Interreg
Danube Transnational Programme
DAREFFORT

Observed Data Exchange Software

WP4 Output 4.2

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STASA Steinbeis Applied Systems Analysis GmbH
Stuttgart, Germany

Dr. Philipp Liedl, Dr. Dirk Meyer, Kim Schwarz

1 Introduction

This report represents the Output 4.2 (Observed data exchange software) and is the result of Activities 4.2 *development of the data exchange software* and 4.3 *deployment, installation and testing of the software*.

This Output is based on the related Deliverables D4.2.1 *Source Code of the integrated data exchange software*, D4.2.2 *User manual for the integrated data exchange software*, as well as D4.2.3 *Outlook of the potential features of a future common data exchange or joint forecasting system, and also comprises the acceptance reports (D4.3.1) and delivery reports (D4.3.2).*

This document provides an overview on the observed software. The source code itself is attached in a separate Annex. Also, the user manual which consists of six parts is attached separately, as well as the Acceptance and Delivery Reports of the countries to which the software has been deployed.

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 (HyMeDES 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.

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.

2 The HyMeDES EnviroNet software

2.1 Architecture of the software

The architecture of HyMeDES 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 WaterML 2.0 format, which is internationally standardized.

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 side 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 solution to achieve a stable running and broadly accepted solution on the long run.

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

In the first mode the software is used as a **distribution node** which collects data from data providers and stores the data in the HyMeDEM data model in a central database. As a distribution node, HyMeDES 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 HyMeDES 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 a **data node**. Data nodes are used by data providers who want to send their data actively to the distribution node. 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 HyMeDES 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 HyMeDES EnviroNet via a Web-API or an FTP-server.

HyMeDES EnviroNet consists of a common code base which can be used as a distribution node or as a data node. The advantage of this architectural design is that code duplication is avoided. Furthermore, installation and updating of data nodes is simplified. Conversion filters can be implemented universally, not depending on whether they run on a data node or the distribution 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 HyMeDES 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 HyMeDES 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 HyMeDES EnviroNet distribution node in the future, which is foreseen to be ICPDR.

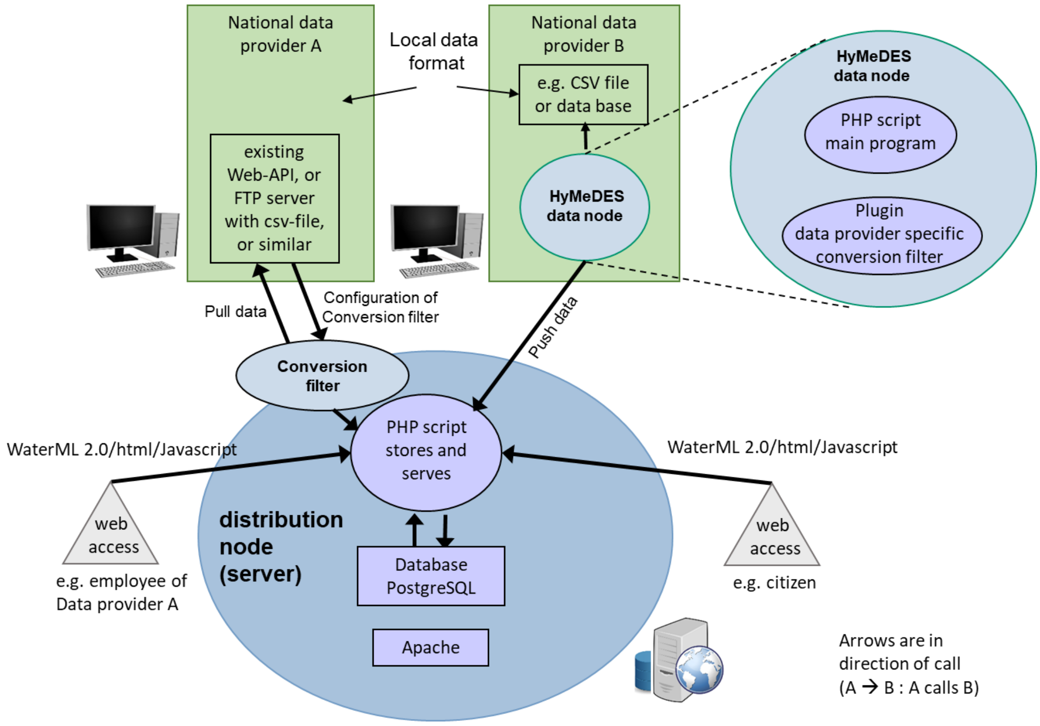

Figure 1 Schematic overview of the architecture of HyMeDES EnviroNet. The arrows are describing the direction of call.

2.2 Technical Requirements

Existing IT infrastructures are used wherever possible. Therefore, the software is coded lightweight in PHP, and the following packages are used: web server (distribution node only) is Apache and the data base on distribution node is PostgreSQL. Webserver and data base are packaged into a Docker container, so the only software to install, if any, is Docker Engine (version >= 19) with Docker Compose (version >= 1.25) and Git to pull the source code.

Server requirements HyMeDES EnviroNet distribution node:

- PHP, minimal version: 5.6.40, recommended max. 7.3.x (included in Docker container)
- Apache, minimal version: 2.4.6, recommended max. >= 2.4.6 (included in Docker container)
- PostgreSQL, minimal version: 9.6.12, recommended max. 11.2.x (included in Docker container)
- Cron/Task scheduler

Use case data pushed to server (conversion filter running on data providers side in a data node)

- PHP, minimal version: 5.6.40, recommended max. 7.3.x (included in Docker container)
- Client Web browser for configuration of conversion filter
- Cron/Task scheduler

Use case data pulled by server (conversion filter running on the distribution node)

- access provision for data pulling from external party via SFTP, FTPS or existing Web-API (HTTPS)
- client web browser for configuration of conversion filter

2.3 Development and implementation of the software

Based on the technical recommendations described in Deliverable 4.1.1 *Flood forecasting and IT expert recommendations* the software of HyMeDES EnviroNet platform has been implemented in the DAREFFORT project.

Summarized, these recommendations are the following:

- data from national data providers are exchanged using existing data exchange interfaces where available,
- data has to be converted into the common data exchange data model HyMeDEM by the common data exchange service and comprised to a common data pool (common data base) according to the HyMeDEM data model,
- the common data exchange service provides the common data pool to clients,
- the development of the software has to be based on established coding standards and to be well commented to be easy maintainable,
- the common data exchange service is a web driven application, light-weight, and easy to implement and to maintain,
- to make the system as open and platform independent as possible the core structure only uses simple and proven web technology (server side: HTTPS, PHP, Cron/Task scheduler, client side [for configuration and administration]: Html5, JavaScript),
- the software is open source,
- data security: authentication is verified using appropriate encryption methods,
- the interaction will be managed by Web APIs,
- using plug-ins (plug-in libraries) is encouraged,
- no direct writing interaction with the underlying databases is allowed (only access via API), reading data from the database can be allowed for special use cases,
- missing data can be imported as csv-files triggered by data provider,

- to be compliant with ICPDR future developments regarding Danube HIS following IT infrastructure has to be supported (all of them are open source):
    - web server: Apache
    - PostgreSQL
    - interoperability with the DanubeGIS
    - compatible user management system (e.g. CIS)

HyMeDES 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 uses simple and proven web technology. The interaction with HyMeDES EnviroNet platform is managed using a web application programming interface (Web-API). 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 (SSL and RSA).

The HyMeDES EnviroNet software is open source 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). The source code is also attached to this document as Annex *Source Code environet-master.zip*. The software itself is deployed via a Docker container, which allows the installation of the software without having to care about dependencies on third party software versions like PHP, Apache, and PostgreSQL, because they are delivered within in the container in one package (*Annex Docker-Installer environet-docker-master.zip*).

The software is licenced under GNU general public license Version 3 of the Free Software Foundation. (https://www.gnu.org/licenses/gpl-3.0).

Implementation of the software has been done by LP VIZITERV and their sub-contractor SRG in close collaboration with PP STASA.

2.4 Graphical user interface of the software

The HyMeDES EnviroNet platform can be maintained by the host of the Distribution node and by the national data providers using a web interface. In the following an overview on this graphical user interface is provided to get an impression of the software. Figure 2 shows the general look and feel of the web interface: As an example, a part of the list of hydrological monitoring stations in Germany is shown.

