MHEWS-A. The pilot system is envisaged to be further developed during the upcoming phases of the SEE-MHEWS-A project.

**Brief regional summary**

There are a number of definitions of South East Europe, starting from territories of Balkan Peninsula countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo (UNSCR 1244/99), Montenegro, North Macedonia, Romania, Serbia, and Slovenia) to more broad term, where territories of bordering countries – Bulgaria, Romania, and Turkey are added to them. In terms of the SEE-MHEWS-A the SEE is considered as even broader region, which includes 18 countries in total: Balkan countries with neighbouring states, as well as Cyprus, Hungary, Israel, Jordan, Lebanon, Moldova, and Ukraine. The region is extremely diverse in terms of climate, physical settings, hydrology, land use, economy, all of which have direct influence on settings of NMHSs of the SEE countries, their present state, needs and ways of future development.

The region is highly diverse in terms of geographic conditions: from Balkan and Carpathian Mountains to steeps in eastern Ukraine. There are several types of climate (and many more subtypes) in the SEE: from humid subtropical climate in eastern Mediterranean to hot desert climate in Jordan. Such significant diversity of natural conditions in the region of interest results in the different nature of floods: flash floods in mountainous areas, riverine floods in plain parts of the river valleys, urban floods due to rainfalls of high intensity, as well as coastal floods of combined sea and riverine influence, or the combination of them. The territory is very dense in terms of rivers, population, damage centers, there is difficult to single out a single significant river, which flows within the borders of a single country – majority of rivers are transboundary rivers. All this requires good shape of hydrological forecasting systems in the countries of the region, high level of cooperation between countries in transboundary aspects.

Many countries, which belong to the SEE region, are developing countries with all specific issues, outlined in the report of the World Bank Group (Assessment of the state of hydrological services in
developing countries, International Bank for Reconstruction and Development/The World Bank, 2018). Below several common needs of the SEE countries are outlined.

All countries of the project indicated strong need in improving their national early warning capabilities in flood forecasting, as all of them have particular deficiencies in terms of forecasting of severe floods. In all countries of the SEE there are regional flood forecasting early warning systems in place, which significantly assist flood forecasters in their daily mission – both in terms of flash floods, as well as in terms of riverine floods. However, continuous increase of capacity of such systems is required to allow even more effective applications of such systems in operational practice.

Sustainability of many flood forecasting services remains a big challenge in the region. There are a number of ongoing projects from country to country, but in many cases further support of newly implemented technologies remains an issue due to under insufficient budgets of several Services of the region.

Better cooperation between meteorologists and hydrologists on the step of preparation and issue of flood forecasting products is still required in many countries of the Region. Hydrological forecasters are looking to more suitable meteorological products to be available for them (including timing, format). This is even more valid for the countries with different entities, responsible for meteorology and hydrology (separate NMS and NHS). Taking into account flashy nature of floods in mountainous areas of the region ensemble meteorological products are considered to have significant value in the region, to have ability to account for its uncertainty.

Due to geographical and political conditions of the region there are many rivers, crossing multiple national borders. In many cases Agreements of transboundary data sharing are not developed (or should be significantly improved) to let effective flood forecast and management activities to be implemented. Many countries from the region are still developing their flood forecasting capabilities – from observations to data products communication to end users.

Present report aims to describe the current status of the National Hydrological Services of SEE countries to better understand their existing specific issues in the field of the end-to-end flood forecasting and early warning chain of actions.

South East Europe river basin survey

To fulfil the main goal of the second phase of the SEE-MHEWS-A project – development of pilot flood early warning system (EWS) for one of the river basins in SEE – the assessment of national (as well as a river basin) capabilities in end to end flood forecasting and early warning should be accomplished. The assessment should consider different pieces of flood EWS chain, with special regards to the initial settings (flood prone areas, end-users needs, etc.), observations and data acquisition, historical and ancillary data, data management and existing flood forecasting capabilities. Results of such an assessment would give an idea on the pilot river basin, where flood forecasting services are the most
needed, and availability of data (both operational and historical) allows development and implementing flood forecasting techniques.

The assessment survey of the SEE NMHSs (SEE survey), used in this work, is based on the WMO Commission for Hydrology (CHy) Assessment Guidelines for National Hydrological Services (NHSs) (or other water authority, responsible for issuing flood forecasts and warnings within a country) to evaluate their End-to-End Flood Forecasting and Early Warning System to assist WMO Members in improving their understanding of such systems and in assessing their abilities in this regard. The assessment covers specific parts or processes of the flood EWS, from data acquisition to forecast dissemination and communication to end users, it seeks to identify the strengths, weaknesses and gaps of the NHS in flood forecasting to provide recommendations or guidelines on how to improve current practices. The description of the SEE survey, given below, is partly taken from the CHy draft document “Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems”.

The SEE survey was developed as the tool (framework) used to collect the information and to assess the degree of readiness and ability to deliver services needed for the provision of flood forecasts and warnings that relate to WMO recommended practices and procedures. The survey is organized as the template in excel form. It includes description of the survey, followed by seven sections designed to assist with collecting the information needed for the assessment (Appendix 1).

Description of the SEE survey includes basic information about the assessment: name of the country, river basin name (if it is national assessment, then should be left blank), institution(s) involved in the assessment, evaluator(s) name (who is filling out the template), date of the assessment. Each of the seven sections that comprise the survey are listed below. Each covers a specific link of the chain in the flood forecasting process.

I. Institutional
II. Observations and Data Acquisition
III. Historical and Ancillary Data
IV. Data Management
V. Meteorological Forecast and Products
VI. Hydrological Models and Forecast
VII. Flood Forecasting Products

Each of presented sections has several subsections, which are devoted to specific area of the section’s topic. Below definition of the sections is given, which provides generic information about each section’s topic.

I. Institutional

This section is focused on the “Institutional” setting and seeks to collect general information about the institutional and legal framework of the country in the context of E2E EWs for flood forecasting, and its national institutional structure for provision of such services.

II. Observations and Data Acquisition
This section focuses on the identification of existing hydrometric stations in the NHS, their time series, and the processes used for data acquisition. This section gathers specific features about each station, such as the type of equipment, the existence of rating curves, and their condition. It also allows the evaluators to capture general elements about stations network conditions. In addition, similar meteorological, climatological, and oceanic information useful for hydrological modelling purposes could be collected. This section might require the use of auxiliary tables to collect station information and other pertinent information.

III. **Historical and Ancillary Data**
This section allows the collection of historical data (e.g., period of record) and additional information useful for selecting practices and procedures that would help improve the performance or capability of an early warning system. It allows the gathering of information for providing an overview regarding the general availability, quality, and format of the data.

IV. **Data Management**
This section is designed to assist in identifying and documenting the data management system, its architecture, procedures and practices followed in within the NHS to manage data and in sharing them with the main actors linked to EWS. The management of data impacts on the effectiveness of the early warning system. I should also include specifics regarding the database in use.

V. **Meteorological Forecast and Products**
It is of fundamental importance to have access to meteorological forecasts and specific products for the production of hydrology forecasts. This section allows the compilation of information, including the details regarding the availability, frequency, and spatial and temporal scales of meteorological forecast products of pertinence to advancing hydrological modelling to support flood forecasting.

VI. **Hydrological Models and Forecast**
The purpose of this section is to collect information about models, and techniques used to generate hydrological forecasts. It also allows the gathering of information about the interoperability of the flood forecast system, such as the ability of using different models and of visualizing results.

VII. **Flood Forecasting Products**
A description about the type of products generated for flood forecasting is captured under this section. It also is intended to collect information related to the activities involved in generating flood forecast and products to satisfy stakeholders’ and users’ requirements.

The structure of the SEE survey template includes both national and basin level assessments, while the items as well as the information included in either might vary. For example, the national assessment will include only high-level information (i.e. not flood-type specific), while the items included in a basin assessment would be more specific and in-depth, depending on the type of flooding being addressed.
The evaluators should start the national level assessment and then, based on the findings, they should select the pertinent tab(s) to complete the basin assessments. According to proposed structure of the survey, sections have subsections that cover the national assessment and basin level assessments according to different flood types. Each section of the survey is organized as a table (spreadsheet) and includes the following information:

- **Item**
  This is a listing of all the items considered necessary to assess the capabilities of the organization related to a given section.

- **Guidance for Evaluators**
  This part provides guidance information to the evaluator on what elements to consider for determining a score to be applied.

- **Grading scheme**
  This includes a dictionary for grading (or description of the grades) as well as the grades themselves. Not every item in the survey is graded, as some of them require specific detailed answer, rather than grading score. In this case for such items there is no grading description. A qualitative grading scheme is adopted for the AM in which the evaluators have to assign the grade based on the goals and the nature of the item under consideration. The suggested grading scheme includes six scores from 0 (not existing) to 5 (best practices are followed). To ease work for the evaluators, scoring descriptions for grades 1, 3, and 5 are given in the survey. It is left to the discretion of the evaluators if their responses are graded using intermediate scores, e.g., 1.5, 2, and 4. It should be noticed that not every item could be scored quantitatively. For some items only qualitative descriptions can be used. These are filled in the column of the survey under “Evaluators Comments”.

- **Evaluator Comments**
  This part was designed to record additional information that would be helpful in the overall assessment, which might be unique for each case.

The SEE survey is accompanied with the network table “Observational network table.xlsx” (Appendix 2), which was designed to collect metadata of existing hydrometric and meteorological stations (including coordinates, elements measured, sampling interval, transmission frequency, equipment used and etc.), to ease analyzing of capabilities of existing observations and data acquisition processes.

Assessment process, designed by the CHy task-team on the Assessment Guidelines, includes several steps of assessment, where one of the most important steps is implementation of the assessment template (survey) in field by external evaluator(s) through interviewing experts of NMHS, National disaster management authority, and other institutions involved in the process of end-to-end flood forecasting. In this particular case, given the large number of the countries – Members of the SEE-MHEWS-A Project, the only feasible way of implementing the assessment is through the self-assessment.
To assist in this quick information note was written (Appendix 3) with several tips on how to fill out the survey.

The SEE survey together with quick information note and observational networks table were send out to focal points of all countries-members of SEE-MHEWS-A (on 25th of April 2019). The survey was filled out by experts of the countries – 12 SEE countries-members of SEE-MHEWS-A responded. Representative of Cyprus provided an overview of their activities regarding capacities in flood forecasting and warning. Representatives of several other countries, which did not provide the filled surveys, excused themselves for not providing results due to urgent operational issues. The assessment can be updated once more countries provide responses. The list of responded countries with information on proposed pilot river basin (from each of the countries), as well as contact person(s), who filled out the SEE survey is given in table 1 below.

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<tr>
<th>No</th>
<th>Country</th>
<th>River(s) proposed</th>
<th>Institution (NMHS)</th>
<th>Contact person</th>
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<td>1</td>
<td>Albania</td>
<td>Drin and Vjosa</td>
<td>Institute of Geosciences and Energy, Water and Environment (IGEWE)</td>
<td>Ms. A. S. Hiraldo&lt;br&gt;<a href="mailto:amparosamper@hotmail.com">amparosamper@hotmail.com</a></td>
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<td>2</td>
<td>Bosnia and Herzegovina</td>
<td>Vrbas, Neretva</td>
<td>Hydrometeorological Service of Republic of Srpska (RHMZ RS), Federal Hydrometeorological Institute (FHMI), Agency for Watershed of Adriatic Sea Mostar (AVPJM)</td>
<td>Mr. Darko Borojevic (RHMZ RS)&lt;br&gt;<a href="mailto:d.borojevic@rhmzrs.com">d.borojevic@rhmzrs.com</a>&lt;br&gt;Mr. Nino Rimac (FHMI)&lt;br&gt;<a href="mailto:nino.rimac@fhmzbih.gov.ba">nino.rimac@fhmzbih.gov.ba</a>&lt;br&gt;Mr. Emil Bakula&lt;br&gt;<a href="mailto:ebakula@jadran.ba">ebakula@jadran.ba</a></td>
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<td>Kamchiya</td>
<td>National Institute of Meteorology and Hydrology</td>
<td>Mr. Eram Artinyan&lt;br&gt;<a href="mailto:eram.artinian@meteo.bg">eram.artinian@meteo.bg</a></td>
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<td>Neretva</td>
<td>Meteorological and Hydrological Service of Croatia (DHMZ)</td>
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<td>Marcal</td>
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<td>Jordan</td>
<td>Jordan, Zarqa</td>
<td>Jordan Meteorological Department</td>
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<td>Montenegro</td>
<td>Zeta river, and several others</td>
<td>Institute of Hydrometeorology and Seismology of Montenegro</td>
<td>Mr. Ervin Kalac <a href="mailto:ervin.kalac@meteo.co.me">ervin.kalac@meteo.co.me</a></td>
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<td>Mr. Ruslan Reviakin</td>
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Current state of flood forecasting capabilities in SEE countries

The state of flood forecasting capabilities, with special focus on end-users needs, real-time and historical data availability, data management, available NWP outputs, and hydrological models and techniques being used, is prepared based on the information, provided in the SEE river basin surveys only. Level of details of description and analysis below fully depends on the survey results of a particular county – some countries were much more prescriptive and detailed than the others. Some countries also did not fill out several sections of the survey – thus information of such sections is not described in the text below. Flood forecasting capabilities of 12 responded countries (table 1) are analyzed below. The surveys (initial responses) are given in Attachments 1-12. The filled out network tables are given in the tables of Appendix 4. Below is information about current capabilities of the SEE-MHEWS-A countries responded in general, as well as with respect to the pilot basins provided.
Albania

**General context**

The Drin and the Vjosa rivers are the two major Albanian rivers, which frequently suffer from severe floods. The Drin River basin (19,000 km²) runs along North Macedonia, Kosovo (UNSCR 1244/99), Albania and Montenegro, discharging its waters into the Adriatic Sea, in the north of Albania (Figure 1). It has four natural lakes and a cascade of three reservoirs with hydropower plants (HPPs). The main tributaries of the Drin River are the White and the Black Drin, the Moraca and the Buna Rivers. Floods on the Drin River are caused by rainfalls of high intensity and big amount (over 200mm in 24h and/or 500mm in two days or more) sometimes combined with snowmelt and dam release (which causes backwaters effect near the Shkoder/Skadar Lake). This causes floods every year in the floodplain, causing damages especially in the low part of the Drin river – near confluence of the Buna River and the Shkoder (Skadar) Lake area.

The Vjosa River Basin (6,808 Km²) is located in the south of Albania discharging its waters into Adriatic Sea (Figure 1). The river runs along Greece and Albania and has two main tributaries: The Drino river (also transboundary) and the Shushica river. One third of the headwaters are located in Greece. Floods on the Vjosa river are caused by high intensity rainfalls sometimes combined with snowmelt. Recent construction of bridges has increased the flood risk in some particular areas of the river. Most of the flooding problems are in the flood plain of the river.

Both flash floods and riverine floods happen in these basins. In addition, most of the big cities of Albania suffer from urban flooding, as they do not have effective drainage system due to wrong design or inefficient maintenance, which is unable to cope with frequent high intensity rainfalls (20mm/h and more).
Figure 1. – Observational networks in the Drin and the Vjosa rivers’ basins
National Meteorological and Hydrological Service

Institute of Geosciences, Energy, Water and Environment (IGEWE) is the NMHS of Albania, and is the former Hydrometeorological Institute that was merged with other institutions in 2008. There are different departments in IGEWE, including the National Centre for Forecasting and Monitoring of natural hazards. The Centre is not legally defined in the structure of the IGEWE, but experts from two departments contribute to its operation (Department of Climate and environment and Department of Water Economy and Renewable Energies). There are two more state meteorological services in Albania: Meteorological Military Service, which is responsible for meteorological stations maintenance, which are in WMO GTS exchange, and providing weather forecast for military operations; and Albcontrol Meteorological Service, which provides weather forecast for the airspace within Albanian territory.

There is a Water Management Agency (AMBU) of Albania which is responsible for development and implementation of policies, strategies, plans, programs and projects regarding water management (water quantity and quality), including the participation in international agreements for transboundary waters.

The Civil Protection of Albania is the major end user of IGEWE hydrometeorological services. There is a MoU between IGEWE and Civil Protection of Albania, which clarifies the role of both institutions regarding forecasting of natural hazards. It clarifies the frequency and type of products for weather forecast and issuing additional risk bulletins in case of crisis. According to the MoU, IGEWE continuously monitor meteorological and hydrological phenomena in accordance with WMO standards, as well as issue flood warnings within a Daily risk bulletin without reference to the specific station (or location) of a river (as alarm levels are not defined for any hydrometric station in Albania). Additional information is provided to Civil Protection during flood events if required. Civil Protection is responsible for warning population, and it requires flood forecast information several days in advance due to its own limitations in mobilizing resources to the areas affected by floods.

IGEWE operate only Monday to Friday, employees are available 24 hours a day only during severe flood events. However, the Daily Risk bulletin is issued every day, and there is an assignment of responsible employees for making the bulletin on a daily basis. The fact that IGEWE is not officially a 24/7 service complicates the situation during crisis situations.

Currently IGEWE is underfunded and has problems with lack of personnel (i.e. there is no money for station maintenance or stream gauging measurements). IGEWE suffers from lack of qualified personnel. As stated in the Action Plan of 2016, the job description of every employee should be clearly listed with specific tasks and especially for crisis situations (flood events).

Standard Operating Procedures (SOPs) are not well developed, there is only a check-list available, which is updated regularly and a standard template (on process of being approved) for the daily risk bulletin and a guideline to interpret the daily bulletin.
Cooperation and coordination between national institutions and transboundary institutions

In 2011, the water and environment management ministries of the Drin riparian countries (Albania, Kosovo (UNSCR 1244/99), Montenegro, North Macedonia) signed a MoU to promote joint action for the coordinated and integrated management of the Drin river basin. In 2016 another MoU was signed by four NHMSs of the Drin river basin to timely exchange hydrometeorological data and to cooperate to improve flood early warning services and transboundary flood management. Further work is needed to better coordinate during a flood event and to establish flood alarm levels at different locations in the basin, standard operating procedure (SOP) and the common alerting protocol (CAP). In 2018, a cross-border water resources agreement between Montenegro and Albania was signed to continue work in the field of water quality, flood protection, water regulation and maintenance and exchange of information, as well as resources mobilization to conduct joint activities.

Institutional agreements on data sharing among different ministries/agencies/data sources

There is a MoU between Civil Protection and IGEWE, which includes data sharing; however, there are interactions with other institutions such as KESH (Albanian State Hydropower company), Prime Minister Office, Ministry of Agriculture, AMBU and mass media regularly call. There is a MoU between KESH and IGEWE to share data and cooperate (however it should be updated). In 2019, a MoU was signed between IGEWE and AMBU for cooperation and sharing hydrometeorological data.

Observations and data acquisition

There are 49 automatic stations in Albania (24 meteorological, 25 hydrometric). They were installed with the support of the World Bank project (40 stations operated by the General Directorate of Civil Emergencies) and GIZ project (9 stations operated by IGEWE). There are also 11 meteorological semi-automated stations in the WMO GTS exchange, which are within responsibility and maintenance of Military Meteorological Service of Albania. Abovementioned stations metadata is given in Appendix 4. Automatic stations are in a poor state, as they have not been maintained since their installation in 2013-2014. In the framework of following projects (EU PRONEWS and GIZ project) they aim to be rehabilitated. In May 2019 24 stations were visited, assessed and sensors recalibrated when possible as part of the PRONEWS Project activities. No alarm or flood levels are defined for any hydrometric station. There are also around 207 manual stations (115 meteorological and 92 hydrometric). Manual stations do not transmit observations in real time mode (at the end of a month station booklets are delivered to IGEWE). Rating curves have not been updated since 2007 and data from 1992 until 2007 have been used to derive the curves, so streamflow calculation cannot be considered as reliable.

Vandalism is an issue – 16 automatic stations suffered from vandalism. It is planned that under the forthcoming EU funded PRONEWS project the protection housing and fences will be constructed.

Observational network within proposed river basins (the Drin and Vjosa rivers) are presented in figure 1, list of the stations with metadata – in Appendix 4. Several important tributaries of the rivers do not have
The hydrometric stations coverage could be improved especially in the tributaries of the Drin River (those inflowing into the Cascade) and the Vjosa River basin (especially Shushica River Carcove River – near the border with Greece). The coverage of the meteorological stations could also be improved: by installing stations in mountainous areas, introducing measurements of snow cover and depth, as well as solar radiation. The meteorological stations from the GTS list cover only main cities of the country. Information on the availability of rating curves for the hydrometric stations of the proposed rivers is given in the Appendix 4 (table 1).

The sampling and transmitting cycle of automated stations differ from station to station. The transmitting cycle can be changed during the flood event manually from the office. The sampling cycle of the hydrological stations is 15-30 minutes and the transmission frequency is from 1 to 2 hours. Meteorological stations have a sampling frequency from 10 min to 30 min (depending on the parameter and location) and transmitting every 2-4 hours. Manual hydrological stations are sampled at 7:00 and 17:00 every day and transfer the data at the end of the month to IGEWE. Hydrological manual data is not being digitized regularly. Manual meteorological stations sample one value at 7:00 am however some stations might sample three times a day (7:00, 14:00 and 21:00), data are transferred to IGEWE at the end of the month, 50% of the data are digitized regularly without quality control. Furthermore, data are not being stored in a centralized database i.e. MCH, but data are kept in different computers in excel files. Meteorological stations from the WMO GTS exchange network sample and transmit every 6 hours.

The stream gauging measurements were digitized in 2013 under the World bank project (digitizing from 1992 to 2007). Further digitization was done for the full network of pluviometric stations for the period 1991-2001 and for the period 2012 to October 2018 and for hydrological manual stations from 1992 to 2011 with support of the PRONEWS project. The result of both (WB and PRONEWS) digitalisations was unsatisfactory (low quality). The result data base is of low quality due to human errors. In the past, rating curves have been developed graphically in millimetric paper, some of these rating curves are available but only in a hard copy. The frequency of streamflow measurements was once or twice per month, not all hydrological stations have rating curves developed. Rating curves are developed for sites at big rivers (the Drin and Vjosa rivers) and one station in the rest of Albanian rivers. The rating curves require update due to significant change of cross sections.

IGEWE owns one weather radar (X-band type), however it has not been functioning since 2016. It is located in Durres town (41°24′20″N, 19°23′5″E) covering part of the country. There are several problems with the internet connection there. Serbian radar covers the north part of Albania, as well as the Drin basin River area. The Vjosa river basin is not covered by radar.

There are four marine stations, three of them are not currently operating. The stations observe sea level with 15 min frequency and transmission frequency every two hours. These stations also observe meteorological variables such as rainfall, temperature, humidity, radiation, air pressure and wind. The Drin and the Vjosa rivers coastal areas are not properly covered by these stations.
In case of transboundary data – for the Drin River data from Kosovo (UNSCR 1244/99), North Macedonia and Montenegro arrive sometimes with hours of delay (within the MoU between the Drin riparian countries). For the Vjosa river there is no data exchange with Greece.

Some automatic stations (financed by the World Bank project) measure snow cover at 7 locations in the country: 5 of them are located inside of the Drin river basin or very close surroundings and 1 – in the Vjosa basin. None of the snow measurements are currently working and were not maintained or calibrated when functional. In general, there is a lack of representativeness of the current snow measurements and rainfall gauges especially in the mountainous areas of the basin, Albanian Alps (as most of the snow measurements are taken at low altitude). There are no snowpack conditions measurements. Snow measurements are sampled every 30 min and transferred every 2 hours.

There are several reservoirs for hydropower production and/or irrigation and there are no data received by IGEWE regarding real-time dam release, or plans of operations. This fact constitutes a big issue for the Drin Flood Forecasting System, which will never be able to get right the forecast in the floodplain unless the dam data is transferred in advance to IGEWE. According to the agreements the KESH hydropower state company should share the data during the flood event only, but not on a regular basis that also constitute a challenge for operational flood forecasting on a daily basis. By law civil protection and the members of the emergency commission of the Drin river which includes the director of IGEWE need to receive the data regarding the dam release in real-time which is insufficient. IGEWE needs in advance (2 to 3 days before) the planned dam release and inflows into the dams and in a detailed format that can be reliable to be used in the forecasting system.

**Historical and ancillary data**

Historical data for manual hydrometric stations are available in paper format, and partly in paper, partly in digital format in case of manual meteorological stations. Automatic stations have short time series – starting from 2013–2014, some of them – with reasonable gaps. The aim is to recover data from the gaps in some of the data loggers of the 24 stations from WB that are still in place. (Appendix 4).

**Data management**

The existing forecast systems informational component is based on the utilization of MCH database (with group of scripts that gathers, reformat, and upload data into MCH database component, which feed the data into the modelling system), which collects data from all automatic stations, and then provides it to the hydrological model (for Drin river only).

**Meteorological forecast products**

**IGEWE** does not run any Numerical Weather Prediction (NWP) model, however it performs analysis of outputs from different models that are available online or within countries agreements. Currently there is shortage of experienced staff to work with NWP activities. There are following NWP products (outputs) which are being used:
IGEWE does not produce any marine forecast in the whole country. Detailed information on the spatial resolution, number of runs per day, and the lead time of the NWP models used are given in the SEE survey (Attachment 1).

**Hydrological models and forecasts**

Since 2010 different international donors have been providing support to improve flood forecasting capabilities of IGEWE:

- **GIZ Project** (started in 2013) – automatic stations were installed (Appendix 4), hydrological model for the Drin river basin was implemented; EU Preliminary Flood Risk Assessment for Drin Basin which enumerates high risk areas; first version of a HEC-RAS 2D model of lake Shkoder and Drin-Buna flood plain was implemented (needs improvements to be used as forecasting tool for flood extent, water levels and duration); other additional tools that are elements of the Drin River Flood Forecasting System were produced.

- **Project supported by the Work Bank**: Procurement of 40 automatic weather, marine and hydrological stations

- **Project supported by the World Bank, WMO and Central Institution for Meteorology and Geodynamics of Austria (ZAMG)** – Action Plan developed with short, medium and long-term goals and investments regarding IGEWE. In this document priorities regarding flood forecasting in the major river basins are set as medium/long-term goals.

