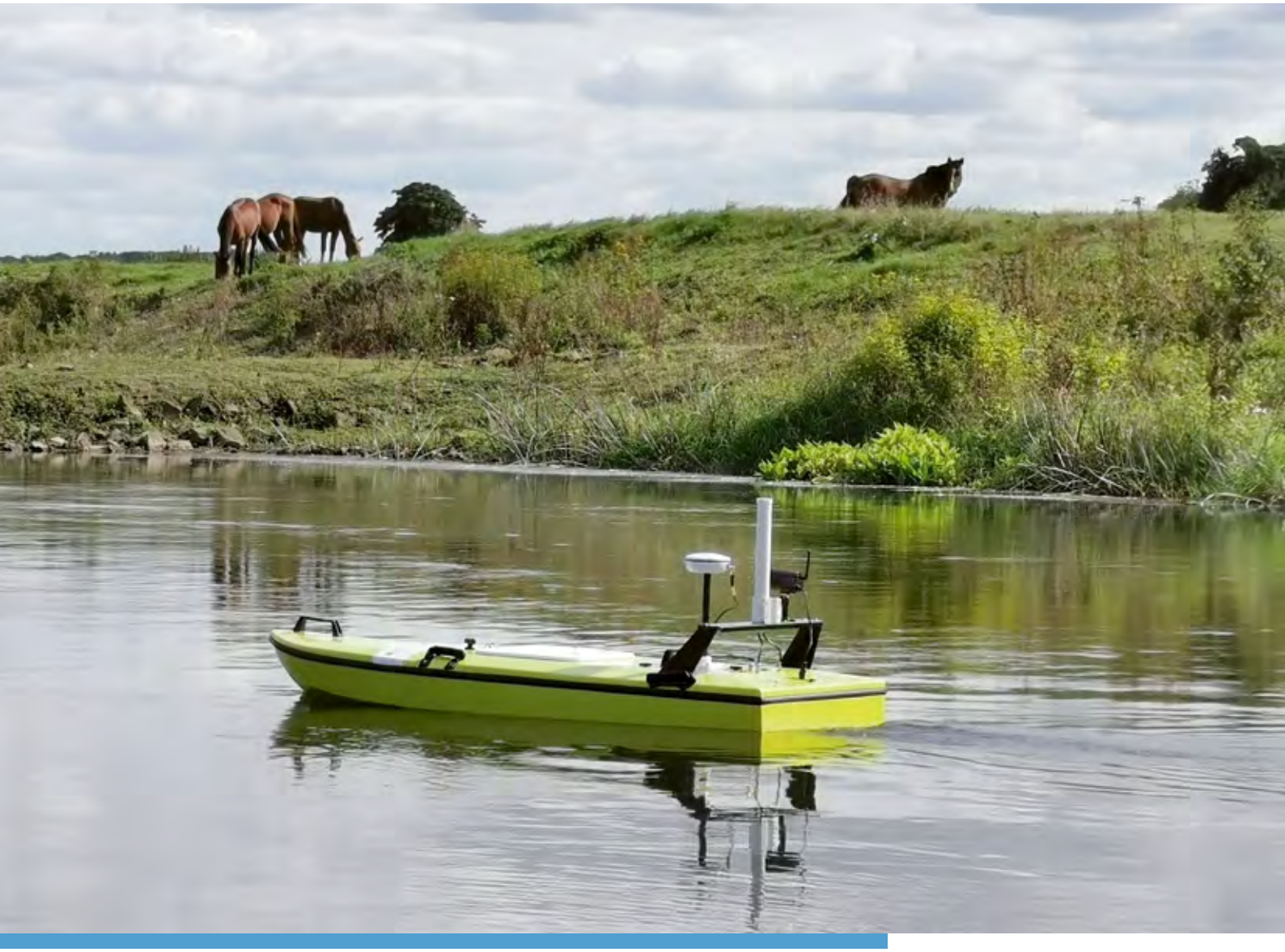
bfg Federal Institute of Hydrology

Annual Report 2020/2021



Imprint

Publisher: Federal Institute of Hydrology
(Bundesanstalt für Gewässerkunde – BfG)
Am Mainzer Tor 1
P.O. Box 20 02 53
56002 Koblenz
Germany
Phone: +49 261 1306-0
Fax: +49 261 1306 5302
E mail: posteingang@bafg.de
Internet: https://www.bafg.de