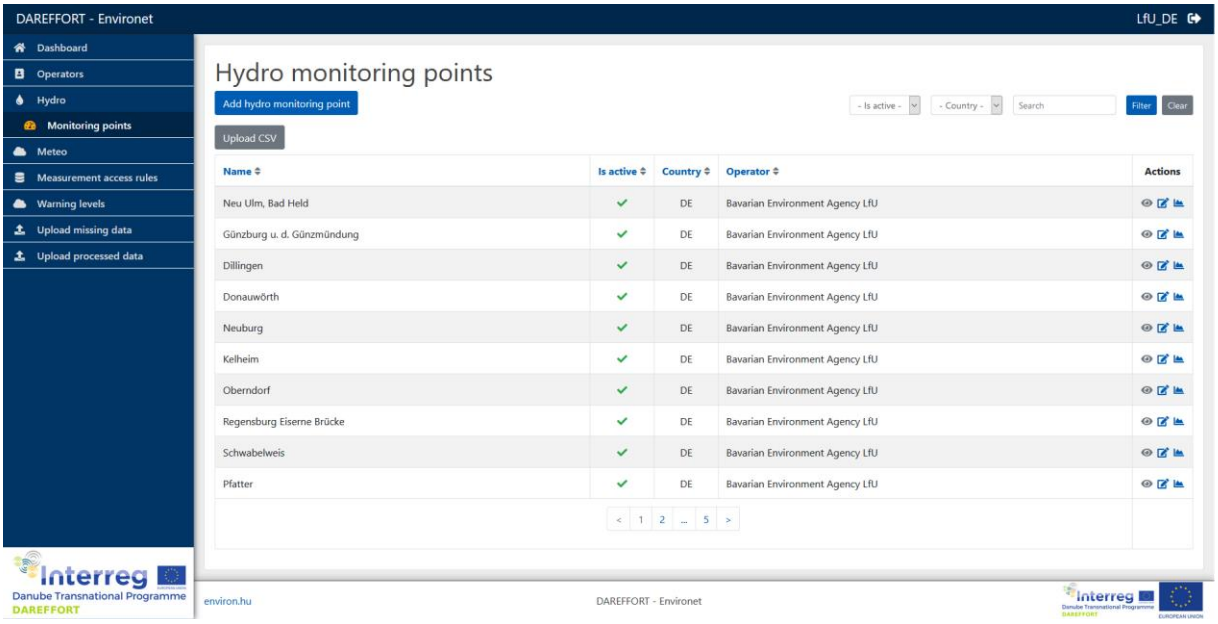

Figure 2 The web interface for maintaining the HyMeDES EnviroNet platform (as seen by a data provider).

In general, the user interface is divided in several sections which can be accessed using the navigation menu on the left of the screen. Depending on the type of user (host of the distribution node or data provider) and the role of the user (e.g. administrator or normal user) the sections shown in the user interface are different.

The full list of available sections is shown in Figure 3.

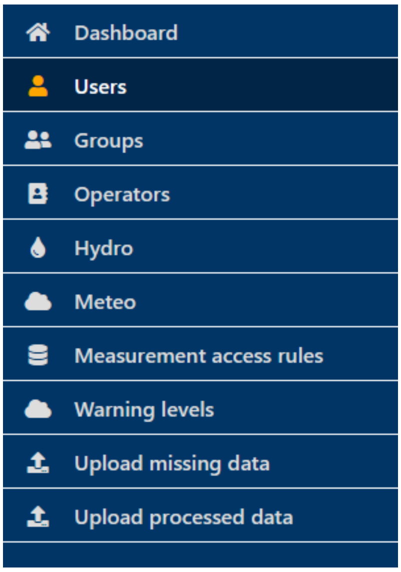

Figure 3 List of sections available in the graphical user interface

After login, the user is welcomed by the “Dashboard” section. The management of users, groups and operators (data providers) in the according sections is the privilege of the administration users of the host of the distribution node. For each user, group and operator access rules can defined and managed.

In the “Hydro” section properties of the hydrological data can be managed. For example, hydrological monitoring points can be defined as shown in Figure 4. For the hydrological monitoring points their name, geographical location, national ID and many other meta data, which are described in the common data model (see Deliverable 4.2.2 User manual, part 2 Technical Documentation of the Database Model) can be defined. Definition and maintenance of the information of the monitoring points can either be done via the web interface (see Figure 5) or by uploading a csv-file, which may contain information for more than one monitoring point, e.g. in order to update the information of all monitoring points at once.

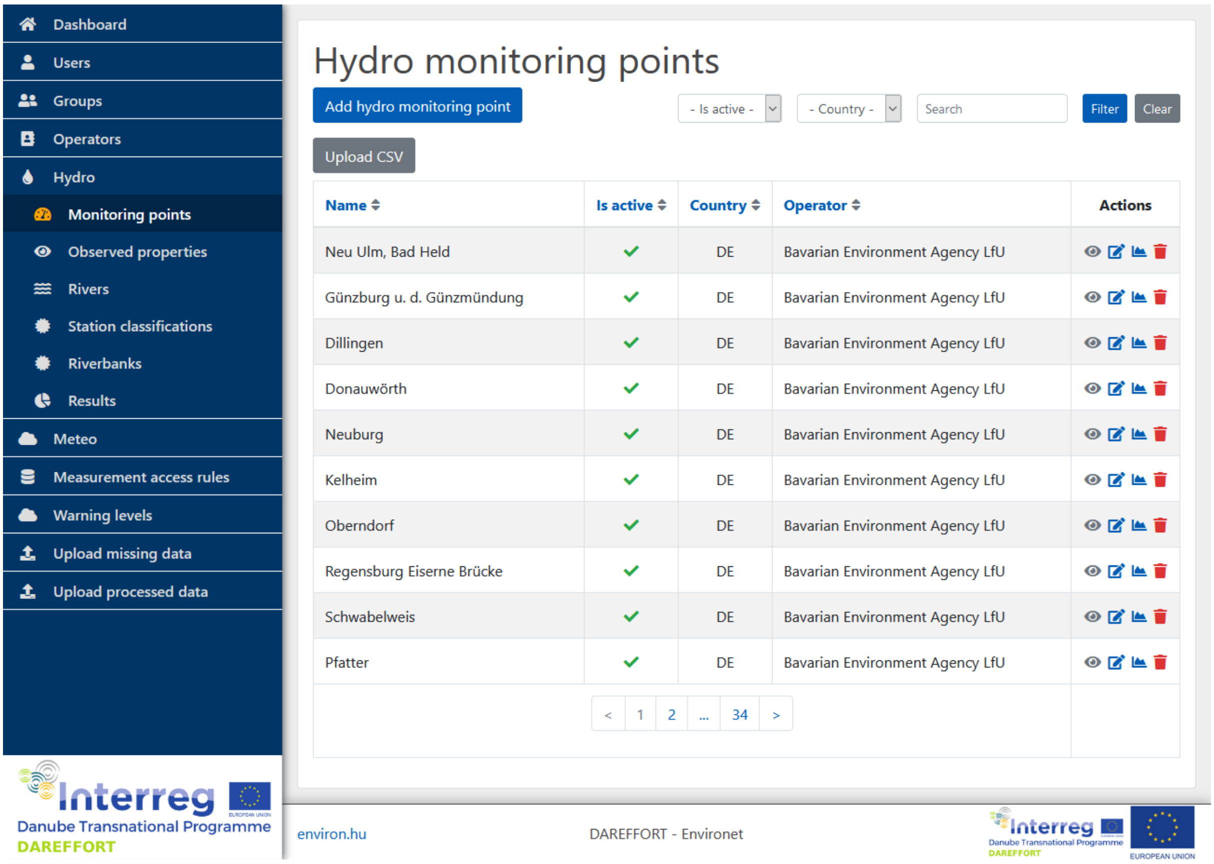

Figure 4 Definition of hydrological monitoring points (as seen by an administrator). The same is available for meteorological monitoring points.

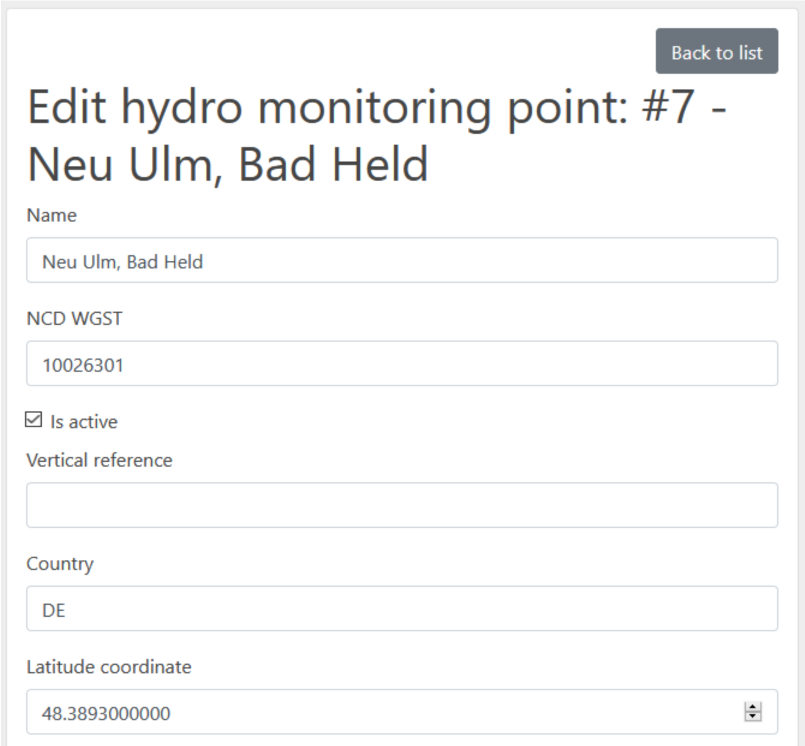

Figure 5 Input screen for editing the information of a hydrological monitoring point