- **EU PRONEWS project** (ongoing) – improvement of the EFAS system in Albania with introduction of a 1km LISFLOOD hydrological model resolution, as well as applying calibration.

In the result there are following flood forecasting capabilities, which exist within the Drin and the Vjosa basins.

There is an implemented flood forecast system in the Drin river basin, based on the *Panta Rhei* hydrological model (developed by Technical University of Braunschweig, Germany) and the reservoir
cascade operational rules model. The model was developed by TU Braunschweig under the framework of GIZ project for IGEWE. The model was used under a NEXUS study for the cascade and IGEWE gave permission to be used by KESH (Albanian hydropower company). The first version of the forecast system has been running since November 2018. The system covers all watersheds of the river. It utilizes the data from automatic hydrometric and meteorological stations, satellite rainfall estimates (source: NOAA Hydroestimator) and outputs of three Numerical Weather Prediction (NWP) models, produced in Montenegro. The data from automatic stations are stored in MCH database, which is connected to the hydrological model. Time step is 1 hour, lead time is up to 5 days. Described flood forecasting system was developed and implemented under the umbrella of GIZ project, which started in 2013 with four NMHSs (Albania, Kosovo (UNSCR 1244/99), North Macedonia, and Montenegro) as partners.

In addition to these capabilities, the hydrodynamic (2D) model was implemented for the high-risk flood areas in the low course of the river (Shkoder Lake area and Buna floodplain). The model is not as accurate as required due to absence of bathymetric data, digital terrain model (DTM) of high precision, as well as appropriate calibration. The status of the model is not operational.

There is no basin level flood forecasting system implemented in the Vjosa river basin.

There are several regional flood forecasting systems, which operationally issue flood forecasts for the whole country, including two proposed river basins. South East Europe Flash Flood Guidance System (SEEFFGS) is used to generate flash flood alerts with 1-hour time step, up to 35 hours lead time, and 4 runs daily. Riverine flood prediction is done using European Flood Alert System (EFAS). EFAS has 5km spatial resolution of a cell, running at the European scale in European Union Joint Research Center (EU-JRC). It has 6 hours’ time step, 7-10 days’ lead time, 2 runs a day is being made. The models used in both systems are not calibrated. Meteorological data only from the GTS stations (see Attachment 2) are provided to the systems in real time mode. SEEFFGS also utilizes satellite data. Both forecast systems outputs are considered by IGEWE as inaccurate due to coarse spatial resolution and the lack of real time input data. Nevertheless, the the tools in a daily basis to assess the risk in absence of better methods.

Forecasts performance is not done for the three models for now. Output correction is done in case of Panta Rhei – an ARMA error model is under experimental testing.

**Flood forecasting products**

The Albanian Civil Protection and IGEWE signed a MoU were the tasks of IGEWE are clarified, including hydrological forecasting. However, term “hydrological forecasts” are not used in the MoU, only hydrological risks are used within the Daily risk bulletin, issued by IGEWE. IGEWE have developed Guidelines (to be approved) to interpret the risk bulletin that will be soon available for the public. The Daily risk bulletin is published at 12:00 every day and alerts are provided to the Civil Protection as soon as possible. The risk bulletin is published in IGEWE’s web page, Facebook, and disseminated by email to different authorities. In case of an extraordinary event, extra bulleting can be published on demand.
In terms of flood risk products – the EU Floods directive is being implemented in the country. In the Drin river, preliminary flood risk assessment has been done. Other preliminary flood risk assessments have been done under PRONEWS project but the results are of low quality due to the quality of the data used. In general, there is a lack of products for the forecast horizons most needed – IGewe do not issue hydrological warnings, but rather provides a risk map by prefecture administrative unit. The risk map is standard and the legend for the different risks.
There are several institutions involved in hydrometeorological services provision (in particular in flood EWS) on the territory of Bosnia and Herzegovina (table 2): Federal Hydrometeorological Institute of Federation of Bosnia and Herzegovina (FHMI), Agency for Watershed of Adriatic Sea Mostar (AVPJM), and the Agency of the Sava river basin (ASRB) – for Federation of Bosnia and Herzegovina, and Hydrometeorological Service of Republic of Srpska (RHMZ RS) and Vode Srpske – for Republika Srpska. There are two river basins proposed as pilots by Bosnia and Herzegovina: the Neretva and the Vrbas rivers basins. There are different capabilities of the flood EWS for these basins, as well as there are different agencies involved in hydrometeorological service provision for – thus description will be given separately basin by basin further below.

Table 2. – Entities hydrometeorological service provision in Bosnia and Herzegovina

<table>
<thead>
<tr>
<th>Political entity of Bosnia and Herzegovina</th>
<th>Institution, involved in flood EWS</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Republika Srpska</td>
<td>Hydrometeorological Service of Republic of Srpska (RHMZ RS)</td>
<td>Hydrometeorological service, Member of WMO (together with FHMI)</td>
</tr>
<tr>
<td>Republika Srpska</td>
<td>Vode Srpske</td>
<td>Water resources management</td>
</tr>
<tr>
<td>Federation of Bosnia and Herzegovina</td>
<td>Federal Hydrometeorological Institute of Federation of Bosnia and Herzegovina (FHMI)</td>
<td>Hydrometeorological service, Member of WMO (together with RHMZ)</td>
</tr>
<tr>
<td>Federation of Bosnia and Herzegovina</td>
<td>Agency for Watershed of Adriatic Sea Mostar (AVPJM)</td>
<td>Hydrological monitoring and forecasting</td>
</tr>
<tr>
<td>Federation of Bosnia and Herzegovina</td>
<td>Agency of the Sava river basin (ASRB)</td>
<td>Hydrological monitoring and</td>
</tr>
</tbody>
</table>
The Vrbas river
The Vrbas river was proposed as a pilot river basin by RHMZ RS (Banja Luka), which is responsible for hydrometeorological service for the central and lower part of the river basin. The information in the section below is mostly from RHMZ RS perspective. Information on the upper river basin’s network is added to the section from the FHMl and ASRB perspective, as this part of the river is under their responsibility in terms of operational hydrometeorology.

General context
The Vrbas river’s length is 240 km, it is one of the Sava river’s tributaries, with mean annual discharge value of 102 m³/s. The Vrbas river basin is 5023 km². The river’s source is located on the Vraniza mount slope at 1780 m alt (Bosnia and Herzegovina part of the Dinaric Alps). The river flows in the north direction, where it inflows into the Sava river near the border between Bosnia and Herzegovina and Croatia. Heavy rainfalls in upper part of the basin of Vrbas river and Vrbanja River (tributary, which inflows into the Vrbas near Banja Luka) are the main source of riverine floods in the river basin. The most significant damages and losses due to flooding occur in Banja Luka area, as well as in the area from Banja Luka to the mouth of the Vrbas River. There is a reservoir in the middle of the river – Bočac reservoir.

Vrbas river basin is located within two political entities in Bosnia and Herzegovina (upper part is located within the Federation of Bosnia and Herzegovina, central and lower parts – within Republika Srpska) – there are two NMHSs and two water management agencies in charge for flood protection and EWS within the basin. Thus there is an issue with national legislations mandating a national agency to provide flood warning information (and other products).

In the Vrbas river basin there are some simple EWS capabilities implemented in 2015 (it was supported by UNDP project): automatic hydrological stations have defined flood thresholds and thus generate SMS to the hydrologists when water level reaches critical values. There are no flood forecasting capabilities implemented on the basin level. Global/regional system for flood prediction is used to provide flood warnings. RHMS RS, usually, provide early warnings 3-4 days in advance with indication in which region flood can potentially occur (without predicted water level values). Some high risk areas are covered, but most catchments remain uncovered of early warnings. End users of flood early warning system’s products, as well as their needs are collected, but not documented in official report.
Hydrometeorological Service of Republic of Srpska

In the Republika Srpska part of the basin NMS and NHS are merged into the single NMHS – RHMS RS, which is in charge by law to produce warnings and forecast for potentially severe weather and flood events. Roles and responsibilities of RHMS RS are not clearly defined – there is some overlapping with the Vode Srpske in terms of hydrological services. Daily operations for supporting the flood EWS carried out only during day hours – evening/night shifts are only used when needed (during severe flood events).

Cooperation and coordination between national institutions and transboundary institutions

Through International Sava River Basin Commission (ISRBC) there is established flood early warning system and Sava hydrological information system for real time data exchange in whole Sava river basin. Academia experience is involved in the EWS process occasionally by sharing knowledge and expertise during conferences. There is no monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS. In terms of decision support services there is main flood protection plan where responsibilities of main players are indicated.

Institutional agreements on data sharing among different ministries/agencies/data sources

In transboundary context there is a Policy on data exchange in the whole Sava river basin under the ISRBC.

Observations and data acquisition

There is existing real-time monitoring service in the Vrbas river basin. Most monitoring stations have maintenance plain, except for 2 stations. In general, there is a high level of reliability of data transmission – all data from stations are transmitted in real time via GPRS mobile internet. There is low risk of vandalism – quite a few situations were registered to be damaged (broken solar panel or stolen battery). Additional security measures were introduced to avoid such situations in the future (fence installed etc.). From operational data acquisition perspective, the Vrbas river basin is within responsibility of following entities: RHMZ RS provide data acquisition in lower and central parts of the basin, FHMI is responsible for meteorological observation and hydrometric data management in upper part of the basin, ASRB perform hydrometric observations in upper part of the Vrbas basin. The map of observational stations is provided in Figure 2.
In terms of adequacy of hydrometric network design – some tributaries of the Vrbas river are not covered by hydrometric observations (for instance, following tributaries of the river: Ugar, Svrakava, Krupa, Suturlija, Turjanica). Most stations are automated (OTT equipment – hydrological stations are with pressure-level sensor). All stations measure and transmit water level and water temperature information, 7 stations (out of 10) additionally perform discharge measurements. In the upper part of the river, there are 4 automatic hydrometric stations only on the main river (no tributaries are covered

Figure 2. – Observational network in the Vrbas river basin
with hydrometric measurements), maintained by ASRB (Figure 2, Appendix 4). Observations and transmission of water level are conducted every hour. There are discharge measurements performed at these gauges, which allow rating curves updating and streamflow calculation in near real-time mode. Data collection frequency is adequate for flood forecasting – 30 minutes. There is calibration plan developed and followed for hydrometric stations. Rating curves are well maintained – majority of hydrometric stations provide discharge information. All stations are operational – they observe and transmit data in near real-time mode (every 30 to 60 minutes).

Data collection frequency of meteorological stations (including rainfall observations) is from 1 minute to 30 minutes. OTT equipment is used (“Pluvio 2”). In upper Vrbas there are 12 automatic meteorological stations (OTT), managed by FHMI (table X, figure 2). All of them observe precipitation, as well as air temperature every hour. Transmission frequency is one hour. Thus all meteorological stations are operational – they transmit data in near-real time mode (every 30 minutes).

In the Vrbas river basin there is a reservoir with HPP Bočac. There is data exchange of inflow, outflow, as well as other information only before and during the flood event.

Snow variables (depth, SWE) are measured only at the main meteorological station in Banja Luka.

There are radar(s) installed, but data are not adjusted to ground stations, thus it is not suitable to use for the flood forecasting purposes at the moment.

**Historical and ancillary data**

Metadata for hydrometric, as well as for meteorological stations are available with updated zero readings, coordinates, equipment type, date of installation, and other information. Hydrological data in the lower and central parts of the basin are available mostly for the period from 1950-1960-s until 1990. Then after installing new instruments – since 2015/2016 and until present time. In the upper part of the basin data archives are available beginning from the early 2000s. For majority of meteorological stations in all parts of the basin data time series are available from February 2016, for other 4 station (in the central/lower parts of the river’s basin) – from early-mid 1960-s. Most of historical data are available in digital format (in Excel and TXT).

**Data management**

All measured data are stored in servers, owned by RHMS RS and FHMI.

**Meteorological forecast products**

Meteorological forecasting products are provided by RHMS RS. Rainfall and temperature forecasts outputs of at least three deterministic NWP models are used in operational work in digital format. Wind speed and direction forecast maps are available only as image products. Meteorological forecast products of FHMI are presented below (in the section, devoted to the Neretva river).
**Hydrological models and forecasts**

At the moment there is no formal flood forecasting procedure in place for the Vrbas River. As well as there is no model/functionailities used in the basin for flood forecasting.

**Flood forecasting products**

Threshold-based flood alert and flood forecasting (automatic hydrological stations have defined thresholds and generate SMS to the hydrologist when water level reaches some value). RHMS RS provide early warnings, 3-4 days in advance.

**The Neretva river**

The Neretva river was proposed as a pilot basin by FHMI and the Agency for Watershed of Adriatic Sea Mostar. The river is also considered as a pilot by Croatia, where relatively small, but significantly high flood prone coastal area of the river basin is located (see below – in the report section, devoted to Croatia). The Neretva river survey (Bosnia and Herzegovina part) was filled in by the Agency for Watershed of Adriatic Sea Mostar, and FHMI (section, devoted to Meteorological forecasting products).

**General context**

The Neretva river’s length is 225 km; basin area is 11.798 km². It origins in Bosnia and Herzegovina in mountains near the border with Montenegro, then flows 203 km before the border with Croatia. The lower part of the river (22 km) flows in Croatia, then it inflows into the Adriatic Sea. It is considered to be one the largest rivers of the eastern part of the Adriatic basin. There are a number of significant cities and towns, located on the river, including Metković, Ulog, Konjic, Jablanica, Mostar, Opuzen and others. The manmade influence on the regime of the river is significant – there are nine HPPs on the Neretva river and its main tributaries (the Rama and the Trebisnjica rivers), which provide flood protection, power generation and water storage. The river’s runoff is significantly influenced by karstic processes. Rain and snowmelt are the main contributors to flooding in the river basin.

**Federal Hydrometeorological Institute of Federation of Bosnia and Herzegovina**

There is a joint NHMS of Federation of Bosnia and Herzegovina (FHMI), which is together with Republic Hydrometeorological Service of Republika Srpska (RHMZ RS) is the member of WMO. Roles and responsibilities of FHMI are well defined: meteorological forecasting and provision of operational data on water levels at hydrometric stations, which are under FHMI responsibilities (every 4 hours, or more often).

The Agency for Watershed of Adriatic Sea Mostar have responsibilities and obligation by law to provide hydrological forecast products and warn civil protection, media, etc. before and during extreme hydrometeorological conditions. However, in terms of regional flood forecasting systems – EFAS and SEEFFGS – FHMI is the main partner, as there are 2 hydrological forecasters on duty in FHMI in hydrology sector, as well as meteorologist on duty during extreme hydrometeorological conditions, which is very important for hydrological forecasting. FHMI produce hydrological forecasting products
based on regional forecast systems and send them to the Agency for Adriatic river basin and civil protection 3 days in advance as informal notifications (FHMI do not have law obligation to perform flood forecasting).

End users’ needs are known and documented, perhaps it should be reviewed more often.

*Cooperation and coordination between national institutions and transboundary institution*

Flood EWS is working in transboundary context, and there are open national sharing and agreements in place. Collaboration of main players of EWS for flood forecasting with Universities, academia, and research institutions is done occasionally mainly in conferences. There is a monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS in place. SOPs are developed, documented and reviewed. AVPJM provide decision support services to partner agencies via phone contact or embedded forecasters – any institution can call for extended hydrological services without documentation.

*Institutional agreements on data sharing among different ministries/agencies/data sources*

There is a local/national data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed. There is no transboundary data sharing policy, legal framework or agreements between Bosnia and Herzegovina and neighbouring countries and institutions.

*Observations and data acquisition*

There is a rigorous monitoring service in place with its all aspects maintained (maintenance plans and budgets are in place for all items). High level of reliability of data transmission (statistics and backup paths available). Hydrometric network is considered to be good: many tributaries have gauges at outlets, however several important parts of a river do not have gauges. There are an adequate number of visits for staff gauge readings, operational checks, etc. Hydrometric station equipment is calibrated regularly, calibration sessions are traceable and regular, to WMO or equivalent standards.

There are 18 automatic hydrometric stations and 6 staff gauges in the Neretva river basin, maintained by the AVPJM (Table 3). There is also 1 staff gauge, maintained by RHMZ RS. All the stations have real time data transmission. Once a day FHMI receive data from the Adriatic Sea Watershed Agency, applying QA/QC of the data, calculate discharge, and archive the data. Later FHMI publish all data in Hydrology Annual (hard copy and CD).
Table 3. – Monitoring networks in the Neretva river basin

<table>
<thead>
<tr>
<th>Territory</th>
<th>Owner</th>
<th>Number of hydrometric stations</th>
<th>Number of meteorological stations</th>
<th>Data flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Automatic</td>
<td>Manual</td>
<td></td>
</tr>
<tr>
<td>FBiH</td>
<td>Adriatic Sea Watershed Agency - Mostar</td>
<td>18</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>FHMI (Sarajevo)</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elektroprivreda HZHB Mostar (HP)</td>
<td>10</td>
<td></td>
<td>real-time data</td>
</tr>
<tr>
<td></td>
<td>Elektroprivreda BiH Sarajevo (HP)</td>
<td>11</td>
<td>7</td>
<td>real-time data</td>
</tr>
<tr>
<td>RS</td>
<td>RHMZ RS (Banja Luka)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments: FBiH - Federation of B&H (Upper, middle and downstream part of Neretva river); RS - Republika Srpska (Upper part of Neretva river).

Spatial distribution of stations is provided in figure 3. Detailed table with hydrometric and meteorological stations together with their metadata is given in Appendix 4. Manufacturers of the hydrometric equipment, which is in use: OTT Hydrometry, SEBA Hydrometrie, SIAP+MICROS with real time transmission. Some stations are with observer. All instruments are installed with adequate resolution, ranges, and no significant interferences. Ratings are well maintained (regularly updated), ratings are available for all important gauges. Meanwhile the hydrometric network is not adequate for the majority of mountainous areas of the Neretva river.

There are nine water river reservoirs in the Neretva river basin (figure 4) – thus there is a huge influence on the river’s streamflow by hydropower. It was mentioned in the river basin survey that data from reservoir manager(s), including storage level, outflows are fully adequate.

Some of a river’s catchments in flow formation area have few or no precipitation and temperature measurements, as well as other synoptic elements. There is sufficient number of visits for check gauge readings, gauge maintenance, etc. Calibrations process is traceable and regular, according to WMO standards.
There is no weather radar installed in the river basin. Some pertinent transboundary data are available with delays. Snow courses are evenly distributed (snow depth and coverage are observed).

Figure 3. – Observational networks in the Neretva river basin, proposed by Federal Hydrometeorological Institute of Federation of Bosnia and Herzegovina (FHMI) and Meteorological and Hydrological Service of Croatia (DHMZ)
Historical and ancillary data

FHMI and AVPJM are responsible for maintaining data archives for the Neretva river basin. There are complete metadata available for hydrometric, as well as for meteorological stations – with updated zero readings, coordinates, equipment type, date of installation, and other information. Hydrometric data time series are of reasonable duration – from early 2000s until present time both in paper and in digital format. Meteorological data (air temperature, precipitation) data series are available for the period from 2007 until present time.

There is MAP product available for selected catchment, based on rain gauges’ data only.

Up-to-date cross-sections with adequate spacing are available for the most important locations (sections of the river).

Rating curves are updated, they cover different periods of flow, including peaks, low flows and ice conditions.

Spatial data electronic layers are used in hydrological practice (globally available layers). There are impact data available for usage at flood prone locations, including vulnerability, exposure data and flood mapping.

Historical information and traditional knowledge are only applied to a few locations and used for analyses such as flood frequency determination.
There are a number of HHPs in the Neretva river basin, thus information on their regime and regulation rules are vital for development a flood forecasting system. Reservoir inflows, storage and outflows, as well as operation rules (both historical and present) are available.

Hydrometric transboundary data are available – all data, including flow data received in near real-time. There are some snow data available – mostly depth measurements (at stations).

**Data management**

All measured data are stored in owned servers by FHMI. Historical data products are offered according to interoperability standards (data structures and metadata) and are stored in own servers in a client-server scheme providing web services. In terms of real-time data – all pertinent data are readily available when needed; web services are available. The amount of transboundary historical available digital data is close to the optimum according to the current purposes of the flood warning system. Data products are produced according to interoperability standards (data structures and metadata).

Most of the data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures. Some web services are available.

Records and documents are stored digitally according to developed protocols. Most of procedures that must be automated are indeed automatic. Access to records and documents is available by ftp or http clients.

All data (real-time and historical) have passed QA/QC procedures, based on mostly automated methodology with human intervention. Procedures are properly documented and catalogued and have available reliability indexes or metrics.

Data input/output procedures are automated. Some of them with advanced graphical functionality.

**Meteorological forecast products**

The ICON Model from DWD, as well as GFS data from NCEP are used as initial and boundary conditions for NWP. Deterministic forecast of meteorological elements is performed by running WRF-NMM with 4 km spatial resolution once a day for the next 96 hours; and NNMB (6 km spatial resolution), once a day for the next 96 hours. Additionally, for precipitation accumulations 1-h ICON model outputs (7 km resolution) for the next 120 hours are used. Accumulations are calculated with 1-hour interval for the lead time 0-78 hours, and every 3 hours for the interval 78-120 hours.

**Hydrological models and forecasts**

The AVPJIM is responsible for providing hydrological forecasts in the Neretva river basin. Overall forecasting approach is considered to be appropriate: performance metrics are met most of time; appropriate time step is used. Forecasts are issued with lead times greater than 5 days. Regarding different aspects of the system (watershed models, routing models, etc.) it was mentioned in the survey, that procedures should be improved.
**Flood forecasting products**

Flood maps in development and available at a limited number of forecast sites of the Neretva river basin as static libraries. The suite of flood forecasting products is adequate to serve all user's needs and forecast horizons requested. User's feedback indicates the format is adequate and easily understood. All products provided satisfy the timeframe required by users.
Bulgaria

General context

The Kamchiya river basin was proposed as the pilot river basin for the SEE-MHEWS-A Project. The river is located in the eastern part of the country, it forms in the result of confluence of two rivers – Golyama Kamchiaya and Luda Kamchiya, which originates in eastern Balkans and flow eastward. It inflows into the Black sea 25 km to the south of the city of Varna. The river’s length is 244 km, basin area – 5358 km².

The most severe damages from floods occur in Varna district (Avren municipality, Dolni Chiflik municipality), mouth area of the river, for which both rainfalls and intensive snowmelt are the main sources of flooding.

There is no adequate flood EWS developed for the mentioned river basin, rather than regional FFGS – Black Sea Middle East FFGS (BSMEFFGS), which is used only for generating flash flood early warnings. However, there is a big need in the system, which will be capable of riverine flood forecasting with up to several days’ lead time.

There is well-defined national/subnational legislation in Bulgaria, which reflects clear functions covering the area of flood early warnings. Users and user needs are well documented in the documents of Black Sea River Basin Directorate

National Hydrological Service

NMS and NHS are merged into the single institution – National Institute of Meteorology and Hydrology (NIMH), which serves as NMHS of Bulgaria. Roles and responsibilities of NIMH for flood EWS are defined in the Water Act - Art.171 par. 6. NIMH operates during day hours, but evening/night shifts exist when needed (during severe flood event).

Cooperation and coordination between national institutions

The basin of Kamchiya is only within Bulgarian territory, thus there is no aspect of transboundary cooperation between institutions.

Academia’s experience in the field of flood forecasting and warning is shared occasionally mainly in conferences.

Flexibility of organizational structure is identified as high, it has performed well during recent severe events and has established surge capacity and procedures.

Roles and responsibilities of staff involved in the service, as well as Standard Operating Procedures are documented well and reviewed regularly.

NIMH has established Incident Management policy and procedures. There is a focal point defined for quality management and performance assessment. The Service also provides decision support service to partner agencies via specific arrangements.
Institutional agreements on data sharing among different ministries/agencies/data sources

There is a local/national data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed.

Observations and data acquisition

Only hydrometric station information was provided, which is highlighted in Appendix 4, as well as in Figure 5. There are six hydrometric stations within the Kamchiya river basin. Streamflow measurements are performed at all hydrometric stations, and thus streamflow values are calculated in near real-time mode. Sampling interval is 12 hours, which is described in the river basin survey as low frequency of measurements to describe flood formation processes of the river. All hydrometric stations are near-real time data transmission stations. Maintenance of the hydrometric network is considered to be fully appropriate with WMO standards – calibration regime is traceable and regular, there are no significant interferences on sites, rating curves are well maintained (regularly updated), ratings are available for all stations.

Figure 5. – Hydrometric network in the Kamchiya river basin.

There was no information provided regarding meteorological stations network, however it was mentioned in the survey that some river catchments in the flow formation area have too few or even no precipitation and temperature measurements. In total there are eight rainfall gauges and six air temperature stations. Some stations have low frequency of precipitation measurements. There are
manual readings of rainfall amounts. Rainfall is transmitted in near real-time, air temperature data are not transmitted in real-time.

There is one synoptic station within the Kamchiya river basin – in the town of Varna (near the river’s mouth).

Radars are not used for flood forecasting purposes in NIMH.

The Kamchiya river inflows into the Black Sea, there are a number of operational sea level stations used, however near the river mouth’s area some gaps in sea level observations and forecasts exist.

There is not enough available data on reservoir management, available in real-time (or near real-time) mode.

There are eight locations where snow depth and cover are manually measured once a month, there are no SWE measurements.

**Historical and ancillary data**

NIMS is responsible for the storing and managing hydrometeorological data archives. In table 1 (Annex 3) metadata of hydrometric stations of the Kamchiya river basin are presented, highlighting updated zero readings, coordinates, equipment type, date of installation and other. Historical data are available from 1950-s (for some – from 1920-s, 1930-s) until present time. Time series are available mostly in digital format, however paper format is also used at some extent.

Information on cross sections is available, however in majority of cases spacing is not adequate. Cross sections are updated only at sites where hydrometric station is installed.

Impact data information includes vulnerability, exposure and flood maps, which are generally available for all vulnerable flood-prone locations.