Editors: Yvonne Strunck, BfG
Susanne Schäfer, BfG
Ruth Trautmann, BfG

Translations: Ruth Trautmann, BfG
Dagmar Kronsbein, ICWRGC

Picture credits: Cover: BfG's remote control ArcBoat "Q" in action, BfG
P. 8: Lukas Gojda / Adobe Stock
P. 12: Hils, BfG
P. 24: Hils, BfG
P. 36: Udo Weber / Adobe Stock
P. 44: Udo Weber / Adobe Stock
P. 52: Iffezheim lock on the Rhine (Rhine km 334), Leonard / Adobe Stock

Design: unicom Werbeagentur GmbH
Print: BMDV's printing firm network

ISSN 0170 – 5156

DOI: 10.5675/BfG-Jahresbericht_2020/2021_EN

Content

Message from our Director General

Dear reader,
BfG's Annual Report presents a range of subject areas that our staff were engaged with during the 2020/2021 reporting period. What many of these activities have in common is the importance of time scales, making one thing clear: the merits of long-term observations. Water (eco-)systems are in constant change. This is why we record phenomena from current observations through to long-term trends and natural variations. Results are put into context to enable evaluation.

The devastating precipitation events in July 2021 made us aware of how vulnerable existing transport infrastructures and society as a whole are. In general, climate research findings suggest that hydrological extreme events might become ever more frequent. We therefore provide tailored advice to the federal ministries of transport and environment, the *Länder* (states), the Federal Waterways and Shipping Administration (WSV) as well as national and international river basin commissions. We deploy models to allow for integrated impact assessments of flood protection efforts on large German rivers and to deliver water level forecasts for transport providers operating on major federal waterways. We engage in the implementation of the DAS Core Service "Climate and Water" (*DAS-Basisdienst Klima und Wasser*) established under the German Strategy for Adaptation to Climate Change (*Deutsche Anpassungsstrategie an den Klimawandel* – DAS). As part of the network of higher federal authorities within the portfolio of the Federal Ministry for Digital and Transport, we have set up modules of a comprehensive advisory service. In 2020 and 2021, we launched new forecasting products facilitating long-term fleet, transportation and infrastructure planning.

Since 2009, the WSV has already been in charge of the water management-related maintenance of federal waterways. In June 2021, its range of tasks was complemented by the responsibility for their water management-related development. We therefore provide continuous guidance to the WSV regarding ecologically optimised waterway maintenance and development works on the federal waterways. Our activities in the reporting period included providing specific digital map applications used in the context of WSV projects.

Digitalisation opens up new ways of insight generation in various fields of work. Under our R&D project "Monitoring station of the future" (*Messstation der Zukunft*, MONDE 1), we developed and tested innovative methods of sampling, sample processing, analysis and data interpretation for monitoring and assessing water quality during the reporting period.

Apart from our day-to-day tasks, it is crucial to maintain a long-term, future-oriented organisational structure and equipment of our institution. We rose to this challenge by developing the "BfG 2030" strategy, involving interviews with several external BfG partners. At this point, I would like to thank them for their support.

In retrospect, the years of 2020/2021 were very special indeed: our everyday lives (both in the private and working spheres) were – and still are – impacted by the coronavirus and the related COVID-19 pandemic. A strong sense of responsibility guided all of BfG's employees in delivering their tasks under these particular circumstances. With the pandemic's minor and major issues in mind, we regard this 2020/2021 Annual Report as a documentation of our work in a challenging period of time, and we can be proud to have mastered this stage. My sincere thanks go to all colleagues at BfG.

Dr Birgit Esser
Director General of the Federal Institute of Hydrology

Koblenz, April 2022

BfG's departments

Quantitative hydrology

Petra Herzog
has been head of the Quantitative Hydrology division since 2017.

We study water levels and streamflows, the geometry and morphological condition of waterways. These studies and measurements go far beyond the narrower scope of the waterway itself. They also cover the floodplains, the developments in the catchment area and the effects of global climate change. The development and appropriateness of measuring methods, including carrier systems, as well as quality assurance of the acquired data are an essential part of this work. In this context, we take advantage of state-of-the-art procedures and approaches, including Artificial Intelligence elements, to satisfy the needs of users within the Waterways and Shipping Administration (WSV).
Combined with appropriate simulating and forecasting models, these measurements provide the basis for reliable assessments of the effects of hydraulic-engineering projects and water management practices, water level forecasts and trends in streamflow generation in the catchments. In order to meet the growing information demand on climate change and waterways, we follow an integrated research approach and provide needs-based services to policymakers and staff responsible for the operational management at federal and *Länder* (state) levels. Specific information portals host our products to make them accessible to internal and external users.

