Interreg
Danube Transnational Programme
DAREFFORT

2018 - 2021

Danube River Basin Enhanced Flood Forecasting Cooperation DAREFFORT

Technical Summary

A comprehensive summary on the achievements of the project

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ASP3 – Slovenian Environmental Agency - Slovenia
ASP4 – Ministry of the Environment and Spatial Planning of the Republic of Slovenia - Slovenia
ASP5 – Joint Research Centre- European Commission - Belgium
ASP6 – World Meteorological Organization
ASP7 – International Sava River Basin Commission - Croatia
ASP8 – Federal Ministry of Sustainability and Tourism; Department – Water / Subdep. Water Balance - Austria
ASP9 – Bavarian State Ministry of the Environment and Consumer Protection - Germany
ASP10 – Czech Hydrometeorological Institute – Czech Republic
ASP11 – Republic Hydrometeorological Service of Serbia - Serbia
ASP12 – State Hydrometeorological Service of the Republic of Moldova - Moldova

Contents

Foreword

The Danube and its tributaries have been crossing mountains and plains in their almost unchanged riverbeds for thousands of years, disregarding national and administrative boundaries. Nevertheless, even decades ago, several countries made only limited data and information available on the water level and flood protection status of their rivers. In recent years, information has changed hands on the basis of bilateral agreements, but for others, information could only be obtained by browsing the Internet, sometimes in a rather complicated way.

This situation is significantly changed by the DAREFFORT project, in which all authorized meteorological and hydrological data of the Danube River are stored in a central database and made available online to all licensed hydrological / flood protection institutions for further processing in virtually real time. The project also looks at what these further processing is like. It assesses the following:

- the path and frequency of information flow,
- the characteristics of flood forecasting systems in operation and under development,
- proposed directions for improvements.

It is to be appreciated that several ministries, meteorological and hydrological institutions from the 12 countries of the Danube have joined forces to work out their proposals that are essential for the future.

For my part, I can only congratulate you on all this.

Lajos Illés
Managing Director
VIZITERV Environ Ltd.

DTP2-064-2.1 DAREFFORT – Danube River Basin Enhanced Flood Forecasting Cooperation
The project is funded by the European Union and the Member States

The Danube, which is past, present and future
entwines its waves in tender friendly clasps.
Out of the blood our fathers shed in battles
flows peace, through our remembrance and regard,
creating order in our common matters,
this is our task, we know it will be hard[1]

A Dunának, mely múlt, jelen s jövendő,
egymást ölelik lágy hullámai.
A harcot, amelyet őseink vívtak,
békévé oldja az emlékezés
s rendezni végre közös dolgainkat,
ez a mi munkánk; és nem is kevés.

József Attila: A Dunánál

1. INTRODUCTION

Zoltan Balint
Representative of the Lead Partner

The battle which our ancestors fought is to be transformed into a battle for our common future, creating order in our common matters. In this process the Danube serves the well-being of every citizen in the basin, in which science, research and sustainable development, flood management and shipping are done together in the hope of a bright future. We hope this report and the entire DAREFFORT project will serve the same purpose.

Flood forecasting, data collection and harmonized data sharing is becoming of crucial importance along the countries of the Danube River Basin. Precipitation, water stage, discharge, water temperature and ice phenomena are measured isolated in each country. They are only shared with neighbouring countries under bilateral (sometimes limited multilateral) agreements. Respecting these already existing agreements, this situation is to be surpassed after the completion of the DAREFFORT project.

Researchers make great effort, sometimes parallel with each other in the same topic, to develop new flood forecasting models or methodologies. Joining forces, thinking together, using human and other resources while strengthening each other, would lead to results more efficiently. We hope this will also be a result of the project.

[1] 1 Translated by Peter Zolimon

Realizing all these chances and all the benefits, 12 countries joined forces in 2018 to cooperate in flood related data collection and data processing, as well as working out a joint road map for common flood forecasting or at least for exchanging forecasting results.
The 12 countries are:
Germany, Austria, the Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Ukraine, Romania, Serbia, Bulgaria, Moldova.

In addition to these countries relevant international organizations also assisted the work. These are:
- International Commission for the Protection of the Danube River (ICPDR)
- The World Meteorological Organization (WMO)
- Joint Research Centre of the European Union (JRC)
- International Sava River Basin Commission (ISRBC)

Besides the direct project partners (mostly the hydrometeorological institutions of the various countries), certain ministries or hydrometeorological agencies also participated in the work as Associated Strategic Partners.

The task was divided into 5 Work Packages as below:
1. Management issues - Work package 1
2. Communication - Work package 2
3. Evaluation of forecasting - Work package 3
4. Harmonized data exchange - Work package 4
5. Knowledge transfer – Work package 5

This summary report follows the above structure, however it combines Work Packages 1 and 2 into one chapter with the title DAREFFORT Partnership. All the outputs of the project are publicly available on our official website:

http://www.interreg-danube.eu/approved-projects/dareffort

We would like to express our appreciation to the management of VIZITERV Environ Ltd, the Lead Partner of the project, for the generous support given in all aspects of the implementation of the work. And we wold like to say thank you for the support in the financial and IT aspects to the staff of VIZITERV Environ.

All Project Partners have manifested diligent, devoted work in order to reach the present results of the project. We hope the continuation will start soon and it will be equally successful.

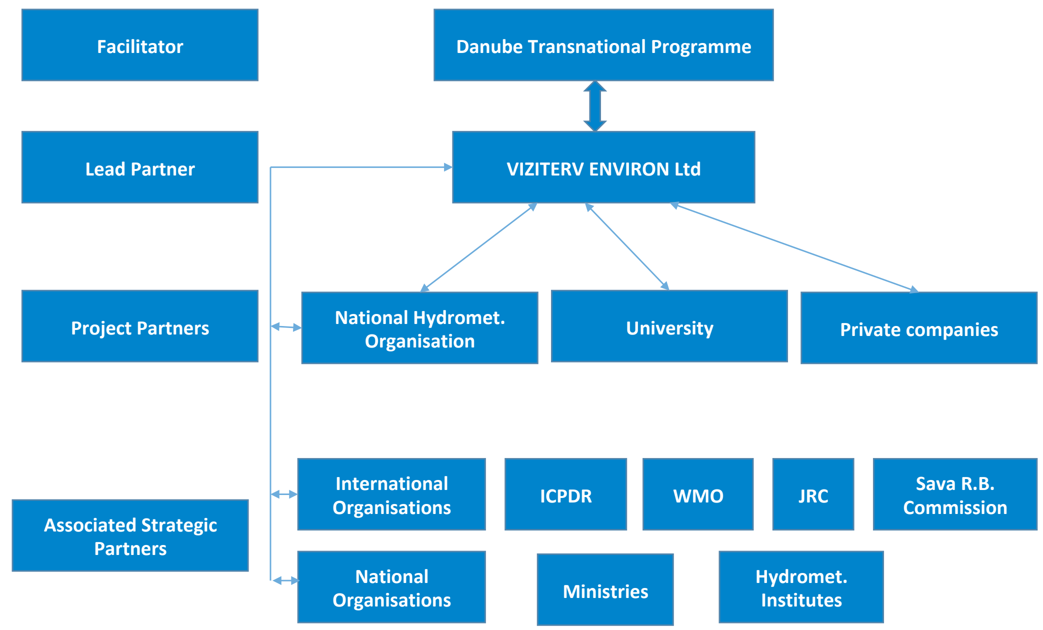
2. THE DAREFFORT PARTNERSHIP

Ildikó Czeglédi[1], Péter Juhász[1], Tímea Jenei-Pravda[2]
[1]VIZITERV Environ Ltd., Hungary
[2]General Directorate os Water Management, Hungary

The 3-year implementation of the DAREFFORT project started in June 2018. Having on board 11 project partners (PPs) and 7 national and 5 international organizations as associated partners (ASPs), the DAREFFORT Partnership represents 12 countries and its activity covered the entire Danube River Basin. The project brought together partners from the hydrology, hydrometeorology, water management, research and environmental sectors to achieve the goal of establishing a standardized international hydrometeorological data exchange platform that can improve the quality and efficiency of flood forecasting services in the Danube region.

Diversity of the partnership played a key role in the success of the project. Taken into account the geographic scope of the project as well as its sectorial coverage and level of stakeholders, a diverse composition could ensure durability and applicability of the project results. In line with the project's main focus on hydrologic data exchange and forecasting issues, several participating institutes are responsible for hydrometeorological observation, data providing and forecasting on national level, while others are legal entities of water management, planning, regulation and river maintenance and monitoring in order to secure preventive flood defense. In addition, the involvement of SMEs added international know-how on data analyses, software development, economic calculations and communication. Participation of a renowned university also supported the knowledge transfer towards RDI sector and higher education. The policy background of the partnership is secured through the ASP role of four ministries supporting the application of the project outputs at the decision making level. Transferability of all project results is ensured on Danube basin level by the involvement of ICPDR and the Sava River Basin Commission, while Europe-wide and global utilization, dissemination and harmonisation is achieved by the involvement of the Joint Research Centre of the EU Commission (JRC) and the World Meteorological Organization (WMO).

The project organisation structure reflected this diverse nature of the partnership and the special scope of the project. The partnership was coordinated by the Lead Partner (LP) who also served as the direct contact between the project and the Joint Secretariat (JS) of the Danube Transnational Programme (DTP). The LP dedicated a Project Manager, a Financial Manager, a Project Coordinator and a Project Assistant from its staff members to the Project Management Team (PMT). In order to ensure high quality outputs, a Quality Management Team was also set up according to the DTP requirements, consisting of a Quality Manager and two senior experts as Peer-Reviewers.

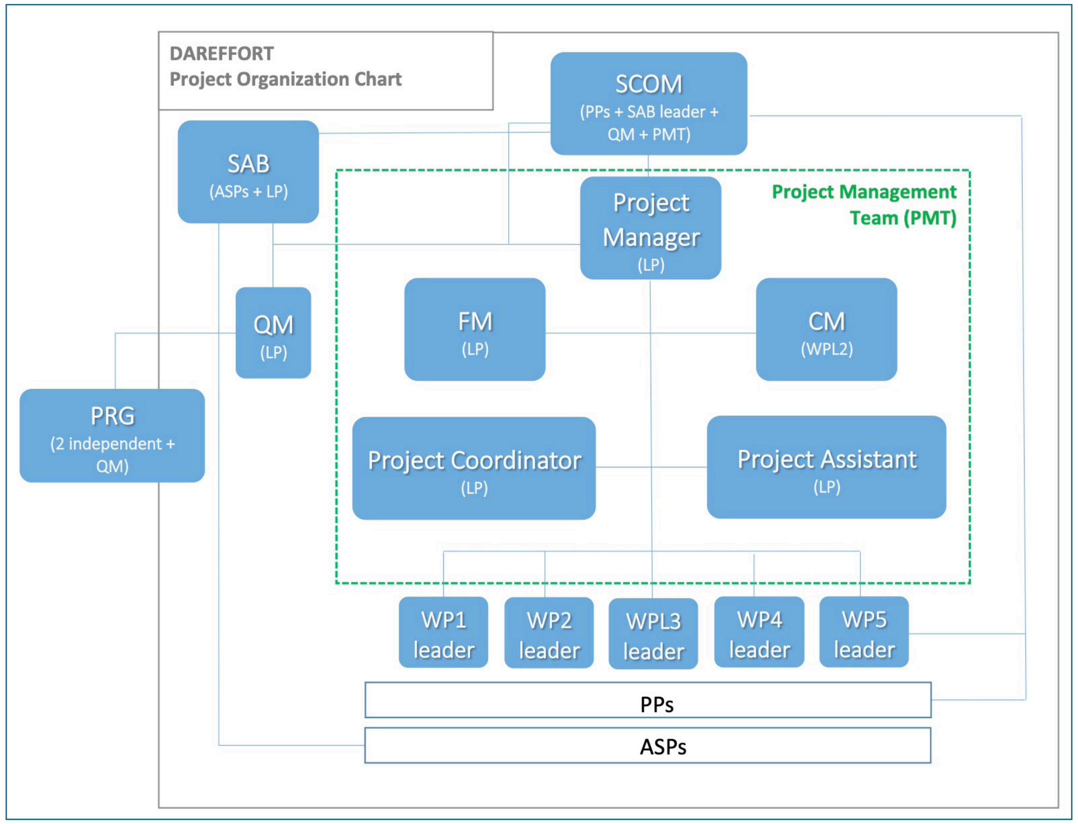


The Project Steering Committee (SCOM) included a representative of each PP, the Project Management Team, the Quality Manager and the leader of the Strategic Advisory Board (SAB), formed by the ASPs. While the SCOM served as the main supervisor and decision making body which follows the progress, the SAB has supported the SCOM in strategic and horizontal decision-making, addressing technical or other questions. Besides the day-to-day communications, the SCOM meetings were held in each period of the project, and the SAB meetings were organized annually, integrated into the periodic project meetings.

The PMT communicated regularly with the partners and responded to technical and other project management related queries in a timely fashion. To keep track of the ongoing tasks and financial spendings, Quarterly Internal Reports were required from each partners in the middle of each period.

The PMT provided a project management toolbox with all necessary information, protocols and templates to support the efficiency of project implementation. The mutual work was also supported by a dedicated FTP server hosted by LP with all the files and documents needed.

The Work Package Leaders (WPLs) were responsible for the tasks in their work package and for delivering the expected outputs. Furthermore, they supported the communication flow among involved partners as well as towards external stakeholders. One of the most challenging tasks were the organization of dissemination events and expert



workshops in all nine partner countries with project information leaflets translated and printed in partners' national languages for these domestic events. All the events were organized with great success. However, many of the PPs and ASPs are data providers themselves, we have outreached to all the relevant organisations in order to involve the data provider from each participating countries:

Data Providers	Country
Bavarian Environment Agency	Germany
German Weather Service	Germany
Federal Ministry of Agriculture, Regions and Tourism	Austria
National Institute of Meteorology and Hydrology of Bulgaria	Bulgaria
General Directorate of Water Management	Hungary
Croatian Meteorological and Hydrological Service	Croatia
Czech Hydrometerological Institute	Czech Republic
State Hydrometeorological Service of the Republic of Moldova	Moldova

Data Providers	Country
National Institute of Hydrology and Water Management	Romania
Republic Hydrometeorological Service of Serbia	Serbia
Slovak Hydrometeorological Institute	Slovakia
Slovenian Environment Agency	Slovenia
Ukrainian Hydrometeorological Center	Ukraine
Hungarian Meteorological Service	Hungary

The 2020-21 Covid-19 pandemic situation had two major effects on our activities. Firstly, it has become impossible to organize face-to-face meetings, therefore the 4th, 5th and the final 6th project meeting was held online. Second, it required a lot more effort than originally planned to keep up all the tasks going amidst the crises and lockdowns. All of our partners were effected to some extent, but still, DAREFFORT project was able to deliver the expected the number of capitalisation and dissemination events, because in 2019 and early 2020 the project partners participated in more external events than it was proportionally expected.

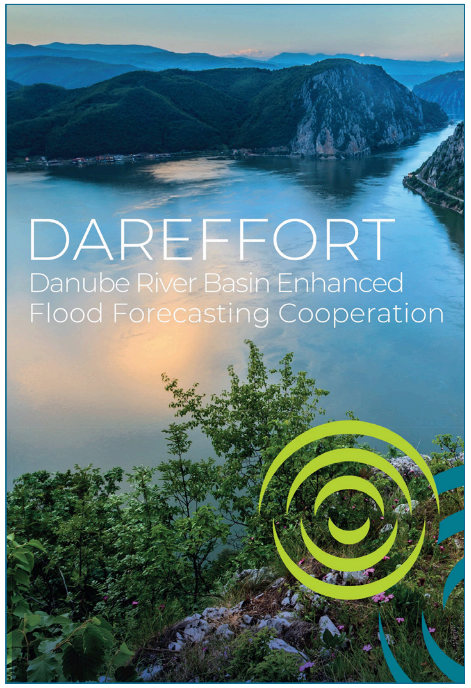
List of DAREFFORT meetings:
Kick-off meeting: 13-14. September 2018.- Budapest
1st Periodic Meeting with Capitalisation event and DAFF event: 4-5. February 2019. – Vienna
2nd Periodic Meeting: 28-29. May 2019. - Bucharest
3rd Periodic Meeting: 19-20. November 2019. - Bratislava
4th Periodic Meeting: 26-27. May 2020. – Online due to COVID-19 pandemic
5th Periodic Meeting: 05-06. November 2020. – Online due to COVID-19 pandemic
6th Periodic Meeting, Final conference and DAFF event: 29-30. April 2021. – Online because of COVID-19 pandemic Periodic Meeting: 26-27. May 2020. – Online due to COVID-19 pandemic

The work of the PMT was supported by a Communication Manager provided by the General Directorate of Water Management – Hungary.