There is not enough historical data on reservoir management.

**Data management**

Some data products are stored in owned servers, or are readily available in partner institutions servers (by public or private access) in a client-server scheme with minimal functionalities (web sites, ftp servers, http servers). Most of data is collected at monthly basis and are available after a month. Most of real time data and products are readily available at the start of the forecasting session. Data and products are available in a timely fashion.

Data ingestion procedures are partially automated. Most of the data ingestion is done manually. Some data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures.
Most historical data have passed QA/QC procedures. Most of the ingested real-time data are subject to QA/QC procedures and some reliability indexes or metrics are available. QA/QC procedures for both historical and real-time data are based on partially automated approaches with human intervention.

Relational databases and DBMS are used in operational practices (e.g. MS Access, MySQL).

TXT and CSV formats are the most widespread data formats in the Service in terms of utilization in operational hydrology.

Data input/output procedures are partly automated (there is an interface to manually and automatically import data).

**Meteorological forecast products**

Meteorological forecasting products are issued by NIMS. Regarding rainfall forecast – there is a high resolution (both spatial and temporal) QPF, issued with a time step, that meet the needs of preferred potential hydrological model. Outputs of this kind are available in digital format for a forecast horizon for at least 3 days. The same is valid for air temperature forecast, as well as for other major meteorological variables used in operational hydrology (including dew point temperature).

There is no ensemble NWP capability in the moment.

Deterministic seal level forecasts are issued at the NIMH with relatively high spatial and temporal resolution.

**Hydrological models and forecasts**

There is no basin level hydrological model applied or used in the Kamchiya river basin. Regional flash flood warning system BSMEFFGS is the only system, which is used to assist in generating flash flood alerts.

**Flood forecasting products**

As previously said there is only BSMEFFGS system, which effectively operates in Bulgaria, and it is the only flood forecast system operating for the proposed basin. Not all end user’s needs are met with the products, which are generated by the system, as more long-term lead time forecasts are highly required. There are no flood maps available for Kamchiya River Basin at NIMH.
Croatia

The Neretva river basin was proposed by Meteorological and Hydrological Service of Croatia (DHMZ) as the pilot river basin for the SEE-MHEWS-A Project. Description of hydrometeorological services availability in Bosnia and Herzegovina part of the river basin, described above (see section “Bosnia and Herzegovina – river Neretva”). The river system, as well as observational networks of the river is shown in Figure 3.

General context

The most significant damages and losses due flooding on the Neretva river in Croatia happen at Metković town. The sources of flooding in this area are considered to be of complex nature: heavy rainfalls, reservoir operations in Bosnia and Herzegovina, insufficient local drainage and sewer system, river-sea interactions – are all influencing the flooding at this location.

National Meteorological and Hydrological Service

DHMZ is hydrometeorological service of Croatia. Roles and responsibilities within the Service are well defined according to national policies and regulations. Daily operations for supporting the flood EWS in terms of weather forecasting are carried out in 24/7 mode. DHMZ is also responsible for hydrological monitoring (water levels), and hydrological forecasts (using existing operative hydrological forecasting system for some basins). Real-time hydrologic monitoring of water levels is 24/7. Other operations for supporting the flood EWS are during day hours, but evening/night shifts are used when needed.

There is no clearly defined legislation at the national level mandating a national agency to provide flood warning information and products, as the new law about meteorological and hydrological activities in Croatia, which covers flood warning topics, is still in final preparation stage. There are two entities, which are responsible for flood warnings: DHMZ and Croatian waters (Hrvatske vode).

Cooperation and coordination between national institutions and transboundary context

Transboundary collaboration with institutions of Bosnia and Herzegovina regarding operation of flood EWS has not been established yet. Academia experience on flood modelling and forecasting is shared with DHMZ occasionally mainly in conferences. There is no monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS. Regarding flexibility of organizational structure there is informal surge capacity and procedures in place.

Institutional agreements on data sharing among different ministries/agencies/data sources

There is a local/national data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network). There are no agreements for transboundary cooperation that cover Neretva river basin.
**Observations and data acquisition**

Observational network map is provided in Figure 3, information on stations could be found in tables of Appendix 4. There are 11 hydrometric stations in the Croatian part of the Neretva river basin, which have quite good distribution across the Croatian part of river basin. Nearly half of the stations (seven) transmit measurements in near real-time mode (every hour), and have from 15 to 30 minutes sampling interval. Almost all stations measure water level (and temperature), only one of the (7259, *Prud preljev uzv.*) performs discharge measurements. It is mentioned in the survey, that definition of reliable rating curve is impossible due to sea influence at most locations.

There are 22 meteorological stations in the area with joint air temperature and precipitation measurements (10 stations), and precipitation measurements only (12 stations). There are 7 synoptic stations. There are only 2 automatic stations, which transmit data in near real-time mode (1-hour sampling and transmission frequency). Other stations operate at daily time interval with monthly transmission frequency (climate stations). Synoptic stations are equipped with a shelter for air temperature measurements at 2 m (*Schneider58660*), precipitation Hellman rain gauge, pluviometer (*Lambrecht99.15072.020000*). Automatic weather stations have following equipment: air temperature at 2 m is measured in a shelter (*Rotronic HC2*), precipitation – *Meteoservis MR3* heated.

Climate stations: air temperature at 2m in a shelter (*Schneider*) and precipitation Hellman rain gauge, Precipitation stations: Hellman rain gauge.

Data verification frequency for both hydrometric and meteorological data is regularly done on monthly basis. Station calibration regime is regular, according to WMO standards.

There are no weather radars in the area of interest.

There is only one station that measures sea water level at influence of Mala Neretva (distributary channel of the Neretva river, which inflows into the sea near to the main channel of the Neretva river) to sea (*7499 Ustava ušće nizv., Mala Neretva*).

As it was mentioned earlier, the is no agreement in the transboundary context, thus there is no data available from the upper river basin, located in Bosnia and Herzegovina.

Snow depth is manually measured at all meteorological stations, and snow coverage is measured at synoptic stations.

**Historical and ancillary data**

DHMZ is responsible for data archiving. There are complete metadata available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other parameters. Hydrometric data time series (water level only) are available in digital format beginning from end of 1930-s (several stations), for the majority of stations – starting from 1960-s, 70-s. All hydrometric data are in digital form. Due to sea influence (tides) there are no reliable rating curves developed at hydrometric gauges of the area.
Regarding meteorological stations metadata – coordinates, station height, date of installation is available, data about the equipment is available in most cases. Notes about changes in instrument(s) and environment are mostly missing. Meteorological long term data series are partly in paper, partly in digital form. For the majority of stations data are available starting from early 1980-s. Mean areal precipitation series are available for selected river catchments, based on rainfall gauges’ data.

There are data on cross-sections with adequate spacing in majority of cases, but not up-to-date everywhere.

Vulnerability, exposure data and flood mapping are generally available for all vulnerable flood-prone locations – the data are provided by the Authority of Croatian Waters.

Historical information and traditional knowledge on historical flood heights only apply to a few locations and used for analyses such as flood frequency determination.

Snow depth measurements archives are available at all meteorological stations (with more than 6 years’ duration) in partly paper and partly digital (more digital) form.

Topographic and land use/cover data are available for urban areas: GIS layers (LC/LU, infrastructure, buildings, etc.).

**Data management**

Historical as well as real-time data products are stored in DHMZ owned servers. Historical hydrological data is available for viewing on website and can be uploaded on request on ftp or sent by e-mail. Real time hydrological data is exchanged in CSV files via ftp servers in hourly frequency. All meteorological real time data and products are available on request through web services. Data is ingested automatically from ftp repositories for automatic hydrometric stations and manually from non-automatic stations.

Records and documents are stored digitally according to protocols developed by DHMZ. Most of procedures that must be automated are indeed automatic. Access to records and documents is available by ftp or http clients.

All hydrological data have passed QA/QC procedures but there are no available reliability indexes or metrics. Historical QA/QC methodology is based on mainly manual procedures following properly documented protocols. There are no QA/QC procedures implemented for real time hydrometric data.

Database type is of relational type (SQL). Data formats, which are widespread used at the Service – CSV.

Input and output Interfaces - data input/output procedures are partly automated (there is an interface to manually and automatically import data). Real time data is automatically imported and historical data is imported and exported manually.

**Meteorological forecast products**
DHMZ uses ALADIN numerical weather prediction model to produce its in-house meteorological forecast products. Products are derived by an in-house operational suite run at grid spacing up to 2 km for 72 hours ahead with 1-hr output frequency. Model is currently updated every 6 hours through local data assimilation system. DHMZ also uses ECMWF Integrated Forecasting System (ECMWF-IFS). Global Atmospheric Model components in use are: ENS - Ensemble Forecasts (every 12 h, resolution ~ 18 km / 91 level, lead time +15 days); HRES - High-Resolution Forecast (every 12 h, resolution ~ 9 km / 137 level, lead time +10 days); Extended-Range Forecast; Long-Range (Seasonal) Forecast. We also use Ocean Wave Model - ECWAM.

DHMZ runs wave model, which is coupled with ALADIN model. No other in-house specific ocean water level forecasts are available. Institute of Oceanography and Fisheries produce short range sea level forecasts (link: http://www.izor.hr/web/guest/visoke-i-niske-vode).

**Hydrological models and forecasts**

DHMZ does not have its own model for the Neretva river – there are no formal flood forecasting procedures are in place on a basin scale level. However, there are several regional systems used for flood prediction in Croatia, and in particular in the Croatian part of the Neretva river: EFAS (EU Flood Awareness System – that is the early warning and monitoring component under the Copernicus Emergency Management Service (CEMS), operational since 2012) and SEEFFGS (developed by Hydrologic Research Centre, operational since 2015). EFAS provides both riverine (up to 10 days ahead) and flash floods (up to 5 days ahead) warnings while SEEFFGS gives up to 6 hours in advance warnings on flash floods. Flash flood warnings are disseminated through the Meteoalarm.

Some high risk areas are covered with efficient flood warning service, but most catchments of the river still remain uncovered. User needs within the basin area are collected but not documented in an official report. However, requirements of end users (in particular decision makers) are known, documented and reviewed.

Provision of longer lead time alert or watch services is not in operation. Only short to medium lead time alerts are issued.

The hydrological model used for EFAS is LISFLOOD, that is a hybrid between a conceptual and a physical based spatially distributed (5 km grid cells) rainfall-runoff model combined with a routing module (Kinematic wave equations) in the river channel. LISFLOOD calculates a complete water balance at a 6-hourly or daily time step for every 5km grid cells of the EFAS domain. FFGS is considered as a semi-distributed model with the hydrologic model configured and the parameters estimated for each sub-basin within domain.

EFAS and SEEFFGS have been recently calibrated. There is a regular EFAS headline score available at the EFAS web page: The Continuous Ranked Probability Skill Score (CRPSS) for lead times 1,3,5, and up to 10
days for the previous month across the \textit{EFAS} domain for catchments larger than 2000km$^2$. There is no systematic efficiency validation of \textit{SEEFFGS}.

Lead time for the forecast products are as follows: \textit{EFAS} – up to 10 days, \textit{SEEFFGS} – 1, 3, 6 hours (risk product – up to 36 hours with 12 hours’ frequency). EFAS runs twice a day automatically at ECMWF, \textit{SEEFFGS} runs 4 times per day at Regional center in the FFGS Regional Center (in Turkish Meteorological Service).

There are serious deficiencies of the existing regional flood forecasting systems: \textit{EFAS} model is not adapted to the specific terrain and hydrological conditions of the focus area, as well as it does not account for strong influence of HPPs in the upper part of the Neretva river basin (in Bosnia and Herzegovina). Flash floods do not have any significant influence on the coastal area of the Neretva river basin in Croatia.

\textit{Flood forecasting products}.

Threshold-based flood alerts and flood forecasting is in operational use: flood threshold levels are set and provided by Croatian Waters for all the territory of Croatia. Flood forecasting service varies across catchments but all catchments are covered: \textit{DHMZ} have well developed hydrological model for the Sava river catchment in Croatia, but not for any river within the Adriatic catchment – only regional flood forecasting systems are used (see above).

Flood maps are not available as Croatian Waters are responsible for flood risk maps and for flood defence system.

\textit{DHMZ} provides customized products for different users – for example 24/7 hydrological real time monitoring for \textit{Croatian Waters}.

User’s feedbacks indicate, that the format is adequate and easily understood – it is standardized interchange of data with \textit{Coastal Waters} for years and it goes well.

Not all areas have appropriate products to satisfy the users – when \textit{DHMZ} receives flood notification for the Neretva river in Bosnia and Herzegovina or Croatia – monitor the situation and according to forecast and its time of forecast vs. real time data we could issue warnings.
Cyprus

General context

Cyprus is the only island state in the SEE region. Cyprus has no transboundary river basins, nevertheless, is suffering from floods and flash flood events resulting in human fatalities and millions of euros of damages. Due to previous flood experience Cyprus joint SEE-MHEWS-A project and was represented to all meetings, from projects early beginning, with high rank personnel.

The most widespread flood events in Cyprus are flash flood events, with time of concentration of less than 3 to 4 hours between the storm event and the resulting flood. The area affected mostly and mainly by flash flood events is the area of the capital, Nicosia, and the suburban areas as also some other coastal urban areas with special geomorphology.

The area of Cyprus is not covered by the WMO/FFGS although it was twice requested by the Department of Meteorology (CyMET) officially from WMO.

The Official Authorities in Cyprus

The Department of Meteorology of Cyprus (CyMET) is the Authority for Meteorology and Climatology i.e. for monitoring the weather and climate and the issuance of forecast and warnings. According to a Decision of the Council of the Ministers, CyMET is responsible to issue all the relevant warnings and distribute them via EMMA, when the forecasted accumulated precipitation is suspected to result in flash flood events.

The Water Development Department (WDD) is the Authority for Hydrology with specific duties and responsibilities as regards floods i.e.:

1. The collection and treatment of hydrological, hydrogeological and other data for the study, design, maintenance and safety of water related development works and the protection and management of water resources and water bodies.
2. The implementation of the technical aspects of the EU Floods Directive and the corresponding national legislation.

CyMET and WDD are in very close collaboration in order to fulfil their responsibilities against floods. The data collected by CyMET are adequately transferred to WDD to be used for the necessary purpose.

The practice

WDD collected all relevant data regarding historical floods and flash flood events and identified nineteen (19) Areas of Potentially Significant Flood Risk - APSFRs (presented on the following chart).

According to the charts index:

1. the bold blue line represents the APSFRs
2. the light blue line represents the rivers
3. the pink polygons represent the catchment areas of the APSFRs
4. the yellow polygons represent the water reservoirs and
5. the light blue polygons the natural lakes

For all the 19 APSFRs, WDD prepared a Flood Risk Management Plan, according to the standing EU Directive, which includes a program of measures related to:

1. Prevention
2. Protection
3. Preparedness and
4. Recovery

The program of measures includes both horizontal measures that apply generally for the whole island as well as specific measures for each of the 19 APSFR. The preparedness measures include 4 measures (see below) related to the development of flood early warning systems that are currently not available in the country.

The lack of the FFGS limits the abilities of Cyprus to develop its operational early warning systems in order to reduce the severe risks of floods that the country faces.
Greece

General context

The most widespread flood events in Greece are flash floods (with time interval between observable causative event and the flooding of less than 4-6 hours). The Attic peninsula is the area, where most significant damages from floods occur due to heavy rainfalls, and insufficient local drainage. There is a regional flood forecast system BSMEFFGS in place.

There is a well-defined national/subnational legislation with clear functions covering the area of flood early warnings. It was indicated that, most or all catchments are not covered by flood EWS. User needs collected but not documented in an official report. User needs are known, documented and reviewed. Occasionally alerts are provided for longer time.

National Meteorological and Hydrological Service

The section was not filled in.

Cooperation and coordination between national institutions and transboundary context

There are a number of transboundary rivers in Greece, so in general flood EWS is working in transboundary context. Open national sharing and agreements in place.

There is a monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS.

No surge capacity and staff overwhelmed during recent events.

Roles and responsibilities of staff involved in the service, as well as SOPs are documented but not updated often.

Formal Incident Management is in place.

Quality management handbook or documented procedures.

Decision support services is decided by the staff at the office.

Institutional agreements on data sharing among different ministries/agencies/data sources

There is no local/national data sharing policy, legal framework or agreements among institutions.

There is a transboundary data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).

Observations and data acquisition

Observational networks metadata was not provided together with the SEE river basin survey, thus there was no possibility to map spatial distribution of observational stations.
Most aspects of networks are maintained, but there is no formal maintenance schedule. Data transmission path (station to forecast center) has reasonable success rate of transmissions, however some limitations exist. There are no or few occurrences of vandalism, mitigation measures are in place at several levels.

Some tributaries have gauges at outlets, other important parts of a river do not have gauges. Some of the basin's gauges have low frequency of measurements to describe flood formation process. Data verification frequency is not adequate for the majority of stations. Calibration was performed prior to service, occasional, with some traceability. All instruments are installed with adequate resolution, ranges, and without significant interferences. Regarding rating curves at hydrometric stations’ locations it was mentioned in the survey, that there is a lack of streamflow measurements to update curves, absence of ratings at important points. However, in mountainous areas ratings are well maintained (regularly updated) and available for all important stations (gauges).

Regarding meteorological network following can be said. Some of the basin's meteorological stations have low frequency of measurements. Data verification frequency is fully adequate. Calibration regime is traceable and regular, to WMO or equivalent standards. There are too few meteorological stations in mountainous areas.

Operational transboundary data are not available.

Some measurements (snow depth and coverage, snow water equivalent) are available with limited distribution at daily time step.

*Historical and ancillary data*

Decentralized Administrations of Greece, Special Secretariat for Water are responsible for data archiving. For both hydrometric and meteorological data complete metadata are available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other. Reasonable duration (more than 6 years) of hydrometeorological time series are available for both calibration and validation a model without significant gaps and breaches in stationarity. Mostly all data are available in electronic digital form.

Mean areal precipitation is available for majority of river catchments, based on both radar and satellite estimations and gauge measurements (however there is a doubt about the reliability of radar estimations).

Many synoptic elements are archived (incl. temperature, cloud cover, wind speed, and others).

There are cross-sections available with adequate spacing. They are up-to-date, and cover most of important sections of main rivers.

Historical information on rating curves is available with reasonable updates.

High resolution spatial data are nationally available for important data types for modelling purposes.
Historical information and traditional knowledge — broad programme to incorporate such knowledge into archives and used for analyses such as flood frequency determination.

Data on reservoir inflows, storage and outflows are available with more than 6 years’ duration without significant gaps in digital format. Both current and previous reservoir rules are available.

Snow course metadata are limited or unavailable for many gauges.

Reasonable duration (more than 6 years) of snow course data for both calibration and validation a model without significant gaps and breaches in homogeneity.

Combined sewer and storm water (drainage) systems data, as well as DEM and topographic and land use/cover data are available in digital format.

**Data management**

Historical data products are offered according to interoperability standards (data structures and metadata) and are stored in own servers, or are readily available in partner institutions servers (by public or private access) in a client-server scheme providing web services.

No real time data are provided by own or third party ground networks (point data).

There is a scarce amount of transboundary historical data available (digital, digitalized or digitized) and transboundary real-time point data collected or processed by the Hydrological Service in relation to the needs of the warning system. ftp channels for exchange of data products (i.e. Time series, maps) with key providers have been set up. Communication capabilities are expanding.

Data ingestion procedures are partially automated. Most of the data ingestion is done manually. Some data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures.

Records and documents are stored digitally according to local policies, or according to protocols developed by the Hydrological Service. Most of procedures that must be automated are indeed automatic. Access to records and documents is available by ftp or http clients.

Some QA/QC procedures have been implemented to some of the historical and real-time data. Methodology relies mainly on manual procedures following properly documented protocols.

Relational database and DBMS are in use (e.g. SQL, ORACLE)

Data input/output procedures are not automated. Manual data ingestion.

**Meteorological forecast products**

Some meteorological products are provided by NMS and some are derived from other companies. Rainfall deterministic forecasts of resolution (spatial and temporal) and of time step that meet the needs of the preferred hydrological model are available in digital format for a forecast horizon of at least 3 days. Air temperature deterministic forecast is of coarse resolution (e.g. resolution of global NWP);
products are digitally available. Wind speed and direction forecast maps, as well as sea level forecast are available only as image products and not in the preferred time step.

Hydrological models and forecasts

There is not a designated provider. Forecasting approach is not appropriate, or no formal flood forecasting procedures are in place. Rainfall-snowmelt-runoff model type (spatial resolution) (if used as main forecast procedure) fits for its purpose – performance metrics are being met or exceeded. There are several models, which are used in practice: HEC GEO-HMS, HEC-HMS, and NRCS. Model calibration/validation is reviewed every 6 years.

Flood forecasting products

Level of service – occasional flood forecasting. Many catchments are not covered but some services in high risk areas. Flood risk maps available for all forecast sites in real-time. Flood risk maps available for all forecast sites in real-time. The suite of customized products for specific end-users is adequate to serve all user’s needs and forecast horizons requested. All products are presented in a standardized consistent manner to avoid confusion among users. Some formats are adequate and others difficult to understand. Not all areas have appropriate products to satisfy the users.
Hungary

**General context**

The Marcal river basin was proposed as the pilot river basin for the SEE-MHEWS-A Project. The catchment area of the river is 3076 km², the river’s length is 91 km. The Marcal river is the right tributary of the Raba river, which is not far from the confluence with the Marcal (near the town of Gyor) inflows into the Danube.

The river is fed primarily by rainfalls and/or snowmelt in its catchment area. The flood type is considered to be riverine, as the time interval of the observable causative event is normally greater than 6 hours.

There is no approach implemented in terms of models to provide flood warnings on the river, only some local-basin analysis based on monitoring to produce warnings for short-term lead time (occasionally alerts are provided for longer lead time also).

**National Meteorological and Hydrological Service**

NMS and NHS are separate entities. Roles and responsibilities of the NMS are well defined; daily operations are carried out always during day hours but evenings/night shifts are only used when needed. The same is valid for NHS, which is called General Directorate of Water Management.

**Cooperation and coordination between national institutions and transboundary context**

Early warning system is not working in transboundary context. There is no data sharing across international boundaries. Relevant players of the EWS are working well together through symposiums, joint publications, open sharing. There is a monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS.

NHS have informal surge capacity and procedures in case extreme events. Roles and responsibilities of staff involved in the service are documented well and reviewed regularly. The same is for the standard operating procedures – they are documented well and reviewed regularly.

NHS have a focal point for quality management and performance assessment, which are existing managers.

There are specific arrangements for selected institutions in terms of decision support service.

**Institutional agreements on data sharing among different ministries/agencies/data sources**

There is a local/national data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed.

There is a transboundary data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).

**Observations and data acquisition**

50
Observational network in the Marcal river is presented in Figure 6. Information about the hydrometric, as well as for meteorological network can be found in Appendix 4.

There are 23 hydrometric stations in the basin, nearly half of them monitor water level, as well as discharge to maintain and update rating curves (12 stations). These 12 stations provide data in real-time (near real-time) mode – every hour, their sampling interval is 15 minutes. Other gauges provide water level measurements, some of them are manual (staff gauges), their sampling and transmission intervals
are longer. Hydrometric network design is considered to be good in the basin with extensive coverage, however some important parts of a river do not have gauges. There are 12 operational real-time stations, other stations have low frequency of measurements to describe flood formation process. Rating curves are well maintained (regularly updated), ratings are available for all important stations.

There 5 meteorological stations in the basin: all of them observe precipitation, 1 of them has additional measurements of air temperature and humidity, another one – air temperature, moisture and pan evaporation. Observational frequency of meteorological stations varies from 15 minutes to 1 hour, and to 24 hours (2 stations). Three meteorological stations out of five can be considered as near real-time stations with transmission frequency from 10 minutes to 1 hour. More information about equipment type can be achieved from in Appendix 4.

Observational data verification frequency is fully adequate – it is done on a regular basis. Calibration regime of both hydrometric and meteorological stations is done prior to service, occasional with some traceability. All instruments are installed with adequate resolution, ranges, and no significant interferences.

The river basin is covered by weather radar data, however these data could not be considered as applicable for flood forecasting, as the radar outputs are not adjusted to ground stations data.

No snow measurements are performed in the Marcal river basin.

**Historical and ancillary data**

There are quite long time series available of water level and river discharge data – beginning from 1950-s – 1970-s for the majority of gauges. Almost all data are digitized. Time series of observed meteorological elements are available mostly in digital format (paper format – only for 1 station) beginning from: 1970-s for 2 stations, 1992 – for one station, data series of another stations start in 2002 and 2014.

Complete metadata available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other.

Mean areal precipitation is limited, and is available only for several catchments of the river basin.

There are a number of cross-sections available with adequate spacing in majority of cases, but not up-to-date everywhere.

High resolution spatial data are available for important data types, including elevation, soil, land use, land cover. Vulnerability, exposure data and flood mapping are generally available for all vulnerable flood-prone locations of the river basin.

Regarding historical information and traditional knowledge – there is a broad programme in place to incorporate such knowledge into archives and used for analyses such as flood frequency determination
**Data management**

Historical data products are stored in owned servers in a client-server scheme with minimal functionalities. Most of real time data and products are readily available at the start of the forecasting session. Data and products are available in a timely fashion.

There is a scarce amount of transboundary historical data available (digital, digitalized or digitized) and transboundary real-time point data collected or processed by the Hydrological Service in relation to the needs of the warning system. Ftp channels for exchange of data products (i.e. Time series, maps) with key providers have been set up. Communication capabilities are expanding now.

Records and documents are stored digitally according to protocols developed by the Hydrological Service. Most of procedures are automatic. Access to records and documents is available by ftp or http clients.

Real-time and historical data QA/QC procedures methodologies are manual, following properly documented protocols. In terms of historical data – some QA/QC procedures have been implemented to some of the data. All ingested real-time data are subject to QA/QC procedures and some reliability indexes or metrics are available.

Relational database and DBMS (e.g. SQL, ORACLE) is used. Widely spread data formats are csv, txt, xls, rtf. Data input/output procedures are partly automated (there is an interface to manually and automatically import data).