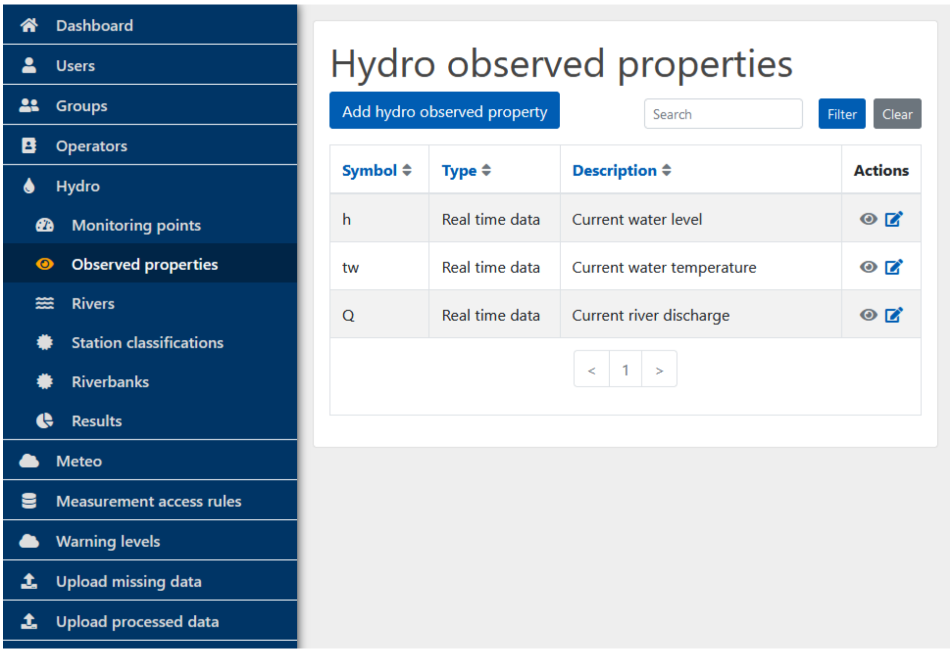

Figure 6 Definition of observed properties for hydrological data.

An administrator can also manage the observed properties for hydrological data that have already been added to the system by the host of the distribution node (see Figure 6). An observed property describes, what kind of property can be measured by a monitoring point (e.g. water level, discharge, …). These observed properties can be added to the monitoring point to define which parameters are measured by the station.

Rivers, station classifications and riverbanks are further sub-sections which contain secondary information about the river and types of stations.

In the sub-section “Results” all data base content of data delivered by the monitoring stations can be accessed. Figure 7 shows an example of water level data (symbol h) of the hydrological monitoring point Bratislava, Slovenia. Whereas the user interface of the HyMeDES EnviroNet software is intended for maintenance purpose, the pure data is shown. A view of timeseries of data in the geographical context in a map is provided by the interactive web based Dareffort EnviroNet Map (see Figure 12). Dareffort EnviroNet Map has been implemented as a proof of concept for the HyMeDES EnviroNet software and is described in Deliverable D.4.1.3 Hydrocode mapping, see also in Output 4.1.

In the “Meteo” section properties of the meteorological data can be managed in the same way as for hydrological data. As an example, in Figure 8 the definition of observed meteorological properties is depicted.

The assignments of different access rights to the data in HyMeDES EnviroNet Distribution Node can be managed via an access control list in the section “Measurement access rules”. As shown in Figure 9 the access rights can be defined in a very detailed granularity by station, parameter, type of data and access time.

Each data provider can specify any number of warning levels as they are defined in their country. For each warning level, the data provider can enter a short description for display in graphs and the official long description of the warning level. Also, the data provider can choose a colour which may be used for display purposes. In Figure 10 an example for entering a warning level is shown. For each hydrological monitoring point and observed property, the data provider can set thresholds above which the warning level is active.

The data provider can upload missing data. Missing data could occur when the data node can’t upload to the data distribution node. The data node still has all the data, but it has to be uploaded manually. This might occur because of internet connection error. Missing data can be uploaded via standardized csv-files in the section “Upload missing data”.

Also, historical (processed) data can be uploaded by csv-files in the section “Upload processed data accordingly.

For the conversion filters, described in section 2.5, 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 HyMeDES EnviroNet platform.

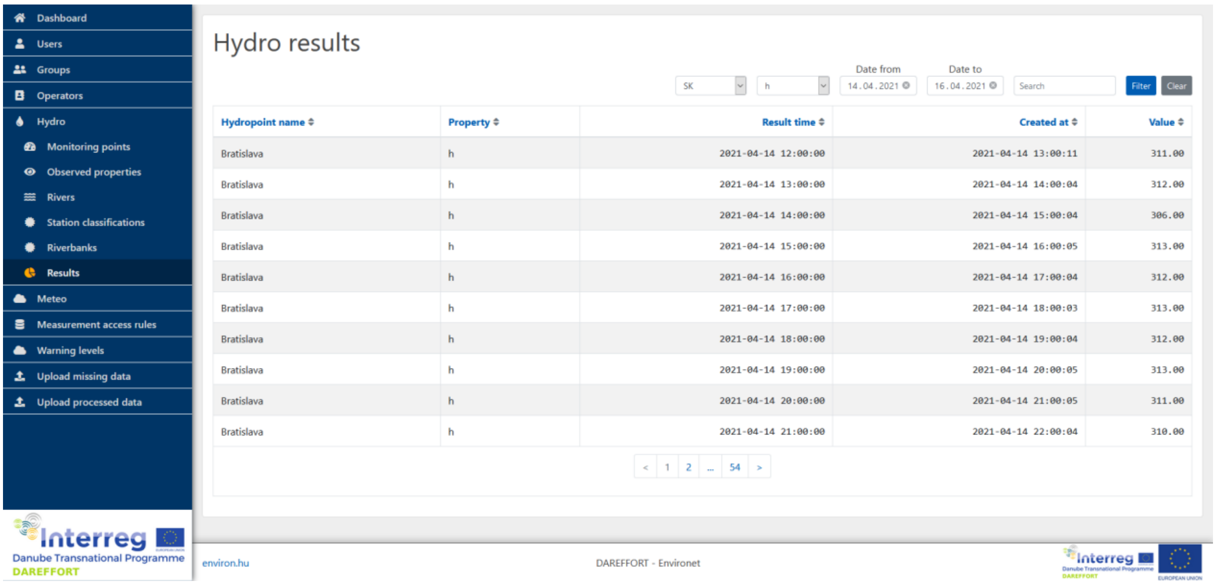

Figure 7 Access to data in the database.

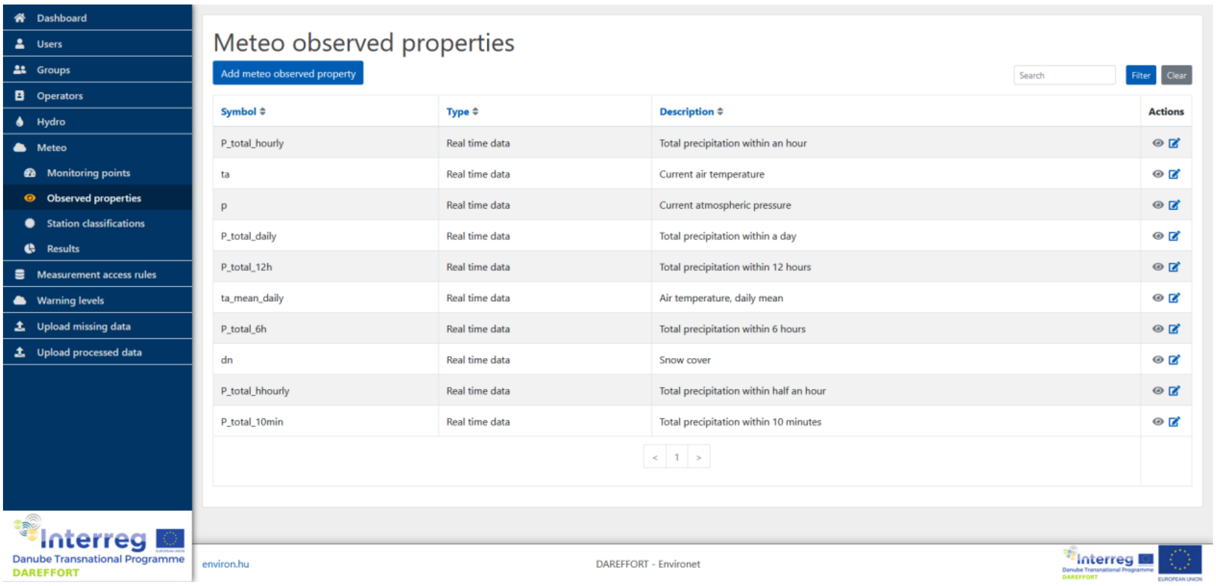

Figure 8 Definition of observed properties for meteorological data.