The DAREFFORT project initially consisted of a series of challenges in terms of communication: multilingual scene of participants with various aspects of interest and levels of delegation.

The project partners needed to establish local support and understanding of the common vision and mutual advantages. That is why the outputs of DAREFFORT were not limited to the preparation of a hydrological and meteorological forecast system, but also include the examination of the forecast methodology of each and every participating countries, and also e-learning modules for spreading knowledge and for supporting the usability of the systems in the future. A significant part of the efforts, almost 40 percent of the communication budget allocated in DAREFFORT, was at the project teams' disposal to spend it on organising events, production of promotional materials and creating other opportunities to distribute information and transfer knowledge, not only between project partners, but more importantly to audience outside the project.

During the DAREFFORT project, our activities covered "internal communication" (among project partners and associated strategic partners) and "external communication" (from project partners to the outside of the project).



On one hand, for the project participants and professional stakeholders, our main task in communication was to keep them informed on the state of the project. Effective cooperation required us to maintain a collection of all required documentation and materials. We built an up-to-date database of the partners' contacts. We recruited subscribers for our newsletters, launched Facebook and LinkedIn profiles and updated the website regularly. DAREFFORT posters appeared at the offices of all project partners, this way we raised good spirit, and supported project members dedication and commitment to the program.

For the general public our main goal was to raise awareness of the importance of flood-prevention and the necessity of the system developed in DAREFFORT project. A 6-paged foldable flyer was prepared at the beginning and at the end of the project with the basic information for the public about the motivations and results of DAREFFORT. We also sent out press releases on the occasion of the launching ceremony in Budapest. A final press release is also due at the end of the DAREFFORT project to inform the greater public internationally about the improvements in the cooperation of institutions responsible for flood and ice management in the Danube Basin.

We created all the necessary files to have a uniform representation: presentation templates and document templates. We prepared other communication materials, like rollups and posters to help project partners to be successful on conferences, exhibitions and other events. All the project materials were prepared in compliance with the Danube Transnational Programme Visual Identity Guidelines.

DAREFFORT also required project partners to inform professional stakeholders, and educate the general audience locally. These events were also bidirectional, and enabled PPs to collect valuable feedback from the audience, about requirements, expectations, and technical preparedness. Such events helped the project partners to develop and setup e-learning modules in a way that it suits the users the best in the future. The total number of audience at the national workshops and dissemination events exceeded 2000 people. Two short videos were also prepared which summarised the reasons behind establishing DAREFFORT and the expected outputs and social benefits.

DAREFFORT Communication in numbers
2x4000 information flyers in English and **8x200** in national languages of partners
12 event participations, presenting DAREFFORT project to professional audience
9 workshops and dissemination events in 2019 reaching more than 2000 people
14 newsletters to **150** recipients during the 3 years of DAREFFORT project
500 Technical Summaries on the achievement of the project

Group photo at the 1st Periodic Meeting with Capitalisation event and DAFF event, 4-5. February 2019, Vienna

3. EVALUATION OF FORECASTING

3.1 Evaluation of flood and ice forecasting WP3 Output 3.1

Mojca Šraj, Mira Kobold, Sašo Petan, Nejc Bezak, Andrej Vidmar, Mitja Brilly
University of Ljubljana, Faculty of Civil and Geodetic Engineering, Slovenia

3.1.1 Introduction

The main aim of the DAREFFORT project was to give a comprehensive overview about the complex national flood and ice forecasting systems, to eliminate the shortcomings of the existing forecasting practices as well as to improve the exchange and availability of hydrological and meteorological data between the participating countries with the establishment of a common data exchange platform, which is a prerequisite for the future Danube Hydrological Information System (DanubeHIS) of ICPDR. To achieve this goal, a detailed questionnaire was prepared as part of WP3 and the results were evaluated. The questionnaire contained 116 questions covering the following: the countries' hydrological and meteorological data availability, recording methods and coverage with the monitoring networks, coding and national database systems, data flow, forecasting time intervals and accuracy, response times, cross-border issues and data dissemination, etc.

The evaluation of the questionnaires and national reports was the basis for a review of flood and ice forecasting systems and methodologies in 12 Danubian countries, as well as of JRC and ISRBC as good practices of cooperation. From non-participating countries, Bosnia and Herzegovina also supported the project by completing the questionnaire. The review is divided into four major topics related to meteorological data, hydrological data, ice data, and the national hydrological forecasting service. These results were the basis for suggesting a unified and mutually agreed upon list of data that all data providers are capable of providing.

3.1.2 Meteorological data

Meteorological observations are an essential part of flood and ice warning and forecasting systems. Generally, within meteorological networks various data are collected. The most important variables are precipitation, air temperature, air humidity, wind speed, air pressure, solar radiation, sunshine duration, evaporation, soil moisture, snow depth, and snow water equivalent.

We have to stress that actual measurements of evaporation and transpiration are performed only in some countries at few meteorological stations. Furthermore, potential evaporation is measured only in some places. Soil moisture measurements are hardly ever taken. Composite weather radar imagery to be used in hydrological models is not available in all countries. In most countries, there are no systematic measurements of the snow water equivalent or its spatial distribution, despite the fact that the floods in the Danube River Basin are mainly generated in mountainous areas in combination with snowmelt.

The availability and access to meteorological data is different across the countries of the Danube River Basin. Furthermore, not all the data are free of charge in the respective countries. Availability of meteorological data, terms of use for the countries involved in the DAREFFORT project, the number of on-line meteorological stations operated in the Danube River Basin, and information about the type of data provided on the public website are presented in Output 3.1. The countries used their own criteria for selecting the representative stations for the DanubeHIS. The location of the selected stations is presented in Figure 3.1.1. and all other information is given in Output 3.1.

3.1.3 Hydrological data

In the frame of hydrological monitoring all countries collect data on hydrological parameters, i.e., water level, discharge, and water temperature. Some of them collect information about sediment and ice, while there are practically no systematic measurements of water flow velocity. Bed load transport is hardly ever measured. There are no systematic measurements of channel morphology either, with the exception of navigable waterways along the Danube and its tributaries.

Measurements of river stages, and indirectly river discharges, are well developed in all hydrological services. However, the number of observation stations has unfortunately decreased over recent decades and we lost valuable information regarding the heterogeneity and dynamics of the phenomena measured. Furthermore, digitalisation of historical data is lacking in all services.

The availability and access to hydrological data is also different across the Danube River Basin countries and not all the data are free of charge in the respective countries. All countries foster extensive exchange of meteorological and hydrological data and information with domestic and foreign institutions and users. They provide data to international organizations such as the Global Runoff Data Centre (GRDC), the European Flood Awareness System (EFAS), and the Hydrological Information System of the Sava River Basin (SavaHIS). Data are exchanged based on agreements. Procedures for national and international exchange of meteorological and hydrological data exist in all countries.

The countries used their own criteria for selecting the representative hydrological stations on the main rivers and their tributaries in the Danube River Basin proposed for the DanubeHIS. The location of the selected stations is presented in Figure 3.1.2, all other information is given in Output 3.1.

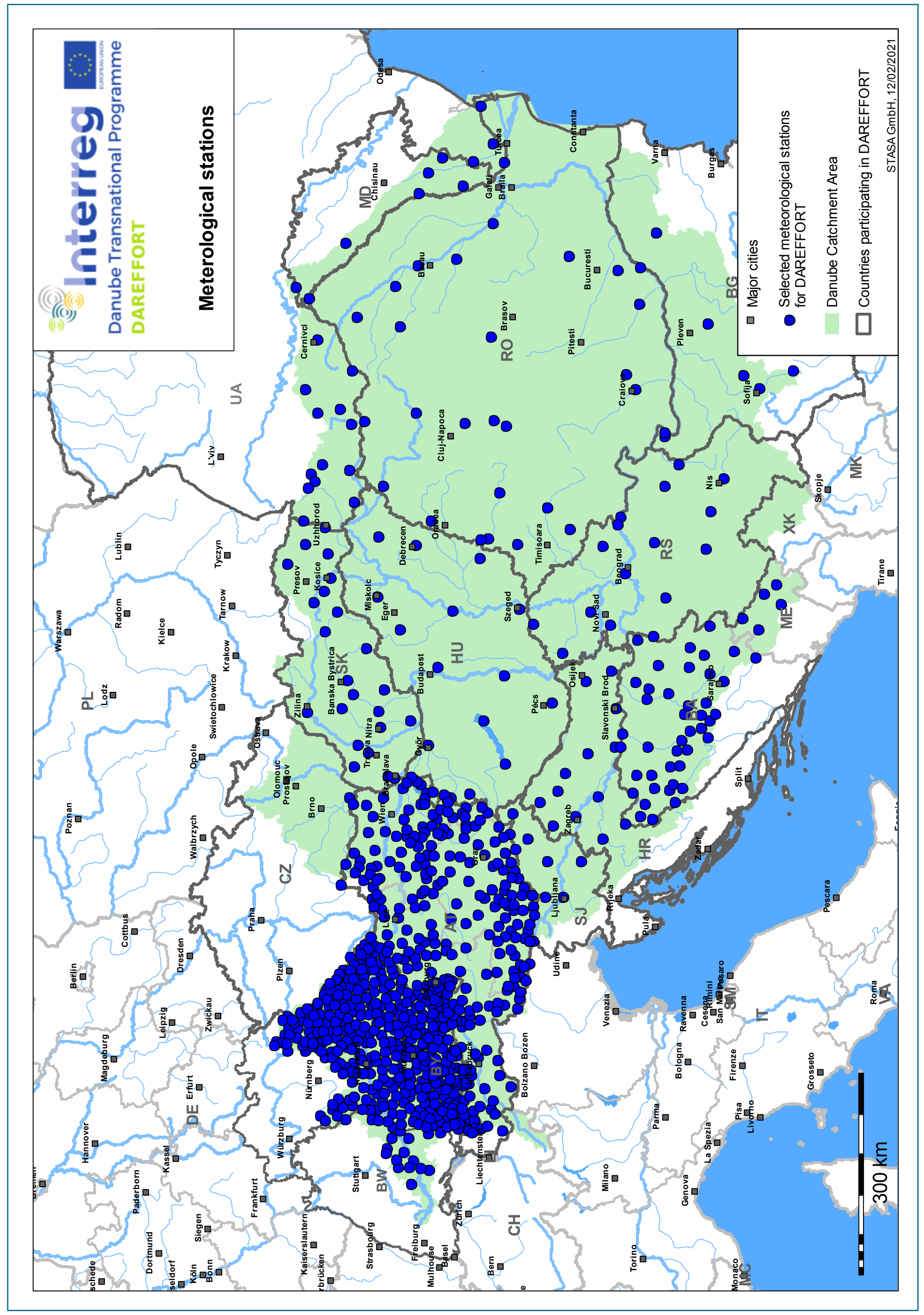


Figure 3.1.1: Map of networks and proposed meteorological stations. Additionally, stations from Bosnia and Herzegovina and Montenegro were added (STASA, 2021)

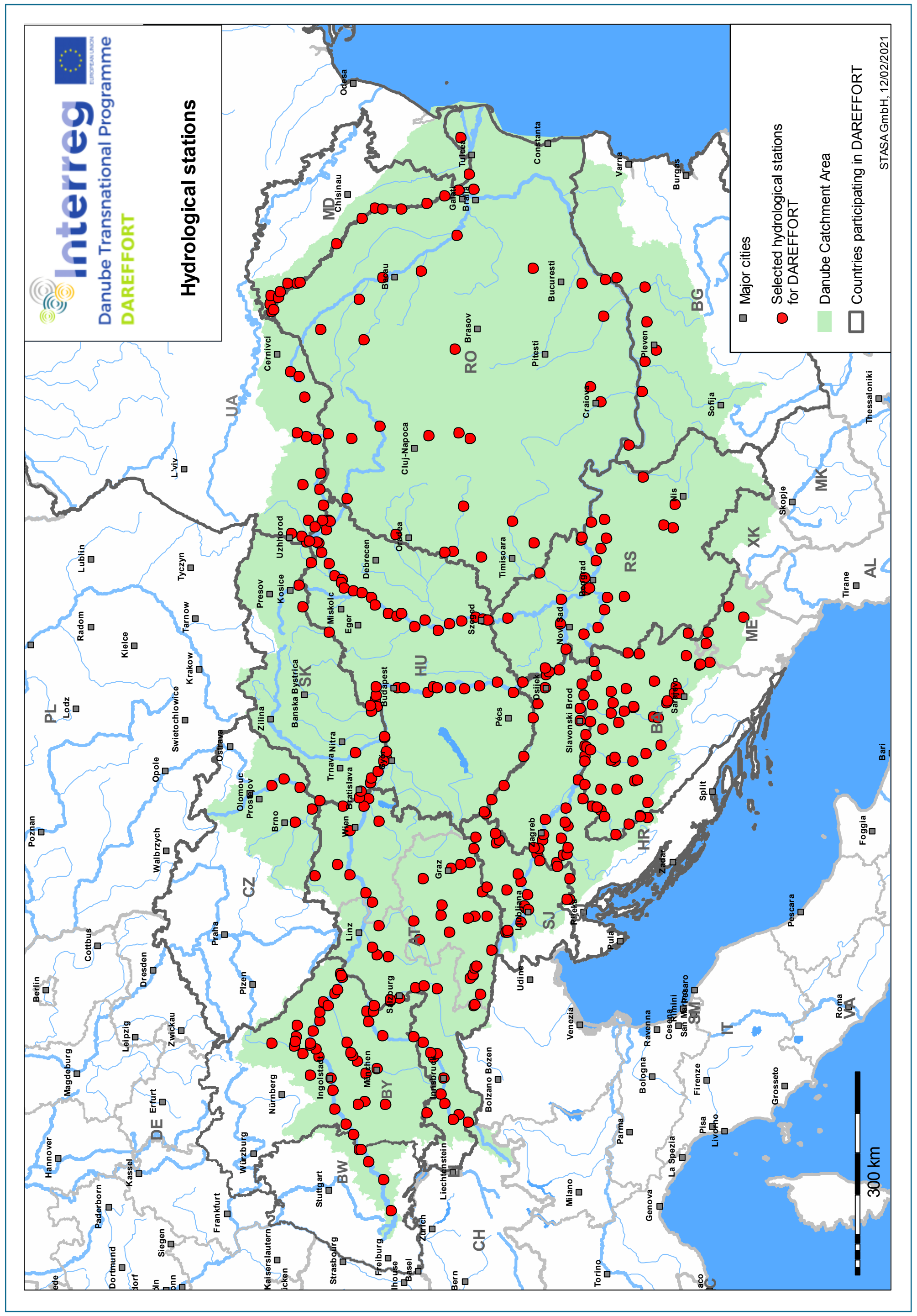


Figure 3.1.2: Map of networks and proposed hydrological stations. Additionally, stations from Bosnia and Herzegovina and Montenegro were added (STASA, 2021)

3.1.4 Ice data

Ice measurements are conducted along the Danube River's main flow and its navigable tributaries, based on the recommendation adopted by the Danube Commission. In other water bodies there are some ice measurements or observations. Because of the frequent problems with ice and historical floods, these services are best organised in Hungary.

3.1.5 Hydrological forecasting

The type and manner of hydrological forecasting are mostly subject to regional natural conditions. In upper and high-slope river reaches, the discharges mostly depend on the local precipitation type and its intensity. In such regions, monitoring systems with as short as possible data transfer time steps are needed for forecasting as the hydrological conditions are prone to rapid changes. The water levels of the lower river reaches are strongly influenced by the drainage from the upper catchments and the low slope of the river channel. Here, the change of hydrological conditions is slower, and the hydrological conditions are maintained for longer periods. Water levels of low-slope rivers may also be affected by ice.

The national hydrological and the meteorological forecasting services of the Danube River Basin countries mostly operate within the same institution, on a door-to-door principle, which means that hydrological services have access to the meteorological data and predictions free of charge, daily consultations with meteorologists are in place and usually both services prepare a joint warning product as well.

A large diversity among the Danube River countries in terms of hydrological and hydraulic models used and the number of models applied was recognized. Among the hydrological models, the deterministic/conceptual/lumped model type predominates over the deterministic/physically based/distributed model type. The lumped models are often used in the semi-distributed manner by catchment division into sub-catchments and/or elevation zones. The hydrological models used in more than one country (organisation) are DHI NAM, HBV/HBV-light, and HEC-HMS. Among the hydraulic/routing models the dynamic wave – hydraulic routing model type predominates over the hydrologic routing model type.