**Meteorological forecast products**

Some of the meteorological products for flood forecasting and warning purposes are provided by NMS of Hungary, some of them are derived from other companies. NWP outputs of major meteorological variables in terms of flood forecasting (air temperature, precipitation, dew point temperature and others) are available of coarse resolution. There are coarse resolution ensemble members (20+) available in terms of rainfall forecast. Probabilistic forecast of air temperature and dew point temperature is based on outputs of several deterministic NWP models.

**Hydrological models and forecasts**

There is some forecasting approach used for the Marcal river basin, however it should be improved (based on the local basin analysis). Forecast lead time of the existing forecast system is grater then 5 days. "Poor man NWP ensemble" is used as input to the hydrological forecast system. Models of the system are calibrated and validated only at setup. There is no systematic model’s performance done in operational mode. Output updating is performed manually.

**Flood forecasting products**

For now, threshold-based flood alert and flood forecasting are implemented. There are flood maps in development and available at a limited number of forecast sites as static libraries.
Customized products for different users are issued - suite of products satisfy part of the users, not all of them. Some of the products are standardized. User’s feedback indicate the format is adequate and easily understood. All products provided satisfy the timeframe required by users.
Jordan

General context

The Jordan river and the Zarqa river (significant tributary of the Jordan river) were proposed for the SEE-MHEWS-A Project by Jordan. Most of the damages from floods occur in the Jordan river valley, as well as other different places due to flash floods (flood mechanism – excess rainfall over catchment area). The service provides short lead time flash flood alerts, it is a continuous service, dams overflow alerts are also issued for this river basin.

National Meteorological and Hydrological Service

NHS and NMS are separate entities in Jordan. NMS – Jordan Meteorological Department – is issuing only flash flood warning using BSMEFFGS products. Hydrological forecasts are issued by Ministry of Water and Irrigation. The service of NMS is continuous and 24/7 (including for flash flood events). Ministry of Water and Irrigation issue early warning for floods and dams overflow, monitor water resources, develop water strategies. The SEE river basin survey was filled by the Jordan Meteorological Department, and Ministry of Water and Irrigation (which is an NHS of Jordan) did not participate in the survey filling process.

Cooperation and coordination between national institutions and transboundary context

The proposed Jordan river basin is a transboundary river. However, there is no data/products sharing in place across international boundaries. There is an occasional knowledge sharing with Academia mainly in conference. There is no monitoring and evaluation of the performance of the relevant players involved in delivering flood warnings.

Roles and responsibilities of staff involved in the service, SOPs are documented but not updated often. Formal Incident Management is in place. Quality management handbook or documented procedures are used to support quality management framework. There are specific arrangements in terms of decision support services for selected institutions.

There is a local/national/transboundary data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).

Observations and data acquisition

There was no information provided on hydrometric stations in Jordan, however the survey section regarding hydrometric network was filled in (information is provided below). There are 13 meteorological stations, operating in Jordan (Figure 6). Majority of most important meteorological elements are measured with 1 hour (AWS) and 6 hours (manual) time interval. All sites with manual stations are also equipped with AWS. Transmission frequency is 1 hour.

Most aspects of network are maintained, but there is no formal maintenance schedule in place.

Transmission is considered to be reliable – there is a reasonable success rate of transmissions.
Some tributaries have hydrometric gauges at outlets. Some of the basin's hydrometric gauges have low frequency of measurements to describe flood formation process. Some of the basin's stations have missing verification checks. Instruments calibration was done prior to service. Many stations/instruments have inadequate range or accuracy, and/or installed in compromised situations. Majority of gauges are without rating curves, or ratings were updated long time ago.

Some of a river's catchments in flow formation area have few or no precipitation and temperature measurements (as well as other elements, observed at synoptic stations), some of the basin's meteorological stations have low frequency of measurements. Calibration was done prior to service. Different types of instruments are used: automatic and manual from different sources and vendors.

Weather radars installed, but data are not adjusted to ground stations.

Transboundary data are not available.

Snow depth is measured at some meteorological stations with daily time step.

In mountainous there is an even distribution of stations, most parts of mountain/urban areas have coverage.

![Map](image)

**Figure 6.** – Meteorological stations in the Jordan river basin (Jordan part of the basin).

**Historical and ancillary data**

Ministry of Water and Irrigation, Ministry of Agriculture, Jordan Meteorological Department are responsible for storing and archiving the data.
Meteorological data archives have long time period (majority of stations – from middle of 20th century), all series available only from manual stations. All series are digitized (XLS format).

Metadata of stations (both hydrometric and meteorological) are not complete (there might be absence of location information, equipment used, or zero readings), not suitable for modelling. Time series of hydrometric data are partly in paper and partly in electronic digital form.

Mean Areal Precipitation (MAP) is available for selected river catchments, and it is based on rainfall gauges only.

Many synoptic elements are archived (incl. temperature, cloud cover, wind speed and others), metadata are not complete (absence of some meta data.), all (mostly) digital.

Some spatial data globally available are used in the Service.

No vulnerability and exposure data etc. are available nationally.

Information on reservoirs (inflows, storage and outflows) is of reasonable duration, without significant gaps, in both paper and digital format; both current and previous reservoir operation rules are available.

Only manual snow depth measurements archives are available (available mainly in digital form).

Combined sewer and storm water (drainage) systems data, as well as topographic and land use/cover data are unavailable.

Data management

Data products are stored in regional servers (private access) for flash flood guidance. There is a server for AWS and meteorological data from manual stations. AWS real time data are available, flash flood data and products are available upon request. No transboundary data are available.

Most of the historical data ingestion is done manually. Some real-time data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures. Some QA/QC procedures have been implemented to some real-time and historical data. QA/QC methodologies are based mostly on manual procedures following properly documented protocols. ORACLE data base is used. The most widely spread formats of data are delimited text, XLS, and CSV formats. Data input/output procedures are partly automated.

Meteorological forecast products

The products are provided by the National Meteorological Service only. Forecast of meteorological elements are available only as image products and not in the preferred time step. Outputs of at least three deterministic NWP models are used in terms of probabilistic forecast.

Hydrological models and forecasts
FFGS (BSMEFFGS) is used to generate flash flood warnings. There is no systematic forecast performance of the BSMEFFGS. There are also basin-based forecasting systems in use composed of numerical/statistical models connected with local terrain information.

**Flood forecasting products**

Occasional flood forecasting is being done in the country. Service varies across catchments but all catchments are covered. There are no flood maps available. There is a lack of products for the forecast horizons most needed. No standardization is used. Some formats are adequate for the end users and others difficult to understand (as FFGS products, for example). Not all areas have appropriate products to satisfy the users’ needs.
Montenegro

General context

The most vulnerable areas in the country in terms of riverine floods are following hydrological systems:

— floods on the system of the Zeta river – the Moraca river – the Skadar Lake and the Bojana river, which is caused by both rainfalls and snowmelt, as well as reservoir operation in the Albanian part of the basin;

— the Lim River basin, including its tributaries (section Gusinje-Berane-Zaton), where floods are induced by rainfall and snowmelt;

— the region of upper Tara River, before entering the canyon (around the settlements of Kolasin and Mojkovac);

— the valleys of the rivers Ibar and Cehotina;

— small rivers of the Montenegrin coast, which basins are heavily urbanized, are affected by flash floods and urban floods.

National Meteorological and Hydrological Service

In Montenegro NMS and NHS are joined – there is an Institute of Hydrometeorology and Seismology of Montenegro, which cover operational hydrometeorological activities in the country. It provides meteorological forecasts as main input to the EWS for flood forecasting and it also warns in case of potential (or existing) adverse flood conditions in the vulnerable zones, provide hydrological analyses based on meteorological forecast and actual hydrological situation. The roles and responsibilities of the Service are well defined. Daily operations for supporting the flood EWS are carried out always during day hours but evening/night shifts only used when needed.

NHMS structure have informal surge capacity and procedures.

E2E Flood EWS is working in transboundary context for a number of basins of Montenegro. Following national data sharing agreements are in place:

— sharing hydrological and meteorological data on daily basis between riparian countries of the Sava river basin;

— sharing hydrological and meteorological data between on daily basis riparian countries of the Drim and Bojana rivers.

Relevant players of the EWS are working well together through open data/products sharing, symposiums, joint publications. There is no monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS.
Roles and responsibilities of staff involved in the service are understood but not documented. Standard Operating Procedures are documented but not updated often. Incidents are managed informally with best efforts.

There is no quality management handbook or documented procedures in place.

Any institution in Montenegro can request Institute for Hydrometeorology and Seismology for extended hydrometeorological services.

There is a local/national/transboundary data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).

There is a centralized system for risk management in circumstances such as emergency situations including protection, rescuing and recovery, according to National Strategy for Emergency Situations and the Law on Protection and Rescue. The coordination team for emergency situations management is established in the country, which is led by Directorate for Emergency situations (Ministry of the Interior of Montenegro). Institute of Hydrometeorology and Seismology of Montenegro represents “the trigger” for convocation coordination team in case of emergency situations (for example, in case of precipitations of high intensity and a forecast of big precipitation amounts for next day’s – meteorologist notify the sector for hydrology which, after performed analyses notify Directorate for Emergency Situations of Montenegro, which is obliged to notify Government and publicity about possible adverse flood situation.

Bearing in mind the hydrological, geological and morphological characteristics of the terrain of Montenegro, the early warning system consists of the early announcement of possible adverse weather events, which may induce floods in all flood prone areas to the relevant service: the Directorate For Emergency Management, which continues to implement the procedures of the Early Warning System.

Observations and data acquisition

There is a rigorous real-time monitoring service in place in Montenegro. Most aspects of operational networks are maintained, however there is no formal maintenance schedule in place. Data transmission path (station to forecast center) has reasonable success rate of transmissions, with some limitations. The transfer of variables from some stations (data on water level and temperature) is still arranged through the GSM, so real-time data from that locations cannot be provided. There is relatively high risk of vandalism, with no significant mitigation plan developed.

Hydrometric gauges are evenly distributed across the country (Figure 7, Appendix 4). Some of the basin’s gauges have low frequency of measurements to describe flood formation process. Some of the basin’s stations have missing verification checks. Calibration regime of hydrometric stations is traceable and regular, to WMO or equivalent standards. Details on equipment of hydrometric stations are given in table X. All instruments are installed with adequate resolution, ranges, and no significant interferences. Regarding rating curves maintenance – it could be said, that there is a lack of measurements to update
curves, as well as absence of ratings at important points. In the moment there is no discharge measurements at any hydrometric station in Montenegro, thus discharge is not calculated in real-time (at the end of the year, water balance analysis is performed to calculate approximate daily values of discharge for yearbook).

Some catchments in flow formation area have few or no precipitation and temperature measurements (see figure X), some meteorological stations have low frequency of measurements, and missing verification checks. There are significant gaps in rainfall observations in mountainous areas, a lot of upper catchments are without stations. Calibration regime of meteorological stations is traceable and regular, according to WMO standards. Real time data are available every 15 minutes (hydrometric), and every 10 minutes (meteorological)

There are no weather radars in use.

Coastal area of Montenegro is mostly covered by operational sea level station data, however some areas have gaps in observations and seal level forecasts.

Some snowpack conditions measurements and calculations (depth, density, mass, SWE) are available with limited distribution and temporal resolution at the meteorological network sites.

There is no reservoir data available in operational mode.

Figure 7. – Hydrometeorological observational networks of Montenegro
**Historical and ancillary data**

Institute of Hydrometeorology and Seismology of Montenegro is responsible for data archives. There are complete metadata available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other. Long term archives are available for the period of at least 6 years, gaps are present in mostly electronic digital form.

Metadata for meteorological (e.g., precipitation and temperature) gauges are available with coordinates, station height, equipment type, date of installation, and possible instrument(s) change, etc. Time series of meteorological data are of reasonable duration (more than 6 years) for both calibration and validation for modelling, without significant gaps and breaches in stationarity. Meteorological data (e.g., precipitation and temperature) format are partly paper and partly digital.

Mean areal precipitation (MAP) is available for selected river catchments based on rainfall gauges. Many synoptic elements are archived (including temperature, cloud cover, wind speed, ...).

Synoptic data format is partly paper and partly digital.

Cross-sections are available with adequate spacing in majority of cases, but they are not up-to-date everywhere.

Historical information on rating curves is available.

Some spatial data globally available are used in the Institute of Hydrometeorology and Seismology of Montenegro.

There is no usage of impact data – no vulnerability and exposure data are available nationally. Historical information and traditional knowledge are only applied to a few locations and used for analyses such as flood frequency determination. Historical information on reservoir inflows, storage and outflows, as well as on reservoir operation rules is not available.

There are some snow data archives with depth measurements available. Snow data record duration is at least 6 years, gaps are present (partly paper and partly digital).

Some pertinent transboundary data are available with delays.

As for sea level stations – complete metadata available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other. Sea level data series with at least 6 years are available (with gaps).

**Data management**

Most of historical data have passed QA/QC procedures. Most of the real-time ingested data are subject to QA/QC procedures and some reliability indexes or metrics are available. Both real-time and historical QA/QC methodologies imply partially automated approaches with human intervention.
Meteorological data are stored in CLIDATA Database. Hydrological data are stored in Hydras Pro software and in Excel sheets. Input format of meteorological and hydrological data is MIS. Output format is CSV and XML. Data input/output procedures are automated, some of them with advanced graphical functionality.

**Meteorological forecast products**

Some meteorological forecast products are provided by the Institute of Hydrometeorology and Seismology and some are derived from ECMWF. Sea water level forecast are not provided by the NMHS. Precipitation forecast maps (rainfall accumulation), as well as air temperature and other weather elements are available with 3 hours’ time step and in GRIIB data file from ECMWF (high resolution for limited area). Prognostic meteograms and maps from the ECMWF ensemble numerical system are used as ensemble products with 3 hours’ time step.

**Hydrological models and forecasts**

Currently basin scale models are not used for hydrological forecasting. They are only used as the tool for generating added value for operational forecaster in emergency situations. These models are in the phase of improvement.

There are several regional EWSs implemented in Montenegro:

- **EFAS** (the whole territory of Montenegro is covered);
- **SEEFFGS** (the whole territory of Montenegro is covered);
- **Panta Rhei** hydrological model (developed by Technical University in Braunschweig, Germany), funded by GIZ Project is implemented for the transboundary Drim - Bojana river system catchment (the basin is shared by Republic of North Macedonia, Albania, Kosovo (UNSCR 1244/99), and Montenegro);
- **Wflow** hydrological model (developed by Deltares throughout project of International Sava River Basin Commission financed by WBIF) is implemented for the Sava River Basin catchment.

Only short to medium lead time flood alerts are issued.

Consistent flood forecasting services levels are maintained across all catchments in Montenegro.

End users and their requirements are both prescribed by the legal regulations and is dealt by the Directorate for Emergency Management of Montenegro. User needs are understood but not well documented.

**Flood forecasting products**

Threshold-based flood alerts and flood forecasts are being issued. Service varies across catchments but all catchments are covered. Generation of Flood risk map products is not applicable – no flood maps available. Suite of products satisfy part of the users, not all of them. All products are presented in a
standardized consistent manner to avoid confusion among users. User’s feedback indicate the format is adequate and easily understood. Not all areas have appropriate products to satisfy the users.
North Macedonia

**General context**

North Macedonia is a country where floods and droughts are normal natural phenomenon, which can occur on all territory of the country. Evidence of floods exist from ancient times, but also from last century till today. There are three main river basins in the country: The Vardar, the Strumica and the Crn Drim river basins. The most severe floods occur on the Vardar river; catastrophic floods were observed in 1916, 1935, 1937, 1962, 1979 with catastrophic outcomes. Following important cities may be flooded: Tetovo and Polog Area, Skopje and Skopsko Pole, Veles, Gradsko Area, Gevgelija Area). Mainly River Vardar and surrounding areas where affected by floods, but also smaller tributaries were affected as well (significant damage occurred). Many cases of flash floods occurrence were registered near the following cities: Negotino (06.07.1995), Radovish (04.12.2008 with two casualties), Shipkovica and Tetovo (03.08.2015, 6 casualties), Skopje and Stajkovci (06.08.2016, 23 casualties). The most flood prone areas in the Vardar River are the following:

- upper part of the River Vardar;
- Polog;
- Middle part of River Vardar;
- Skopsko Pole;
- Veles, Gradsko;
- Demir, Kapija;
- Lower part of River Vardar;
- Gevgelija and Valandovo Area;
- tributaries Crna River;
- Pelagonia Area, Borotinsko Blato flat Area, Upper Part of the River Crna;
- Treska River upper part of the catchment above Makedonski Brod town;
- Kumanovo town and surrounding areas;
- Surrounding areas upper Bregalnica Catchment, middle and lower part of the catchment.

The heaviest events of precipitation occur during November – January, and April - May. Those are the periods when heavy rainfalls and snowfalls occur and affect all basin’s area. Snowfalls happen from November till March, and snow melting process occurs from November till May (depends of area and altitude). Floods of mixed origin (heavy rain and snowmelt) occur from November till March. Rainfall induced floods occur in November and May. Flash floods occur during any period of the year, but the most devastating flash floods happen on small catchment during summer time.
Grappoanalytical method has been applied since 70-s to forecast floods before construction of the dams in the Vardar river basin. Later in 70-s and 80-s, some basic flood EWS existed, which covered the whole area of the country, but now it is not operational any more. In the present time Crisis Management Center and Protection and Rescue Directorate with the help of Hydrometeorological Service of North Macedonia are trying to develop new EWS for flood forecasting (however there are several obstacles, including absence of the complete hydrometeorological network of automatic stations and absence of risk and hazard maps). In the present time there is no modern hydrological model used in the basin.

User needs are collected but not documented in an official report. The hydrometeorological service of North Macedonia provide short and long time alerts, it is a continuous service.

There is a well-defined national/subnational legislation with clear functions covering the area of flood early warnings – Law on hydrometeorological activity (Official Gazette of the Republic of Macedonia, No.103, from 19.08.2008).

**National Meteorological and Hydrological Service**

There is merged NMHS in the country – Hydrometeorological Service of North Macedonia. Weather forecasts and Alert Department of Hydrometeorological service detect potentially adverse weather events and issue alerts in 24/7 mode. During the period of adverse weather conditions, they are continuously informing with additional information about the weather.

Hydrological Sector of the NHMS has responsibility to collect data from hydrometric network (13 stations in the Vardar river catchment once per day), process the information, and spread the informational products to Ministries, as well as Crisis Management Center and Protection and Rescue Directorate, general public and media. In case of extreme flood event, several additional informational products are made and spread during a day. Additional information on reservoirs releases is received during the flood event.

Hydrological sector operates during day hours but evening/night shifts only used when needed (during extreme flood event).

**Cooperation and coordination between national institutions and transboundary institution**

Concerning the Vardar river catchment EWS is not operating in a transboundary context – there was no special agreement concerning this issue neither with Serbia (Pcinja river catchment on Serbian side), nor with Kosovo (UNSCR 1244/99) (Jelashka river catchment is partly in Kosovo (UNSCR 1244/99)), but informal cooperation is on very good level. There is a strong need in Memorandum of Understanding with Serbia, Kosovo (UNSCR 1244/99), and Greece, as well as links to their data. Concerning information from North Macedonia to Greece, in case of high water levels, Hydrometeorological Service of North Macedonia informs Greece Embassy in Skopje.

There is occasional sharing of experience, data and products with Academia mainly during conferences.
Roles and responsibilities of staff involved in the Service are documented but not updated – there is not enough hydrologists to perform their duties. SOPs are documented but updated long time ago.

Incident Management policy and procedures – manage incidents informally with best efforts. No quality management handbook or documented procedures, used in the Hydrometeorological service of North Macedonia.

Institutional agreements on data sharing among different ministries/ agencies/ data sources

In the Vardar River Catchment - there is no transboundary data sharing policy, legal framework or agreements among countries and institutions.

Observations and data acquisition

Maintenance and sustainability of networks – some aspects of the network(s) are maintained, some key ones are not due to budget issues. There is a medium level of reliability of data transmission, statistics and backup paths are available. Some risk of vandalism exists (mitigation measures are in place).

Some tributaries have hydrometric gauges at outlets, other important parts of the Vardar river do not have gauges. Large number of hydrometric gauges have low frequency of measurements (once a day) and once a month transmission. The majority of stations are staff gauges. Some of the basin’s stations have missing verification checks (verification of majority of stations is done 3-4 times a year). Information about equipment used at hydrometric stations can be found in the survey (Attachment 10).

Rating curves maintenance is an issue: there is a lack of streamflow measurements (especially during the period of 2010-2015) to effectively update the curves. In the result there is an absence of ratings at important gauges.

There is a good coverage and distribution of meteorological stations in flow formation areas. However, in mountainous and urban areas there are significant deficiencies in rainfall observations – a lot of mountainous catchments are without stations. Significant number of the basin's meteorological stations (table in Appendix 4) are not real-time stations with once a month frequency of data transmission. Calibration regime of both hydrometric and meteorological equipment used is traceable and regular, according to WMO or equivalent standards (not more often then 3 -4 times a year).

There are two weather radars installed, but their usage is very limited due to lack of calibration and adjustments to ground measurements.

Transboundary data are not available as there are no data sharing policy developed and signed (see above).

Snow measurements are performed regularly at two stations (snow depth, weigh, calculation of SWE are measured/calculated). Snow cover and depth are measured at 19 meteorological stations every day during the period when snow cover exists.
There is significant manmade effect on river flow as there are six reservoirs (table 4) in North Macedonia (five of them are within the Vardar river basin). Reservoir data are received only two times a month, and on daily basis during a flood event.

Table 4. – Information on dams, located in the Vardar river basin

<table>
<thead>
<tr>
<th>№</th>
<th>Dam</th>
<th>River</th>
<th>Nearby town</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Crown</th>
<th>Spillway</th>
<th>Operator</th>
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<td>Mavrovská</td>
<td>Gostivar</td>
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<td>20.746</td>
<td>1236</td>
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<td>ELEM</td>
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<td>Treska</td>
<td>Skopje</td>
<td>41.878</td>
<td>21.193</td>
<td>449</td>
<td>-</td>
<td>ELEM</td>
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<td>Treska</td>
<td>Skopje</td>
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<td>EVN</td>
</tr>
<tr>
<td>5</td>
<td>Kalimanci</td>
<td>Bregalnica</td>
<td>Delcevo</td>
<td>41.973</td>
<td>22.581</td>
<td>520</td>
<td>515</td>
<td>ELEM</td>
</tr>
<tr>
<td>6</td>
<td>Tikves</td>
<td>Crna</td>
<td>Kavadarci</td>
<td>41.403</td>
<td>21.938</td>
<td>269</td>
<td>265</td>
<td>ELEM</td>
</tr>
</tbody>
</table>
Figure 8. – Observational networks (hydrometric and meteorological) in the Vardar river basin, and reservoirs in North Macedonia

**Historical and ancillary data**

Hydrometeorological Service of North Macedonia is responsible for data archiving. Complete metadata exist for hydrometric, as well as meteorological stations are available with, coordinates, equipment type, and possible instrument(s) change and other.

Hydrometric data time series are of long duration, however there are some significant gaps (there were no measurements from 2010 to 2015). Format of data series is mainly in paper.

Meteorological data series (e.g., precipitation and temperature) are of reasonable duration - from beginning of 90-s for majority of stations, without significant gaps and breaches in stationarity; available mostly in digital format.

There is no MAP product available (ever produced) in North Macedonia

River cross-sections are not available.

Historical information on rating curves is not available for majority of stations.

Some global spatial datasets are used in operational hydrology studies.
Impact data, such as vulnerability and exposure data, and etc. are available for key locations in the country.

Historical information and traditional knowledge are only applied to a few locations and used for analyses such as flood frequency determination.

Historical data on reservoir inflows, storage and outflows are available with reasonable duration (however there are significant gaps), mainly in paper format. Reservoir operation rules (historical and present) are available for large reservoirs.

Time series of snow data (depth, cover, SWE at several locations) are available.

Hydrometric transboundary (both historical and real-time) data are not available

Combined sewer and storm water (drainage) systems data exist in water enterprise companies.

There are spatial data in use for urban areas, including Digital Elevation Model (DEM), topographic and land use/cover data.

**Data management**

Real time and historical data from automatic stations (both hydrometric and meteorological) are presented on Internet module for public. The data are raw and stored in DEMAS Data Base System. Historical Data are in Excel files. Hydrometeorological Service Database System (*HydroPro*) is not functioning, there is a shift now to MCH Database System.

Data ingestion procedures are partially automated. Most of the data ingestion is done manually. Some data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures.

Records and documents are stored digitally according to protocols developed by the Hydrometeorological Service of North Macedonia. Most of procedures are automatic. Access to records and documents is available by ftp or http clients. *MCH* Database procedures are being implemented.

Historical data QA/QC procedures have been implemented to some of the data, but main problem is the lack of engineers that are needed to perform their duties. Some part of the ingested real-time data is subject to QA/QC procedures. Mainly manual procedures following properly documented protocols are used as QA/QC methodology.

Databases used are *Demas* database (for data measured at automatic stations), and MCH Database. CSV format is widely used in the Service.

**Meteorological forecasting products**

There is Forecast and Alert Department in the NHMS of North Macedonia, which is responsible for issuing weather forecast. Deterministic forecasts of main meteorological elements are maps are
available only as image products and not in the preferred time step. Outputs of several deterministic NWP models are used as probabilistic forecasts.

**Hydrological models and forecasts**

There are no models developed and implemented in the moment (including rapid-onset events forecasting and warning). Graphoanalytical method is used, based on historical rainfalls and river discharges data. Forecast lead time is 1-2 days. Method is half automated and depend of available data. There is no systematic forecast performance. Output updating is performed manually.