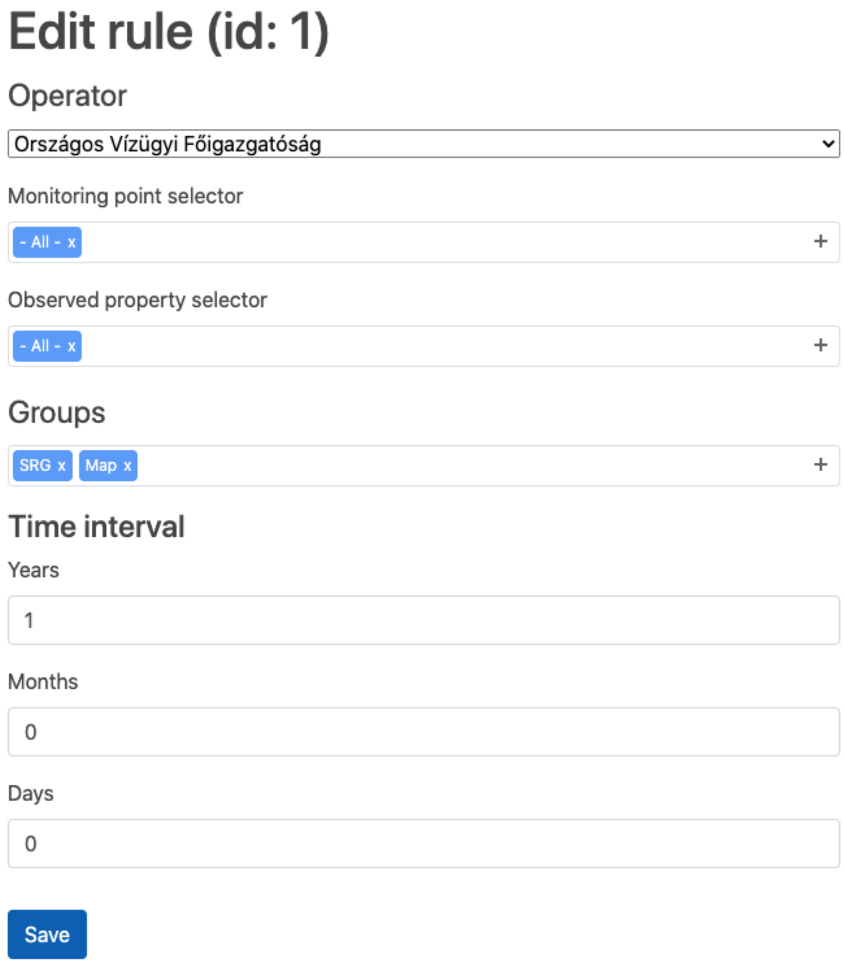

Figure 9 Definition of access rules.

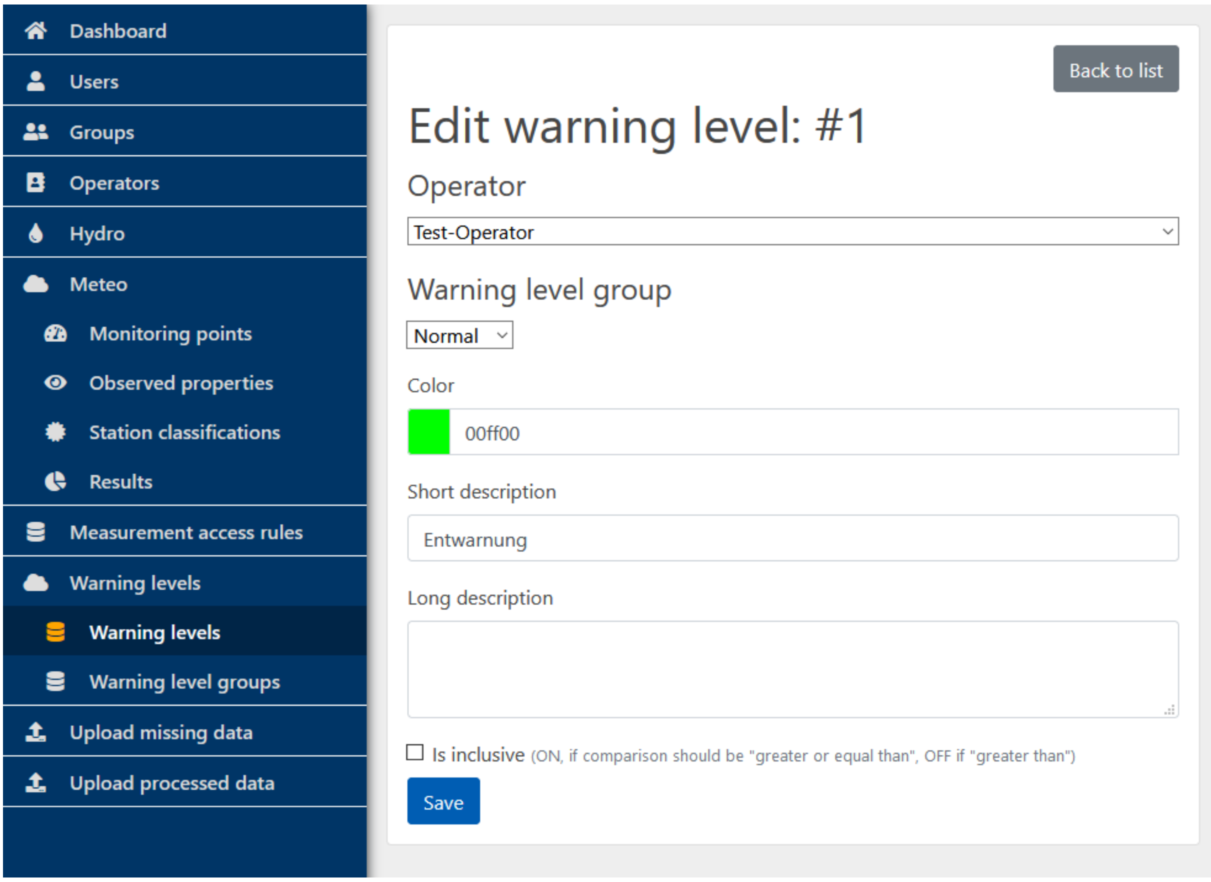

Figure 10 Defining warning levels

2.5 Implemented concept of data conversion

An important requirement for the acceptance of HyMeDES 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.

However, in order to standardize the conversion routines, in the software different standardized conversion filters have been implemented which cover the existing data exchange methods for hydrological and meteorological measured data in the Danube catchment.

The purpose of the conversion filters is to provide a translation from the data format of the data provider to the common data format of HyMeDES EnviroNet platform.

In general, there are the following methods to provide the data: via an FTP-server, via a web API, via HTTP or via a local file stored on the data node. The data is encoded in CSV-file or XML-file. ZIP-files are also supported.

The data provider specific settings for data conversion (conversion filters) are configured via text files. This means that it is possible to make changes in these configurations or to define new conversion filters for potential additional data providers in the future just by editing these configuration text files, without adjusting the source code of the software, as long as the above-mentioned methods for providing the data are used.

Moreover, there are two options to provide the data: Pushing the data (option A) or pulling the data (option B). In the case of option A, a data node is running on a server of the data provider. It regularly accesses the data files and sends them to HyMeDES EnviroNet. In option B, HyMeDES EnviroNet accesses a server of the data provider and pulls data files from it.

In both cases, filter configuration files are identical. The only difference is that the configuration file for option A resides on a server of the data provider and can be edited locally, while in option B, the configuration is hosted by HyMeDES EnviroNet. In the latter case, updates of configuration files have to be sent to the host of the HyMeDES EnviroNet to get in effect. The central server of the HyMeDES EnviroNet is called distribution node.

3 Deployment of the software

The conversion filters have been delivered together with the required software components of HyMeDES EnviroNet to the national data providers 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.

Delivery reports have been provided by PP/ASP countries for which the data provider is not PP. In this case PP STASA has carried out the deployment together with the data provider, and therefore confirms in the delivery report that software has been deployed. These countries are:

- Austria
- Czech Republic
- Germany
- Republic of Moldova
- Republic of Serbia

For those countries in which data providers are directly involved as project partners, acceptance reports of these partners have been delivered:

- Bulgaria
- Croatia
- Hungary
- Romania

- Slovenia
- Slovak Republic
- Ukraine

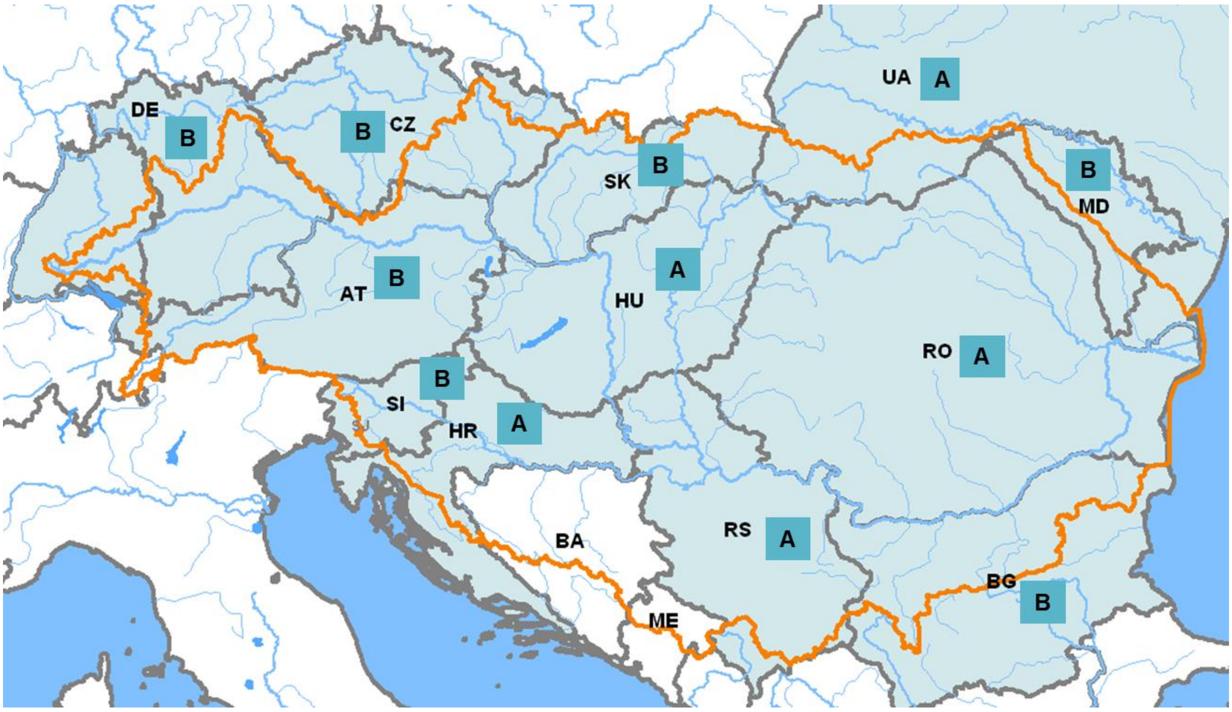

Figure 11 Countries of the Dareffort project in which the software has been deployed (highlighted in cyan) and the implemented method of data provision (option A: Data Node including the country specific conversion filter, option B: Conversion Plugin including the country specific conversion filter on the Distribution Node configured for pulling the data).

Figure 11 shows all countries in which the software has been deployed. The implemented method of data delivery is also depicted. According to section 2.5 in option A, a data node is running on a server of the data provider. It regularly accesses the data files and sends them to HyMeDES EnviroNet. In option B, HyMeDES EnviroNet accesses a server of the data provider and pulls data files from it.

The country specific delivery reports, respectively acceptance reports are attached in separate Annexes of this document. Bugs and issues documented in these reports have been fixed in the final version of the software.

In the acceptance and delivery reports it is confirmed that the HyMeDES EnviroNet is delivered, and that it meets all the acceptance criteria as defined in the requirements document and project scope statement. Moreover, it is stated that the Software has been handed over to operations and the transfer of knowledge from the project team to operations has also been completed. The technical staff of the staff provider has received a training how to install and use the HyMeDES Environet Software either during the Workshop on Software Topics on 27th May 2020 or in individual training workshops.

Furthermore, in the acceptance and delivery reports it is confirmed that the software has been tested and evaluated to verify that all deliverables meet performance, functional and quality requirements defined within the DARFFORT project.

It is also confirmed that transition to operations has been completed.

The acceptance criteria are:

- Software has been installed either as Data Node or Conversion Plugin running on the Distribution Node
- Country specific conversion filter has been implemented and handed over
- Key pairs for accessing Distribution Node have been created
- Data Provider has been registered as a user on the DAREFFORT Project Distribution Node running at LP VIZITERV
- Country specific monitoring points have been configured on the DAREFFORT Project Distribution Node running at LP VIZITERV
- Observable properties have been configured on the DAREFFORT Project Distribution Node running at LP VIZITERV
- Country specific Data Access Rights have been configured on the DAREFFORT Project Distribution Node running at LP VIZITERV

Test and evaluation results confirmed in the delivery and acceptance reports are:

- Access to the DAREFFORT project Distribution Node running at LP VIZITERV is tested and working
- Data is transferred regularly from Data Provider to DAREFFORT Project Distribution Node running at LP VIZITERV is tested and working
- Data transfer is tested to be correct
- Data update intervals are correct

Table 1 shows an overview on the configurations of data delivery for hydrological data from data providers in DAREFFORT. Table 2 shows the same overview for meteorological data. In Germany besides Bavarian Environment Agency (LfU) also meteorological data from German Weather Service (DWD) is collected by HyMeDES EnviroNet Distribution Node. Since this data is publicly available there is no project specific contact person involved. All the data providers listed in Table 1 and Table 2 deliver data to the platform. However, the State Hydrometeorological Service of the Republic of Moldova, SHS still has an issue with exporting measured data from their hydrological and meteorological stations from their internal data base to the foreseen csv-files. Thus, they currently cannot deliver measured data to the platform. However, also for data of SHS proof of concept of data delivery has been provided within the project framework.

Table 1 Configurations of data delivery for hydrological data from data providers in DAREFFORT (option A: Data Node including the country specific conversion filter, option B: Conversion Plugin including the country specific conversion filter on the Distribution Node configured for pulling the data)

data provider	country	option	method	data format	contact person	E-Mail
Federal Ministry of Agriculture, Regions and Tourism	Austria	B	web-API (HTTP)	xml	DI Reinhold Godina	Reinhold.Godina@bmlrt.gv.at
National Institute of Meteorology and Hydrology of Bulgaria, NIMH	Bulgaria	B	FTP	csv	Georgy Koshinchanov	georgy.koshinchanov@meteo.bg
Croatian Meteorological and Hydrological Service	Croatia	A	FTP	csv	Željka Klemar	zeljka.klemar@cirus.dhz.hr
Czech Hydrometeorological Institute CHMI	Czech Republic	B	FTP	xml	Petr Janal	petr.janal@chmi.cz
Bavarian Environment Agency LfU	Germany	B	web-API (HTTP)	xml	Dr. Natalie Stahl-van Rooijen	Natalie.Stahl-vanRooijen@lfu.bayern.de
General Directorate of Water Management (OVF)	Hungary	A	FTP	csv	András Csík	csik.andras@ovf.hu
State Hydrometeorological Service of the Republic of Moldova, SHS	Moldova	B	FTP	csv	Dan Titov	dan.titov@meteo.gov.md
NIHWM National Institute of Hydrology and Water Management	Romania	A	FTP	csv	Marius Matreata	marius.matreata@hidro.ro
Republic Hydrometeorological Service of Serbia	Serbia	A	web-API (HTTP)	csv	Samir Ćatović	samir.catovic@hidmet.gov.rs
Slovak Hydrometeorological Institute SHMU	Slovak Republic	B	web-API (HTTP)	xml	Marcel Zvolensky	marcel.zvolensky@shmu.sk
Slovenian Environment Agency ARSO	Slovenia	B	web-API (HTTP)	xml	Mira Kobold	mira.kobold@gov.si
Ukrainian Hydrometeorological Centre (UHMI)	Ukraine	A	local file	csv	Oleksii Zaivenko	zaivenko@meteo.gov.ua

Table 2 Configurations of data delivery for meteorological data from data providers in DAREFFORT (option A: Data Node including the country specific conversion filter, option B: Conversion Plugin including the country specific conversion filter on the Distribution Node configured for pulling the data)

data provider	country	option*	method	data format	contact person	E-Mail
Federal Ministry of Agriculture, Regions and Tourism	Austria	B	web-API (HTTP)	xml	DI Reinhold Godina	Reinhold.Godina@bmlrt.gv.at
National Institute of Meteorology and Hydrology of Bulgaria, NIMH	Bulgaria	B	FTP	csv	Georgy Koshinchanov	georgy.koshinchanov@meteo.bg
Croatian Meteorological and Hydrological Service	Croatia	A	FTP	csv	Željka Klemar	zeljka.klemar@cirus.dhz.hr
Czech Hydrometeorological Institute CHMI	Czech Republic	B	FTP	xml	Petr Janal	petr.janal@chmi.cz
Bavarian Environment Agency LfU	Germany	B	web-API (HTTP)	xml	Dr. Natalie Stahl-van Rooijen	Natalie.Stahl-vanRooijen@lfu.bayern.de
German Weather Service (DWD),	Germany	B	web-API (HTTP)	csv	publicly available data base is used, therefore there is no contact person	
General Directorate of Water Management (OVF)	Hungary	A	FTP	csv	András Csík	csik.andras@ovf.hu
State Hydrometeorological Service of the Republic of Moldova, SHS	Moldova	B	FTP	csv	Dan Titov	dan.titov@meteo.gov.md
NIHWM National Institute of Hydrology and Water Management	Romania	A	FTP	csv	Marius Matreata	marius.matreata@hidro.ro
Republic Hydrometeorological Service of Serbia	Serbia	A	web-API (HTTP)	csv	Samir Ćatović	samir.catovic@hidmet.gov.rs
Slovak Hydrometeorological Institute SHMU	Slovak Republic	B	web-API (HTTP)	xml	Marcel Zvolensky	marcel.zvolensky@shmu.sk
Slovenian Environment Agency ARSO	Slovenia	B	web-API (HTTP)	xml	Mira Kobold	mira.kobold@gov.si
Ukrainian Hydrometeorological Centre (UHMI)	Ukraine	A	local file	csv	Oleksii Zaivenko	zaivenko@meteo.gov.ua

4 Software tests and observation of stability on the long run

The HyMeDES EnviroNet platform and data delivery from national data providers to the platform has been tested in the period between beginning of September to end of October 2020. For the majority of countries data delivery is running continuously since end of October 2020. Up to now, during a period of about 150 days data of over 600 measuring stations have been delivered regularly, in most cases hourly, to the Distribution Node of the common data exchange platform HyMeDES EnviroNet.