Forecasting accuracy assessment is systematically undertaken only by some services, mostly on an occasional basis only. Systematic assessments of forecasts are only performed by the European Commission's Joint Research Centre (JRC) – for its EFAS forecasts, covering EU member states and associate members. The hydrological and hydrodynamic modelling system uncertainty is further weighted with the uncertainty from the meteorological forecasts. Therefore, the hydrological services tend to issue descriptive forecasts rather than quantitative ones originating from the modelling systems. Thus, experienced hydrological forecasters hold a key role in the critical evaluation of the modelling system results as well as within the decision-making processes of the hydrological forecasting service.

3.2 Common vision of cooperation WP3 Output 3.2

Mojca Šraj[1], Mira Kobold[1], Sašo Petan[1], Nejc Bezak[1], Philipp Liedl[2], Mitja Brilly[1]
[1] University of Ljubljana, Faculty of Civil and Geodetic Engineering, Slovenia
[2] STASA - Steinbeis Angewandte Systemanalyse GmbH, Germany

3.2.1 Introduction

The results of the questionnaire and national reports showed that the organizational structure of hydrological and meteorological services differs among the various countries of the Danube River Basin. The availability and access to meteorological and hydrological data across the Danube River Basin countries is also different. Furthermore, in some countries not all the data are free of charge, while the collaboration of national hydrological and meteorological forecasting services also differs across countries. These differences are mainly due to the relation with the meteorological forecasting service (e.g., door-to-door, separated) and consultations with meteorologists. Reducing the risk of floods, which have become increasingly frequent in recent years, should therefore be aimed at improving the forecasting capabilities on a basin-wide scale. Such an approach is the most cost-effective non-structural tangible solution, which highly reflects the solidarity principle and therefore calls for a strong cooperation between the countries.

3.2.2 Analysis of the information flow among neighboring countries

Analysis of the information flow and exchange of the data among neighbouring countries was conducted based on the information about the data availability with respect to the data exchange and improvement of forecasting conditions prepared as part of the project's Activity 3.1 and the corresponding Output and Deliverables. The borders crossed by the Danube and its main tributaries, along which the flow of information should proceed, are indicated in Figure 3.2.1.

3.2.3 Bottleneck analysis of the update frequencies for real-time hydrological and meteorological exchange of data

Based on the information about the update frequencies of real-time hydrological and meteorological data among the Danube River Basin countries (see Output 3.1), gaps and bottlenecks were identified. Results of the analysis show that both the availability of data as well as the update frequency differ greatly among countries along the Danube River. If a downstream forecasting centre works with national data with a higher frequency than an upstream country can deliver, this will be a bottleneck in the cross-country data exchange. In this case, the data from the upstream country cannot be used optimally by the downstream countries. Figures 3.2.2 and 3.2.3 show the variables foreseen to be transmitted in the DanubeHIS and their update frequency.

3.2.4 Recommendations for improvement

Based on the analyses made in the scope of DAREFFORT, recommendations for the improvement of flood and ice forecasting systems were prepared. Some recommendations apply to both meteorological and hydrological data, including ice. Accordingly, the Danube River countries should consider: the need to improve the measuring network terms of the stations' density and the inclusion of measurements of additional variables; the need for developing meteorological and hydrological products also at regional level; provision of free access to some of the meteorological and hydrological data related to the national forecasting services; collection of historical data records, digitalization, and storage in a database; provision of strong arguments for obtaining financial, technical, and human resources to operate meteorological and hydrological services; a common updating interval at least on a daily basis for the parameters. All countries should provide the following hydrological and meteorological parameters for exchange: water level, discharge, water and air temperature, and precipitation.

Related to the hydrological data, the improvement of the measuring network in terms of the inclusion of ice and snow measurements is recommended, since the combination of extremely rare events is not covered adequately enough by hydrological models and/or forecasting protocols. Besides, the countries should consider a standardized data exchange for sharing the hydrological data. The latter supports the Environet Data Exchange Platform, which was developed under DAREFFORT.

For the development of hydrological forecasting methods and models, it is recommended to: develop hydrological forecasting systems for various catchments of different scales, consider the existing systems; take into account the catchment characteristics while making the decision on which appropriate hydrological and/or hydraulic model to use; improve the relationship between both services in the countries where the hydrological services operate separately from the meteorological services and have a fee-based access to meteorological data and predictions, limited consultation options, and independent warning products; further develop existing modelling methods and use of various models in the development of the hydrological forecasts as well as ensemble forecasting. Where possible, open-source models should be used and fostered to ensure transparency to the users and to make an optimum use of the limited resources; develop systematic forecasting accuracy assessment and critical evaluation of the forecasting for the entire Danube River Basin; continuously enhance the capacity of hydrological forecasting services; consider strengthening the IT support (e.g., staff) and capabilities (e.g., resources, tools) dedicated to flood forecasting in the individual forecasting services; collect all water regime data in a single database, including data from the private sector; improve the cooperation among the hydrological services within the Danube Region; and form regional and/or bilateral agreements.

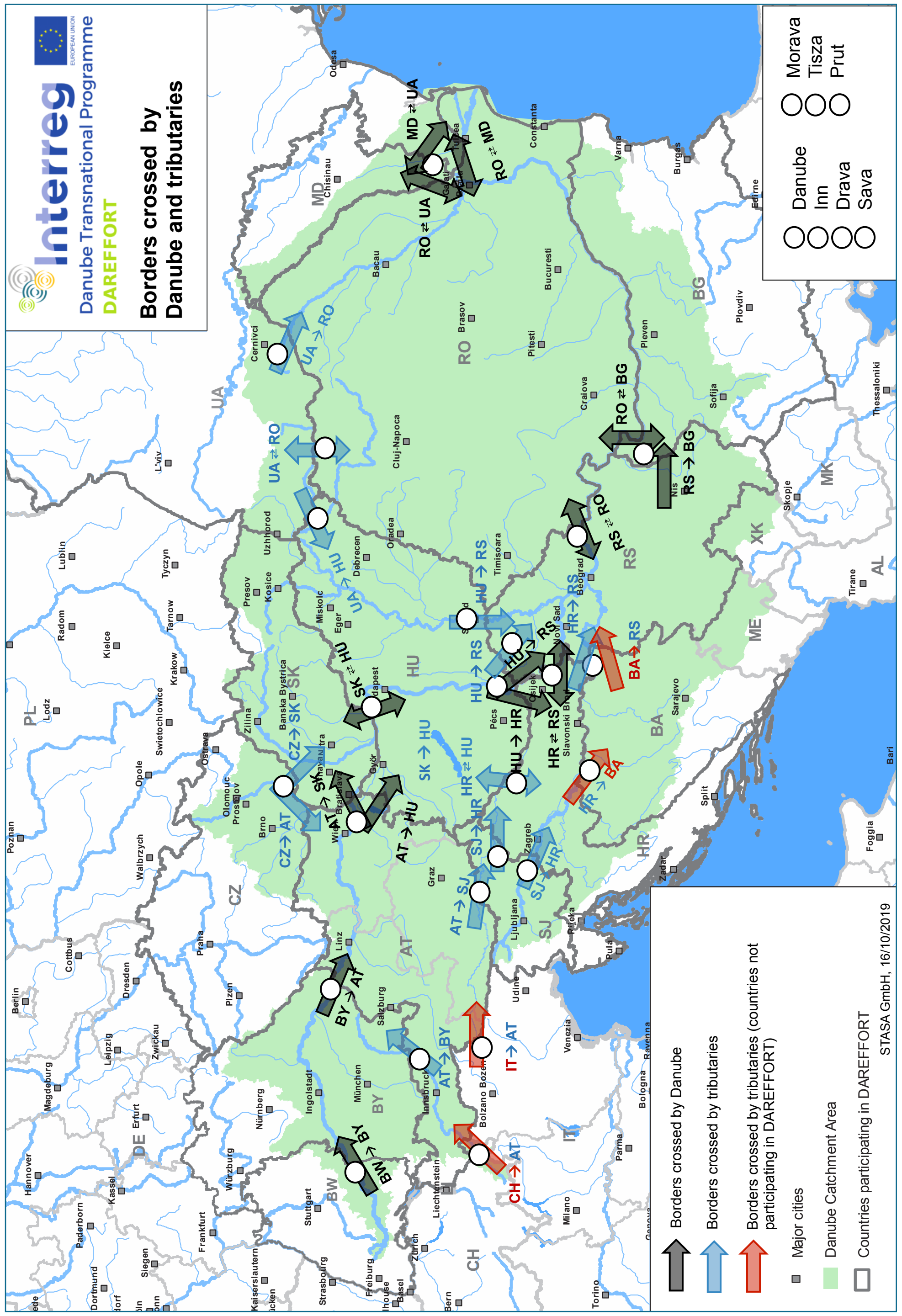


Figure 3.2.1: Necessary information flow along the Danube River and its main tributaries

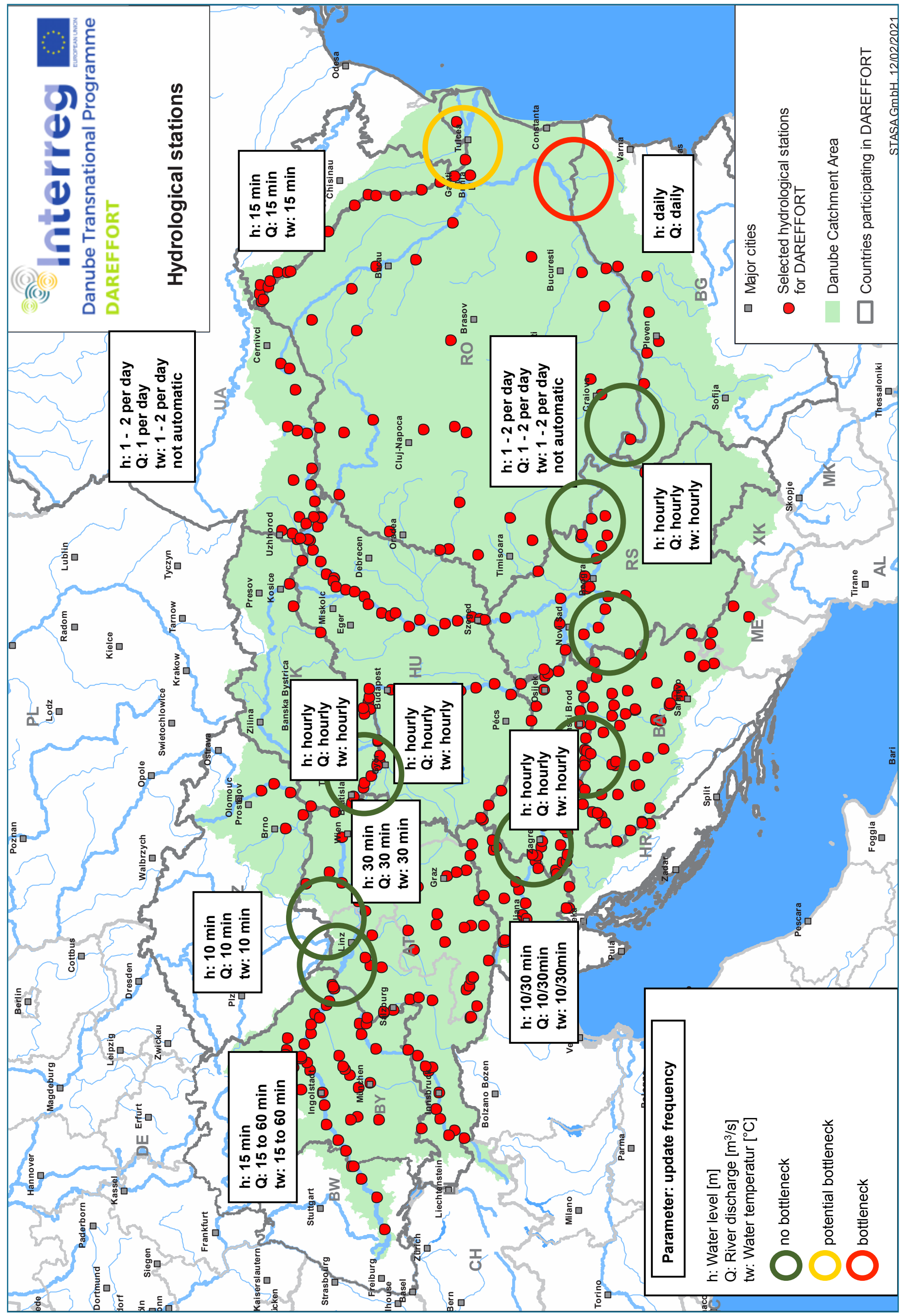


Figure 3.2.2: Update intervals for hydrological stations and recognized bottlenecks in data transfer

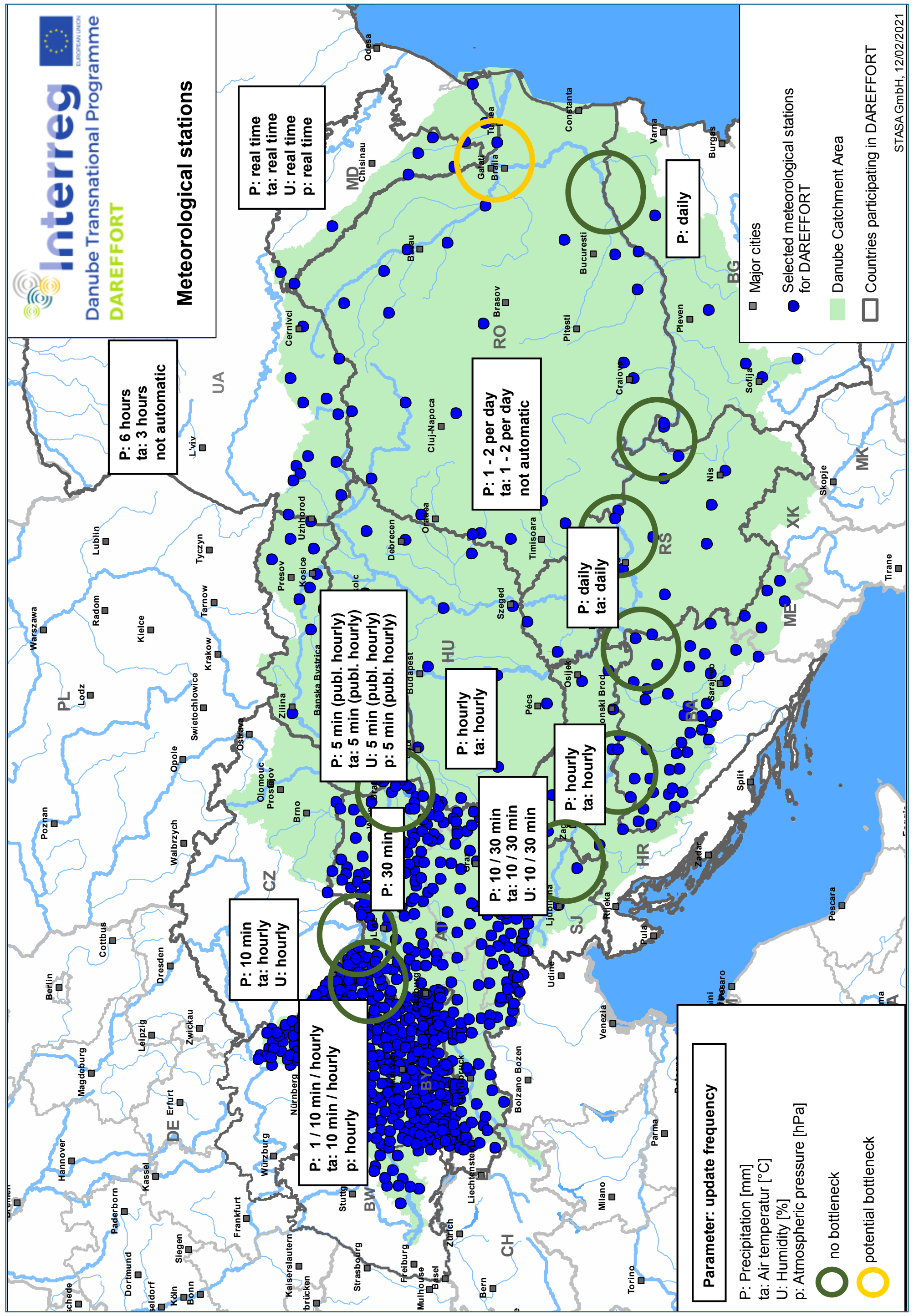


Figure 3.2.3: Update intervals for meteorological stations and recognized bottlenecks in data transfer

3.3. Economic impact analysis of potential future system scenarios WP3 Deliverable 3.2.5

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Economica GmbH, Austria

3.3.1 Introduction

Since ancient times, floods have been natural disasters that humans have had to combat. In modern days, this is truer than ever before. The frequency of natural disasters such as floods is increasing due to climate change. It is estimated that between 1980 and 2013, floods have resulted in the death of 117,000 persons and caused economic damages of around 487 billion dollars (Thielen-del Pozo et al., 2015).