Qualitative Hydrology

Prof Dr Thomas Ternes
took over as head of the Qualitative Hydrology division in 2017.

We study the occurrence, transformation, transport and eco-toxicological effect of contaminants in rivers and coastal waters. In expert reports and research projects we examine the impacts of anthropogenic pollutant inputs on aquatic ecosystems and how they restrict water uses. Thanks to our expertise in the disciplines of chemistry, eco-toxicology, microbiology and radiology, we have at our disposal extensive knowledge about the quality of water in the navigable inland and coastal waters as well as the suspended solids and sediments contained there. Data from a nation-wide monitoring network and special project-related surveys provide the basis for cause-effect scenarios, forecasts and information for the general public. A key element of our work is to mitigate the detrimental effects of federal waterway maintenance and development works on the quality of waters.

Our general tasks include advising the Federal Ministry for Digital and Transport (BMDV), the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Länder and the WSV regarding the consequences of anthropogenic water pollution.

Ecology

Dr Dorothe Herpertz
has been head of the Ecology division since 2015.

The focus of our work is on the ecosystems in and along the federal inland and coastal waterways. We document their current composition and status and develop concepts for environmentally compatible and sustainable management of waters. In addition to studying the origin and extent of ecological changes, we also assess the climate-induced impacts on the ecology of waters and their usability. We show ways to mitigate the negative consequences of anthropogenic interventions. Building on a holistic, impact-focused system approach, we share our knowledge across divisions and find answers to complex ecological questions, enabling us to advise the BMDV, BMUV and other federal ministries in fundamental as well as specific issues. We assist the WSV in all water development procedures, in water maintenance and restoration of ecological connectivity, and we develop concepts and solutions with and for the WSV.

Central Services

Kirstin Ruranski
became head of the Central Services division in 2021.

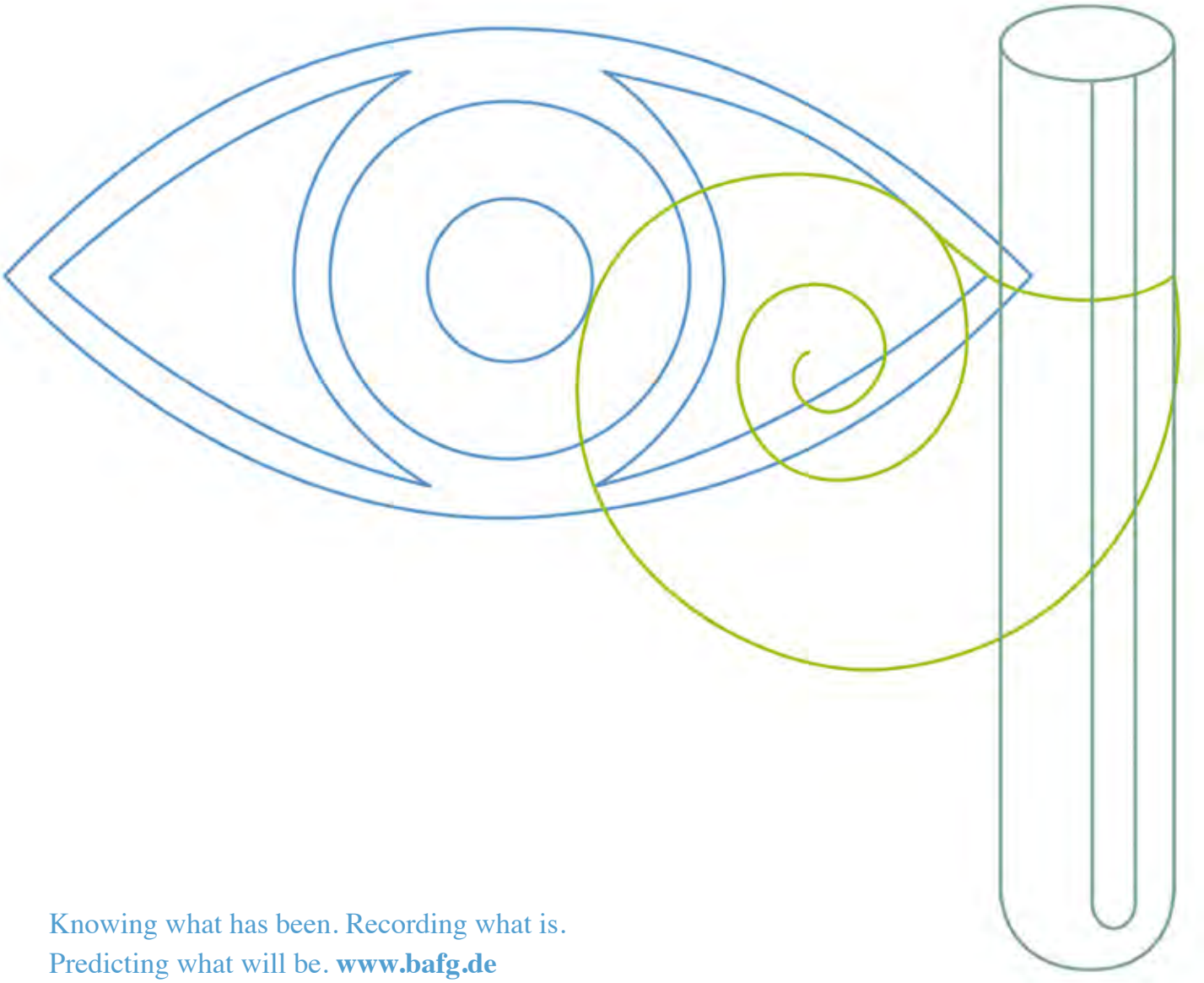
We ensure smooth central business processes and are service providers in all matters related to HR and material resources management, including legal advice, IT, information management as well as property, vehicle and file management. We are also responsible for ensuring that official procedures are lawful and that budget funds are put to efficient use. Information technology is the backbone of our modern and future-oriented digital infrastructure. Our library – the federal central library for hydrology – provides BfG staff and the expert audience with the necessary external knowledge.
Previously, all these operations were assigned to two departments. In recent years, however, BfG's range of tasks experienced major changes both in terms of quantity and quality. In particular, our workforce grew significantly with fixed-term employees now accounting for a share of more than 35%. As a consequence, recruiting, contracting and procurement activities as well as infrastructure support services saw a steady rise, prompting a corresponding increase