The software has been tested by LP VIZITERV and PP STASA in the pre-phase of delivery to the data providers, and also by the data providers after delivery.

Tests for correct storage and delivery of data, particularly values and time stamps have been carried out using the interactive Dareffort Environet Map implemented to demonstrate the capabilities of the common data exchange based on the HyMeDES EnviroNet Platform (see Deliverable D4.1.3 *Hydrocode Mapping* and Output 4.1). This map can be accessed at http://dareffort.stasaapps.de, by project partners with username *dareffort*, and password *Dareffort2020Stasa!*

Figure 12 shows an example of the time series of water level for the hydrological station Budapest, Hungary.

In the time of continuous operation during the past five months only minor issues occurred which could be fixed in short time. The five months of operation of the HyMeDES EnviroNet platform show that the software developed in the Dareffort project is running stable under real live conditions. Conversion of national data formats to the common data format is working flawless. The platform is ready to be handed over to ICPDR for the implementation of DanubeHIS.

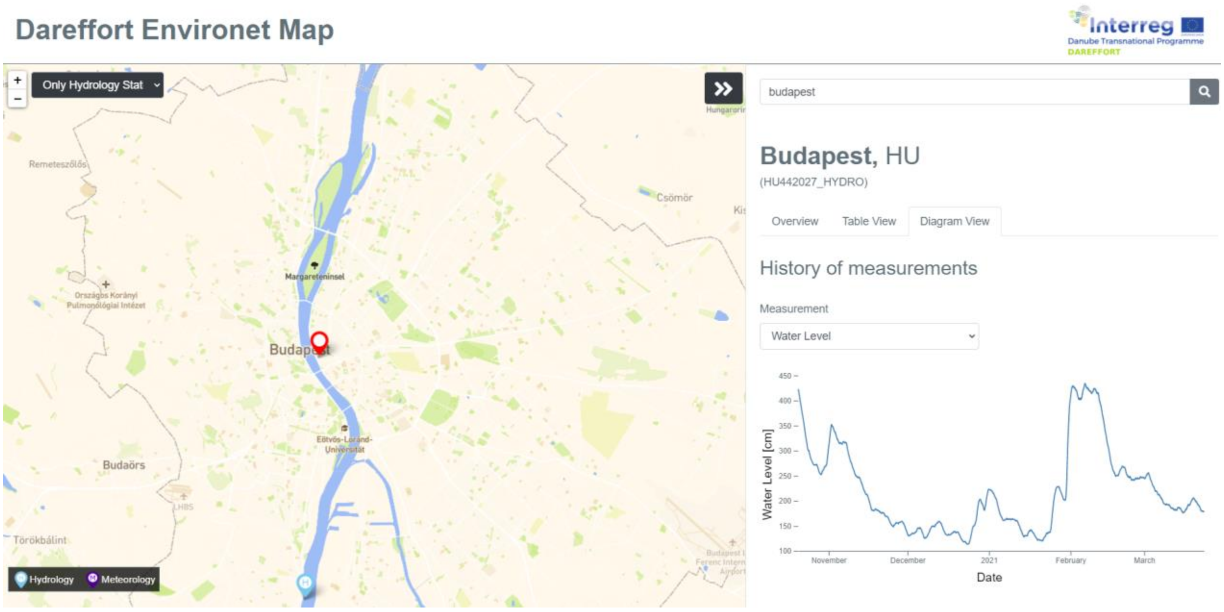

Figure 12 Time series of a hydrological station in Budapest, Hungary shown in Dareffort Environet Map. Data is retrieved from the HyMeDES Environet distribution node.

5 Outlook of potential features of a future common data exchange or joint forecasting system

The outlook of potential features of a future common data exchange or joint forecasting system is strongly related to Output 3.2 *Common vision of cooperation* in general, and the Deliverable 3.2.2 *Evaluation of the possibilities of the international forecasting system's result exchange platform* as well as the identified future Scenarios described in Deliverable 3.2.5 *Economic Impact Analysis*.

Following potential future Scenarios for further developments have been identified:

Scenario 0 – Implementation of a common Danube River Basin *observed* data exchange platform
This scenario is the direct outcome of the DAREFFORT project. A common Danube River Basin data exchange platform is implemented within the project (WP4). Subsequently the exchange platform will be operated by ICPDR. The implementation phase started in June 2018 with the start of DAREFFORT and will be finished at the end of 2021, with the implementation of Danube HIS by ICPDR.

Scenario 1 – Implementation of a common Danube River Basin Forecasting Systems result exchange platform
The software exchange platform HyMeDES Environet developed in DAREFFORT has an open architecture, so that later in the process additional modules can be implemented. In Scenario 1 it is foreseen to exchange forecasting data as a time series. The implementation phase could begin right after the implementation of Scenario 0 is completed and could be ready at the beginning of 2025.

Scenario 2 – Close integration between the National Flood Forecasting and Warning Systems and the existing Regional Flood Forecasting and Warning Systems: EFAS – Copernicus service, SEE-MHEWS-A, SEE-FFG, and SAVA FFWS
There are already several important supra-regional flood forecasting systems like EFAS (European Flood Awareness System), SEE-FFG (South-East Europe Flash Flood Guidance), and SAVA FFWS (Sava Flood Forecasting and Warning System) implemented within the Danube River Basin area. Another important one is currently under implementation: SEE-MHEWS-A (South-East European Multi-Hazard Early Warning Advisory System).

Due to the close relation between the implementation of this scenario and the development and implementation status of different regional systems, this scenario could have two phases:

- Phase I – integration with EFAS (Scenario 2a),
- Phase II – integration with SEE-MHEWS-A, Sava FFWS, and SEE-FFG (Scenario 2b).

Not all Danube river basin countries are represented in SEE-MHEWS-A, SEE-FFG and Sava FFWS. This is only the case for EFAS.

Scenario 3 – implementation of a common Danube River Basin Forecasting Platform
This scenario describes the implementation of a common Danube River Basin Forecasting Platform similar to the common Sava FFWS, which has been implemented recently. This is the most complex and uncertain Scenario.

In this chapter the main findings of deliverable 4.2.3 *Outlook of potential features of a future common data exchange or joint forecasting system* are described, to provide an outlook on the potentials of further developments for which the HyMeDES Environet software developed in the DAREFFORT project could be the basis.

5.1 Intended user groups for a future system

It is very important to exactly define who are the potential users of a future common data exchange or joint forecasting system and the requirements they have.

Since the defined future scenarios are related to professional services of data exchange aimed to flood forecasting experts, users should be mainly the forecasting organizations, and not other organizations like civil protection authorities. Each forecasting organization informs the civil protection authorities itself with the country's own procedures.

Exposure of forecast data to general public is problematic, as scientific data needs to be interpreted correctly and there is a huge potential of misunderstanding the data. Therefore, forecasted data should not made publicly available.

Forecasting organizations are very sensitive to dissemination of the forecasted data. This is also common practice in existing platforms which exchange forecasted data, e.g., in Sava FFWS only the nine hydrometeorological forecasting organizations of five countries have access to the data. There is no access granted to the public.

In conclusion the user groups for future systems described in the scenarios 1 to 3 should be professional experts in the field of flood forecasting.

Data policy should make national forecast organizations comfortable, as they are very sensitive on disseminating forecast results.

5.2 Scope of future systems

According to the participants of a flood forecasting expert workshop on the outlook of the potential features carried out in December 2020, in the future there should be the possibility to view the forecasted hydrological data of all other forecasting services in the Danube basin, as described to Scenario 1. In this context, the regions near the borders in upstream direction for each respective country are of special importance. Having access to forecasted data of upstream near-border gauging stations would be useful to be able to include the data into forecast models for additional runs of the models.

Regarding meteorological forecasted data a great benefit would arise from a common weather forecast for the whole basin, which could be used to make alternative runs of hydrological forecast with it. A common weather forecast would be very important, because this would avoid that an event could occur twice in data if different local meteorological forecasts are used. A common meteorological model would lead to more consistent and comparable forecasts. However, a hi-res forecast of the whole region is computationally expensive and is up to now done for most of the area but not the whole.

From the perspective of the flood forecasting experts participating in the workshop, a joint hydrological forecasting system with a harmonized forecasting model similar to Scenario 3 is currently not needed. EFAS already covers whole Danube basin with its forecasting products.

So, with respect to Scenario 3, future developments should focus on a joint meteorological forecast rather than on a joint hydrological forecast.