**Flood Forecasting Products**

Many catchments are not covered with forecasting products but some of them, especially in high risk areas are covered with hydrological forecasting products. There is a lack of products for the forecast horizons most needed. Available products are presented in a standardized consistent manner to avoid confusion among users. Formats are adequate, but for some users maybe is not. Not all areas have appropriate products to satisfy the users.
Moldova

General context

The Prut river was proposed for the SEE-MHEWS-A Project, as potential pilot basin for implementing hydrological modelling and forecasting system. The river length is 953 km, basin area – 27500 km². The basin is shared between three countries: Ukraine, Romania and Moldova. The river origins in Ukraine, in Eastern Carpathian Mountains, then flows in east-south direction, forming the border between Republic of Moldova and Romania, then inflows into the Danube river near its mouth. There are two HPPs in the river basin: Stanca-Costesti Dam, operated jointly by Moldova and Romania (built on Prut), and HPP in Snyatyn in Ukrainian part of the river basin.

National Meteorological and Hydrological Service

There is a joint hydrometeorological service in Republic of Moldova – State Hydrometeorological Service of Republic of Moldova (http://www.meteo.md), responsible for both meteorological and hydrological services within the country, including the Prut river basin.

Observations and data acquisition

The hydrometric and meteorological network of Moldova is shown in figure 9 (as well as in the table of Appendix 4). There are two hydrometric stations on the Prut river, at one of them (33885, Cahul) streamflow measurements are performed. There are a number of meteorological stations in Moldova, as well as in the described river basin; all of them are synoptic station with 3 hours’ observation and transmission frequency. Equipment specifications are presented in the table of Appendix 4.

Some tributaries have hydrometric gauges at outlets (Figure 9), other important parts of a river do not have gauges, as well as meteorological stations. Some of the basin’s gauges have low frequency of measurements to describe flood formation process. Some of the basin’s stations have missing verification checks. Calibration of instrument was done prior to service. Equipment is both of manual and automatic type, transmission is near real-time for all stations. Some stations/instruments have inadequate range or accuracy or compromised installations. There is a lack of measurements to update rating curves, as well as absence of streamflow measurements and thus absence of ratings at important locations.

The basin is partly covered by weather radar, but the data are not reliable as it is not adjusted to ground stations.

Transboundary data including streamflow data are received in real time (or near real time).

Snow courses are evenly distribution across the basin (snow depth, density, mass, and SWE are measured/calculated) with 5 days’ collection frequency. Snow courses data are collected by staff.

Reservoir data are described in the survey as adequate.
Figure 9. – Hydrometeorological network of Republic of Moldova, and the Prut river basin

**Historical and ancillary data**

State hydrometeorological service of Republic of Moldova is responsible for data archiving. Complete metadata are available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other. Historical information on rating curves is not available. Spatial data are not used.

There are no vulnerability and exposure data available nationally.
Hydrometric data time series start from the end of 1940-s. The data are available partly in paper, partly in digital form. Synoptic data time series are available from 1950-s, 1960-s for the majority of stations partly in paper, partly in digital formats.

Information on reservoir inflows, storages and outflows is available of reasonable duration, without significant gaps, in both paper and digital format. Both current and previous reservoirs operation rules are available. Time series of snow courses data (snow depth, density measurements) are available in partly paper, partly digital format.

**Data management**

Historical data products are stored in owned servers. Most of real time data and products are readily available at the start of the forecasting session. Data and products are available in a timely fashion.

**Meteorological forecast products**

Meteorological forecast products are all provided by the National Hydrometeorological Service of Moldova. Meteorological elements forecasts are available only as image products and not in the preferred time step. NWP models used to generate forecast products are: GFS, UK MetOffice, DWD, COSMO, Alaro, ARPEGE. These models are used to address probabilistic forecast issue (multi model approach).

**Hydrological models and forecasts**

There is a rainfall-runoff model in use (no details are given in the survey), which is considered to be appropriate, but should be improved - performance metrics are being met most of the time. Appropriate time step is used. The model can be run twice a day. Model calibration/validation is reviewed only if a problem arises. There is a program executed monthly that provides statistics on performance. Output updating is performed manually.

**Flood forecasting products**

No flood maps are available. Suite of products satisfy part of the users, not all of them. All products are presented in a standardized consistent manner to avoid confusion among users. User’s feedback indicate the format is adequate and easily understood. All products provided satisfy the timeframe required by users.
Slovenia

Representative of ARSO noted that all Slovenian river basins are covered with the national flood forecasting system, and that ARSO and end-users are fully satisfied with existing flood forecast products, thus there was no intent from the ARSO to propose one of Slovenian rivers for the pilot forecast system development. For this reason, only Institutional setting section was filled out. It was also mentioned, that ARSO have recently prepared a comprehensive report about the Slovenian Hydrological service (Evaluation report on flood and ice forecasting systems and methodologies in the Danube countries, 2019).

General context

There is a well-defined national/subnational legislation with clear functions covering the area of flood early warnings. The most significant damages happen mostly within the Sava river Basin (the cities of Ljubljana and Celje). Mostly torrential rainfall causing rapid rise of the river streams. The time interval of the observable causative event and the flooding for each location is typically greater than 6 hours.

There is an adequate EWS for flood forecasting developed and operational for all important locations. The basin based forecasting system are developed and operative within ARSO. All river basins are already covered with the forecasting system.

The most important end user or the flood forecasting system is within the same institution - the national hydrological forecasting service. The needs of the flood forecasting system end users are known.

The flood forecasting service provides short and long time alerts; it is a continuous service.

National Meteorological and Hydrological Service

NMS and NHS are merged into a single institution – ARSO. The meteorological section of ARSO provide NWP forecasts for the flood EWS as well as daily consultations for the hydrological section on the approaching weather events. The role of hydrological section of ARSO is development and maintenance of the flood forecasting system, issuing bulletins and warnings within the framework of the national EWS for floods and flash floods. Roles and responsibilities of ARSO are well defined.

Cooperation and coordination between national institutions and transboundary institutions

Flood EWS is operating in transboundary context for the Mura river, partly for the Sava river (some casual international sharing of data/products, is in place), but not for the Drava and the Sava rivers. This is conditioned by the relevant institutions decisions within the transboundary basins. There are different levels of interest between the relevant authorities and the academia.

Monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS is not happening.
ARSO is operating with fix organizational structure. SOPs and Incident Management policy and procedures have been recently updated in 2019. There is QMS team established, which assesses performance of the system.

*Institutional agreements on data sharing among different ministries/ agencies/ data sources*

There is a local/national data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed. There is a transboundary data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).
Ukraine

**General context**

The Dniester river basin (Ukrainian part) was proposed for the SEE-MHEWS-A Project. The river length is 1352 km, basin area – 72100 km². It originates in Carpathian Mountains in Ukraine, then flows in south-east direction across Moldova (around 660 km and one third of the basin are in Moldova) to Ukraine again, where it finally inflows into the Black sea. There are two significant HPPs located in the river basin: HPP Dniester (Ukraine, near Novodnistrovsk city in Ukraine), and HPP Dubosari (near Dubosari city in Moldova).

Rain, snowmelt, and reservoir operations are the main sources of floods. Both flash flood (in mountainous areas in upper part of the river) and riverine flood occur in the river basin. They often cause significant damage to a number of big cities in Ukraine (especially, Lviv, Ivano-Frankivsk, Transcarpathian regions), as well as in Republic of Moldova.

In the moment basin scale flood forecasting system composed of physically based and statistical models connected with local terrain information is used to issue flood forecasts and warnings. However, it needs to be improved, especially taking into account, that the highest risk catchments remain uncovered with flood EWS.

**National Meteorological and Hydrological Service**

NHS and NMS are merged into the single institution – Ukrainian Hydrometeorological Center (UHMC). Synoptic forecasts department issue a warning about precipitation to hydrologists, which then use this information for flood forecasts generation. The roles and responsibilities of NMS are well defined. Role of NMHS – storm warnings, informing consumers, assessing the risks of flooding. Daily operations of supporting the flood EWS are always during day hours but evening/night shifts only used when needed (during severe flood event).

**Cooperation and coordination between national institutions and transboundary institutions**

The flood EWS in the Dniester river is working in transboundary context. Some casual international sharing between Ukraine and Moldova institutions is in place. There is no significant knowledge sharing with academia or research institutes, only providing them archive data for scientific research. There are monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS. UHMC have performed well during recent severe events and have established surge capacity and procedures. Roles and responsibilities of staff involved in the service, as well as SOP are documented but not updated often. Incident Management policy and procedures use principles of Incident Management but not formalized in policy. No Quality management handbook or documented procedures are developed so far.

**Institutional agreements on data sharing among different ministries/ agencies/ data sources**
There is a local, national, as well as transboundary data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed.

*Observations and data acquisition*

According to provided information in the Appendix 4 there are 32 hydrometric stations, operating in the Ukrainian part of the Dniester river. In general, the basin is well covered with hydrometric stations (Figure 10), however there are some important parts of a river do not have gauges. All of the gauges are manual stations with twice a day measurements. Discharge is regularly measured at almost all stations (28 stations). Rating curves are well maintained (regularly updated), ratings are available for all important stations (gauges). Transmission frequency of operational data is once a day (every morning).

![Figure 10. – Hydrometeorological network in the Dniester river basin](image)

There are 18 synoptic station in the basin, which measure and transmit every 3 hours. Stations are equipped with manual measurement instruments. Some of a river’s catchments in flow formation area have few or no precipitation and temperature measurements. There are mainly manual stations.

In terms of operational data transmission there is a high level of reliability, statistics and backup paths available. Data verification frequency is fully adequate. Calibration regime of both hydrometric and meteorological stations were done prior to their service. Some stations/instruments have inadequate range or accuracy or compromised installations.
There is very limited usage of weather radars in the basin due to lack of calibration/adjustments.

Coverage of operational sea level stations in the coastal area of the Dniester river is considered to be poor.

Transboundary data are available, but sometimes with delays.

Some measurements (snow water equivalence) are available with limited distribution and temporal resolution. Measurements of depth, density, mass are carried out manually every 10 and 5 days in winter.

UHMC provide adequate data for reservoir managers.

**Historical and ancillary data**

UHMC and subordinated regional centers on hydrometeorology, as well as Central Geophysical Observatory named after B. Sreznevsky are responsible for data collecting and archiving.

Hydrometric stations have been operating since the end of 19th century. Data (both synoptic and hydrometric) archives are available since 1885 till present time mainly in paper format. Synoptic data series are available since 1985 till present time mainly in paper format.

Complete metadata for all the stations are available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other information.

Mean areal precipitation (MAP) is available for limited number of catchments based on rainfall gauges only.

Cross sections information is not available. Historical rating curves are not available.

Only globally available spatial data are used. Vulnerability and exposure data etc. are available for key locations.

There is a broad programme to incorporate historical flood knowledge into archives and used for analyses such as flood frequency determination.

Reservoir data (inflows, storage and outflows) are available with reasonable duration, without significant gaps, in both paper and digital format. Reservoir operation rules (historical and present) – both current and previous rules are available. Snow data archives availability with depth and density data. Snow course metadata are not complete (absence of coordinates of some stations, meteorological station height, etc.). Transboundary data are not available in historical context.

Metadata for sea level stations are limited in information. Sea level data are of limited duration, in partly paper/partly digital format.

**Data management**

The section of the river basin survey was not filled in.
**Meteorological forecast products**

The section of the river basin survey was not filled in.

**Hydrological models and forecasts**

Different entities (regional centers) of UHMC provide hydrological forecasts. Forecast efficiency is appropriate, but should be improved. All models, used within the existing flood forecasting system are appropriate, but they should be improved. Flood forecast lead time is 1-2 days. Appropriate time step is used. There is no ability to address uncertainty so far. Models are calibrated and validated only at setup. Forecast performance is tracked only during a major event. Output updating is performed manually.

**Flood forecasting products**

Following flood products are issued: threshold-based flood alert, flood forecasting (discharge and water level), inundation forecasting. There are consistent services levels across all catchments. No flood maps are available in the moment. The suite of products is adequate to serve all user's needs and forecast horizons requested. Some of the products are standardized. User's feedback indicate the format is adequate and easily understood. All products provided satisfy the timeframe required by users.
The pilot river basin

One of the goals of the current phase of the SEE-MHEWS-A Project is the development and implementation of flood forecasting and EWS for one of the river basins, proposed by the countries-members of the Project (description of the existing observational, data management and flood forecasting capabilities is given in the previous chapter of the report; SEE river basins surveys are given in Attachments 1-12). This chapter describes the pilot basin selection process.

There were following selection criteria developed and taken into account while selecting the pilot river basin:

1. **Strong need**: There should be a strong need in hydrologic forecast system development and implementation, which can be estimated as existence of flood prone areas in the basin without coverage of the effective flood forecasting system (complete absence or simple level of existing hydrological forecast capabilities, which do not meet the requirements of major end-user’s). The system, which is going to be developed and implemented in a pilot river basin, should strongly demonstrate the abilities and benefits of entire system.

2. **Data**: Existing hydrometeorological and ancillary data availability should meet requirements of flood forecasting system. There should be adequate level of spatial observational coverage of the proposed river basin(s), availability of both measured and calculated (e.g. discharge) hydrometeorological elements, historical data availability, reservoir data availability (if applicable), transboundary data availability (if applicable), presence of other ancillary data (e.g. spatial data sets).

3. **IPA country**: the basin should be located within an “IPA-country” (due to project being partially funded by EU through the Instrument for Pre-Accession Assistance (IPA));

4. **Transboundary**: transboundary river basin would be a benefit, as in this case the system will be able to demonstrate the possibility of operation in the transboundary context, which will be reached through strengthening the cooperation of transboundary institutions in terms of data, products, and expertise sharing;

5. **Reservoir**: Reservoir(s) in the river basin would be a benefit, as in such a case the system will be able to show successful cooperation between NMHS (or NHS) with Water resources management institutions, which is very important for successful operation of a flood EWS and not often the case.

Criteria 1, 2 and 3 from the list above must be met (obligatory criteria), while criteria 4 and 5 are not obligatory; however, they give additional points to a basin while the selection process, as transboundary and reservoir’s operation aspects of a basin increase the demonstration strength of entire potential flood EWS system. All proposed river basins were analyzed according presented criteria and information,
provided in the river basin surveys. The analysis is given below for each river, proposed by the countries. Summary is given in table 5.

**Drin river**

1. There are significant flood prone areas in the river basin especially in the low course of the river – near the area of confluence of the Buna River and the Shkoder (Skadar) Lake. Floods are caused by rainfalls of high intensity, sometimes combined with snowmelt and dam releases (which additionally causes backwaters effect near the Shkoder/Skadar Lake). The river basin flood forecasting capabilities are of significant scope of several international projects, though which there were observational network improved and some flood forecasting capabilities implemented (hydrological model together with reservoir model). The basin is also covered with two regional flood forecasting systems: **EFAS** and **SEEFFGS**. It is considered, that flood forecasting capabilities of the existing systems could be significantly improved after solving the real-time data issues (see №2 below), performing models calibration, adopting flood alert levels at all flood prone sites, as well as developing and following SOP in the area of flood forecasting and warning. Adriatic Sea influence on the river regime in the mouth areas should be investigated, and in case of significant influence additional observational and modelling capabilities should be established and installed (including additional sea observational stations, sea level forecast system);

   Thus, the is no significant need to start to introduce another flood forecasting system, it will be more efficient to bring existing basin level, as well as regional flood forecasting systems in better shape – models recalibration (based on the improved input data) should be introduced, EFAS model calibration/validation procedures should be performed.

2. The observational networks seem to have following deficiencies, which should be addressed:

   — all automatic stations have not been maintained since their installation in 2013-2014, the process of stations’ rehabilitation is highly required;

   — rating curves have not been updated since 2007 – existing curves are developed with using 1992-2007 data, thus calculated streamflow values cannot be considered as reliable (due to significant river bed transformations);

   — there are a large number of manual stations (both hydrometric and meteorological), which do not transmit data in real-time; bringing at least part of them into real-time mode will be of significant use for real-time flood monitoring;

   — stations coverage should be increased (especially in mountainous areas): hydrometric stations coverage could be improved especially in tributaries of the Drin River (those inflowing into the cascade of reservoirs) and the Vjosa River basin (especially Shushica River Carcove River – near the border with Greece). The coverage of the meteorological
stations could also be improved: by installing stations in mountainous areas, introducing measurements of snow cover and depth, as well as solar radiation. The meteorological stations from the GTS list cover only main cities of the country.

Reservoir data provision in operational mode on a daily basis should be agreed, so that IGEWE receive real-time values of outflows, inflows, reservoirs water levels. Rules of HPP operations, as well as other relevant information should also available.

There are a number of international projects, going on in Albania, which will hopefully improve situation with real-time data acquisition – e.g. stations’ rehabilitation, introducing of streamflow measurements, as well as rating curves updating, etc. In the moment existing real-time data are inadequate for efficient flood forecasting system implementation.

3. Albania is in the IPA countries list.

4. The Drin River is a transboundary river – it flows along North Macedonia, Kosovo (UNSCR 1244/99), Albania and Montenegro, discharging its waters into the Adriatic Sea, in the north of Albania.

5. There is a cascade of reservoirs on the Drin river. Dam releases contributes to flooding in the downstream of the river. There is a lack of operational data from HPP operators (KESH) – only during severe flood events, as well as information on operational rules of reservoirs’ regulation. Agreement between IGEWE and KESH should be reached in order to supply these data on a daily basis to flood forecasting system.

At this stage of the project the Drin river is not recommended to be selected as the pilot river basin, as criteria 1 and 2 are not met.

**Dniester river**

1. There is a strong need in efficient flood forecasting system in the Dniester river basin – especially in the upper part – where the river and its numerous mountainous tributaries flow across significant cities of Ukraine (regional capital cities). It was reported that so far there is no efficient flood EWS implemented in the basin – existing flood forecasting techniques must be updated, and preferable flood forecasting model(s) should be developed and implemented. The highest risk catchments remain uncovered by flood EWS. The river basin is shared by Ukraine and Moldova (middle to low parts of the basin). However, the most flood prone areas, indicated in the SEE survey, are located in the upper part of the basin, which fully belong to Ukraine.

2. The upper part of the Dniester river basin (Ukraine territory) is evenly covered with hydrometeorological observations, there are discharge measurements at almost all (28 out of 32) hydrometric gauges’ locations and thus streamflow data available in near real-time mode. Hydrometric stations are manual stations with twice a day measurements and once a day (in the morning) transmission, which can be considered as an obstacle to monitor and issue forecasts
for mountainous flashy events, which tend to generate and occur within several hours after heavy rainfall. Meteorological stations have synoptic measurement program – observations and transmission are carried out every 3 hours (rainfall is measured every 12 hours). Some mountainous catchments are not covered with meteorological observations.

3. Ukraine and Moldova both do not belong to the “IPA-countries” list.

4. The Dniester river is a transboundary river (middle part of the basin is in Moldova), the data availability in Moldova part of the basin is under question as the information was not provided (Moldova proposed the Prut river basin). There is a transboundary data sharing policy, using interoperability standards.

5. There are two significant HPPs located in the river basin: HPP Dniester (Ukraine, near Novodnistrovsk city), and HPP Dubosari (near Dubosari city in Moldova). Reservoir data (inflows, storage and outflows) are available in real-time mode, and also historically with reasonable duration, without significant gaps, in both paper and digital format. Reservoir operation rules (historical and present) – both current and previous rules are available.

The Dniester river basin meets almost all criteria – it is lacking efficient flood early warning system, the data can be considered to be sufficient (however more frequent measurements in mountainous catchments are required), there are several reservoirs, and the river basin has transboundary context. The only formal criteria (3 – IPA) is not met, which is obligatory at this phase of the project. The river basin should be considered to be selected for development flood EWS on the latest stages of the SEE-MHEWS-A Project.

**One of the rivers in Greece**

1. There are several areas indicated as the most flood prone areas (including area of the Attic peninsula). The Greece is very affected by flash flood events – the regional system BSMEFFGS is used to support flash flood warning issuance. There are some basin scale modelling and forecasting capabilities, but still many catchments uncovered with hydrological modelling and forecasting.

2. Data availability (as in general for the country) is considered to be sufficient for potential flood forecasting system development and implementation. There are sufficient real-time hydrometeorological observations across the country, as well as radar outputs (which are used together with rainfall gauges to produce MAP for major river catchments), there are updated cross-sections available with adequate spacing for most of important sections of main rivers, as well as other important hydrometeorological and ancillary data.

3. The Greece is an EU Member state.

4. There are several river basins in Greece, which share their basin area with Albania and North Macedonia.
5. Information on reservoirs were not provided in the SEE river basin survey, however it was mentioned in the SEE survey, that data exchange with reservoir managers is effective.

Criteria 1 and 3 are not met, thus at this stage the Greek’s river basin cannot be recommended to be selected as the pilot river basin at this stage of the Project.

**Jordan river**

1. The Jordan Valley, as well as different places in the basin significantly suffer from flash floods. BSMEFFGS is operationally used to support flash flood warnings issue. It was not clear from the SEE survey what is the real need in terms of development/implementation of the flood EWS.

2. The state of the Jordan river basin (which includes its major tributary – the Zarqa river) data availability is not obvious – information only on meteorological network design and features was provided. There was no information provided on hydrometric network conditions. However, it was mentioned, that majority of hydrometric gauges are not supplied with calculated rating curves, or ratings were updated long time ago. The Jordan river is transboundary river, however, there is no data/products sharing in place across international boundaries in the moment.

3. Jordan does not belong to the list of IPA countries.

4. The basin is transboundary – hydrometeorological data availability, as well as the state of flood EWS within Israel, Syria, and State of Palestine is considered to be unavailable. It can be considered as a serious deficiency in terms of flood forecasting system development and implementing.

5. There was no information provided on existing reservoir(s) and reservoirs’ data availability.

There are significant obstacles in selecting the Jordan river for the pilot flood forecasting system implementation: there is a serious lack of observational, transboundary, as well as historical data. (criteria 2 is net met), Jordan is not in the IPA countries list (criteria 3). Thus it is not recommended to select this basin as the pilot river basin at this stage of the Project.

**Kamchia river**

1. The river basin is prone to flooding in the areas near to the coast of the Black sea (in particular several municipalities in the district of Varna). There is no basin level hydrological model applied or used in the Kamchiya river basin. Regional flash flood warning system BSMEFFGS is the only system, which is used to assist in generating flash flood alerts. More longer-term lead time forecasts of riverine floods are highly required by end users.

2. Information about hydrometric network features was provided in the river basin survey. More hydrometric stations are required in the middle part of the river basin – there is only 1 hydrometric station in meddle/lower part, which is far not enough for successful implementation of riverine forecasting techniques. All existing hydrometric stations observe
streamflow, and thus have updated rating curves. All of them are near real-time stations. There is no information on spatial distribution of meteorological stations across the river basin, thus it is impossible to estimate the data availability in terms of operational rainfall data. Regarding ancillary data – it should be noticed, that availability of real-time data from HPP (reservoir(s)) should be increased, as mentioned in the SEE survey.

3. Bulgaria is EU member country.

4. The Kamchia river basin is fully within Bulgaria borders, there is no transboundary aspect in terms of this basin.

5. Information on existing reservoir(s) was not provided in the survey, however it was noticed, that availability of information on reservoirs (both real-time and historical, as well as regulation rules) should be improved.

The Kamchiya river basin could not be selected as the pilot river basin at this stage of the project, as the obligatory criteria 2 and 3 are not met.

Marcal river

1. The river is tributary of the Raba river, which inflows into the Danube. The part of the survey regarding existing flood forecast system shows that there are some modelling and forecasting capabilities in place already (based on local basin analysis), which are used to derive flood alerts for short-term period of time. It was noted, that flood EWS should be improved. Information on damage centers in the Marcal river basin were not provided in the SEE.

2. The observational network seems very sufficient for implementing the modelling and forecasting system – there is a good spatial coverage of station, many of them provide streamflow information (rating curves are well maintained) – it should be mentioned that the density of stations for relatively small river basin as very promising. Existing observational data together with existing ancillary data (cross-sections, detailed spatial data) will definitely allow developing and implementing sophisticated modelling and flood forecasting system, for the Marcal river basin.

3. Hungary is EU Member state.

4. The Marcal river basin is fully within Hungarian borders, there is no transboundary aspect in terms of this basin.

5. No information was provided about reservoirs in the basin.

Taking into account current criteria for the selection (criteria 1 and 3 are not met), it is not recommended to select the Marcal river basin as the pilot river basin for the 2-nd Phase of the Project. However, the river has very high potential to be selected for the flood forecast system implementation on a later step of the SEE-MHEWS-A Project implementation.
The Neretva river basin is transboundary river basin – it is shared by Bosnia and Herzegovina and Croatia (coastal part of the basin). The basin was proposed by both of these countries, which indicates the importance of improving/implementing flood forecasting capabilities in this basin. There is a strong need in development and implementing efficient flood forecasting system in the river basin – Bosnia and Herzegovina (main part of the basin) suffer from floods of mixed origin (riverine, flash-floods, dam releases), as well as coastal areas of the basin in Croatia suffers from coastal floods (freshwaters from the main river reach significantly influenced by HPP releases meet sea waters from the Adriatic Sea) and typical urban flood issues in coastal cities, as sewage system sometime is not capable to absorb heavy rainfalls. Existing flood EWS capabilities should be substantially improved in both countries. There is no basin level system developed in Croatia (only regional SEEFFGS and EFAS, which is not very effective due to lack of adaptation to the local hydrological conditions, including the influence of HPPs (there is no agreement between Croatia and Bosnia and Herzegovina developed on data and products exchange), as well as complex terrain of the coastal area of the Croatian part of the Neretva river basin. The river is significantly influenced by karstic processes, which is vital to take into account while developing flood forecasting models/techniques for the river basin.

The data availability differs across the basin – some parts of the basin are nicely covered with hydrometric and meteorological stations, while other parts of the basin suffer from lack of observations. The largest gaps in terms of operational data availability is absence of data exchange in transboundary context (no data sharing agreement in place between Croatia and Bosnia and Herzegovina), not enough of coastal data (to reflect coastal flooding), absence of discharge measurements in downstream part of the river; there are nine reservoirs in the basin and real-time data are not available on a daily basis (only before and during the flood event). Cross sections are not updated (coastal areas of the river basin in Croatia), so further work should be applied in this direction.