in headcount. In liaison with the BMDV we therefore adapted our division's organisational structure. Since September 2020, our "Central Services" division Z has been made up of three departments: The new Z1 department is mainly in charge of HR management while legal affairs, budget management, contracting and procurement are taken on by the newly established Z3 department. The responsibilities of department Z2 "Information Technology and Information Management" remained unchanged. Together, we ensure that BfG is well-positioned to carry out its expert tasks.

The International Centre for Water Resources and Global Change (ICWRGC)

Harald Köthe
has been head of the International Centre for Water Resources and Global Change (ICWRGC) since 2018.

Since 1975, we have been an inter-ministerially managed German secretariat for the water programmes of the United Nations and are located at BfG. In July 2014, we received recognition as the first German UNESCO category 2 Water Centre in Germany. Working together with the inter-ministerial Water Foreign Policy group (*Ressortkreis Wasseraußenpolitik*), we coordinate Germany's expert contributions to the water programmes of the United Nations, especially for UNESCO, WMO, UNEP and FAO, under the umbrella of UN-Water. We represent the interests of the Federal Republic of Germany in international scientific collaborations on global change and hydrology, e.g. of the Rhine and Danube, and in other regional and global networks. Together with BfG we operate global water data centres and collaborate in research projects at national and international levels. In doing so, we are helping to promote the availability of clean fresh water for people and the environment.



Knowing what has been. Recording what is.
Predicting what will be. **www.bafg.de**

Our strategy „BfG 2030“ and the process behind it

Politics, the operational management of the federal waterways and water management practice all depend on effective and reliable scientific guidance and research. Responding to the complex demands requires long-standing know-how and anticipatory scientific expertise addressing today’s societal, political and scientific issues. Apart from our day-to-day tasks, it is crucial to maintain a long-term thematic perspective involving a future-oriented organisational structure and equipment of our institution. In a systematic and comprehensive approach we rose to this challenge and developed a strategy for BfG.