Effective flood risk management is necessary for mitigating the impact of floods on population, property, and the environment. Early warning systems, which allow for early responses, require high level of forecasting data. Forecasting remains one of the most powerful tools in flood management (Pappenberger et al., 2015). These systems are highly effective at reducing damages caused by floods.

Thus, effective flood forecasting becomes an absolute necessity to minimize damages to life and property in the Danube Basin. DAREFFORT creates a system where hydrological and meteorological data of nations along the Danube Basin are easily accessible to one another, and this will be a major milestone in increased flood prevention in this area. It will improve the lead time and accuracy of flood forecasts in the majority of the participating countries, allowing authorities to react sooner in the case of an approaching flood, which, in turn, will reduce both damages and costs.

Therefore, the DAREFFORT deliverable 3.2.5 Economic impact analysis of potential future system scenarios executed an ex-ante estimation of the economic effects brought about by the outcome of the DAREFFORT project in different scenarios.[1] Hence, a two-step-approach consisting of a cost-benefit analysis (CBA) and an input-output analysis (IOA) was used. In the CBA implementation costs and future running costs are contrasted with future benefits resulting of reduced flood damage costs.[2] The IOA is a macroeconomic tool which can be used to estimate economic impacts of various positive and negative shocks in terms of changes in, inter alia, employment and gross value added (GVA). In the context of DAREFFORT, the IOA is used to calculate GVA and employment effects generated from the CBA results and the running costs.

[1] In the DAREFFORT project, four different potential future system scenarios were elaborated. Two of them were subjected to the quantitative economic analysis. Scenario 0 is the certain, direct outcome of DAREFFORT, a common Danube River Basin observed data software exchange platform. In Scenario 1 forecasting data will be exchanged as well.
[2] Future values are discounted by an interest rate of 2.5 per cent p. a.

3.3.2 Data

The data for the quantitative impact analysis were delivered by the DAREFFORT project partners in each partner country. The project partners contributed by researching economic consequences of previous flood events in their respective countries. In total, information on 72 historical flood events was collected. Between the years 1990-1995, there was almost no damage caused by floods, and between 2015-2019, no significant flood occurred. In the years between 1996 and 2014, the picture is a different one. The years 1997, 2002, 2010, and 2014 saw floods that caused damages in excess of 2 billion euro each, with 1997 being an extreme occurrence that caused over 4 billion euro of damage. It is evident that extreme floods can occur at any time and long periods of calmness are not indicative of intensity of future flood behaviour.

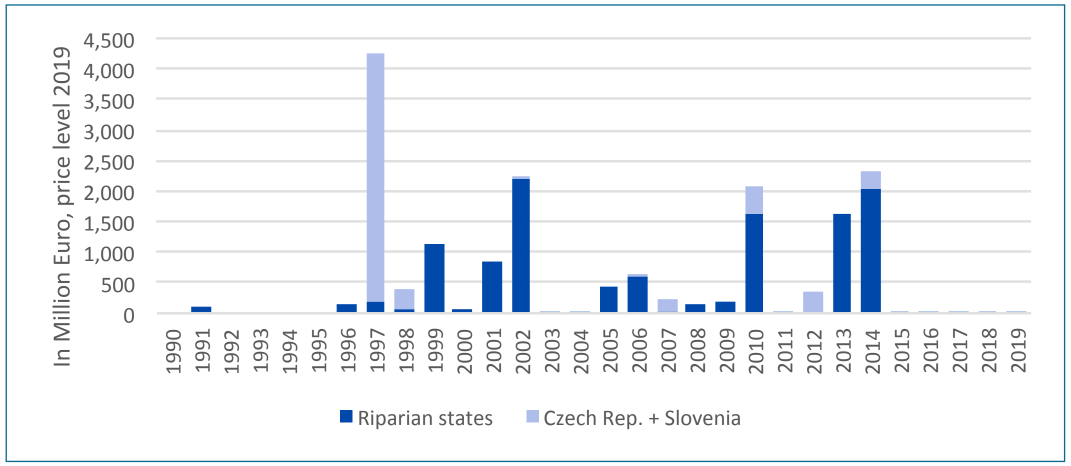

Figure 3.3.1: Losses due to flood damage per year, 1990-2019 - Source: DAREFFORT.

These data were divided into categories by return period and severity (minimum, mean, and maximum damages). Furthermore, the data providers revealed that they expect DAREFFORT/DanubeHIS-related costs to attain 3.5 million euro per year[3] in Scenario 0 and Scenario 1, and additional initial costs of 450,000 euro in Scenario 1.

3.3.3 Cost-benefit analysis

In Scenario 0, Croatia, Romania, Bulgaria, Serbia, and the Ukraine reported anticipated improvements in terms of an extended lead time, Slovakia, and Hungary expect at least a higher accuracy due to the data exchange between all countries. Germany, Austria,

[3] Direct DAREFFORT/DanubeHIS-related costs are only 200,000 euro. However, costs in the "background" (data processing, monitoring, maintenance etc.) also are considered. These costs are already covered in the data providers budgets.

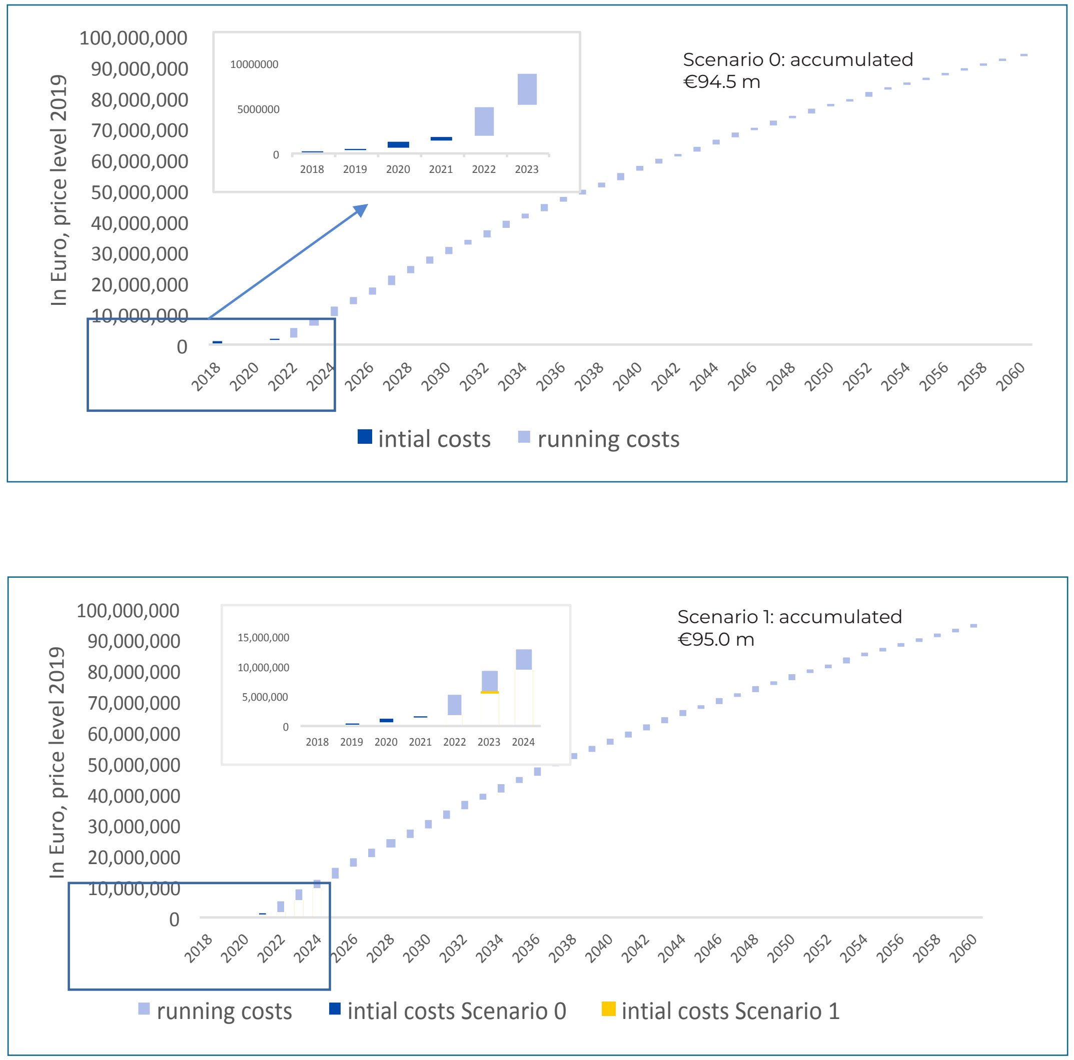

Figure 3.3.2: Cost functions Scenario 0 and Scenario 1 - Source: DAREFFORT

the Republic of Moldova, Czech Republic, and Slovenia do not expect any improvements of their national forecasts. This is not surprising, as Germany and Austria are upstream countries with an ongoing bilateral data exchange, and data from downstream countries do not affect their forecasts. Water in the Czech Republic significantly depends on the precipitation amount, as there are no significant tributaries to the country. Moreover, the

Czech Republic and Austria have bilateral agreements, so there is no expected improvement for the Czech Republic resulting from DAREFFORT. The same applies to Slovenia. In Scenario 1 Germany, Austria and the Republic of Moldova, still do not expect any improvements in terms of a longer lead time or a forecast quality improvement. Slovakia, Croatia, Romania, Bulgaria, Serbia, Czech Republic, Slovenia, and the Ukraine expect improvements of both, lead time and accuracy.

An extensive literature review[4] was used to determine percentages of reduction in potential flood damages in each affected economic activity (agriculture, manufactured products, constructions above ground, constructions below ground, transportation, and other), that can be attributed to a longer lead time or a higher accuracy of the forecasts. Using this information, the potential damage costs in the status quo can be compared to the situation with DAREFFORT/DanubeHIS. If the costs (potential damage costs plus running costs) with DAREFFORT/DanubeHIS are lower than the potential damage costs in the status quo, the system would be beneficial from an economic point of view.

Results of the CBA are displayed in Figure 3.3.3. The yellow lines represent the effects from a minimum damage perspective, the green lines from a maximum damage perspective. Depending on the severity of the future flood events, the costs or benefits arising from DAREFFORT/DanubeHIS will lie between those lines. In the unlikely case of minor damages only, the system will cost more than it can potentially save. Already in the mean damage category, DAREFFORT/DanubeHIS has the potential to save a total of around 3 million euro per year, or 70 million euro cumulatively until 2060. These savings could reach up to 26 million euro annually, or 660 million euro cumulatively until 2060 under the maximum damage perspective. In other words, 1 euro invested in DAREFFORT/DanubeHIS in Scenario 0 has the potential to save 6.98 euro until 2060.

In Scenario 1, even higher effects are expected. The annual difference with the status quo ranges between increased costs of 3.6 million euro and benefits of 26.0 million euro. Cumulatively, the effects range between higher costs of 81 million euro to savings of 2,4 billion euro until 2060. In the mean damage category – the most likely state –, DAREFFORT/DanubeHIS would save up to 426.4 million euro until 2060. 1 euro invested in DAREFFORT/DanubeHIS in Scenario 1 has the potential to save 24.75 euro until 2060.

3.3.4 Input-output analysis

Natural disasters actually may have a positive effect on future value added. This might sound counterintuitive at first, but it becomes clear on closer inspection, as reconstructions stimulate the economy. This is a well know problem in evaluating the economic impact of natural disasters. (Of course, for the affected people in the endangered areas, these events mean dramatic economic hardship.) However, these investments are usually incurred in lieu of different or even more efficient areas of the economy. This implies

[4] Numerous studies were considered in this section: Day, 1970; Chatterton and Farrell, 1977; Smith, 1981; Wind, 1999; ICPR, 2002; Reese, 2003; Carsell et al., 2004; Kreibich et al., 2005, 2007, 2008; Parker, 1991; Parker et al., 2005, 2007; Thieken et al., 2005, 2007; Tunstall et al., 2005; Steinführer and Kuhlicke, 2007; Priest et al., 2011; Penning-Rowsell et al., 2013.

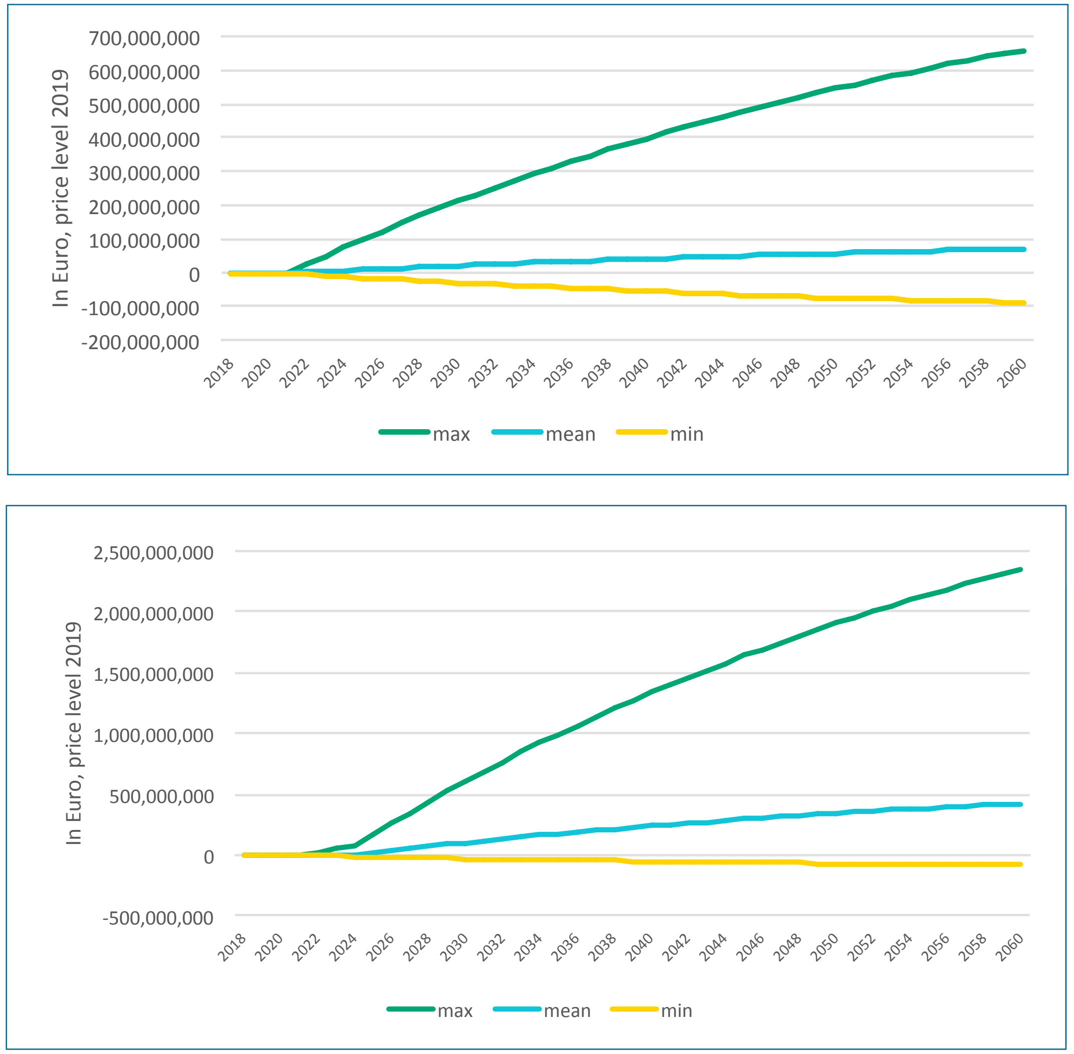

Figure 3.3.3: Total accumulated effects of the CBA, Scenario 0 and Scenario 1 - Source: Economica.

even though no "additional spending" may take place, "spending in different investment goods" is triggered by damage repairs. Therefore, the results of the IOA are to be interpreted, as "vacated capacities" that would have been reserved for the sole purpose of restoring the status quo and now can be used for more beneficial investments.