Bosnia and Herzegovina is an IPA country; Croatia is EU member country.

Neretva river is transboundary river – the basin is shared between Bosnia and Herzegovina and Croatia.

There are nine river basin reservoirs (in Bosnia and Herzegovina part of the basin). Hydrological forecasting services in the Neretva river basin should be substantially improved. The river is significantly influenced by flooding of different origin, as many processes affects flood generation, including rainfall, snowmelt, karst, dam operations (there are 9 HPPs in the basin). There are also coastal processes, affecting the river in Croatian part of the basin (see below), as well as urban issues. Complex basin forecast system should be developed, based on different modelling aspects: routing model of the lower (Croatian part) of the Neretva river, which should be coupled
with hydrologic/hydraulic model(s) of the upper part of the river (under Bosnia and Herzegovina jurisdiction). River modelling system (basin level, or regional one) should be coupled with sea forecast system to be able to take into account sea influence, including “back water” effect. Setup of regional flood forecast system – EFAS –should be adapted to the local hydrological conditions, including the influence of HPPs, complex terrain of the coastal area of the Croatian part of the Neretva river basin. Urban data (including drainage system schematization) and detailed DTM should be available for urban flood (drainage flood) model development/implementation.

Under current project settings (the pilot system should be implemented until the end of 2020) it is not feasible to develop and implement all necessary, actions required for successful implementation of the flood forecasting system for the Neretva river, as the criteria 2 is not met. Thus, at this stage of the SEE-MHEWS-A Project it is not recommended to select the Neretva river basin as the pilot river basin for hydrological modelling and forecasting. However, the river is of great importance to the region, and it is vital to pay attention to the issues of the river on the flowing steps of the Project.

**Prut river**

1. There is a need in flood forecasting system, existing one should be strongly improved. It is not mentioned in the survey where are the damage centers, and what is the real need in the flood forecasting system for the river basin: it was mentioned, that there are some flood forecasting capabilities (a rainfall-runoff model, which should be improved) and that end-users are pretty satisfied with the forecast products, but no details were given.

2. Hydrometric network coverage should be increased: there are only 2 hydrometric stations on the main river, and they are located in the downstream of the river; there are no stations on tributaries. Upper part of the river basin is located in Ukraine, middle part – partly in Romania, and situation with hydrometeorological networks in these countries are not given. Rating curves are not up-to-date, which can be considered as significant obstacle for the development of flood forecasting system.

3. Moldova (as well as Romania and Ukraine) is not an “IPA-country”.

4. The Prut river is flowing across three countries, thus there should be transboundary data/products sharing agreement between these countries in order to develop, implement and run the flood forecasting system. In the river basin survey the state of transboundary data was considered to be adequate, however no additional details were provided, as whether there is exchange on operational data, or data and products, what kind of data and products are shared if so. There was no information provided by either Ukraine, nor Romania – these counties historical and real-time data are required to develop and implement the flood forecasting system in the Prut river basin.
5. There two HPPs in the river basin (one is operated by Ukraine, another one – jointly by Moldova and Romania) – the information on outflows and operational rules was marked as adequate without any other details. It should be revealed further what kind of data are available in real-time mode from HPP managers.

At this step of the SEE-NHEWS-A Project it seems to be too complicated to select the Prut river basin as the pilot for the flood forecasting system implementation, however it can be done on the following stages of the Project, as the river is very important as is shared by three countries. According to data availability criteria (criteria 2), as well as IPA-country criteria (criteria 3) the river cannot pass the selection process.

**Vardar river**

1. There are a lot of flood prone areas in the Vardar river basin, which suffer from frequent flooding – both riverine and flash floods (in small mountainous catchments in summer). Graphoanalytical method has been applied since 1970-s, based on historical rainfalls and river discharges data. Method is half automated and depend of available data. Many catchments of the Vardar river basin remain uncovered with flood forecasting services. There are no hydrological models developed and implemented in the moment (including rapid-onset events forecasting and warning). Definitely, there is a big need in development and implementation of a flood forecasting systems in the proposed river basin.

2. Many hydrometric, as well as meteorological stations are not “real-time” stations (transmit data once a month). Some stations do not measure streamflow, thus discharge data are not available for many sites. Hydrometric stations with near real-time data transmission capability do not perform streamflow measurements, and thus there are no discharge calculated at those locations, which is a serious obstacle in terms of hydrological model development.

   It is highly recommended to upgrade existing observational networks (both hydrometric and meteorological) so that more existing stations transmit observational data in real-time (near real-time) mode, as well as introduce streamflow measurements at important sites to allow accurate rating curves maintenance.

3. North Macedonia is supported by IPA mechanism.

4. The river basin spreads across 4 countries: largest part of the basin area is located in North Macedonia, while several tributaries inflow from territory of Serbia and Kosovo (UNSCR 1244/99). Downstream of the river flows in Greece. Transboundary data are not available as there are no data sharing policy developed between listed countries. There is a strong need in Memorandum of Understanding with Serbia, Kosovo (UNSCR 1244/99), and Greece regarding exchange of operational data and hydrometeorological products.
5. There are five reservoirs in the Vardar river basin, which significantly influence the regime of the river. Data on reservoirs’ operations are available only two times a month, and on a daily basis during a flood event.

Flood EWS is highly required in the Vardar river basin. To develop the effective system several important steps, have to be accomplished, including improvement of existing observational network (e.g. real-time transmission, as well as streamflow measurements introduced), data sharing agreement (between North Macedonia and neighbouring countries) has to be developed in order to make transboundary data available, data on reservoirs’ operations should be available in near real-time mode.

At this phase of the SEE-MHEWS-A Project the Vardar river cannot be recommended as the pilot river basin because data availability criteria (№ 2) is not met.

**Vjosa river**

1. There is a strong need in flood forecasting system in the Vjosa river basin. There is no sustainable flood EWS in place.

2. Existing operational hydrometeorological data are not of sufficient quality, as there is an issue measurement network in Albania, which is not maintained and thus operational data cannot be considered as reliable (there is an ongoing Project in Albania, which will deal with the network restoration).

3. Albania is in “IPA-countries” list.

4. There was no information provided regarding reservoirs in the Vjosa river basin

The Vjosa river basin cannot pass the selection criteria, as there are significant observational data issues in Albania, and thus criteria 2 is not met.

**Vrbas river**

1. The river basin is located within two political entities of Bosnia and Herzegovina: upper part of the river basin is located in Federation of Bosnia and Herzegovina, while the middle and lower parts of the basin – in Republika Srpska). Thus hydrometeorological service of end users within this basin is done by two hydrometeorological services – FHMI and RHMS RS, as well as by two water management agencies. There are a number of flood prone areas near significant cities, located in the downstream of the river (near the Banja Luka area, capital of Republika Srpska and below to the river’s confluence into the Sava river). The river basin has simple early warning system, based on trigger levels at each of hydrometric station. At the moment there is no formal
flood forecasting procedures in place for the river, as well as there are no functionalities used in the basin for flood forecasting.

2. Both real-time and historical data availability can be considered to be on a required level in terms of development and implementation of flood EWS: network coverage is sufficient (however several tributaries remain uncovered by observational networks), data collection frequency is adequate for flood forecasting – 30 minutes. There is calibration plan developed and followed for hydrometric stations. Rating curves are well maintained – majority of hydrometric stations provide discharge information. All stations are operational – they observe and transmit data in near real-time mode (every 30 to 60 minutes).

There is Bočac HPP and reservoir in the middle river. Outflow data are shared only before and during the flood event, however for successful operation of a flood forecasting system operational data on a daily basis (as well as historical data) are needed, which should include: outflow, inflow, water level of the reservoir and near the HPP, rules of operations; thus HPP managers should be included into the data sharing agreement.

As mentioned above there are several entities, which are responsible for observational activities in the basin, operational (as well as historical) data exchange between these agencies should be secured to allow successful implementation of flood EWS.

3. Bosnia and Herzegovina is an IPA country.

4. The river is fully located within Bosnia and Herzegovina boundary – thus, there is no transboundary context. However, there are two political entities within the river basin – Federation of Bosnia and Herzegovina and Republika Srpska – with two different NMHSs, respectively. Building coordination and enhanced cooperation between these two Services will be required to implement the flood forecasting system, and can be recognized to some extent as transboundary issues.

5. Bočac HPP and reservoir operates in middle part of the river.

Above mentioned text evidences that mandatory criteria are met, and thus the Vrbas river basin can be recommended as the pilot river basin for this stage of SEE-MHEWS-A Project.

**Zeta river (or other)**

1. Montenegro is a mountainous country, with rapid river regime, and significant floods of different nature, including flash floods, riverine floods and urban floods. There are a lot of flood prone areas, indicated in the SEE river basin survey, which lack effective flood forecasting and warning service. Currently basin scale models are not used for hydrological forecasting. They are only used as the tool for generating added value for operational forecaster in emergency situations. The Institute of Hydrometeorology and Seismology is making use of some regional products (EFAS, SEEFFGS), as well as transboundary basin flood forecast system, based on Panta
Rhei hydrologic model. It was not described in the survey, but it seems that the models should lack calibration (without discharge data, also this was mentioned in the survey filled in by Albania – as they share the same transboundary basin with Montenegro).

2. Observational networks (both hydrometric and meteorological) seem to have good areal coverage (stations are evenly distributed across the country), however it was mentioned, that some of mountainous areas lack observations.

There is a serious deficiency of hydrometric network: there is an absence of streamflow measurements, which does not allow rating curves updating, and thus calculating discharge on a real-time basis. Historical ratings are available (based on historical streamflow measurements), but for such a mountainous country as Montenegro it is very important to update ratings often. Organization of routine streamflow measurements is a vital step towards improvements of flood forecasting service in the country.

3. Montenegro is in the IPA countries list.

4. Many river basins (especially the largest ones) are transboundary.

5. There are a number of water river reservoirs in Montenegro.

Several important river systems were proposed as potential pilot (basin) for the SEE-MHEWS-A Project. These basins are of great importance, but without accurate discharge information (criteria 2 is not met) it would be difficult to develop and implement efficient modelling and forecasting system for the basin(s) proposed.

Results of the river basins versus 5 criteria analysis are summarized in Table 5.
Table 5. – Proposed river basins versus selection criteria

<table>
<thead>
<tr>
<th>№</th>
<th>River basin(s)</th>
<th>Country</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Strong need</td>
</tr>
<tr>
<td>1</td>
<td>Drin</td>
<td>Albania, Kosovo (UNSCR 1244/99), Greece, Montenegro and North Macedonia</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Dniester</td>
<td>Ukraine, Moldova</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>One of the rivers in Greece</td>
<td>Greece/ potentially neighbouring country(ies)</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Jordan</td>
<td>Jordan, Israel, Syria, State of Palestine</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Kamchiya</td>
<td>Bulgaria</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>Marcal</td>
<td>Hungary</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>Neretva</td>
<td>Bosnia and Herzegovina, Croatia</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>Prut</td>
<td>Moldova, Romania,</td>
<td>+</td>
</tr>
<tr>
<td>№</td>
<td>River basin(s)</td>
<td>Country</td>
<td>Criteria</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>Vardar</td>
<td>North Macedonia, Greece, Serbia, Kosovo (UNSCR 1244/99)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Vjosa</td>
<td>Albania, Greece</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Vrbas</td>
<td>Bosnia and Herzegovina</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Zeta (or other)</td>
<td>Montenegro /potentially neighbouring country(ies)</td>
<td></td>
</tr>
</tbody>
</table>

Performed analysis indicated that the Vrbas river basin can be selected as the pilot river catchment at this phase of the SEE-MHEWS-A Project – there is a possibility to develop and implement a flood forecasting early warning system for this river basin under the current Project settings. If resources are available at this stage of the Project another catchment could be also selected for the pilot flood forecasting system implementation. All other rivers from the proposed river list should be taken into account at the next steps of the Project and considered to be priorities for possible expansion of flood forecasting and early warning system of SEE.
Recommendations

Recommendation, listed below, are based on the information provided in the river basin surveys only. It should be said that there is significant variety in level of flood forecasting capabilities across the region; nevertheless, a number of common recommendations are given in this section.

It should be noted that more detailed and targeted recommendations for each of the proposed river basins in the region should be developed based on more detailed assessment of each NMHS, which can be considered on the next steps of the SEE-MHEWS-A Project.

Organization of flood forecasting service

The legal mandate to issue hydrological forecasts and warnings should be developed and implemented. It is recommended that clear description of hydrological forecasting products, required by a country, as well as its characteristics (types of forecasts, lead-time, issue format, forecasting phenomena, end-users and etc.) should be well described in the ToR of a Service. Chapter D.1.3 of the WMO Technical Regulation Volume III describes different aspects of hydrological forecast and warning services.

Cooperation with other national institutions, involved in the water-related activities, should be clarified. Roles and responsibilities of these institutions, involved in the flood EWS, should be well described (e.g. cooperation between NMHS of NMHS of Bosnia and Herzegovina - Republika Srpska and water agency Vode Srpske are not well defined as there are some overlapping of their activities). It is recommended, that all roles of different institutions, involved in flood EWS, are clarified.

Valid for the river basins: Drin, Neretva, Vjosa, Vrbas

Cooperation with transboundary institutions should be established in several cases. It is highly recommended that transboundary data (and possibly product) sharing agreements should be developed in several cases to let effective exchange of hydrometeorological data and products to support flood EWS development and implementation in transboundary basins.

Valid for: Neretva (Croatia – Bosnia and Herzegovina), Vardar (North Macedonia – neighbouring countries), Vjosa (Albania – Greece)

Sustainability of flood forecasting services regarding different aspects (e.g. staff, knowledge, equipment, software) in several countries is an issue, as there is a persistent underinvestment of the Services.

Observations and data acquisition

Network design should be evaluated in accordance with the requirements of a flood forecasting and warning system (does it reflect data requirements of a flood EWS in a particular part(s) of the basin with respect to major damage centers?). In some cases, it was obvious that there is an absence of required initial observational data (hydrometric, meteorological, as well as snow cover) in some part of river systems, especially in mountainous parts. Additional hydrometric stations should be installed on tributaries of a main river (including especially those inflowing into the cascade of reservoirs).
coverage of the meteorological stations networks should be also improved: by installing stations in
mountainous areas, introducing measurements of snow cover and depth.

**Valid for the river basins:** all basins except for the Marcal

In several countries there is a serious insufficiency in maintenance of hydrometeorological networks.
Automatic hydrometric and meteorological stations were installed with the help of different projects
(supported by the World Bank, EU etc.). After the projects finish there seem to be serious lack of the
networks maintenance – absence of the stations equipment maintenance (including equipment check),
as well as calibration which results in malfunctioning of stations. This results in poor quality of
observational data, which feeds into the flood EWS. For such particular cases supervision of hydrometric
and meteorological observing stations should be arranged according to recommendations of chapter
D.1.1 *Hydrological observing networks and stations* of Volume III of the *WMO Technical Regulations*
(WMO-No. 49): e.g. every station is inspected at least once every six months to ensure the correct
functioning of instruments and maintenance of a high standard of observations and other
recommendations. Inspection of meteorological stations for the purposes of flood EWS should be
arranged in the manner described in 3.1.1 of Part III of Volume I of the *Manual on the Global Observing
System* (WMO-No. 544).

**Valid for:** Drin, Vardar, Vjosa, Zeta or other Montenegrin river

Real-time streamflow calculation with sufficient quality is of vital importance to hydrological modelling
and forecasting (upstream river stage and discharge are the variables, the most required by forecasting
techniques). In many countries of the SEE region, there seem to be a lack of discharge data in terms of:
measurement sites (discharge is not measured at important locations), quality of data (rating curves
require significant update and maintenance). Regular streamflow measurements, as well as technique
for rating curves development and updating should be implemented at important sites.
Recommendations on appropriate organization of streamflow measurements can be found in WMO
*Technical Regulations* Volume III, in Chapter D.1.2 *Observing and reporting programme for hydrological
observing stations*, as well as in Chapter 2 *Methods of observations* of WMO *Guide to Hydrological
Practices* Volume I (WMO-No.168). Extensive material on streamflow gauging and rating curve updating
is given in the WMO *Manual on stream gauging* (WMO-No.1044).

**Valid for the river basins:** Drin, Vardar, Vjosa, Vrbas

There are a number of rivers where significant portion of river flow is generated in mountainous areas.
Thus snow dynamics plays significant role in their hydrological regime. Snow characteristics
measurements which allow snow water equivalent (SWE) calculation is important factor, which can
significantly improve flood modelling during spring melt period. Introducing snow courses
measurements in mountainous areas will increase reliability of flood forecast during spring melt season.

**Valid for the river basins:** Neretva, Vardar, Vrbas
Observational frequency at hydrometric stations in mountainous parts of several SEE river basins should be increased, as now it is considered to be inadequate (for example twice a day) with respect to the speed of flood formation process. Existing frequency may miss flood peaks in between the measurements, which results in inadequacy of operational monitoring, as well as unitization of hydrometric time series in modelling process (as they may not include peaks, which were missed during measurements). It is recommended to consider installation of automatic measurement equipment, which will allow performing frequent hydrological measurements.

*Valid for the river basins:* Dniester, Vardar

There is a significant number of hydrometric stations without real-time transmission of observations. These stations are located at a very sensitive and important parts of the river basin. Adding functionality to transfer observations in real-time (or near real-time) mode will significantly increase the value of observational data from such stations. These data will be of significant importance to flood EWS.

*Valid for the river basin:* Vardar

Vandalism is reported to be an issue in several countries, thus adequate protection measures should be organized and implemented.

*Valid for the river basins:* Drin, Vjosa

Several rivers of the SEE region are exposed to sea influence in the coastal areas, including backwater effect, and classical cases of coastal flooding (of mixed nature – caused by marine and riverine processes) of the cities and towns, located in the coastal areas of the rivers (e.g. Metković town in Croatia). Flood forecasting in the coastal areas are always challenging due to different sources of flooding, and thus data and models, which are required in such areas. Influence of a sea the coastal areas should be investigated, and in case of significant influence marine station(s) should be installed (or recovered) to get sea level observations as boundary conditions for hydrological modelling system.

*Valid for the river basins:* Drin, Neretva, Vjosa

**Historical and ancillary data**

There are a number of water river reservoirs in the rivers of the SEE regions; some of them have reservoir cascades (e.g. Drin, Neretva, Vardar). Real-time dam release data from reservoirs are not available on a daily basis in many cases. Many countries of the region have MoUs with reservoir operators, according to which dam release data (as well as other operational information) are available only during the flood event. However effective operation of flood EWS requires real-time reservoir data on a daily basis, as forecasting approaches, used in operational forecasting, tend to utilize continuous modelling techniques. Data sharing agreement between NMHSs of the countries and reservoir managers should be developed and implemented to make sure following information (both real-time and historical) is available across the SEE region: dam release, inflow (both calculated and forecasted), storage levels, operation rules.
Valid for the river basins: all rivers with reservoirs.

Information on cross-sections is highly required in the areas, where potentially hydrodynamic model can be implemented. In many cases cross-sections were derived long time ago and need to be updated.

Valid for the river basins: Neretva, Kamchiya

Meteorological forecasts and products

Meteorological forecasting products in several cases are available only as image products and not in preferred time step (the rivers: Jordan, Prut, Vardar). Limited number of SEE countries have probabilistic meteorological forecasts (ensembles), thus one of the SEE-MHEWS-A Project’s objectives regarding implementation of ensemble forecasting seem very reasonable.

Hydrological modelling and forecasting

Proposed basins are partly covered with flood forecasting products, but they are based on local basin analysis or simple relationships (developed long time ago). Mostly threshold-based flood alerts are issued. More reliable and sustainable basin level flood forecasting techniques are required, which can operate with utilization of ensemble meteorological forecast products.

Only a few river basins (including the Drin river basin) have flood forecasting system implemented. Existing flood forecasting models were calibrated only at their implementation. Recalibration of watershed models’ parameters might be needed.

Operational forecast performance should be implemented to allow constant monitoring of its quality. Information on operational forecast verification is given in the Guide to Hydrological Practices (WMO-No. 168), fifth edition, 41.3 and 41.3.1.

It is recommended to make sure that all necessary data are available for operation of existing regional flood forecasting systems (e.g. SEEFFGS, BSMEFFGS, and EFAS). In many countries models, which constitute regional systems, remain uncalibrated, which significantly influence their efficiency. Number of countries have reported, that regional models do not account for the specific terrain and hydrological conditions of the focus area. Hence, recommendations touch provision of historical data to support groups of the models, so that calibration is done, as well as all possible information is taken into account in models’ setup. Flood forecasting performance of the regional flood forecasting and warning systems should be introduced.

Valid for the basins: majority of the SEE basins.
Conclusions

Presented report includes description of the river basin survey, developed and implemented in the SEE domain in order to understand current capabilities of the Countries-Members of the SEE-MHEWS-A Project in flood forecasting and early warning process, including overall structure of the Service, data acquisition and management, available meteorological forecast products, as well as hydrological modelling and forecasting techniques.

Criteria for selecting the pilot river basin was developed and described in the report. It is based on the strong need in flood forecasting services in a basin from one hand, and current capabilities of observational networks and data management procedures from the other hand. All proposed river basins for development of the pilot flood EWS have deficiencies in terms of flood forecast products, thus they all indicated strong need in development and implementation of flood forecasting system in all proposed basins. However only the Vrbas river basin met all criteria, required for flood EWS to be developed and implemented on this pilot phase of the SEE-MHEWS-A Project. Other proposed river catchments including river catchments from SEE-MHEWS-A countries that did not at this time respond to the survey will be considered during further phases of the SEE-MHEWS-A project (subject to availability of funds).

Analyzed responses from 12 countries of the region showed variety of current state of flood forecasting and early warning systems. However, there are several commonalities across the countries. Recommendations on what actions should be applied to improve operational flood forecasting capabilities of the NMHSs are given in Recommendation section of the report. It should be noted that more detailed and targeted recommendations for each of the proposed river basins in the region could be developed based on more detailed assessment of each NMHS, which may be considered on the latest steps of the SEE-MHEWS-A Project.
References

- Development and Implementation of International and Regional Flash Flood Guidance (FFG) and Early Warning Systems. Project Brief. Black Sea and Middle East – FFG
- Global Flash Flood Guidance System – Regional Implementation Requirements. South East Europe Region
- South East Europe Flash Flood Guidance System. Forecaster Guide
- WMO. Resolution 15 (Cg-XVI). Establishment of an Advisory Group for the WMO Flood Forecasting Initiative
- WMO. Resolution 21 (Cg-XV). Strategy for the enhancement of cooperation between national meteorological and national hydrological services for improved flood forecasting.
Attachments

There are 13 attachments, which include 13 filled SEE river basin surveys.
Appendix 1. The SEE river basin survey - template

<table>
<thead>
<tr>
<th>General information about basin flood forecasting assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
</tr>
<tr>
<td>River basin</td>
</tr>
<tr>
<td>Institution</td>
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<tr>
<td>Evaluator</td>
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<tr>
<td>Evaluator's incl. e-mail</td>
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<tr>
<td>Date</td>
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<td>Item #</td>
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<tr>
<td>4</td>
</tr>
</tbody>
</table>
| 5 | Is there an adequate flood early warning system(s) for the above mentioned basin(s)? | Adequate system refers to recommended practices and procedures are being followed. For 3 and 5, provide short description (e.g. since when the system has been operational, or during when it was operational) | 1 - No, there has never been an EWS covering a basin or there was a system but it stopped working  
3 - There are some communities with EWSs or such EWSs are not adequate  
5 - Yes, there is an adequate EWS developed and operational for all basins |
| 6 | What approaches are used to provide flood warning in above mentioned watersheds? | Provide brief information (e.g. which partners participated or are participating in the development and implementation of the modelling approaches?) | 1 - None or some local-basin analysis based on monitoring  
3 - Global/Regional system for flood prediction  
5 - Basin-based forecasting systems composed of numerical / statistical models connected with local terrain information |
| 7 | What are the priority areas/basins that would benefit most from having an EWS | Based on the above analysis, a "basin level" survey will be performed for each one. Is there or will there be a consistent level of service throughout the country or a phased approach that prioritizes investments on high risk areas? | 1: Most or all catchments are not covered by Flood EWS  
3: Some high risk areas are covered but most catchments remain uncovered  
5: Consistent services levels across all catchments |
| 8 | Identification of end-users and consultation | Is there documentation regarding the end users and identification of their requirements? | 1: No documentation available regarding user needs  
3: User needs collected but not documented in an official report |
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td><strong>Requirements of end users (in particular decision makers)</strong></td>
<td>5: Users and user needs are documented annually</td>
</tr>
<tr>
<td></td>
<td>Is there an understanding of the requirements of end-users in terms of timeliness, frequency of updates, accuracy of forecasts, minimum period of advance warning necessary?</td>
<td>1: No understanding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: User needs are understood but not well documented</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: User needs are known, documented and reviewed</td>
</tr>
<tr>
<td>10</td>
<td><strong>Provision of longer lead time alert or watch services</strong></td>
<td>1: No. Only short lead time alerts are issued</td>
</tr>
<tr>
<td></td>
<td>Does the NHMS provide early advice of potential flooding allowing emergency responders to prepare early for possible events?</td>
<td>3: Occasionally alerts are provided for longer time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: Yes, the service provides short and long time alerts, it is a continuous service</td>
</tr>
</tbody>
</table>