Today, setting up development strategies is established practice, also in public institutions. This is particularly true in the area of departmental research driven to engage in the right activities in an innovative way at all times. We therefore launched a broad systematic process involving all of BfG's specialist fields to develop our "BfG 2030" strategy. Based on specific societal and scientific challenges, we devised visions, missions and strategic goals to guide BfG in its institutional role and its work. The process involved the following steps:

(© Whitedesk, AdobeStock)

(1) Five *BfG fields of action* were outlined for guidance and positioning purposes:

- Policy advice for the Federal Government
- Guidance and expert opinions on the operational management of waterways for the Federal Waterways and Shipping Administration (WSV)
- Guidance for the *Länder* (states)
- Research and development
- Contributions to international water policies
- Development of BfG as a public authority in its role as a modern employer well-equipped with future-proof resources

(2) The subsequent *context analysis* aimed to identify the key challenges of the years to come by taking various perspectives. Preparations included structured interviews with addressees of our range of services and with national and international partners while also considering the views of BfG's experts. In addition, the analysis was complemented by an extensive summary of legal and other parameters, such as provisions and recommendations from high-level national, European or international strategies, agreements and bodies.

(3) *Prioritisation and strategic goals*: Based on these preliminary steps, BfG's management inferred a total of nine societal, political and scientific issues and challenges that are of particular technical and strategic relevance for our mandate as a federal departmental research institute and for BfG's fields of action. Neutrally termed as "phenomena", these issues and challenges now serve to shape the basic structure of our strategic agenda (fig. 1). For each of the nine phenomena, we set strategic goals. These goals relate to our research subject, i. e. the