5.3 Potential features of a common Danube River Basin Forecasting Systems result exchange platform (Scenario 1)

The results of Deliverable 3.2.2 *Evaluation of the possibilities of the international forecasting system's result exchange platform* show that the benefits different countries may have from this platform are very heterogenous. In summary, the **bilateral exchange of hydrological and also meteorological forecasts** between countries is already common practice between neighbouring countries. Therefore, to justify the development of a **Danube wide forecasting result exchange platform**, benefits in addition to the bilateral exchange of forecasting results have to be derivable from such a solution. Particularly forecasting experts from downstream countries Croatia, Romania, and Bulgaria see an additional benefit of a Danube wide forecasting result exchange platform for improving short term and medium-term hydrological forecasts and warnings. Forecasting experts from downstream countries see additional benefits in extending the lead time. A further benefit could be the improvement and standardization of data interfaces functionalities of the national systems.

The HyMeDES Environet platform developed in the DAREFFORT project could serve as a technical basis for the development of Danube wide forecasting result exchange platform. However, enhancements in the data model have to be made to cope for the special characteristics of forecasted data. Also, the output format WaterML 2.0 is not suitable for exchanging forecasted data, particularly regarding ensemble forecasts and grid data. The goal is to integrate the features in an open and modularized architecture in order to being able to implement additional modules in the future.

Regarding data policy, precise guidelines would be very important in order to make an exchange of forecasts across the whole Danube basement possible. Especially the liability for the results is an issue which hinders the exchange of the results. Therefore, this has to be addressed in a data policy agreement, e.g., by stating that the forecasting institutes are not liable for the forecasting results or the products that result from further processing and adding a statement that the forecast results have the character of unproved raw data. In addition, also the exchange of forecasting results free of charge is an issue for some of the countries.

Main potential features of a forecasting system's result exchange platform therefore could be:

Feature: Standardization of exchange of forecasted data
A forecasting system's result exchange platform would require an international standardization of exchange of forecasted data. Yet, there is no such standard to exchange ensemble forecasts, grid data and to harmonize lead times and update intervals, different spatial and temporal resolutions. The development of this platform could catalyse the efforts to develop appropriate standards for exchanging forecasted data which could also improve bilateral data exchange.

Therefore, it will be a big challenge to harmonize all of these topics within the Danube river basin. The technical requirements for an exchange of forecasting results vary widely between the involved countries. It is estimated that exchanging forecasting results requires at least as much effort in coordination and harmonization as the exchange of measured data implemented in the DAREFFORT project, because of a large variety of data formats for forecasted data and forecasting models, as well as prerequisites for using them.

Not only the formats would have to be harmonized, but also the exchange intervals for forecasting results, because the exchange has to be adapted to the many different forecasting models which are currently in use in the Danube catchment.

Feature: Exchange of forecasted data as time series
Timeseries of observed data and forecasts are fundamentally different because forecasted time series have two timestamps: The timestamp at which the forecast was calculated (result time) and the timestamp of the data forecasted (phenomenon time). This can be solved technically, but WaterML 2.0 as used as a standard for observed data could not be used for providing forecasted data without tweaking this data format.

Nevertheless, the exchange of forecasted data as time series as a subset of the exchange of forecasted data is more feasible than the exchange of forecasted data in general including grid data and ensemble forecasts.

Additionally, an exchange platform for forecasted time series might be also made capable of storing multiple forecasted time series for the same point on the river, with different result time stamps, if there is no well-defined rule how to replace forecasted timeseries having older result time stamps with new ones.

From a technical point of view, it is very reasonable that the described challenges can be solved. Forecasted time series could be exchanged via the HyMeDES Environet platform developed in the Dareffort project by enhancing the data model for the second timestamp in forecasted timeseries and using an enhanced WaterML-format or another data format for providing the data to forecasting centres or other expert users. Also, some kind of uncertainty intervals for forecasted data points in the time series could be implemented in the data model.

Feature: Exchange of ensemble forecasts
Resulting from Deliverable 3.2.2, the exchange of ensemble forecasts between countries is seen as useful. But the prerequisites and boundary conditions of ensemble forecasts are very different in each country. An exchange of ensemble forecasts therefore requires a high degree of coordination and harmonization. The forecasts, but especially the boundary conditions and scenarios, must be standardised in order to use ensemble forecasts across countries.

The exchange of ensemble forecasts would add an additional dimension to the exchange of forecasted timeseries: In addition to each result time stamp an array of timeseries with the different ensembles exists. Also, the ensemble configuration must be stored in the data model, otherwise the data of the ensembles are not interpretable.

Exchanging ensemble forecasts also would require harmonizing the ensemble configurations between countries, at least between neighbouring countries, otherwise forecasting centres cannot make use of the ensemble forecasts from upstream countries.

Whereas the implementation of ensemble forecasts in the data model of a forecasting results exchange platform technically is feasible, but complex, the harmonization of the ensemble configurations between the countries is very difficult and would require the forecasting centres to cooperate very closely and change their own ensemble configurations or at least calculate the harmonized ones in addition. This would also require that all forecasting centres create ensemble forecasts for the potential harmonized configurations.

5.4 Potential features for an integration with existing systems (Scenario 2)

There are already existing supra-regional flood forecasting systems, like the European Flood Awareness System (EFAS), the Sava Flood Forecasting and Warning System (Sava FFWS), South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A).

According to the workshop on the outlook on future developments the existing systems should be linked together, but not replaced by a new system. The goal should be to make best use of existing systems.

Scenario 2 therefore describes a close integration between the National Flood Forecasting and Warning Systems and these existing Regional Flood Forecasting and Warning Systems.

Feature: Transmission of measured data from the HyMeDES Environet platform into EFAS

The aim of the European Flood Awareness System (EFAS) is to support preparatory measures before major flood events strike, particularly in the large trans-national river basins and throughout Europe in general. EFAS is the first operational European system monitoring and forecasting floods across Europe and is in full operation since 2021 as part of the Copernicus EMS (https://www.efas.eu).

The platform provides complementary, added-value information (e.g., probabilistic, medium range flood forecasts, flash flood indicators or impact forecasts) to the relevant national and regional authorities. Furthermore, EFAS keeps the Emergency Response Coordination Centre (ERCC) informed about ongoing and possibly upcoming flood events across Europe.

Almost all countries in the Danube catchment actively participate in providing data to EFAS (except Moldova), and in using the products of the EFAS platform.

Therefore, a useful feature in Scenario 2 for a closer integration with EFAS would be the transmission of observed data from the HyMeDES Environet platform to EFAS, as up to now every data provider is delivering observed data to EFAS individually. Also, according to the outcome of the workshop on potential features and developments this kind of use of the HyMeDES Environet platform should be foreseen in the future.

Currently, EFAS uses more gauging stations than available on HyMeDES Environet platform. Regional Report of EFAS delivered within WP3 EFAS get data from 478 hydrological stations in Danube catchment whereas the HyMeDES Environet platform currently comprises 329 hydrological stations. This is linked to the fact that HyMeDES Environet data is potentially publicly available, while EFAS data is not. However, the data model implemented in the HyMeDES Environet platform is capable to handle all in-situ parameters which are delivered to EFAS by the individual countries.

The Meteorological Data Collection Centre is operated by KISTERS AG and the Global Precipitation Climatology Centre (GPCC) of the German Weather Service (DWD). KISTERS AG hosts the data base, quality control procedures and gridding schemes, and GPCC oversees and improves the quality control procedures and acts as focal point for meteorological data providers.

The stations from which EFAS currently collects data and which are not already available on the HyMeDES Environet platform, could be added to the platform. Since the HyMeDES Environet platform has a very flexible access rights management, stations, observed properties and data particularly foreseen to be used by EFAS only can be restricted for access from the regular purpose of future Danube HIS.

From a technical point of view the parameters currently collected by EFAS from each country in the Danube catchment separately could be transmitted via HyMeDES Environet platform if the data providers enhance their data transfer to the HyMeDES Environet platform by the observed properties and stations specified by EFAS. The data model of the HyMeDES Environet platform is capable to handle the in-situ data collected by EFAS.

However, this scenario requires a consent between ICPDR as the host of Danube HIS, EFAS, and the data providers.

Feature: Transmission of hydrological forecasts from EFAS to the HyMeDES Environet platform

Currently it is possible to include national forecasts into the EFAS system using a Web Map Service (WMS) interface. It is quite rudimental, more tight forecasts, for example the 5-day-forecast of a gauging station are a problem, because no standards exist. There is a Country Report with additional information on the capabilities of EFAS. EFAS also offers a Sensor Observation Service (SOS), where the WaterML 2.0 standard was modified to be able to integrate forecast time series because there are no commonly agreed standards on forecasted data.

An additional feature could be that EFAS provides their hydrological forecasts, at least for border areas, to the HyMeDES Environet platform. This feature could be an alternative to the forecasting systems result exchange platform describes in Scenario 1, which could avoid the requirements of standardization of data formats for forecasting results.

Transmission of hydrological forecasts from EFAS to the HyMeDES Environet platform could be technically feasible but would require technical coordination with EFAS on the data format and protocol to use, e.g., one that EFAS already uses (Web Map Service WMS or SOS service). Accordingly, adjustments to the data model of the HyMeDES Environet platform would be necessary and also the implementation of an appropriate transfer protocol.