### 2- Institutional Setting of the National Hydrological Service

#### Organizational framework

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Are the NMS and NHS merged into a single institution?</td>
<td>yes/no</td>
</tr>
<tr>
<td>2</td>
<td>Is there a NMS?</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>What are the roles and responsibilities of NMS for flood EWS?</td>
<td>Provide description</td>
</tr>
<tr>
<td>4</td>
<td>Are the roles and responsibilities of the NMS well defined?</td>
<td>yes/no. Provide information</td>
</tr>
<tr>
<td>5</td>
<td>Are the daily operations for supporting the flood EWS carried out 24 hours per day?</td>
<td>Does the NMS provide, in particular, an around-the-clock service during emergencies? Explain if there are differences depending on days of weeks, evenings, nights, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: Day shifts and weekdays only as needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: Always during day hours but evening/night shifts only used when needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: Continuous 24x7</td>
</tr>
<tr>
<td>6</td>
<td>Is there a NHS?</td>
<td>yes/no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>What are the roles and responsibilities of NHS for flood EWS?</td>
<td>Provide description</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>7</td>
<td>Are the roles and responsibilities of the NHS well defined?</td>
<td>yes/no. if no, provide information about what needs to be improved</td>
</tr>
</tbody>
</table>
| 8 | Are the daily operations for supporting the flood EWS carried out 24 hours per day? | Does the NHS provide, in particular, an around-the-clock service during emergencies? Explain if there are differences depending on days of weeks, evenings, nights, etc. | 1: Day shifts and weekdays only as needed  
3: Always during day hours but evening/night shifts only used when needed  
5: Continuous 24x7 |
| 9 | 4- Cooperation and coordination between national institutions and transboundary institution (as required) |   |   |
|   | Is the E2E Flood EWS working in transboundary context | yes/no (if no - explain weaknesses/gaps) |   |
| 1 | Are the relevant players identified that should be contributing to the transboundary flood EWS and are they fulfilling their obligations? | Are there International memberships and relationships/formal agreements with neighbouring countries to ensure coordination where hazard and risk possibly have transboundary impacts. Explain | 1: No sharing across international boundaries  
3: Some casual international sharing  
5: Open national sharing and agreements in place |
| 2 | Are the relevant players working well together and with Academia to deliver the flood EWS? | Describe relationships. Are there any mechanism of collaboration of main players with Universities, academia, research institutions? Explain | 1: No sharing with academia or research institutions  
3: Occasional sharing mainly in conference  
5: Open sharing, symposiums, joint publications |
<table>
<thead>
<tr>
<th></th>
<th>Is there a monitoring and evaluation of the performance of the relevant players involved in delivering flood EWS?</th>
<th>yes/no</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Flexibility of organizational structure</td>
<td>Does the NHS have an organizational structure that is scalable for extreme events? Indicate how it works</td>
<td>1: No surge capacity and staff overwhelmed during recent events</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5: Have performed well during recent severe events and have established surge capacity and procedures</td>
</tr>
<tr>
<td>5</td>
<td>Roles and responsibilities of staff involved in the service?</td>
<td>Does the NHS define and document roles and responsibilities of staff involved in the service? Is everyone is aware of what they have to do and when</td>
<td>1: No - roles understood from working in the team but not documented</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5: Yes - documented well and reviewed regularly</td>
</tr>
<tr>
<td>6</td>
<td>Standard Operating Procedures</td>
<td>Does the NHS have Standard Operating Procedures that are developed, documented and reviewed?</td>
<td>1: No - procedures understood from working in the team but not documented</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5: Yes - documented well and reviewed regularly</td>
</tr>
<tr>
<td>7</td>
<td>Incident Management policy and procedures</td>
<td>Does the NHS have established Incident Management policy and procedures? For example, this refers to having to elevate operational activities when there is a big event</td>
<td>1: Manage incidents informally with best efforts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5: Yes formal Incident Management in place</td>
</tr>
<tr>
<td>8</td>
<td>Quality Management and performance assessment</td>
<td>Does the NHS have a focal point for Quality</td>
<td>1: No Quality management handbook or documented procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Management and performance assessment?</td>
<td>3: Yes - QMS a responsibility of existing managers</td>
</tr>
<tr>
<td>---</td>
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<td>----------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QMS team established</td>
<td>5: Yes - QMS team established</td>
</tr>
<tr>
<td>10</td>
<td>Decision support services</td>
<td>Does the NHS provide decision support services to partner agencies via phone contact or embedded forecasters?</td>
<td>1: The staff at the office decides</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3: Any institution can call for extended services no documentation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5: There are specific arrangements for selected institutions</td>
</tr>
<tr>
<td>5-</td>
<td>Institutional agreements on data sharing among different ministries/ agencies/ data sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Local/National context</td>
<td>Indicate if institutional agreements at local/national level for sharing data are in place. Indicate if data infrastructure agreements have been developed.</td>
<td>1 - There is no local/national data sharing policy, legal framework or agreements among institutions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - There is a local/national data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - There is a local/national data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed.</td>
</tr>
<tr>
<td>2</td>
<td>Transboundary context</td>
<td>Indicate institutional agreements at bi- or multinational level applicable to transboundary basins. Indicate specific data sharing and infrastructure agreements developed.</td>
<td>1 - There is no transboundary data sharing policy, legal framework or agreements among countries and institutions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - There is a transboundary data sharing policy, and there is agreement for contributing to basic data infrastructure development (co-financing for a network).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - There is a transboundary data sharing policy, using interoperability standards. Under this legal framework, spatial data infrastructure has been developed.</td>
</tr>
</tbody>
</table>
## II - Observations and Data Acquisition

<table>
<thead>
<tr>
<th>Item #</th>
<th>Item Description</th>
<th>Guidance for evaluator</th>
<th>Grading Scheme</th>
<th>Evaluator comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-</td>
<td>National</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 1      | Existence of Real-time Monitoring Service | Is there a monitoring service in place and operational based on real time data and the dissemination of related products? | 1: No Monitoring Service  
3: Occasional monitoring is performed  
5: There is a rigorous Monitoring Service in place |                   |
| 2      | Maintenance and sustainability of networks |                          |                |                   |
| 3      | Data transmission path (station to forecast centre) | Describe if transmission path is suitable, reliable, are there any limitations, any back-up transmission path(s), indicate the transmission method (e.g., physical mail, electronically, etc.) and frequency | 1: transmissions frequently fail, and/or no statistics kept  
3: reasonable success rate of transmissions, some limitations  
5: high level of reliability, statistics and backup paths available |                   |
| 4      | Risks of vandalism | Mitigation measures? | 1: high risk, some occurrences, no significant mitigation  
3: some risk and occurrences, some mitigation |                   |
<table>
<thead>
<tr>
<th></th>
<th>Adequacy of hydrometric network design</th>
<th>1 - absence of gauges (or too few) within a river basin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number of stations, location (provide a table, or map).</td>
<td>3 - some tributaries have gauges at outlets, other important parts of a river do not have gauges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - gauges give even coverage over differing parts of the river system and exist at outlet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>Data collection frequency</th>
<th>Adequate for riverine flood forecasting requirements?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 - not adequate for the majority of gauges</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 - some of the basin's gauges have low frequency of measurements to describe flood formation process</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 - high level of reliability, statistics and backup paths available</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3</th>
<th>Data verification frequency</th>
<th>Sufficient visits for staff gauge readings, operational checks, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 - not adequate for the majority of stations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 - some of the basin's stations have missing verification checks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 - fully adequate</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4</th>
<th>Calibration regime</th>
<th>Frequency of calibrations, calibrations recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 - rudimentary checks, irregular</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 - prior to service, occasional, some traceability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 - are traceable and regular, to WMO or equivalent standards</td>
<td></td>
</tr>
</tbody>
</table>

<p>| 5 | Equipment | Provide station metadata, noting the type, the manufacturer, manual or automatic, real time transmission or not, etc. |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Section</th>
<th>Description</th>
<th>1 - Many stations/instruments have inadequate range or accuracy, and/or installed in compromised situations</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Equipment limitations</td>
<td>Sufficient range, mounting OK, lack of interferences</td>
<td>3 - Some stations/instruments have inadequate range or accuracy or compromised installations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - All instruments are installed with adequate resolution, ranges, and no significant interferences</td>
</tr>
<tr>
<td>7</td>
<td>Rating curves maintenance</td>
<td>Are gaugings frequent enough and updated regularly?</td>
<td>1 - majority of gauges are without rating curves, or ratings were updated long time ago</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - lack of measurements to update curves, absence of ratings at important points</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - ratings are well maintained (regularly updated), ratings are available for all important stations (gauges)</td>
</tr>
<tr>
<td>8</td>
<td>Adequacy of rainfall and temperature network design</td>
<td>Number of stations, location (provide a table, or map).</td>
<td>1 - main catchment(s) and tributaries without gauges at important locations (near damage centers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - some of a river’s catchments in flow formation area have few or no precipitation and temperature measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - good coverage and distribution in flow formation areas (upper stream catchments)</td>
</tr>
<tr>
<td>9</td>
<td>Data collection frequency</td>
<td>Adequate for riverine flood forecasting requirements? Taking into account times of</td>
<td>1 - not adequate for the majority of gauges</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>10</td>
<td>Data verification frequency</td>
<td>Sufficient visits for check gauge readings, gauge maintenance, etc.</td>
<td>3 - some of the basin's gauges have low frequency of measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - fully adequate</td>
</tr>
<tr>
<td>11</td>
<td>Calibration regime</td>
<td>Frequency of calibrations, calibrations recorded</td>
<td>1 - not adequate for the majority of stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - some of the basin's stations have missing verification checks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - fully adequate</td>
</tr>
<tr>
<td>12</td>
<td>Equipment</td>
<td>Obtain station metadata, noting the type, the manufacturer, manual or automatic, real time transmission or not, etc.</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>Adequacy of synoptic network design</td>
<td>Number, location (provide a table, or map)</td>
<td>1 - poor coverage in many catchments in upper part of a river basin</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - some of a river's catchments in flow formation area miss synoptic measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - good coverage and distribution in flow formation areas (upper stream catchments)</td>
</tr>
<tr>
<td>14</td>
<td>Weather radars</td>
<td>Number, type and location, map of coverage, calibration, etc.</td>
<td>1 - limited usage, lack of calibration/adjustments</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - radars installed, but data are not adjusted to ground stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - radar mosaic with gauges correction procedures, covering significant part of the basin/region</td>
</tr>
<tr>
<td>15</td>
<td>Adequacy of</td>
<td>number, location of stations; measurements</td>
<td>1 - poor coverage in the relevant</td>
</tr>
<tr>
<td>Table 2: Data adequacy, quality, and distribution of operational ocean level station data (downstream boundary conditions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>113</td>
<td>Operational ocean level station data (downstream boundary conditions)</td>
<td>frequency; forecast locations, etc.</td>
<td>coastal areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - mostly covered with measurements, however some parts have gaps in observations and forecasts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - good coverage and distribution of ocean level stations at coastal zone</td>
</tr>
<tr>
<td>16</td>
<td>Transboundary data</td>
<td>Transboundary data are available in real-time for all pertinent networks?</td>
<td>1 - transboundary data are not available</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - some pertinent data are available with delays</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - all data including flow data are received in real time (or near real time mode)</td>
</tr>
<tr>
<td>17</td>
<td>Adequacy of (operational) snow network design for snow water equivalence</td>
<td>number, location (obtain a table, or map)</td>
<td>1 - no snow measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - some measurements (snow water equivalence) are available with limited distribution and temporal resolution</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - snow courses are evenly distributed</td>
</tr>
<tr>
<td>18</td>
<td>Snowpack condition</td>
<td>depth, areal coverage, density, and SWE</td>
<td>1 – nothing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - snow depth and coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - depth, density, mass, SWE</td>
</tr>
<tr>
<td>19</td>
<td>Data collection frequency</td>
<td>Adequate for RF requirements? Weekly, monthly, etc.</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>Equipment</td>
<td>Provide station metadata, noting the type, the manufacturer, manual or automatic, real time transmission or not, etc.</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>Reservoir</td>
<td>Adequate data for reservoir manager(s), inflow forecasts, storage level, outflows</td>
<td>-</td>
</tr>
</tbody>
</table>

3- Flash Flood (FF) and Mechanisms
<table>
<thead>
<tr>
<th></th>
<th>Adequacy of hydrometric network design</th>
<th>Adequate for flash flood forecasting requirements?</th>
<th>Data verification frequency</th>
<th>Calibration regime</th>
<th>Equipment</th>
<th>Rating curves maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>number of stations, location (provide a table, or map)</td>
<td>Adequate for flash flood forecasting requirements?</td>
<td>Sufficient visits for staff gauge readings, operational checks, etc.</td>
<td>Frequency of calibrations, calibrations recorded</td>
<td>Provide station metadata, noting the type, the manufacturer, manual or automatic, real time transmission or not, etc.</td>
<td>Are gaugings frequent enough and updated regularly?</td>
</tr>
<tr>
<td>2</td>
<td>Adequate for flash flood forecasting requirements?</td>
<td>Adequate for flash flood forecasting requirements?</td>
<td>Sufficient visits for staff gauge readings, operational checks, etc.</td>
<td>Frequency of calibrations, calibrations recorded</td>
<td>Provide station metadata, noting the type, the manufacturer, manual or automatic, real time transmission or not, etc.</td>
<td>Are gaugings frequent enough and updated regularly?</td>
</tr>
<tr>
<td>3</td>
<td>1 - absence of gauges (or too few) in mountains/urban area</td>
<td>1 - not adequate for the majority of gauges</td>
<td>1 - not adequate for the majority of stations</td>
<td>1 - rudimentary checks, irregular</td>
<td>1 - majority of gauges are without rating curves, or ratings were updated long time ago</td>
<td>1 - majority of gauges are without rating curves, or ratings were updated long time ago</td>
</tr>
<tr>
<td>4</td>
<td>3 - some watersheds have gauges at outlets, other important parts of mountains (with different geomorphologic conditions) do not have gauges</td>
<td>3 - some of the basin's gauges have low frequency of measurements to describe flash flood formation process</td>
<td>3 - some of the basin's stations have missing verification checks</td>
<td>3 - prior to service, occasional, some traceability</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>5 - gauges give even coverage over differing parts of mountainous/urban areas</td>
<td>5 - high level of reliability, statistics and backup paths available</td>
<td>5 - fully adequate</td>
<td>5 - are traceable and regular, to WMO or equivalent standards</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>1 - not adequate for the majority of gauges</td>
<td>3 - some of the basin's gauges have low frequency of measurements to describe flash flood formation process</td>
<td>5 - fully adequate</td>
<td>3 - prior to service, occasional, some traceability</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequacy of rainfall and temperature network design</td>
<td>Number of stations, location (obtain a table, or map) (Note temperature is for snow accumulation and ablation modelling, evapotranspiration estimation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1 - absence of, or too few, stations in mountainous/urban areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - significant gaps in rainfall observations in mountainous/urban areas, a lot of upper catchments are without stations, uneven distribution</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>5 - even distribution of stations, most parts of mountain/urban areas have coverage</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Adequacy of snow network design for snow water equivalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
<td>1 - no snow measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - some measurements (snow water equivalence) are available with limited distribution and temporal resolution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - snow courses are evenly distribution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Snowpack condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>1 - nothing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - snow depth and coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - depth, density, mass, SWE</td>
</tr>
<tr>
<td>Item #</td>
<td>Item Description</td>
<td>Guidance for evaluator</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1-</td>
<td>National</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Organization(s) responsible for data archives</td>
<td>list all organizations involved in storing and managing hydrometeorological data archives (hydrometric, synoptic, snow, etc.)</td>
</tr>
<tr>
<td>2-</td>
<td>River Flood (RF) and Flash Flood (FF) assessment (by basin)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Metadata for hydrometric stations</td>
<td>incl. coordinates, level datum (if being used in hydrodynamic model application for coastal area, a common datum is needed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Suitability of hydrometric data for modelling purposes</td>
<td>gaps, homogeneity (dams construction, equipment change);</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydrometric data format</td>
<td>Minimum requirements for model calibration and validation are considered to be 3 years each</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>Hydrometric data format</td>
<td>Minimum requirements for model calibration and validation are considered to be 3 years each</td>
</tr>
<tr>
<td>4</td>
<td>Metadata for meteorological (e.g., precipitation and temperature) gauges</td>
<td>Minimum requirements for model calibration and validation are considered to be 3 years each</td>
</tr>
<tr>
<td>5</td>
<td>Suitability of meteorological data (e.g., precipitation and temperature) for modelling purposes</td>
<td>Minimum requirements for model calibration and validation are considered to be 3 years each</td>
</tr>
<tr>
<td>6</td>
<td>Meteorological data (e.g., precipitation and temperature) format</td>
<td>Minimum requirements for model calibration and validation are considered to be 3 years each</td>
</tr>
<tr>
<td>7</td>
<td>Mean areal precipitation (MAP)</td>
<td>Minimum requirements for model calibration and validation are considered to be 3 years each</td>
</tr>
<tr>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Meteorological/Climatological synoptic data availability</td>
<td>temperature, rainfall intensity, cloud cover, windspeed, direction, solar radiation, soil temperature …</td>
</tr>
<tr>
<td></td>
<td>1 - temperature available only</td>
<td>3 - temperature and some synoptic</td>
</tr>
<tr>
<td></td>
<td>5 - many synoptic elements are archived (incl. temperature, cloud cover, windspeed, …)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Metadata for Meteorological/Climatological synoptic stations</td>
<td>incl. coordinates, equipment</td>
</tr>
<tr>
<td></td>
<td>1 - limited or unavailable for many gauges</td>
<td>3 - not complete (absence of coordinates of some stations, meteostation height, etc.)</td>
</tr>
<tr>
<td></td>
<td>5 - complete metadata available with coordinates, station height, equipment type, date of installation, and possible instrument(§) change and other</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Synoptic data format</td>
<td>paper, digital; consider this question for different synoptic elements</td>
</tr>
<tr>
<td></td>
<td>1 - paper</td>
<td>3 - partly paper and partly digital</td>
</tr>
<tr>
<td></td>
<td>5 - all (mostly) digital</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>cross-sections</td>
<td>number, date of last update, adequacy of spacing</td>
</tr>
<tr>
<td></td>
<td>1 - not available, or not up to date</td>
<td>3 - adequate spacing in majority of cases, not up-to-date everywhere</td>
</tr>
<tr>
<td></td>
<td>5 - adequate spacing, up-to-date, coverage of important sections of main rivers</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>rating curves</td>
<td>number, date of last update, number of</td>
</tr>
<tr>
<td></td>
<td>1 - not available, or not up to date, or available only in low flow areas</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Spatial data</td>
<td>available measurements of a curve</td>
</tr>
<tr>
<td>----</td>
<td>--------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - available with reasonable updates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - covering different periods of flow - peaks, ice conditions, regularly updated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>14</th>
<th>Impact data</th>
<th>type (elevation, soil, land use, land cover), method of acquisition, resolution, format</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 - do not make use of or access existing available data at global level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - use some data globally available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - higher resolution data nationally available for important data types for modelling purposes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>15</th>
<th>Historical information and traditional knowledge</th>
<th>vulnerability and exposure data; flood trigger levels defined, census data, flood maps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 - no vulnerability and exposure data etc. are available nationally</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - vulnerability and exposure data etc. are available for key locations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - vulnerability, exposure data and flood mapping are generally available for all vulnerable flood-prone locations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3-</th>
<th>Additional items - mechanisms</th>
<th>historical flood heights, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 - do not consider within national archives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - only apply to a few locations and used for analyses such as flood frequency determination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - broad programme to incorporate such knowledge into archives and used for analyses such as flood frequency determination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1</td>
<td>Reservoir inflows, storage and outflows</td>
<td>storage-elevation relationship, record duration, gaps, formats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - not available, or little availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - reasonable duration, no significant gaps, both paper and digital format</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - more than 6 years duration without significant gaps, digital format</td>
</tr>
<tr>
<td>2</td>
<td>Reservoir operation rules (historical and present)</td>
<td>need operating rules or policies, how they have changed over time or not, record duration, length, gaps, format</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - not available, or little availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - current rules are available, but previous rules are not available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - both current and previous rules are available</td>
</tr>
<tr>
<td>3</td>
<td>Snow data archives availability</td>
<td>Which elements are available: SWE, depth, density, others?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - not available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - only depth measurements, point measurements on stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - snow courses with depth, density, SWE estimation</td>
</tr>
<tr>
<td>4</td>
<td>Snow course metadata</td>
<td>incl. coordinates, equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - limited or unavailable for many gauges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - not complete (absence of coordinates of some stations, meteostation height, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - complete metadata available with coordinates, equipment type, date course started, and possible instrument(s) change and other</td>
</tr>
<tr>
<td>5</td>
<td>Snow data record duration</td>
<td>gaps, homogeneity (equipment change); consider this question for different snow elements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - not available or limited duration (less than 6 years)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - at least 6 years, gaps are present</td>
</tr>
</tbody>
</table>
|   | 6 | Snow data archives format | paper, digital; consider this question for different snow elements | 1 - paper  
|   |   |   |   | 3 - partly paper and partly digital  
|   |   |   |   | 5 - all (mostly) digital  
|   | 7 | Hydrometric transboundary data | in case of transboundary river | 1 - transboundary data are not available  
|   |   |   |   | 3 - some pertinent data are available with delays  
|   |   |   |   | 5 - all data including flow data are received in real time (or near real time mode)  
|   | 4- | **Addition items for Coastal Flood (CF) assessment** |   |   
|   | 1 | Metadata for ocean level stations | incl. coordinates, equipment | 1 - limited in information or unavailable for many gauges  
|   |   |   |   | 3 - not complete (absence of location information, equipment used, or zero readings)  
|   |   |   |   | 5 - complete metadata available with updated zero readings, coordinates, equipment type, date of installation, and possible instrument(s) change and other  
|   | 2 | Suitability of ocean level data for modelling purposes | gaps, stationarity (equipment change) | 1 - limited duration (less than 6 years)  
|   |   |   |   | 3 - at least 6 years, gaps are present  
|   |   |   |   | 5 - reasonable duration (more than 6 years) for both calibration and validation a model without significant gaps and breaches in homogeneity  

### IV - Data Management

<table>
<thead>
<tr>
<th>Item #</th>
<th>Item Description</th>
<th>Guidance for evaluator</th>
<th>Grading Scheme</th>
<th>Evaluator comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-</td>
<td>Accessibility of data (point and gridded)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item #</th>
<th>Item Description</th>
<th>Guidance for evaluator</th>
<th>Grading Scheme</th>
<th>Evaluator comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Ocean level data format</td>
<td>paper, digital</td>
<td>1 - paper</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - partly paper and partly digital</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - all (mostly) digital</td>
<td></td>
</tr>
</tbody>
</table>

#### 5- Additional items for Urban Flood (UF) assessment

<table>
<thead>
<tr>
<th>Item #</th>
<th>Item Description</th>
<th>Guidance for evaluator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Combined sewer and storm water (drainage) systems data</td>
<td>if exists, in what format? Drainage network, pipe sizes, surface channel locations and characteristics, outlet locations and control structures, operation policies, inlet locations, elevations to a known datum, etc.</td>
</tr>
<tr>
<td>2</td>
<td>Digital Elevation Model (DEM)</td>
<td>Lidar data are useful depending on desired modelling accuracy</td>
</tr>
<tr>
<td>3</td>
<td>Topographic and land use/cover data</td>
<td>city layout, incl. bridges, road features, building location (sill elevations), land use and land cover, etc.</td>
</tr>
<tr>
<td></td>
<td>Historical</td>
<td>Indicate communication channels, frequency and client server schemes</td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1- There is no on-going systematic or reliable data or product storage or related infrastructure in place.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Data products are stored in owned servers, or are readily available in partner institutions servers (by public or private access) in a client-server scheme with minimal functionalities (web sites, ftp servers, http servers).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - Data products are offered according to interoperability standards (data structures and metadata) and are stored in own servers, or are readily available in partner institutions servers (by public or private access) in a client-server scheme providing web services.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Real-time</th>
<th>Indicate the availability of real time data and products (point/gridded/both), communication channels and frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>1 - No real time data provided by own or third party ground networks (point data).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3- Most of real time data and products are readily available at the start of the forecasting session. Data and products are available in a timely fashion.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5- All pertinent data are readily available when needed. Web services are available.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Transboundary (historical and real time)</th>
<th>Indicate type of data acquired (point/gridded/both), providers, communication channels, frequency and length of available data series</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>1- There is a scarce amount of transboundary historical data available (digital, digitalized or digitized) and transboundary real-time point data collected or processed by the Hydrological Service in relation to the needs of the warning system. ftp channels for exchange of data products (i.e. Time series, maps) with key providers have been set up. Communication capabilities are expanding.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - The amount of transboundary historical digital data available is satisfactory to according to the current purposes of the warning system. Also, transboundary real time data (point or gridded) is gathered according to operational times. Data products are stored in owned servers, or are readily available at partner institutions servers (by public or private access) in a client-server scheme with minimal functionalities (web sites, ftp servers, http servers).</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - The amount of transboundary historical available digital data is close to the optimum according to the current purposes of the warning system. Also, real time data (point and gridded) is gathered according to operational times. Data products are produced according to interoperability standards (data structures and metadata) and are stored in owned servers, or are readily available at partner institutions servers (by public or private access) in a client-server scheme providing web services.</td>
</tr>
<tr>
<td></td>
<td>Data Ingestion Procedures</td>
<td>Indicate automation degree of data ingest procedures, use of transfer protocols and web services (in and between local and external context)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - Partially automated. Most of the data ingestion is done manually. Some data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Mostly automated. Most of the data are ingested automatically from ftp/http repositories or from web pages using web scraping procedures. Some web services are available.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - Fully automated. All the data are ingested automatically from ftp/http repositories or web services. Data exchange adjusts to interoperability standards.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>5</td>
<td>Records and Document Management Procedures</td>
<td>1 - Records and documents are stored digitally according to local policies, or according to protocols developed by the Hydrological Service. Most of procedures that must be automated are indeed automatic. Access to records and documents is available by ftp or http clients.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Records and documents are stored according to local policies, or according to protocols developed by the Hydrological Service. At least, catalogue protocols and services have been developed. Also, some of the records and documents are stored according to international standards. Most procedures that can be automated are indeed automatic. Access to records and documents is available by ftp or http clients. Some graphical interfaces for records and document management have been implemented.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - Records and documents are stored according to protocols developed by international consortiums (standards). Catalogue service is fully automated, records and document management web services have been implemented, including graphical user interfaces and web applications.</td>
</tr>
<tr>
<td>2-</td>
<td>Data Quality Assurance and Quality Control procedures</td>
<td>1 - Some QA/QC procedures have been implemented to some of the data</td>
</tr>
<tr>
<td>1</td>
<td>Historical data</td>
<td>Indicate portion of data subjected to QA/QC</td>
</tr>
<tr>
<td></td>
<td>Database type</td>
<td>Indicate type of database, provide software name</td>
</tr>
<tr>
<td>---</td>
<td>---------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1 - No database - data are stored in files (Flat file database) (e.g. delimited text, fixed width text, spreadsheet, gridded data).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Non relational Database Model</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - Relational database and DBMS (e.g. SQL, ORACLE)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Real-time QA/QC methodology</th>
<th>Indicate QA/QC procedures used to assure the quality of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td>1 - Mainly manual procedures following properly documented protocols</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Partially automated approaches with human intervention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - Mostly automated with human intervention. Procedures are properly documented and catalogued.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Real-time data</th>
<th>Indicate portion of data subjected to QA/QC procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>1 - Some of the ingested data are subject to QA/QC procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Most of the ingested data are subject to QA/QC procedures and some reliability indexes or metrics are available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - All ingested data are subject to QA/QC procedures and some reliability indexes or metrics are available.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Historical QA/QC methodology</th>
<th>Indicate QA/QC procedures used to assure the quality of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>1 - Mainly manual procedures following properly documented protocols</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Partially automated approaches with human intervention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - Mostly automated with human intervention. Procedures are properly documented and catalogued.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>3 - Most data have passed QA/QC procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - All data have passed QA/QC procedures and have available reliability indexes or metrics</td>
</tr>
</tbody>
</table>
**Data formats**

Indicate formats of data handled by database system (input and output procedures), e.g. CSV, XML, WaterML2.0

**Input and output Interfaces**

Indicate data I/O main characteristics

1 - Data input/output procedures are not automated. Manual data ingestion.