The IOA[5] transforms the running costs and the results of the CBA into GVA and employment effects. Running costs (expenses for staff and material/maintenance) paid by

[5] The IOA was only performed for Scenario 0.

the national hydrological and meteorological institutes stimulate the economy, lead to GVA, and generate or secure jobs. These expenses are thus transformed to a direct annual GVA. Due to purchases of intermediate goods for these activities, the direct GVA increases by the so-called indirect effect generated in the supply network. Aggregating direct and indirect effect equals the total GVA effect. The highest total GVA effect can be expected in Austria (829,958 euro), Germany (766,372 euro), and Romania (585,923 euro). The other countries range between 259,942 euro in Slovenia and 39,880 euro in Ukraine. The highest total employment effect resulting from the running costs can be observed in Romania, where 10.5 jobs can be created or secured, followed by Germany (4.3), Austria (2.7), Slovakia (2.7) and Hungary (2.4).

The economic impact analysis was performed in three perspectives: minimum, mean, and maximum damage categories. Under a minimum perspective, the GVA effects resulting from the CBA are marginal. For all countries[6] combined, the total annual effect amounts to 206,841 euro. However, for the mean (5,583,686 euro) and maximum (25,648,617 euro) damage categories, the effects are expected to be much higher. Similar to the GVA, employment effects in the minimum perspective are rather small, creating or securing a total of only 6.2 work places. In a mean perspective, the total employment effect would be 205.7. In a maximum perspective this number rises to 932.8.

3.3.5 Conclusion

These findings lead to the conclusion, that from an economic point of view, DAREFFORT/DanubeHIS will be beneficial, if mean or maximum flood damages accrue. Only in the case of just minor flood damages, the costs exceed the benefits. Also, it can be recommended to implement Scenario 1, as the costs just rise slightly, but the potential benefits increase substantially. However, it is important to base the decision not only on economic aspects since they are just one aspect when it comes to answering the question if a flood warning system should be implemented or not. Furthermore, social and ethical aspects should be taken into account, as flood warnings not only save property, but also lives.

3.3.6 References

The complete list of references can be found in the full report.

[6] As for the countries, Germany, Austria, Republic of Moldova, Czech Republic and Slovenia no cost savings are expected, no GVA effects will be experienced.

4. HARMONIZED DATA EXCHANGE
4.1. Policy recommendations for exchange of data WP4 Output 4.1

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4.1.1 Introduction

For the exchange of data between countries in the Danube catchment it is essential to achieve a consent of the conditions and regulations under which the exchange takes place. The challenges of a common transnational exchange of hydrological and meteorological data are manifold. Each country has a different IT infrastructure that is only compatible with each other to a limited extent. The hydrological and meteorological data collected in each country, and in particular the collection intervals, are also very different.

Beyond the technical challenges, the legal framework for data exchange must be clarified and a common ground has to established.

It is already common practice to exchange data with neighbouring countries on the basis of bilateral agreements. This exchange has usually grown and been established at technical level over many years and is often very specifically tailored to the needs of the individual countries. A simple transfer of the conditions for this bilateral data exchange to the level of the entire Danube catchment is therefore not possible.

In order to establish a smooth data exchange that covers the entire Danube Basin and meets all the needs of the individual countries, a common data policy and a common data format for the exchange of data must be developed and established.

According to these aims recommendations necessary to elaborate the data policy document for the future DanubeHIS by FP-EG and ICPDR have been elaborated in DAREFFORT project, but also recommendations for the technical operation of the common data exchange platform.

4.1.2 Data policy recommendations

The data policy sets up the legal framework, which defines the conditions and permissions which apply to use the data on the common data exchange platform.

An elaborated and comprehensive data policy is a prerequisite for all data providers, regardless of the country in which they operate. Different questions must be addressed in the data policy document, such as:

- Should the data be available unrestricted and free of charge?
- Which data is provided?
- To which groups should the data be provided (general public, forecasting centres, universities, etc.)?
- Restrictions of data transfer to third parties / use in commercial products?
- Liability for the data?
- Additional conditions, like source of data has to be mentioned?

In order to establish common recommendations for a data policy for DanubeHIS during DAREFFORT project a survey has been carried out among project participants to evaluate existing data policy regulations in the countries, but also to get an overview on the country specific needs and requirements for this data policy document. In addition, exiting data policy documents for relevant multi national hydrological and meteorological data exchange platforms such as Sava HIS or SEE-MHEWS-A have been analysed. The results of the analysis and the survey have been discussed in workshops on data policy topics during the periodic project meetings.

The following recommendations are derived as the partners proposals for the data policy document of DanubeHIS:

Regarding the **availability of data**, it is recommended to make the data of the common data exchange platform available unrestricted and free of charge, where possible. This should be particularly the case for hydrological forecasting centres in the Danube catchment. This is in line with the WMO Resolution 25 (Cg-XIII) – "Exchange of Hydrological Data and Products", and WMO Resolution 40 (Cg-XII) – "Policy and Practice for the Exchange of Meteorological and Related Data and Products". In these resolutions the WMO encourages its members to provide on a free and unrestricted basis those hydrological data and products which are necessary for the provision of services in support of the protection of life and property and for the well-being of all peoples. "Free and unrestricted" means non-discriminatory and without charge. "Without charge", in the context of this resolution means at no more than the cost of reproduction and delivery, without charge for the data and the product themselves.

Specific usage, like using the data in commercial products or redistributing the data to third parties can be restricted, depending on the purpose and/or user group, as described below.

With respect to the **provision of data** a minimum set of parameters should be defined. Following parameters can be regarded as commonly agreed within the DAREFFORT consortium regarding measured data: water level, discharge, water temperature as hydrological real time parameters and precipitation as meteorological real time parameter. In addition to the minimal set of parameters it can be recommended to foresee an option to expand this list by additional parameters in the future.

It is further recommended to define a **common update time interval of the parameters** which the data providers provide the data to the platform in the data policy document, at least as a recommendation. From the experience in the Danube catchment for real time measured data this could be hourly, and for historical data daily (updated once a year). Also, the monitoring stations for which the data is provided to the platform should be defined in the data policy, and could correspond to the list of hydrological stations and meteorological stations earlier in the DAREFFORT project. This list should be made adjustable in the future (e.g. by placing it into the appendix of the data policy).

For retrieving the data from the platform OGC WaterML 2.0 data format standard is recommended, and has been implemented in the software of the platform.

Regarding the **groups to which the data should be provided,** the following stakeholders, and corresponding restrictions have been identified:

- **Hydrological forecasting centres:** Access should be unrestricted and free of charge for internal usage. This is agreed by all participants of the survey.
- **Universities / Public research institutions:** Access should be unrestricted and free of charge for internal usage. In case of publications and research projects the data source has to be cited, and from case to case data providers have to allow for using the data specifically.
- **Private research institutions:** Access should be unrestricted and free of charge for internal usage. In case of publications and research projects the data source has to be cited. From case to case data providers have to be asked for agreement on using the data.
- **General public:** Access should be unrestricted and free of charge for private usage.
- **Companies (e.g. Harbours, Power suppliers, shipping companies):** Access should be unrestricted and free of charge for internal usage. Also here, depending on the specific case a separate agreement with data providers could be necessary.

However, **restrictions should apply for data transfer to third parties or using the data in commercial products.** Specifically, re-distribution of the data by third parties should be prohibited or only allowed by written permission of the data provider. Also, usage of the data in commercial products could also be prohibited or only allowed by written permission by the data provider, and could be charged, whereas usage of the data in non-commercial products could be allowed by written permission of the data provider.

Because all the countries already have different regulations regarding re-distribution or commercial use, it could be necessary to also receive written permission from the countries from which the data is used.

A very important topic of data policy is the **liability for the data.** In this context it is recommended, and common practice in existing data policies, to make the data receiver responsible for appropriate data handling, and interpretation of the data. The data provider should not be made liable for the accuracy of the real time and other data provided. Data providers should not be liable for any loss or damage, cost or claims arising directly or indirectly from the use of the data.

Additional recommendations are that the origin of the data should be cited in any case when using the data. This is common practice. In the ongoing process of implementing the data policy after the project, higher level authorities should be involved at an early stage. It also is recommended to implement a flexible data policy solution, which enable the data provider to handle with the different groups according to the different national data policies and reflect possible changes of the national data policy.

4.1.3 Recommendations on technical operation

Besides a comprehensive data policy, coordinated technical specifications are also essential for a smooth and flawless operation of DanubeHIS in the future. Therefore, recommendations from flood forecasting and IT experts have been elaborated at an early stage of the project before implementing the software to ensure high standards for the development of the software, and to avoid bottlenecks in the later operation. These standards have to be conform and compatible with already existing technologies used by data providers in all countries, but also ICPDR as the future operator of DanubeHIS. Therefore, the technical recommendations summarized in the following are based on an in-depth review of the existing technical capabilities of the hydrological and meteorological stakeholders in the Danube catchment.

Real time hydrological data

For real time hydrological data, it is recommended for data providers to use an FTP-Server or Web-API for the data exchange.

The minimum common update interval for the parameters is daily. For automatic stations there is a minimum common update interval of one hour. The long-term goal should be to achieve an update interval of at least one hour for the agreed parameters of the data policy. Parameters exchanged by all countries are **water level, discharge and water temperature** which are the minimum of agreed parameters. The exchange of additional available parameters is welcomed.

Real time meteorological data

As for hydrological data, an FTP server or a Web API is recommended for data exchange of real time meteorological data. The data should be updated at least daily, better would be hourly on the long term.

Only **precipitation** can be delivered in all countries using the data exchange interface at the moment, which meets the draft specifications of minimal set of meteorological data foreseen to be exchanged in future DanubeHIS. However, more parameters could be provided by most of the countries, therefore it could be possible to exchange **air temperature** in addition in the future.

Processed historical hydrological and meteorological data

Processed historical hydrological data should be uploaded or made available on an FTP server using a defined template csv file, because most of the countries already use this method for exchanging processed data.

Duration of persistent storage of real time data

Currently the regular practice is to publish processed data once a year. Therefore, the duration of storage of the real time data should be at least one year to avoid temporary data gaps in the database as far as possible. On the other hand, real time / unprocessed data should not be available indefinitely, because of possible data incorrectness.

4.2 Observed data exchange software WP4 Output 4.2

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4.2.1 Introduction

The challenges of a common cross-national exchange of hydrological and meteorological data are manifold. Each country has a different IT infrastructure, and different data formats, which is only compatible with each other to a limited extent. Also, the country-specific hydrological and meteorological data and especially the data update intervals are very different.

In the following the common data exchange platform developed in DAREFFORT project, which is called Danube Hydrological and Meteorological Common Data Exchange Service (EnviroNet) are described. The suffix “EnviroNet” stands for environmental information network which indicates that the software service is able to deal with a variety of environmental data and could be easily extended in the future. Commonly, and in the following the platform is called “EnviroNet”.

The conversion and mapping of the data between national data formats and the common data format for exchanging data has been another crucial topic to be solved in DAREFFORT project. The basis here for this is a common data model, which has been elaborated in the project and implemented in the software.

4.2.2 The Architecture of EnviroNet software

The architecture of EnviroNet serves to establish a stable, common ground to collect and make available existing hydrological data from data providers and handle all the conversion, transport, security, and standardisation requirements attached to that goal.

To achieve the aims of the project the hydrological and meteorological data provided in each country in the Danube basin are converted to the common data exchange format (HyMeDEM), stored and distributed in an appropriate way.

Since there are many partners involved in this process, especially data providers, it is necessary to have a decentralised and modularised solution. This ensures that horizontal growth is possible easily with respect to data providers, the maintenance effort is kept to a minimum for each partner, and the accessibility and availability of data for the end users is maximised.

The data conversion takes place on site of the data providers, where possible, to ensure that they can apply changes in their local formats to the conversion rules on their own without involving the central host. The data from national data providers collected and converted to the common data exchange format are stored in a centralised storage solution, from which the data will be distributed to end users. The centralised service is necessary and preferred over a cloud based or distributed software solutions to achieve a stable running and broadly accepted solution on the long run.

According to the different roles in the common data exchange service EnviroNet can act in two different modes, as **distribution node** and as **data node:**

In the first mode the software is used as **distribution node** which collects data from national data providers and stores the data in the HyMeDEM data model in a central database. As a distribution node, EnviroNet can provide data to clients in Water-ML 2.0 format via a web-API. The distribution node will be part of the DanubeHIS in the future, and it is foreseen that ICPDR will host this EnviroNet distribution node after the DAREFFORT project ends. Therefore, the technical specifications have to be kept compliant to ICPDR future developments (see also detailed description below).

The second operation mode is called **data node.** Data nodes are used by data providers who want to send their data actively to the distribution node. In the data node **conversion filters** (plug-ins) are used to convert the data from national data format to the common HyMeDEM data format. The conversion filters are tailored to the national data formats. The conversion filters can also run directly in the EnviroNet distribution node and pull the data from the data providers' servers. In this case the data providers have to ensure that the data to be exchanged can be accessed by EnviroNet via a Web-API or an FTP-server.

EnviroNet consists of a common code base which can be used as a distribution node or as a data node.

To keep the maintenance effort in balance between data providers and host of the data exchange service, configuration of the conversion filters are manageable by the data providers. Necessary maintenance tasks are limited to situations in which data providers make significant changes like adding new stations to EnviroNet, changing server addresses or making changes to the data exchange protocol, e.g. by assigning national data fields to corresponding HyMeDEM entities. Therefore, the conversion plugins running directly in the EnviroNet distribution node are accessible by the data providers for configuration.

In order to keep the maintenance effort low, especially if a national data provider makes changes in the local data format or Web-API, the conversion plugins are configurable by easy maintainable configuration files, without making changes in the source code. This ensures that national data providers can maintain their conversion plugins as easy as possible. No programming skills are required to maintain the conversion filters.

Data security is ensured by authentication using appropriate encryption methods (separate tool for generating key pair on data providers side). The public key list for authentication should be managed by the host of EnviroNet distribution node in the future, which is foreseen to be ICPDR.

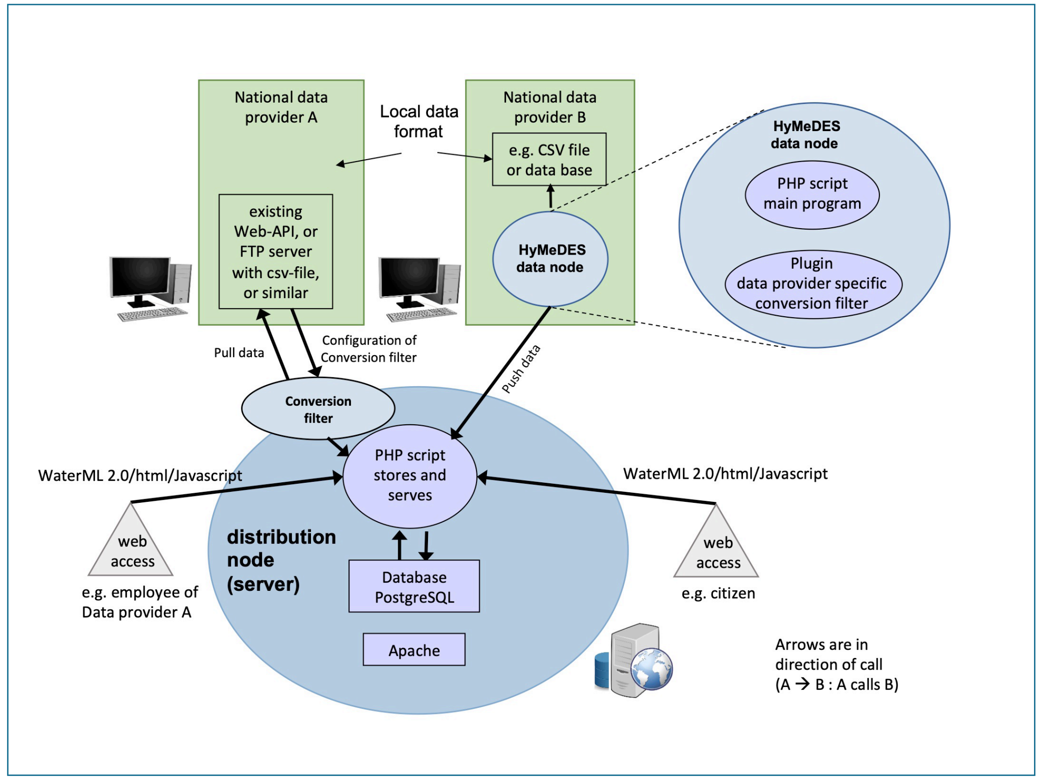

Figure 4.2.1: Schematic overview of the architecture of EnviroNet.