Feature: Integration with SEE-MHEWS-A

WMO is currently implementing the project 'South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A), which provides guidelines for development of the technical part of the system and for all activities necessary to establish advisory system operations. From the Danube basin countries, the National Meteorological and Hydrological Services of Croatia, Hungary, Moldova, Romania, Slovenia, Ukraine and Bulgaria (Serbia is considering) are partners to the SEE-MHEWS-A project. These countries have agreed to exchange meteorological and hydrological data, information, forecasts and advisories under the SEE-MHEWS-A.

The SEE-MHEWS-A has furthermore set up 4 limited area numerical weather prediction models running quasi-operationally at ECMWF, covering the whole SEE region, with forecasts to be available for all the project partners of SEE-MHEWS-A.

Hydrological models will be implemented during the current SEE-MHEWS-A project phase for a pilot river catchment in Bosnia and Herzegovina and North Macedonia, but this is planned to be expanded to cover other river catchments from the region during further phases of the project. Both meteorological and hydrological forecasts will be available to the project partners via SEE-MHEWS-A Common Information Platform, which is under development.

There is already an existing cooperation between EFAS and SEE-MHEWS-A, also between Sava FFWS and EFAS.

Based on the goals of the SEE-MHEWS-A project, and the participating countries an integration of the results of the weather prediction models from SEE-MHEWS-A into a future Danube River Basin Forecasting Systems result exchange platform (see section 5.3) based on the HyMeDES Environet platform could be useful.

In addition, as proposed for the integration with EFAS, data providers in the Danube catchment could send their data via the common data exchange platform HyMeDES Environet (future Danube HIS).

The WMO would be open to discuss cooperation with SEE-MHEWS-A-countries. Discussion is also required with the SEE-MHEWS-A Steering Committee, consisting of the Directors of NMHSs from the region.

Regarding an integration of the results of the weather prediction models from SEE-MHEWS-A into a future Danube River Basin Forecasting Systems result exchange platform would require agreement with the SEE-MHEWS-A Steering Committee and definition and coordination of the data format and protocol to exchange the forecasted weather data as well as its implementation.

The transmission of the data to SEE-MHEWS-A via the HyMeDES Environet platform would likely be technically possible, similar to the transmission of the data to EFAS.

Feature: Integration with Sava FFWS

The establishment of a joint Flood Forecasting and Warning System in the Sava River Basin (Sava FFWS) is a component of the project "Improvement of Joint Actions in Flood Management in the Sava River Basin". The project was funded by the Western Balkans Investment Framework (WBIF) and implemented by the World Bank between 2016 and 2018. For more information about Sava FFWS and their activities please refer to https://www.savacommission.org/project_detail/24/1

The Sava FFWS provides an integrated forecasting system, covering the complete Sava River Basin. The beneficiary countries are Bosnia and Herzegovina, Croatia, Montenegro, Serbia and Slovenia, while the entire process is coordinated by ISRBC in accordance with the Protocol on Flood Protection to the Framework Agreement to the Sava River Basin.

All countries in the Danube catchment which are also in the Sava river basin use Sava FFWS to send data to the platform, and also have access to the provided data of Sava FFWS.

The possible integration of hydrological and meteorological observed data using the API of Sava HIS could be a first step towards an exchange of data with Sava HIS. In addition, a closer integration of the results of Sava FFWS to a future Danube River Basin Forecasting Systems result exchange platform could be useful to avoid parallel developments.

From a technical point of view a close integration of the results of Sava FFWS with a future Danube River Basin Forecasting Systems result exchange platform is feasible, but would require the definition and coordination of the data format and protocol to exchange, as for the integration with EFAS or SEE-MHEWS-A.

5.5 Possibilities of the implementation of a common Danube River Basin Forecasting System (Scenario 3)

According to section 5.2 future developments related to the implementation of a common Danube River Basin Forecasting Platform should focus foremost on a joint meteorological forecast. Therefore, a potential purpose and feature of common Danube River Basin forecasting system could be the provision of a common weather forecast serving as input for hydrological forecasts.

As mentioned in section 5.2 a substantial benefit would arise from a common weather forecast for the whole basin, because this would avoid that an event could occur twice in data if different local meteorological forecasts are used. In addition, a common meteorological model would lead to more consistent and comparable forecasts. A forecast with high-resolution inputs would be needed. However, a hi-res forecast of the whole region is computationally expensive and is up to now done for most of the area but not the whole.

Regarding a potential joint hydrological forecasting system, the development of a Danube specific system with a harmonized forecasting model is currently not required, from the perspective of the flood forecasting experts participating in the workshop on the outlook on future developments. EFAS already covers the whole Danube basin with its forecasting products. According to EFAS with recent and future planned upgrades of EFAS there will be also an increase in forecast accuracy on the short term due to better capturing the uncertainty by using more forecasts and improving the spatial resolution of the hydrological model. So instead of establishing an additional forecasting platform, it could be more useful to enhance the integration between future Danube HIS with EFAS as described in section 5.4.

However, in the future scenarios elaborated for Deliverable D3.2.5 Economic impact analysis the implementation of a common Danube River Basin Forecasting Platform similar to Sava FFWS has been proposed. Also, as an outcome of Deliverable D3.2.3 Recommendations for improvement of the flood and ice forecasting systems it is recommend to develop hydrological forecasting systems for various catchments within the Danube River Basin (micro, meso and macro scale) taking into account already existing systems at different scales, particularly the only Danube wide forecasting system EFAS and the Sava forecasting system from the ISRBC. Since several countries in the Danube river basin are also part of the Sava river basin a potential option could be to develop a joint forecasting platform similar to Sava FFWS, if national forecasting centres could see benefits on top of using existing platforms or their national forecasts on the long term. Like Sava FFWS, this platform could be developed as an open platform for managing the data handling and forecasting process, allowing a wide range of external data and models to be integrated. Similar to Sava countries the countries in the Danube catchment are using very different forecasting systems. However, the Danube catchment is much larger, and more countries and diverse systems are involved. Therefore, implementation effort will be much higher than for Sava FFWS. Depending on the plans of ICPDR, future Danube HIS could be used as the data platform to access real time hydrological and meteorological data for such a platform. Also, Danube GIS could be integrated providing spatial layers for the platform. A local platform for the Danube river basin could enhance the collaboration between the forecasting centres and also improve the harmonization of national forecasts and help to improve the cross national knowledge exchange between the flood forecasting experts.

However, this is the most complex and uncertain Scenario, and without defining the concrete purposes and special coverage to be achieved with such a platform it is not possible to estimate the feasibility of an implementation. However, based on the fact that there are more countries involved than for example in Sava FFWS the complexity of an implementation would be much higher, also regarding implementation time and costs. Extensive duplication of efforts for similar activities and results with the regional systems, could not be avoided. The complexity of operation, maintenance and updates is also a big challenge.

6 Glossary

API
An application programming interface (API) is a computing interface that defines interactions between multiple software entities by defining the kinds of calls that can be made, how to make them, and the data types to be used.

Conversion Filters
The conversion filters (plug-ins) are used to convert the data from local data format to the common HyMeDEM data format. They run either on the data nodes on side of the data providers or on the distribution node, in case that data providers are not able to install a data node on their own site.

Data Node
Data nodes are the part of the HyMeDES EnviroNet software which run on side of the data providers 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.

Distribution Node
The central server software, which is the backbone of HyMeDES EnviroNet platform, and which runs on the central server, hosting the data base in which common data is stored.

FTP
The File Transfer Protocol (FTP) is a standard network protocol used for the transfer of computer files from a server to a client on a computer network.

GitHub
GitHub, Inc. is a provider of Internet hosting for software development and version control. It offers the distributed version control and source code management (SCM) functionality of Git, plus its own features. It provides access control and several collaboration features such as bug tracking, feature requests, task management, continuous integration and wikis for every project

GUI
Graphical user interface. The GUI of the HyMeDES EnviroNet software enables users to configure and maintain the stations' information and data stored in the distribution node.

HyMeDEM
HyMeDEM stands for Hydrological and Meteorological Data Exchange Model. It is the common data model implemented for the HyMeDES EnviroNet platform. The data model consists of the data base model which is used to store the common data on the distribution node server, and of a WaterML 2.0 based data model to retrieve the data from the distribution node and make available for end users.

HyMeDES EnviroNet
HyMeDES EnviroNet is the common data exchange software which has been developed in the DAREFFORT project to enable data exchange in the whole Danube catchment. HyMeDES is the abbreviation of Hydrological and Meteorological Common Data Exchange Service. The suffix "Envi-

roNet” stands for environmental information network which indicates the software service is able to deal with a variety of environmental data and could be easily extended in the future.

Web API

A Web API is an application programming interface which directly uses web technology. It can be used for example to acquire data in csv or xml-format directly from a webserver.

Contact STASA Steinbeis Angewandte Systemanalyse GmbH
Lange Straße 8
70173 Stuttgart
Germany

Internet: www.stasa.de
Email: liedl@stasa.de
Tel: +49 711 50448861
Fax: +49 711 50093240

Editors: Dr. Philipp Liedl (managing director)
Dr. Dirk Meyer
Kim Schwarz