3 - Data input/output procedures are partly automated. (there is an interface to manually and automatically import data)

5 - Data input/output procedures are automated. Some of them with advanced graphical functionality. ("machine to machine" plus all the functionalities under 1 and 3)

<table>
<thead>
<tr>
<th>Item #</th>
<th>Item Description</th>
<th>Guidance for evaluator</th>
<th>Grading Scheme</th>
<th>Evaluator comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1-</strong></td>
<td>National assessment</td>
<td>If you have more than one provider, list them all</td>
<td>1- They are not provided by the National Meteorological Service (NMS)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Service provider of the meteorological forecast products</td>
<td></td>
<td>3- Some are provided by NMS and some are derived from other companies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5- They are all provided by the National Meteorological Service</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Provider(s) of the Ocean water level forecast</td>
<td>Needed for the downstream boundary condition</td>
<td>1- They are not provided by the National Ocean Service</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3- Some are provided by Ocean Service and some are derived from other companies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5- They are all provided by the National Ocean Service</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meteorological forecast products available for River Flood (RF) and Flash Flood (FF) modelling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Rainfall (deterministic Quantitative Precipitation Forecast - QPF)</td>
<td>Ascertain the updating frequency (e.g. every 6 hr), temporal and spatial scales, and its availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - Precipitation maps are available only as image products and not in the preferred time step</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Coarse resolution (e.g. resolution of global NWP) products are digitally available</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - High resolution (spatial and temporal) at time step that meet the needs of the preferred hydrological model are available in digital format for a forecast horizon for at least 3 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Rainfall (probabilistic QPF)</td>
<td>Number of ensemble members (spatial and temporal), forecast horizon</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - Outputs of at least three deterministic NWP models are used (&quot;poor man ensemble&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - 20+ low resolution ensemble members</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - 20+ high resolution ensemble members</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Temperature (deterministic forecast)</td>
<td>Ascertain the updating frequency (e.g. every 6 hr), temporal and spatial scales, and its availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - Temperature forecast maps are available only as image products and not in the preferred time step</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Coarse resolution (e.g. resolution of global NWP) products are digitally available</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 - High resolution (spatial and temporal) at time step that meet the needs of the preferred hydrological model are available in digital format for a forecast horizon for at least 3 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Temperature (probabilistic forecast)</td>
<td>Number of ensemble members (spatial and temporal), forecast horizon</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - Outputs of at least three deterministic NWP models are used (&quot;poor man ensemble&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - 20+ low resolution ensemble members</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>5 - 20+ high resolution ensemble members</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Dew point temperature (deterministic forecast)</td>
<td>Ascertain the updating frequency (e.g. every 6 hr), temporal and spatial scales, and its availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - Temperature forecast maps are available only as image products and not in the preferred time step</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - Coarse resolution (e.g. resolution of global NWP) products are digitally available</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - High resolution (spatial and temporal) at time step that meet the needs of the preferred hydrological model are available in digital format for a forecast horizon for at least 3 days</td>
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<tr>
<td>---</td>
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<td></td>
</tr>
<tr>
<td>6</td>
<td>Dew point temperature (deterministic forecast)</td>
<td>Number of ensemble members (spatial and temporal), forecast horizon</td>
<td>1 - Outputs of at least three deterministic NWP models are used (&quot;poor man ensemble&quot;)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - 20+ low resolution ensemble members</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - 20+ high resolution ensemble members</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Wind speed and direction (probabilistic forecast)</td>
<td>Number of ensemble members (spatial and temporal), forecast horizon</td>
<td>1 - Wind speed and direction forecast maps are available only as image products and not in the preferred time step</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - Coarse resolution (e.g. resolution of global NWP) products are digitally available</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - High resolution (spatial and temporal) at time step that meet the needs of the preferred hydrological model are available in digital format for a forecast horizon for at least 3 days</td>
<td></td>
</tr>
<tr>
<td>3-</td>
<td>Riverine Flood (RF) forecasting in coastal area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Ocean water level forecast (deterministic)</td>
<td>Ascertain the updating frequency (e.g. every 6 hr), temporal and spatial scales, and its availability for the downstream boundary condition</td>
<td>1 - Ocean water level forecast maps are available only as image products and not in the preferred time step</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - Coarse resolution (e.g. resolution of global NWP) products are digitally available</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>5 - High resolution (spatial and temporal) at time step that meets the needs of the preferred hydrological/hydrodynamic model, and these are available in digital format for a forecast horizon for at least 3 days</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ocean water level forecast (probabilistic)</td>
<td>Number of ensemble members (spatial and temporal), forecast horizon</td>
<td>1 - Outputs of at least three deterministic NWP models are used (&quot;poor man ensemble&quot;)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - 20+ low resolution ensemble members</td>
<td></td>
</tr>
<tr>
<td>Item #</td>
<td>Item Description</td>
<td>Guidance for evaluator</td>
<td>Grading Scheme</td>
<td>Evaluator comments</td>
</tr>
<tr>
<td>-------</td>
<td>------------------</td>
<td>------------------------</td>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>1-</td>
<td>National assessment</td>
<td></td>
<td>1. There is not a designated provider</td>
<td>3. There are different organisations that provide the different forecasts</td>
</tr>
<tr>
<td>1</td>
<td>Provider of Hydrological Forecast</td>
<td>If more than one, list all of them. For example River Flood forecast could be provided by NHS or a basin authority, while Flash Flood forecast could be by NMS</td>
<td>3. There are different organisations that provide the different forecasts</td>
<td>5. Different organizations provide the forecasts but all under one agency or they work closely together</td>
</tr>
<tr>
<td>2</td>
<td>Forecasting approach</td>
<td>Describe what type of modelling approach and system are used (e.g. &quot;gauge-to-gauge&quot; correlation, watershed model, routing model).</td>
<td>1. Not appropriate, or no formal flood forecasting procedures are in place</td>
<td>3. Appropriate, but should be improved - performance metrics are being met most of the time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Fit for purpose - performance metrics are being met or exceeded</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Procedure(s) for rapid-onset events</td>
<td>Are there any procedure, in particular for rapid-onset events?</td>
<td>1. There are no interactions/procedures</td>
<td>3. Some instructions are drafted but not completed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. There are instructions/procedure to address rapid-onset events</td>
<td></td>
</tr>
<tr>
<td>2-</td>
<td>Hydrological model(s) available for River Flood (RF) and Flash Flood (FF) forecasting (by basin)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Rainfall-snowmelt-runoff model type (spatial)</td>
<td>Spatial resolution (lumped/semi-)</td>
<td>1. Not appropriate, or no formal flood forecasting procedures are in place</td>
<td></td>
</tr>
<tr>
<td>1. Resolution (if used as main forecast procedure)</td>
<td>distributed/distributed. Please record the model name, provider, software. If unique, then obtain details on its methodologies for runoff generation.</td>
<td>3. Appropriate, but should be improved - performance metrics are being met most of the time.</td>
<td>5. Fit for purpose - performance metrics are being met or exceeded.</td>
<td></td>
</tr>
<tr>
<td>2. Routing model type (if used as main forecast procedure)</td>
<td>Describe routing approach used (e.g. Maskingam, Maskingam-Cunge, hydrodynamic).</td>
<td>1. Not appropriate, or no formal flood forecasting procedures are in place.</td>
<td>3. Appropriate, but should be improved - performance metrics are being met most of the time.</td>
<td>5. Fit for purpose - performance metrics are being met or exceeded.</td>
</tr>
<tr>
<td>3. Watershed model (if used as main forecast procedure)</td>
<td>Combination of Rainfall-snowmelt-runoff models are combined with a routing model (e.g. hydrodynamic model) to produce the basin forecast. Describe the watershed modelling approach used.</td>
<td>1. Not appropriate, or no formal flood forecasting procedures are in place.</td>
<td>3. Appropriate, but should be improved - performance metrics are being met most of the time.</td>
<td>5. Fit for purpose - performance metrics are being met or exceeded.</td>
</tr>
<tr>
<td>4. Forecast lead time</td>
<td>This refers as to how far into the future the forecast is issued.</td>
<td>1. Lead times of 1-2 days.</td>
<td>3. Lead times of 3-5 days.</td>
<td>5. Lead times of greater than 5 days.</td>
</tr>
<tr>
<td>5. Forecast Computational Time Step</td>
<td>Minutes, Hour(s), Daily</td>
<td>1. Too coarse a time step is used.</td>
<td>3. Temporal resolution could still be improved.</td>
<td>5. Appropriate time step is used.</td>
</tr>
<tr>
<td>6. Ability to address uncertainty</td>
<td>If yes, describe procedure. Indicate if you provide ensemble members or any post processing</td>
<td>1. &quot;Poor man NWP ensemble.&quot;</td>
<td>3. &quot;Poor man NWP ensemble&quot; + disturb initial hydrological conditions.</td>
<td>5. NWP multi member ensemble + disturb initial hydrological conditions.</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>3. The model(s) can be run at most twice a day.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. The model(s) can be run as many times a day as needed

1. Models are calibrated and validated only at setup

3. Model calibration/validation is reviewed only if a problem arises

5. Model calibration/validation is reviewed at least every 5 years

1. There is no systematic forecast performance.

3. Forecast performance is tracked only during a major event

5. There is a program executed monthly that provides statistics on performance

1. Output updating is performed manually

3. Statistical bias adjustment is automated

5. Kalman filter(s) is applied

---

### VII - Flood Forecasting Products

<table>
<thead>
<tr>
<th>Item #</th>
<th>Item Description</th>
<th>Guidance for evaluator</th>
<th>Grading Scheme</th>
<th>Evaluator comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National assessment</td>
<td></td>
<td>1: occasional flood forecasting</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Level of service</td>
<td>What is the type and level of service provided?</td>
<td>3: Threshold-based flood alert and flood forecasting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5: Threshold-based flood alert; flood forecasting, vigilance mapping, inundation forecasting</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Coverage of service</td>
<td>Is there a consistent level of service throughout the</td>
<td>1: Many catchments not covered but some services in high risk areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>country or a phased approach that concentrate on high risk areas?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3: Service varies across catchments but all catchments are covered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5: Consistent services levels across all catchments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Risk based approach/Generation of Flood (risk) map products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Does the NHMS generate Flood (risk) maps? Indicate what type, the frequency, and what triggers the generation of them. If not, are there any other institutions in charge for flood risk mapping? Explain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1: No Flood maps available</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3: Flood maps in development and available at a limited number of forecast sites as static libraries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5: Flood risk maps available for all forecast sites in real-time</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2- by basin

| 1 | Risk based approach/Generation of Flood (risk) map products |
|   | Does the NHMS generate Flood (risk) maps? Indicate what type, the frequency, and what triggers the generation of them. If not, are there any other institutions in charge for flood risk mapping? Explain |
|   | 1: No Flood maps available                                       |
|   | 3: Flood maps in development and available at a limited number of forecast sites as static libraries |
|   | 5: Flood risk maps available for all forecast sites in real-time |

| 2 | Customized products for different users |
|   | Does the NHMS provide a range of products for different users and for different time periods? Time periods in this case is referring to the forecast (warning) lead time |
|   | 1: There is a lack of products for the forecast horizons most needed |
|   | 3: Suite of products satisfy part of the users, not all of them |
|   | 5: The suite of products is adequate to serve all user's needs and forecast horizons requested |

| 3 | Consistency of product presentation |
|   | Does the NHMS have a standardized approach of product presentation with a uniform and consistent "look and feel"? |
|   | 1: No standardization is used |
|   | 3: Some of the products are standardized |
|   | 5: All products are presented in a standardized consistent manner to avoid confusion among users |

<p>| 4 | Format in which products are |
|   | Are your products in a format |
|   | 1: Do not know |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Timeframes to issue products</td>
<td>Are the products provided in the timeframes required by the users (web, sms, phone, fax, bulletins...sirens)? Timeframes here refer to lead time. For example if a flash flood is in effect the sirens would satisfy better than a fax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: Do not know</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: Not all areas have appropriate products to satisfy the users</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: All products provided satisfy the timeframe required by users</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>issued</td>
<td>that is easily understood and interpreted by users?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: Some formats are adequate and others difficult to understand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: User’s feedback indicate the format is adequate and easily understood</td>
</tr>
</tbody>
</table>
# Appendix 2. The SEE river basin survey – observational network table

<table>
<thead>
<tr>
<th>№</th>
<th>Index</th>
<th>Station name</th>
<th>River*</th>
<th>Latitude, dec. deg</th>
<th>Longitude, dec. deg</th>
<th>Altitude of “0” reading/ meteo site**, m. abs</th>
<th>Elements***</th>
<th>Observation frequency, hr</th>
<th>Transmission frequency, hr</th>
<th>Equipmen t type</th>
<th>Time of operation: from … to …, yyyyymm</th>
<th>Data series evaluable from … to …, yyyyymm</th>
<th>Format of data series* ***</th>
<th>Comments</th>
</tr>
</thead>
</table>

* - if hydrological gauge
** - if hydrological gauge - altitude (m. abs) of zero reading, if meteorological - altitude (m. abs) of meteorological site
*** - list elements, which are measured
**** - paper/digital
Appendix 3. Quick guide to the SEE river basin survey

The Survey is based on the materials of WMO Assessment Guidelines for the End-to-End Early Warning Systems for Flood Forecasting (E2E EWS for FF), which was prepared by the WMO Commission for Hydrology. The survey should be filled in for a country’s river basin, which is vulnerable to river floods and is suffering from lack of implemented flood forecasting system.

The survey is prepared in a spreadsheet form of the Excel file (SEE-MHEWS-A River basin survey.xlsx). There are 8 spreadsheets which should be filled in electronically (in Excel). First spreadsheet (Description) contains basic information about the Survey evaluator (e.g. expert, who is filling the survey), county and the river basin. The other spreadsheets have common structure with 5 columns:

- item № (number of item, e.g. question of the survey)
- Item Description
- Guidance for evaluator (contains brief information about what is needed to be filled in)
- Grading scheme (can be used as additional guidance for an expert/evaluator)
- Evaluator comments – the filled, which should be filled in, preferably in a detailed manner.

Tables (spreadsheets) have different subsections: all subsections of tables I, IV, VI and VII should be filled, however fill only relevant subsections (which reflect flood type and flood mechanisms of floods within proposed basin) of tables II, III, V.

There are several specific items regarding observational stations network metadata for a basin, which should be filled in additional table-template (Network_table.xlsx) for every of the following survey items (if applicable):

- Table II “Observations and Data Acquisition”: items 2.1, 2.8, 2.13, 2.15, 2.17, 3.1, 3.7, 3.9
- Table III “Historical and Ancillary Data”: items 2.1, 2.4, 2.9, 3.4, 4.1

The survey (excel file) should be filled for one basin, if several river basins are proposed please fill in survey for each of them – so that in the result there are one excel file for each basin.
Appendix 4. Observational networks, proposed by the SEE countries for the SEE-MHEWS-A Project
### Observational stations networks in the Drin and the Vjosa river basins, proposed by Albania for the SEE-MHEWS-A Project

<table>
<thead>
<tr>
<th>Index</th>
<th>Station name</th>
<th>River</th>
<th>Lat., deg. north</th>
<th>Long., deg. east</th>
<th>Alt.*, m abs</th>
<th>Elements</th>
<th>Sampling interval</th>
<th>Transmission frequency</th>
<th>Equipment</th>
<th>Period of operation</th>
<th>Data series period</th>
<th>Format of data series</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBA 1</td>
<td>Dajc</td>
<td>Drin</td>
<td>41,9855</td>
<td>19,4151</td>
<td>0.8</td>
<td>Water level</td>
<td>15 min</td>
<td>60 min</td>
<td>SEBA</td>
<td>2014/09-2019/06</td>
<td>2014/09-2016/11; 2018/03-2018/04; 2019/06-pres. time</td>
<td>Digital</td>
<td>Operational. Theoretical rating curve is available</td>
</tr>
<tr>
<td>SEBA 2</td>
<td>Fierze</td>
<td>Drin</td>
<td>42,2489</td>
<td>20,0444</td>
<td>Not available</td>
<td>Dam level, rainfall</td>
<td>30 min</td>
<td>60 min</td>
<td>SEBA</td>
<td>2014/09-2019/06</td>
<td>2014/09-2018/07</td>
<td>Digital</td>
<td>To be replaced or repaired soon. Dam storage elevation curve.</td>
</tr>
<tr>
<td>SEBA 3</td>
<td>Gri</td>
<td>Drin</td>
<td>42,3163</td>
<td>20,0579</td>
<td>Not available</td>
<td>Water level</td>
<td>15 min</td>
<td>60 min</td>
<td>SEBA</td>
<td>2014/09-2015/07</td>
<td>2014/09-2015/07</td>
<td>Digital</td>
<td>To be replaced or repaired soon.</td>
</tr>
<tr>
<td>Index</td>
<td>Station name</td>
<td>River</td>
<td>Lat., deg. north</td>
<td>Long., deg. east</td>
<td>Alt.*, m abs</td>
<td>Elements</td>
<td>Sampling interval</td>
<td>Transmission frequency</td>
<td>Equipment</td>
<td>Period of operation</td>
<td>Data series period</td>
<td>Format of data series</td>
<td>Comments</td>
</tr>
<tr>
<td>-------</td>
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Comments: * - altitude of zero reading (in case of hydrological station), or meteorological site (in case of meteorological station)

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Observational stations in Albania, installed with the support of the World Bank project (continuation)

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154
Observational stations in Albania, installed with the support of the GIZ project

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Hydrometric stations network of the Vrbas river basin (Republika Srpska part of the basin), proposed by Bosnia and Herzegovina for the SEE-MHEWS-A Project

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<td>Data series period</td>
<td>Format of data series</td>
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Comments: * - H – water level, Q – discharge, T – water temperature
Meteorological stations network of the Vrbas river basin (Republika Srpska part of the basin), proposed by Bosnia and Herzegovina for the SEE-MHEWS-A Project

<table>
<thead>
<tr>
<th>Station name</th>
<th>River</th>
<th>Lat., deg. north</th>
<th>Long., deg. east</th>
<th>Alt. of zero reading, m abs</th>
<th>Elements*</th>
<th>Sampling interval</th>
<th>Transmission frequency</th>
<th>Equipment</th>
<th>Period of operation</th>
<th>Data series period</th>
<th>Format of data series</th>
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<td>Pliva</td>
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<td>30 min</td>
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<td>1965.4.</td>
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<td>44,779073</td>
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<td>44,663235</td>
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<td>OTT</td>
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<td>2016.2.</td>
<td>digital</td>
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<td>Kotor Varoš</td>
<td>Vrbana</td>
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<td>44,609544</td>
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<td>2016.2.</td>
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<td>Crna Rijeka</td>
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<td>44,418610</td>
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<td>Sava</td>
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<td>45,10417</td>
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<td>30 min</td>
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<td>2016.2.</td>
<td>1961.1</td>
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<tr>
<td>Station name</td>
<td>River</td>
<td>Lat., deg. north</td>
<td>Long., deg. east</td>
<td>Alt. of zero reading, m abs</td>
<td>Elements *</td>
<td>Sampling interval</td>
<td>Transmission frequency</td>
<td>Equipment</td>
<td>Period of operation</td>
<td>Data series period</td>
<td>Format of data series</td>
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<td>T;H;P;PI</td>
<td>1min-30min</td>
<td>30 min</td>
<td>OTT</td>
<td>2016.2</td>
<td>2016.2</td>
<td>digital</td>
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<tr>
<td>Čelinac</td>
<td>Vrbanj a</td>
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<td>44.733775</td>
<td>5</td>
<td>T;H;P;PI</td>
<td>1min-30min</td>
<td>30 min</td>
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<td>2016.2</td>
<td>2016.2</td>
<td>digital</td>
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</table>

* - T – air temperature at 2m, P – precipitation, H – humidity, W10 – wind speed at 10 m, W2 – wind speed at 2 m, GR – global radiation, PI – precipitation intensity
**Hydrometric stations network of the Vrbas river basin (Federation of Bosnia and Herzegovina part of the basin), maintained by the “Agency for Sava river basin”**

<table>
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<tr>
<th>Station name</th>
<th>River</th>
<th>Latitude, dec. deg</th>
<th>Longitude, dec. deg</th>
<th>Altitude of &quot;0&quot; reading, m. abs</th>
<th>Elements</th>
<th>Sampling interval</th>
<th>Transmission frequency</th>
<th>Equipment</th>
<th>Period of operation</th>
<th>Data series period</th>
<th>Format of data series</th>
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<tbody>
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<td>17,40</td>
<td>516,41</td>
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<td>1 hour</td>
<td>1 hour</td>
<td>SEBA, Demas</td>
<td>9.9.2002 - 2019</td>
<td>9.9.2002 - 2019</td>
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<td>Bistrica</td>
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<td>599.13(rel.)</td>
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<td>1 hour</td>
<td>1 hour</td>
<td>SEBA, Demas</td>
<td>2010 - 2019</td>
<td>2010 - 2019</td>
<td>digital, paper</td>
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</table>

*Comments: h – water level, q – discharge*

**Meteorological stations network of the Vrbas river basin (Federation of Bosnia and Herzegovina part), maintained by the “Agency for Sava river basin”**

*Comments: t – air temperature, p - precipitation*

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<th>River</th>
<th>Latitude, dec. deg</th>
<th>Longitude, dec. deg</th>
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<th>Elements</th>
<th>Sampling interval</th>
<th>Transmission frequency</th>
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<td>p, t</td>
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<td>1 hour</td>
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Meteorological stations network of the Vrbas river basin (Federation of Bosnia and Herzegovina part), maintained by the Federal Hydrometeorological Institute of Federation of Bosnia and Herzegovina (FHMI)

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<th>Station name</th>
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<th>Longitude, dec. deg</th>
<th>Elements</th>
<th>Sampling interval</th>
<th>Transmission frequency</th>
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<th>Data series period</th>
<th>Format of data series</th>
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<td>1 hour</td>
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<td>2016 - 2019</td>
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<td>1 hour</td>
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<td>2016 - 2019</td>
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<td>1 hour</td>
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<td>2016 - 2019</td>
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<td>1 hour</td>
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<td>automatska OTT</td>
<td>2016 - 2019</td>
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<td>digital, paper</td>
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<td>digital, paper</td>
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<td>Name</td>
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<td>Latitude, dec. deg</td>
<td>Longitude, dec. deg</td>
<td>Altitude of &quot;0&quot; reading</td>
<td>Element</td>
<td>Observations frequency, hr</td>
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<td>Time of operation: from ... to ..., yyyyymm</td>
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<td>17,79</td>
<td>16,25</td>
<td>t, chem</td>
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<td>automatska OTT</td>
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<tr>
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<td>1 hour</td>
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*Comments: h – water level, q - discharge*
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*Comments: p – precipitation, t – air temperature, h – humidity*
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<th>Station name</th>
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<th>Lat., deg. north</th>
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<th>Alt. of zero reading, m abs</th>
<th>Elements</th>
<th>Sampling interval</th>
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### Hydrometric stations network of the Neretva river basin, proposed by Croatia for the SEE-MHEWS-A Project

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<th>Station name</th>
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Weather stations network of the Neretva river basin, proposed by Croatia for the SEE-MHEWS-A Project

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<th>Station name</th>
<th>Lat., deg. north</th>
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<th>Alt. of meteo site, m abs</th>
<th>Elements</th>
<th>Sampling interval</th>
<th>Transmission frequency</th>
<th>Equipment</th>
<th>Period of operation</th>
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<td>Transmissio n frequency</td>
<td>Equipment</td>
<td>Period of operation</td>
<td>Data series period</td>
<td>Format of data series</td>
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Hungary

Hydrometric and meteorological stations network of the Marcal river basin, proposed by Hungary for the SEE-MHEWS-A Project

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<th>Station name</th>
<th>River</th>
<th>Lat., deg. north</th>
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<th>Alt. of zero reading, m abs</th>
<th>Elements</th>
<th>Sampling interval, hr</th>
<th>Transmission frequency, hr</th>
<th>Equipment</th>
<th>Period of operation</th>
<th>Data series period</th>
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Jordan Meteorological stations network of the Jordan river basin, proposed by Jordan for the SEE-MHEWS-A Project

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North Macedonia

Hydrometric stations network of the Vardar river basin, proposed by North Macedonia for the SEE-MHEWS-A Project

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Ukraine
Hydrometric stations network of the Dniester river basin, proposed by Ukraine for the SEE-MHEWS-A Project

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<th>Transmission frequency, hr</th>
<th>Equipment</th>
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