4.2.3 Implementation and delivery of the software

Based on the technical recommendations described in section 4.1 the architecture shown in section 4.2.2 the software of EnviroNet platform has been implemented in the DAREFFORT project, in order to create and establish a cross-national data exchange platform in the Danube catchment. EnviroNet serves as the technical basis for DanubeHIS operated by ICPDR. The software uses existing data exchange interfaces of data providers where available, in order to keep the effort for the national data providers as low as possible. This implies that the national data providers only host their own data, and not the data of other countries.

The development of the software has been based on established coding standards. It is a web driven application, light-weight, and easy to implement and to maintain. In order to make the system as open and platform independent as possible the core structure only

DTP2-064-2.1 DAREFFORT – Danube River Basin Enhanced Flood Forecasting Cooperation
The project is funded by the European Union and the Member States

uses simple and proven web technology. These are on server side: HTTPS, PHP, Cron/Task scheduler, and on client side Html5, JavaScript. The interaction with EnviroNet platform is managed using a web application programming interface (Web-API). The software is open source. It is compliant with ICPDR future developments regarding DanubeHIS, and therefore supports the following IT infrastructure of ICPDR.

Data security is ensured by authentication using appropriate state of the art encryption methods.

The EnviroNet software is open source and based on web technologies. It is written in PHP and uses state of the art standard components and tools like Apache and PostgreSQL. The source code of the software is available on GitHub (https://github.com/environet/environet).

An important requirement for the acceptance of EnviroNet and future DanubeHIS is that the effort for national data providers to transfer the data to the platform is as little as possible, but at the same time meet high standards of data availability and quality. Therefore, during the implementation of the software for each national data provider the conversion rules and routines have been defined and elaborated individually.
These conversion filters have been delivered together with the required software components of EnviroNet to the national data provides in the second half of 2020. With each data provider online meetings have been carried out to configure the data transfer to their needs and requirements. During this deployment phase beta tests and bug fixes have been carried out. All data providers have provided acceptance or delivery reports, and have been introduced in online meetings, and workshops how to use the platform.

4.2.4 Maintenance of the software platform

The Platform can be maintained by the host of the Distribution node and by the national data providers using a web-interface, as shown in Figure 4.2.2.

Data providers' information can be maintained as well as the list of hydrological and meteorological stations from which data is delivered. Of course also the parameters which are provided by each station can be configured individually.

The assignments of different access rights to the data in EnviroNet Distribution Node can be managed via an access control list, in a very detailed granularity by station, parameter, type of data and access time.

Missing data can be uploaded via standardized csv-files. Also historical data can be uploaded this way.

For the conversion filters easy to understand text configuration files are used, which can be modified by national data providers if they make changes to their IT infrastructures which have an impact on data delivery to EnviroNet platform.

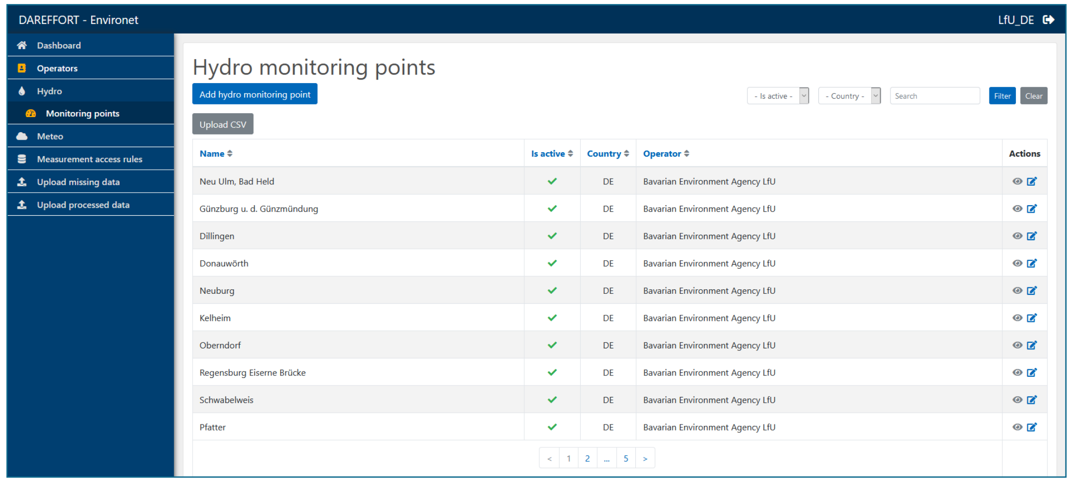

Figure 4.2.2: The web interface for maintaining the EnviroNet platform

4.2.5 Prove of concept under real life conditions

In order to demonstrate the capabilities of the common data exchange based on the EnviroNet Platform and the common data model implemented in DAREFFORT project a webtool has been developed. As a proof of concept this webtool acquires the data stored on the EnviroNet Platform via the implemented API in WaterML 2.0 format and shows the information in an interactive map of the Danube catchment.

Initial tests and bug fixes have been carried out to achieve a smooth and flawless operation of the platform.

After these initial tests in September and October 2020, the EnviroNet platform has been running in continuous operation for about 100 days up to the day this document is written.

During this time data from over 600 hydrological and meteorological measuring stations across the Danube catchment is delivered at least daily, but in most cases hourly to the EnviroNet Platform.

In the time of continuous operation only minor issues occurred which could be fixed in short time. The first four months of operation of the EnviroNet platform show that the common data exchange concept and software developed in DAREFFORT project is working in practical application under real life conditions. The platform is ready to be handed over to ICPDR for the implementation of DanubeHIS.

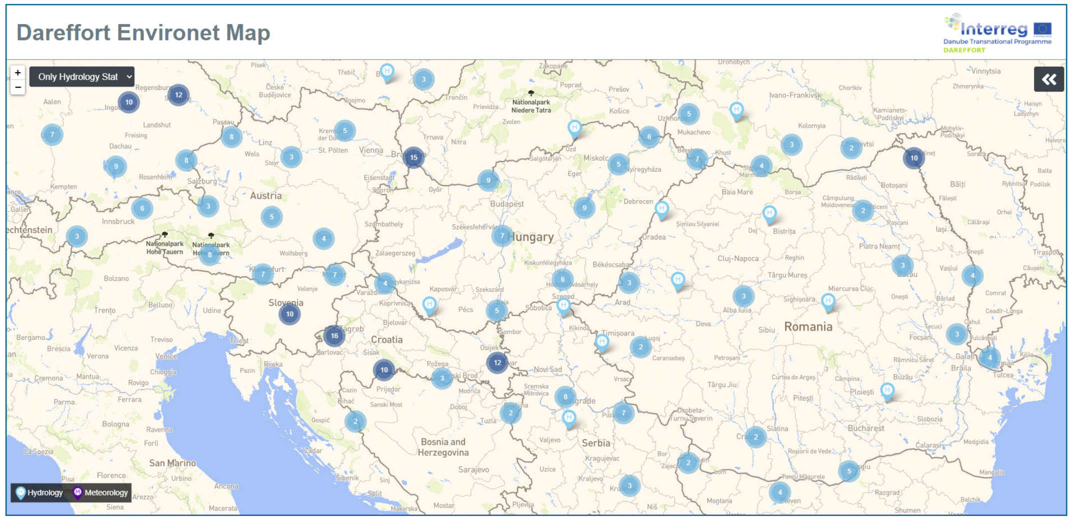

Figure 4.2.3: Overview of the hydrological stations (the number in the circles represent the number of stations in this area).

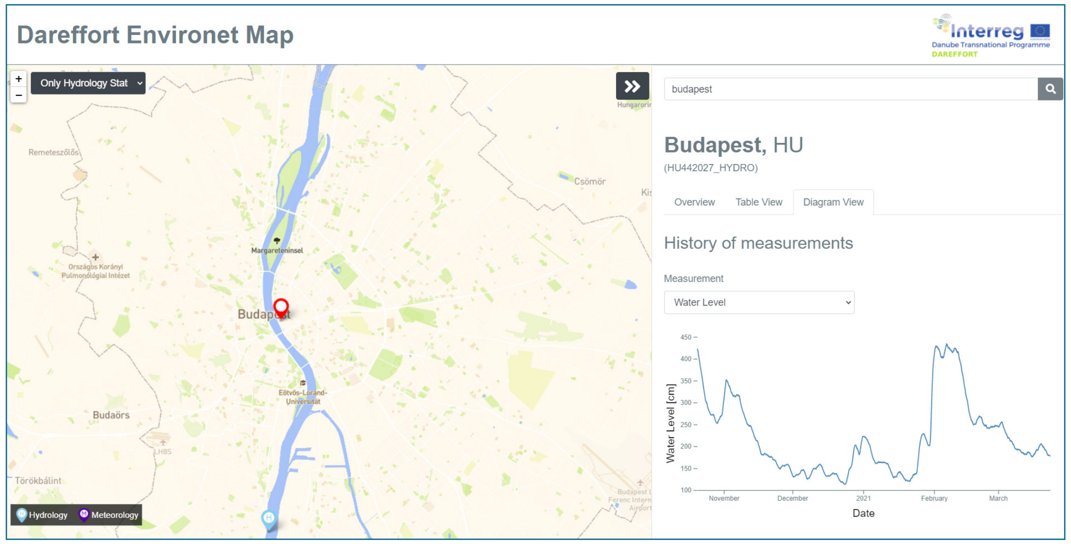

Figure 4.2.4: Example of a hydrological station in Budapest with its current information

5. KNOWLEDGE TRANSFER
5.1 Expert workshops on knowledge exchange WP5 Output 5.1

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5.1.1 Introduction

Within the work package 5, dedicated to knowledge transfer, 9 national knowledge exchange expert workshops on flood and ice forecasting were organized and carried out by dedicated partners, in each of the 9 partner countries (ECONOMICA in Austria, NIMH BAS in Bulgaria, CW in Croatia, STASA in Germany, OVF in Hungary, NIHWM in Romania, SHMU in Slovakia, UL in Slovenia, UHMC in Ukraine). The invited lecturers were experts in the field of operational flood forecasting and / or relevant hydrological research domains, the other participants were representatives of stakeholders and of other institutions with interest on the use of hydrological forecasting and warning products.

5.1.2 Summary of the workshops

The first part of the workshops was dedicated to a detailed overview of DAREFFORT project in which the lecturers presented the background, duration, start of the project, estimated full budget, potential partners and areal coverage. Lecturers introduced also the scope of the project, the content and the goals of each work package, as well as the previous and next steps in the project.

The second part of the workshops was generally dominated by presentations of national forecasting services and systems and of national and international projects in progress with related topics.

An important part of the meetings was the discussion between the participants on topics such as: future requirements and improvements in transnational forecasting systems, how to facilitate the flood protection of the region and to enhance the flood safety of the whole Danube Basin involving the 14 stakeholder countries, possibilities of different type of data exchange, the importance of high quality data in hydrological modelling, hydrological forecasts and uncertainties, significance of fast sharing of the hydrological and meteorological data in the closest possible real time standard format, flash floods forecasting system, needs for continuous training, specialization of personnel, the role and benefits of international cooperation between National Hydrological Forecasts Centres, in other regional projects coordinated by WMO.
At the end of the meetings, the standardized questionnaire was handed out and filled in by the participants.

5.1.3 Evaluation report of the questionnaires

The evaluation report summarizes mainly the results of the questionnaires prepared in WP5 of the DAREFFORT project, supporting information gathering from stakeholders, but also summarizes some of the conclusions and recommendations from the knowledge exchange expert workshops. Some of the main conclusions of the evaluation report are presented below.

In most of the participating countries, interested stakeholders use the hydrological information and forecasts received directly from hydrological service or from dedicated websites on a daily or weekly basis, they find it easy to understand and they find it useful or very useful. The current availability of hydrological information and forecasts is improved compared to the past. The quality of hydrological information and forecast products, in terms of accuracy, timeliness and access, perceived by the respondents from the participating countries is considered good by most of the stakeholders.

According to the warning lead time mentioned by most of the stakeholders in order to properly make decisions and take actions in the case of a forecasted hydrological event, the duration is 12 - 24 hours, or 3 - 6 hours.

It is necessary to further improve flash flood forecasting and warning methodologies in order to increase the warning lead time for flash floods, but without increasing too much the false alarm rate. New radar products and quantitative precipitation forecast products are needed in order to improve the hydrological forecast performance in the future.

Although most respondents do not require additional assistance and / or training for the interpretation, understanding and use of the hydrological information and forecast products, in countries like Hungary, Bulgaria, Slovenia, Slovakia, there is a significant percentage of the interested stakeholders that need additional assistance.

For the implementation of E-learning tools some popular and easy to use online platforms were suggested and the main subjects proposed are related to the accuracy of forecasts and use of ensemble forecasts, and in general description of hydrological forecasting methodology.

The use of dedicated mobile applications and web services capable to provide real time updates of the warnings are among the most popular suggestions for the improvement of the dissemination of the hydrological information.

The resulting conclusions are intended to contribute to the improvement of future hydrological forecast and warning products, in order to better serve and support the needs of different stakeholders, in their activities.

5.2 PILOT ACTION ON LIMITED EXTERNAL MODEL ACCESS WP3 OUTPUT 5.2

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National Institute of Hydrology and Water Management, Romania

5.2.1 Introduction

In general, the cooperation between hydrological forecast centres in transboundary river basins, use one of the following two approaches:

- Exchange of real time observation data (water level, discharge, etc.) and hydrological forecasted data for representative river sections, based on bilateral data exchange agreement;
- Implement and operate a common Flood Forecasting and Warning System, covering the entire, or the most important part of the transboundary river basin.

The main objective of the implementation of the Activity 5.2 pilot action was to investigate and evaluate the possibility of using a new innovative cooperation approach, between forecasting services of two neighbouring countries, respectively by giving external access to a downstream neighbouring country (secondary National Forecast Centre) for using and running independently a hydrological forecasting model, which is part of the forecasting system of the upstream country (main National Forecast Centre).

This could be considered, in fact, a combined approach of the two standard cooperation solutions between different National Forecast Centres, within a transboundary river basin, with the advantage of avoiding the difficulties of implementation, maintenance and upgrade of a complete common Flood Forecasting System, while keeping the possibility for the secondary Forecast Centre to use independently the shared operational hydrological forecasting modelling components.

5.2.2 Summary of the workshops

The geographic scope of the pilot action, is represented by the Danube sector between Bogojevo and Iron Gate Reservoir, an area of great importance for both Serbia and Romania, taking into consideration that on this sector the Danube River receives major inflow contribution from his tributaries, and that the Iron Gate Reservoir is jointly operated by the two countries.

The analysis of the multiple-coincidence of flood waves on the Danube and its tributaries provides very interesting and useful results, demonstrating also the importance of an accurate simulation of the superposition and routing processes on this Danube sector for real time flood forecasting activities.

5.2.3 Design and concept of operation

For the implementation of the pilot action, an experimental environment was configured on the hardware infrastructure of NIHWM National Forecast Centre. All the software used for the implementation of this experimental testing environment were based on open source or license free software packages.

The design and concept of operation are based on the following main assumptions:

- The selected modelling component that will be shared is a hydraulic routing model, for the Danube sector between Bogojevo and entrance in the Iron Gate I reservoir (Bazias section), for the implementation of which HEC-RAS hydraulic routing model is used.
- The model is one of the components of the operational models used by the National Hydrologic Forecast Centre from Serbia (main Forecast Centre), with complete access to the detailed model configuration and results in different sections.
- The National Hydrologic Forecast Centre from Romania (secondary Forecast Centre), as a downstream country, will be able to access and run this model, for analysing different what-if scenarios evolution from upstream Danube, Sava, Tisa and Velika Morava, in order to have the possibility to estimate with greater lead time the possible evolution of the inflow to Iron Gate Reservoir.
- The model can be used by the secondary Forecast Centre also as support for other operational tasks / activities.

5.2.4 Implementation of HEC-RAS hydraulic routing model for the pilot area

Within the pilot action, a specific implementation of a hydraulic routing model was done, in order to be used for testing the new concept for sharing a forecasting model between the two national forecasting services.

The model implementation was done using the Hydrologic Engineering Centre's (CEIWR-HEC) River Analysis System (HEC-RAS) software, which allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modelling.

The resulted hydraulic model was tested, adjusted and validated using selected historical flood events, from the years: 2006, 2010, 2013 and 2014. Figure 5.2.1, present some selected model simulation results for the Bazias section (entrance of the Danube in Romania), compared with the observed inflow hydrograph on Iron Gate I Reservoir, estimated based on the real time reservoir operation data, for a representative period from 2014, including the historical flood event from May 2014.

5.2.5 Recommendations for possible extension within the Danube River Basin

The pilot action was successfully completed and the experiences show good potential for using the results and, in general, this approach in the future, after the project ends, for improving the flood forecasting capabilities in both cooperating countries.

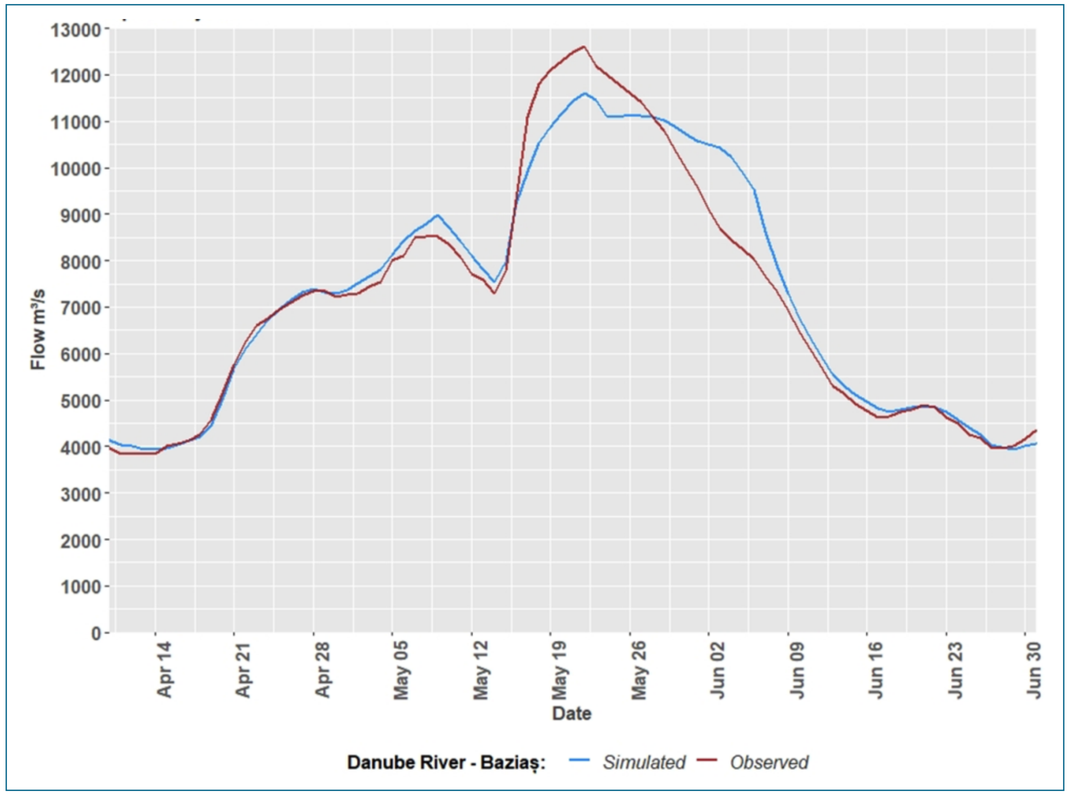

Figure 5.2.1: Simulated and observed discharge hydrographs, on the Danube River – Bazias section, April – June 2014

Based on the pilot action experience, we consider that this approach could be extended on other sectors within the Danube River Basin, with the following general recommendations:

- This specific way of sharing a hydraulic routing model (or a hydrologic routing model) between a main and a secondary Forecast Centre could be used for any Danube River sector. The technical solution used for the implementation could be different, in relation with the particularities of the existing forecasting platform, hardware and software infrastructure from the cooperating partners.
- We recommend this approach with priority for the important river sectors on the Danube or on the main tributaries of the Danube, where we have a great influence during flood events from the existing important reservoirs.
- The sharing of modelling component could be extended also for rainfall-runoff models.
- The sharing of hydraulic routing components, potentially between most of the Forecast Centres within the Danube River Basin, could provide great benefits if they were coupled and used in combination with the rainfall-runoff ensemble simulations outputs from a regional system (e.g. EFAS).

5.3 Guidelines on data management WP3 Output 5.3

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5.3.1 Introduction

The summary of good practices, recommendations of the project covers different aspects of data management in relation with the flood forecasting activities, starting from the monitoring network, data collection, data management processes, data pre-processing and postprocessing modules used in relation with the flood forecasting models and/or in support of different flood forecasting and warning system activities.

5.3.2 Current status of monitoring networks

A reliable hydrological forecast depends, to a great extent, on the quantity and quality of the measured meteorological and hydrological input data, provided by the national monitoring systems of individual countries.
On the current status of monitoring networks, it should be mentioned that although most countries in the Danube River Basin have made significant progress in the modernization of the meteorological and hydrological monitoring networks and the modernized networks provide high quality data for forecasting models and warning procedures, there is still room for improvements.

5.3.3 Recommendations for improving the monitoring activity in the Danube River Basin

In general, in all the countries within the Danube River Basin, the existing National Monitoring Station Networks are able to provide the necessary input data (in term of both spatial and temporal resolution) for hydrological forecasting and warning elaboration in case of fluvial flood events, in medium and large river basins.

However, the actual National Monitoring Station Networks, could not fully satisfy the observational input data needs for flash floods and pluvial flood forecasting and warning activities. Also, as medium- and long-term perspective, we consider it is unrealistic to assume that the future extension and modernization of National Monitoring Station Networks will be able to satisfy the specific high spatial and temporal resolution needs for properly forecasting flash flood events, even in the most developed countries.

We consider that a dedicated research and development EU program could be the best option, in order to propose and test several new adequate monitoring solutions, that will be able to complement the existing information from the national networks, in order to provide significantly improved input data that could further support the improvement of flash flood forecasting and warning products.

Among the main recommendations for research topics, we could mention the following: develop a new generation of sensors (robust, very low maintenance, threshold oriented, not necessarily high accuracy, significantly low priced compared with the existing sensors), develop dedicated mobile applications, that will allow the people to provide directly standardized real time observational reports on rainfall and runoff intensities, develop new data fusion methods, that will be able to use and combine all available monitoring data.

Involvement of people in the monitoring process will also have the advantage of improving the awareness and understanding of these hazards, helping them to better understand and react on received warning messages.

5.3.4 Guideline on data management related to hydrological forecasting activities

Traditionally, data management aspects related to hydrological forecasting activities were generally considered mainly in relation with the management and preparation of observational input data for the hydrological forecasting models (e.g.: collection, storage, quality-control, gap filling, general time series operations, final formatting according to each model requirements).

Recent developments in Flood Forecasting Systems (extensive use of high-resolution NWP, radar, and/or satellite gridded input data, implementation of distributed rainfall-runoff and routing models, multi-model approach, generation of ensemble forecasts), resulted in a significant increase of requirement of data management processes (data storage, data import / export and data processing general functionalities). Significantly greater amount of data and information needs to be processed and distributed between different components and/or system modules at different levels, different time and in different format.

The Flood Forecasting and Warning System (FFWS) needs special meteorological products, both for the real time operation and for the model calibration. Taking into consideration the importance of meteorological input data for the hydrological forecasting activities, it is mandatory to continue the implementation, maintenance and periodical upgrade of national meteorological monitoring and forecasting systems, in order to provide the specific needed meteorological products for the FFWS.

Hydrological forecasters proper training, formation and team stability need to be recognized as having a high priority. It is highly recommended to implement Flood Forecasting System simulators, or at least post event simulation analysis functionalities, for better preparing the forecasters to analyse, interpret, and elaborate warnings during extreme events conditions.
During extreme flood events, we could also have significant problems in operating the monitoring networks, important hydrometric stations could be flooded / damaged, impossible to make / get further observation from some river sections, and we have to deal with increased uncertainty in estimating the peak discharge values (significant rating

curve extrapolation). A good design of data management processes and operations could limit the negative impact on the final forecast products of such conditions.
In order to improve also the last component of the End-to-End Flood Forecasting System chain, it is recommended to implement, maintain and prepare periodical upgrade of national integrated information systems for data and product exchange in real-time between all the institutions involved in the management of emergency situations generated by floods.

Taking into consideration the existing limitations encountered at national level in many countries, on financial, hardware, and human resources, but also in order to reduce the duplication of several data management activities, it is recommended to increase the support provided from the Regional Systems toward the National Systems.

5.3.5 Conclusions and final recommendations

Implementation of Flood Forecasting and Warning Systems needs to be understood and planned as a continuous process. After each implementation stage, based on the lessons learned, on the new scientific and technological development both for the models and monitoring, the design and plan for the next system upgrade is recommended to be made.

Data management components are critical components within a flood forecasting and warning system, and in general are used to support the following main functionalities:

- pre-processing and provision of input data for the hydrological forecasting models;
- implementation of real-time data and products workflows between Flood Forecasting Centres;
- postprocessing of model results and generation of final hydrological forecasting and warning products;
- hydrological forecasting model configuration, calibration and validation;
- supporting forecasters training activities.

When designing the Flood Forecasting and Warning Systems, and especially the data management part, it is recommended to follow a modular, flexible, robust structure approach in order to support the Hydrological Forecasts Centres to operate and elaborate the official forecasts and warnings under different type of failure scenarios for the data communication, and/or different flood forecasting system components.

The significant increase in the complexity of data management processes, embedded in the National Flood Forecasting and Warning Systems, require proper maintenance activity and the strengthening of the IT support (skilled staff) and the IT capabilities (resources, tools, services) dedicated to flood forecasting, in the individual forecasting services.
In order to accelerate the general improvement and adoption of new advanced tools on data management related to flood forecasting activities, it is recommended to improve the cooperation among the hydrological services within the Danube River Basin by organising regular expert meetings on flood forecasting.

5.4 E-learning on flood and ice forecasting practices

Ildikó Czeglédi
VIZITERV Environ Ltd., Hungary

The main goal of the e-learning course elaborated in the framework of DAREFFORT project is to provide the necessary information for the future professional users of the data exchange system developed by the project, as well as to support the better understanding of flood and ice forecasting in general, and to represent the Project's contribution to this field.

Specific requirements of the e-learning course are defined by the Application Form of the project. Based on these, three main target groups have been identified for the e-learning course:

1. Broad public: everyday people, having no background knowledge of flood forecasting or hydrology, with a general interest in the topic.
2. National/regional public authorities: potential users of the EnviroNet data exchange system and/or of the future DanubeHIS, with assumed background knowledge, interested in practical, actual information. This group includes the decision-makers of these authorities as well, with assumed background knowledge, more interested in strategic and policy aspects.
3. Higher education and research: university students and researchers, with assumed background knowledge, interested in the scientific background and how is it applied in practice.

The project partners have agreed at the 3. project meeting in Bratislava, that Moodle[1] will be used as the framework for our e-learning course, as it is a widely used, open source platform, and there are positive experiences about previous uses of it within our partnership (UL). Besides Moodle enables a lot of activities (tools) that facilitate the practical use of the course.

First, a list of topics have been suggested by WP5 leader than refined and discussed with LP and involved partners. Based on this, the modules (and the topics they cover) have been defined and assigned to a partner who will be responsible for the elaboration of the content.

The course includes 10 modules covering various relevant topics, aimed at the different target groups, and referring to the outcomes of the DAREFFORT project where appropriate.

[1] https://moodle.org/

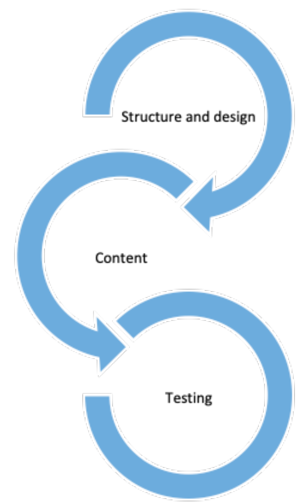
The material itself include presentations, videos, excel sheets, word, pdf documents, links and images as appropriate and necessary considering the given topic and the targeted stakeholder group.

In terms of graphic design of the course, the requirements and recommendations of the *"Danube Transnational Programme Visual Identity Guidelines for Projects"* is applied.

The structure of the DAREFFORT e-learning tool is described in the table below:

Module title	PP responsible for content
1. Introduction to Flood and ice forecasting in the Danube River Basin	VIZITERV
2. Flood forecasting and warning systems	UL
3. Hydrological and meteorological monitoring networks and real-time data acquisition	UL
4. Forecasting the formation and evolution of ice phenomena on rivers	OVF
5. Flash flood forecasting and warning	NIHMW
6. Verification of hydrological forecasts	NIHMW
7. The EnviroNet data exchange system	VIZITERV
8. Data life cycle	STASA
9. Representative National Flood Forecasting and Warning Systems within the Danube River Basin	NIHMW
10. Representative Regional Flood Forecasting and Warning Systems within the Danube River Basin	NIHMW

The elaboration of the course was supervised by WP5 leader and coordinated by LP, both contributing to the content as well.



Firstly, the structure and design of the learning material were defined in the 4th period of the project. Following this, the content of the modules were elaborated and uploaded to our e-learning test site by the responsible partner in the 5th period. Finally, all project partners and strategic partners performed a thorough testing of the beta version in each partner country and prepared a Test report about their findings. Altogether, more than 200 detailed remarks were received and handled during the finalization of our e-learning tool in the last period of the project.
The final version of the DAREFFORT E-learning course is publicly available on the official website of the project (http://www.interreg-danube.eu/approved-projects/dareffort).

The whole course can be explored as a guest, or the progress and test results can be tracked and recorded with a free registration, enabling the integration of the course into higher education curricula or into training programmes of potential users of the data exchange platform.

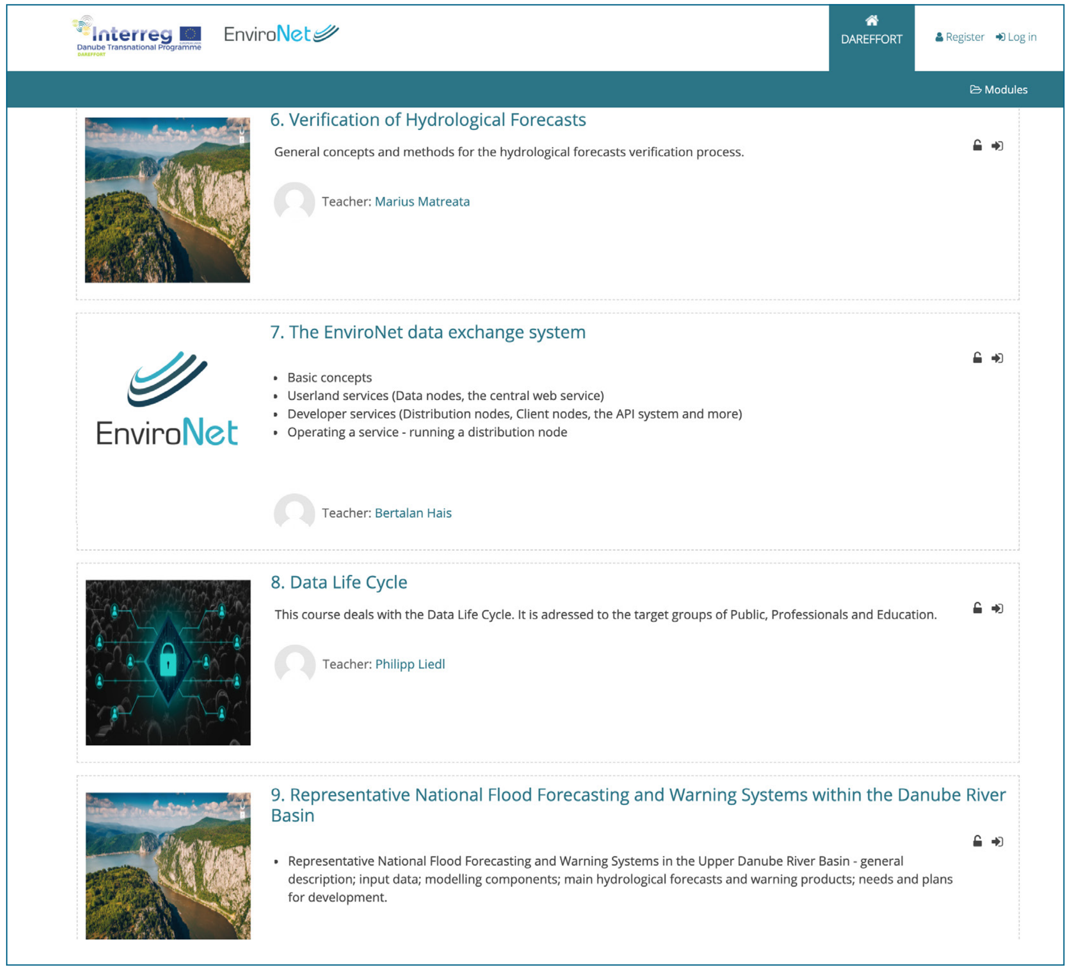
The first module mainly designed for the broad public and those seeking summarized information about flood and ice forecasting in the Danube River Basin or about the DAREFFORT project itself. This module does not require any background knowledge on the topic and also includes interesting information, videos and images on the most historic past flood events on the Danube.

The second module includes the basic concepts of flood forecasting and warnings (why forecasting and why warnings) and what is needed for flood forecasting (models, data, etc.) is elaborated. In the third module, the basic concepts of the hydrological and meteorological monitoring, data collection, processing and dissemination and data acquisition are presented. The course is dedicated to professionals and students with basic knowledge about main hydrological and meteorological processes.

The fourth module is about the river ice phenomena. It presents the ice cover monitoring in the Danube River Basin, and describes the theoretical background of river ice forecasting: the formation of ice, water energy balance, river ice freeze-up, ice cover breakup, disappearance of ice. Also introduces the river ice forecasts of the National Hydrological Forecasting Services.

The fifth module is about flash flood forecasting and warning. It describes particularities of Flash Flood generation mechanisms and early warning systems for flash floods forecasting. The future needs and research priorities, for improving the monitoring and forecasting systems, to better support the flash floods warning process are also discussed. The sixth module presents the general concepts and methods for the hydrological forecasts verification process.

The seventh module describes the EnviroNet data exchange system, developed by the DAREFFORT project. The learning material includes the presentation of the basic concepts of the system, and the complete User Manual of the software on Userland services (Data nodes, the central web service), Developer services (Distribution nodes, Client nodes, the API system and more), and on Operating a service - running a distribution node.



The eighth course deals with the Data Life Cycle. It is addressed to the target groups of Public, Professionals and Education as well. It contains information on the purpose of common data exchange; and answers the questions of ‘what kind of data is collected?’, and ‘where does the data come from?’ It also presents the data providers of the participating countries, shows which data is delivered by each provider, compiles the used methods of data acquisition and transfer and includes a few typical case studies. It also covers WaterML 2.0 specifications, description and how to use it, an overview of the data structure and description of the common data model.

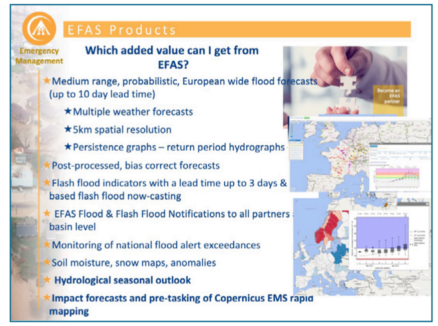
The last two modules introduce the Representative National (9.) and Regional (10.) Flood Forecasting and Warning Systems within the Danube River Basin. The topic reviews eight national systems in the basin, presenting their general information, modelling components, products characteristics, and future development plans. The last module describes concepts and main objectives; input data; modelling components; main products; ongoing and future plans for development for the following:

- European Flood Awareness System (EFAS),
- Flood Forecasting and Warning System for the Sava River Basin (Sava FFWS),
- South-East Europe Flash Flood Guidance System (SEE-FFGS), and the
- South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A).

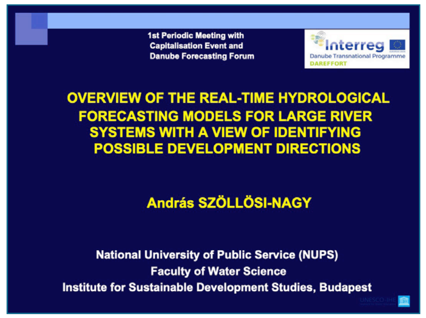
5.5 Summary of the presentations at the first DAFF Conference

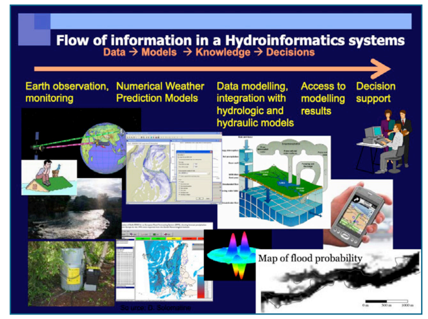
Presentations by: EU-JRC, Austria, Bulgaria, Croatia, DHI-Czech Rep., Germany, Hungary, ICPDR, Romania, Serbia, Slovakia, Slovenia, Ukraine, Rhineland Pfalz

4-5. February 2019, Vienna

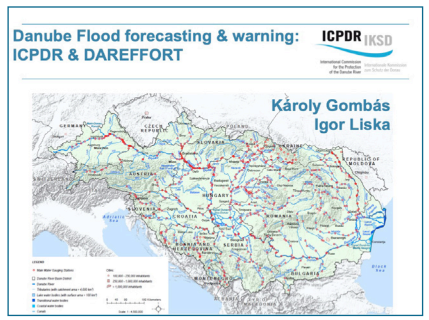


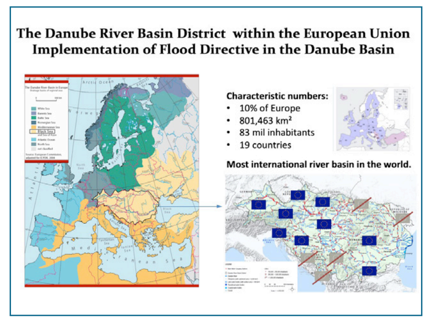
Key words: Medium range flood forecasts; Flash flood indicators; Notifications to all partners; Monitoring of national flood alert exceedances; Soil moisture & snow maps; Hydrological seasonal outlook



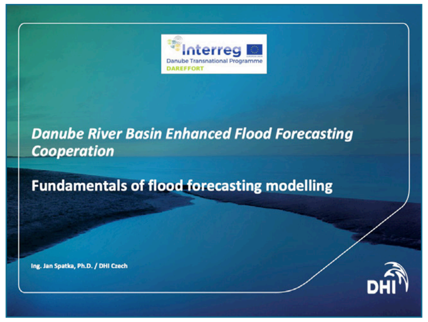


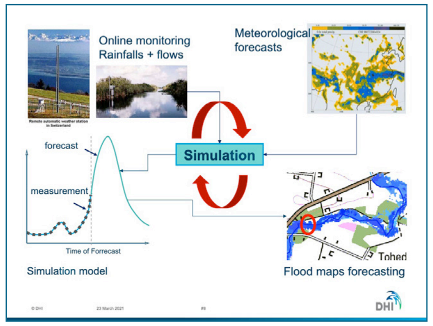
Key words: Real-time, Operational hydrological forecasting models; State-space analysis: Discrete models; Structural-stochastic recursive models; Lessons learned and outlook



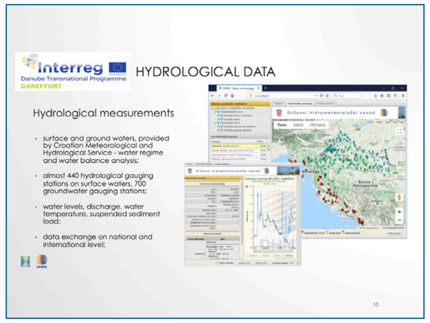


Key words: Flood Action Programme; Basin-wide targets; Improvement of flood forecasting and early warning;
Sub-basins; EU Floods Directive; Danube Declaration 2016; Danube Hydrological Information System

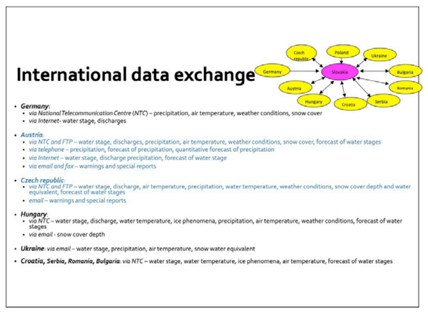




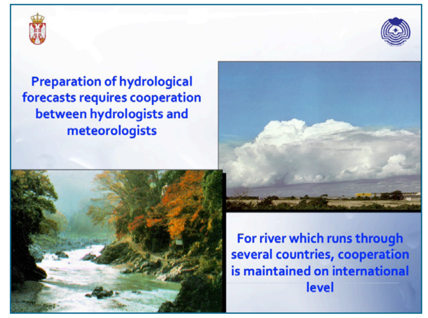
Key words: Principles of Flood forecasting systems and system architecture; Data collection; FF system solution; Integration platform; Mathematical model structure



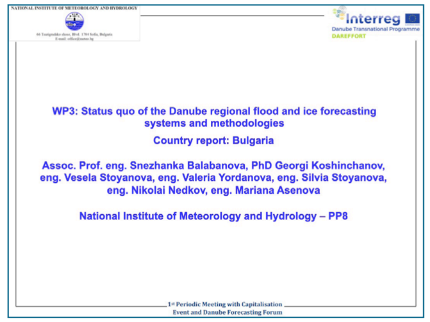
Key words: General data; Hydrological data; Meteorological data; National hydrological forecasting service

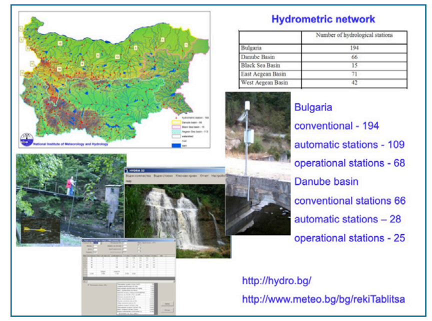


Key words: Measurement network-hydrology; Measurement network-meteorology; SHMU's data policy; Stations for DanubeHIS;

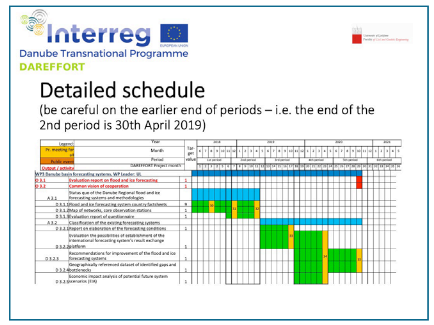


Key words: Organizational structure of RHMS; Meteorological and hydrological station network; Early warning and alert process; Location of Serbia; Basic climatic feature; Surface water balance; Flood vulnerability in Serbia; Flood protection organization; Weather forecasting products; Information systems

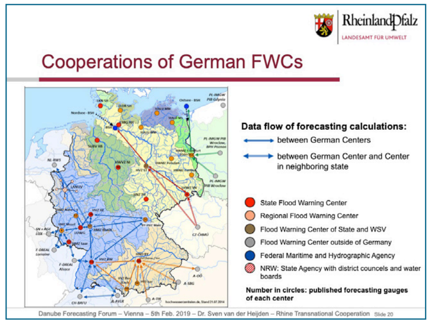




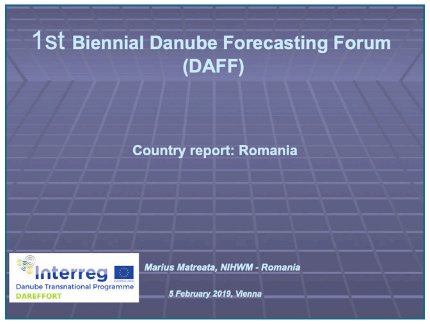
Key words: Historical facts; Hydro-meteorological network; Data flow, data processing, data exchange; National hydrological forecasting service; Hydrological models; Structure of the early warning system

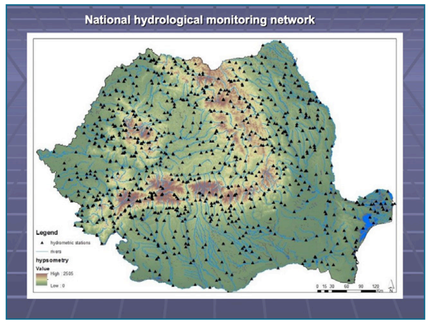


Key words: Detailed schedule; National reports; Questionnaire; The way forward; Flood and ice forecasting systems country sheets; Map of network

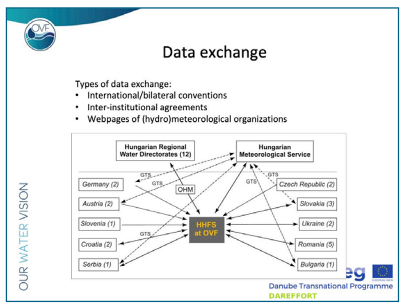


Key words: River Rhine Overview; Flood forecasting in Germany; Responsibilities for flood warning along the River Rhine; Agreement of cooperation; Forecasting chain; Data transfer and models; Flood portals

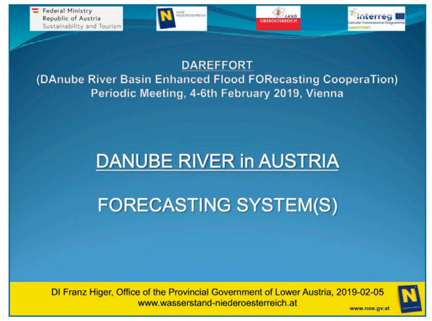


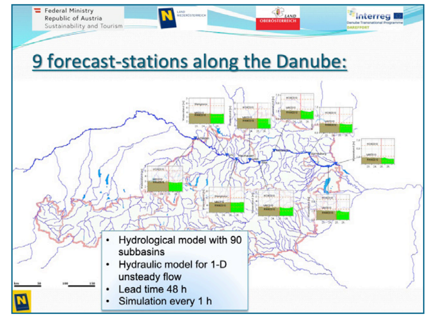


Key words: Overview of the Romanian Danube River Basin; River network; Regional meteorological centers; National forecasting center; Cross border collaboration; National Forecasting and Modelling System

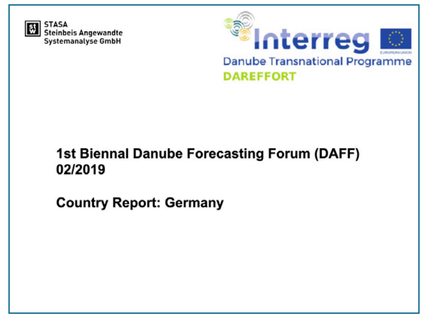


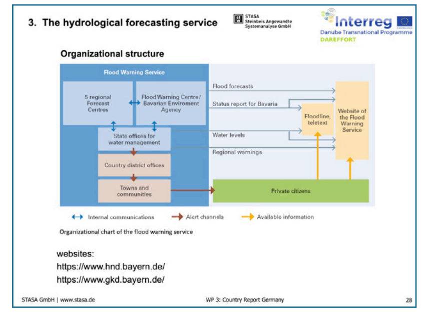
Key words: Geographical features; Hydrological simulation and forecasting system; Data exchange; Produces/outputs; Hydroinfo Dissemination System





Key words: Hydrological network/surface water; Meteorological data; Forecasting systems; 9 forecast-stations along the Danube; Data flow and cooperation; Data dissemination and publication





Key words: The Danube in Germany; Hydrological and meteorological forecasting service; Monitoring and data inventory; The process of hydrological forecasting; Modelling systems

Key words: Centers of hydrological forecasts; Hydrological observation network; Data processing, database; Main types of hydrological forecasts; Main hydrological models; Main users of hydrological forecasts

Flood forecasting, data collection and harmonized data sharing is becoming of crucial importance along the countries of the Danube River Basin. Precipitation, water stage, discharge, water temperature and ice phenomena are measured isolated in each country. They are only shared with neighbouring countries under bilateral (sometimes limited multilateral) agreements. This is to change after the completion of the DAREFFORT project.

Researchers make great effort, sometimes parallel with each other in the same topic, to develop new flood forecasting models or methodologies. Joining forces, thinking together, using human and other resources while strengthening each other, would lead to results more efficiently. We hope this will also be a result of the project.

Realizing all these chances and all the benefits, 12 countries joined forces in 2018 to cooperate in flood related data collection and data processing, as well as working out a joint road map for common flood forecasting or at least for exchanging forecasting results.

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