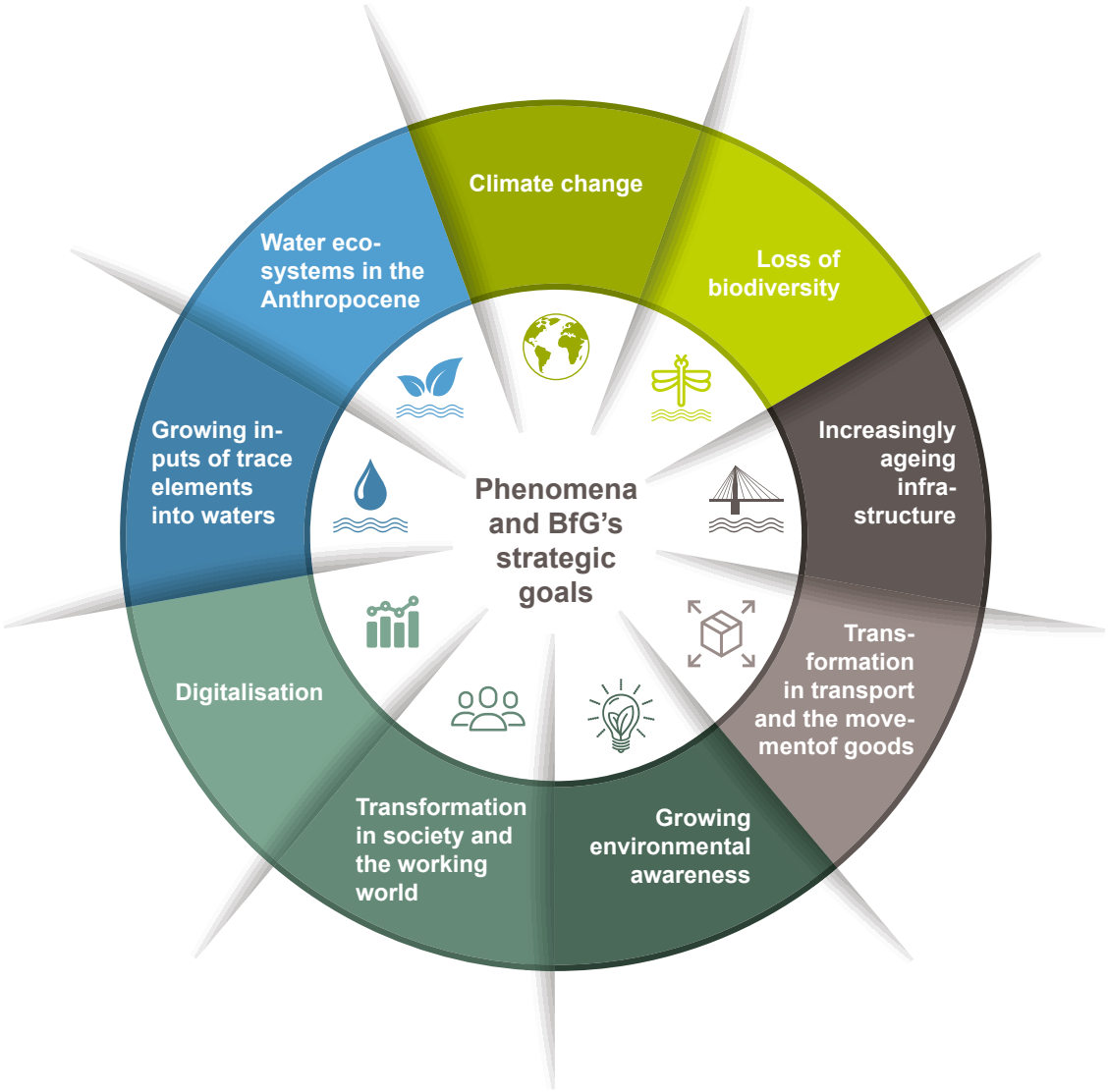


Fig. 1: Phenomena setting the framework for BfG's strategic goals

federal waterways in their role as water (eco-)systems, including their uses and catchment areas, but also to BfG in its role as a public service institution and to its employees' interests and concerns.

(4) *Operational target scheme*: We then organised hosted workshops in which our department heads and other BfG experts set operational targets complementing the strategic framework. Participants were asked to bring in – from their specific expert perspective – targets and initial actions to be considered in the upcoming years and to phrase them in accordance with the so-called SMART principles[1], meaning that they are as realistic, agreed and time-bound as possible.

The result was a scheme of operational BfG targets that underwent a final management review to prioritise and balance the participants' input.

(5) *Product finalisation*: The last step in BfG's strategy development procedure will be to finalise and refine the array of products that have emerged from the process, for example with regard to a target group-specific communication of the BfG strategy's contents.

The subsequent implementation of the "BfG 2030" strategy will aim to systematically tackle the operational targets and related efforts in order to reach the desired state in 2030.

1 **SMART** is an acronym that stands for "Specific, Measurable, Agreed, Realistic, Time-bound".

Elbe and Elbaue near Wittenberg.
(© Marco Rudolf, AdobeStock)

Our strategy development procedure implied a fairly comprehensive methodological and participatory approach, including keeping the workforce up to date about the progress and integrating specific staff involvement activities. The reasoning behind this approach was to achieve the highest possible level of employee identification with the process and the goals set as a prerequisite for bringing strategic theory down to earth and filling the implementation process with life. Another key characteristic of our strategy process was to prefer impact-driven over activity-focused goals for our administrative and technical tasks and to consider the future strategic governance from the outset (Balanced Scorecard[2]).

Our work has set the continuous process of BfG's strategic development on its way.

Contact:
Dr Dorothe Herpertz
(herpertz@bafg.de)
Dr Sebastian Kofalk
(kofalk@bafg.de)

2 The **Balanced Scorecard** is a management tool translating a strategy into specific goals and performance measures. Different categories (financials, customers, processes, development perspective) are considered to convey a balanced, integrated and realistic view.

Water Monitoring – From the small to the large scale

How are our waters evolving? How can the effects of development and maintenance works on our waterways be described? What are the impacts of climate change? To answer these questions we need long-term water monitoring data. In this chapter, we present a wide range of water monitoring efforts, reaching from local-scale to national and cross-border activities. As different as they may seem, they all share two key characteristics: they require a long-term perspective, and they make data and insights accessible to third parties. For the collection of multiple water parameters we apply state-of-the-art procedures and methods that are constantly being enhanced.

Monitoring of dredging operations – pollutant accumulation in aquatic organisms

Let us first take a look at the monitoring of regional, relatively small-scale sediment management activities in our waters. Sediments are both a sink and a source of pollutants in waters. In moving sediments, bound pollutants can be released and harm the aquatic environment. A question often posed is whether sediment management activities, such as the relocation of dredged material, can cause a rise in pollutant concentration (bioaccumulation) in aquatic organisms. Given the multitude of drivers, an adequate conclusion on the impacts of dredging operations on bioaccumulation is still pending. Meanwhile, researchers employ different approaches to assess the bioavailability of substances, helping to estimate the environmental risk inherent to dredging activities. In an attempt to explore the potential effects of dredging activities on the pollutant accumulation in biota we installed stainless steel cages filled with blue mussels in the shipping lane of the Baltic Sea lagoon of Strelasund in August 2019, for example. We also introduced so-called passive samplers into the water body to analyse the concentration of dissolved contaminants during the dredging operation (fig. 2). For less water-soluble (hydrophobic) organic pollutants in the aqueous phase, a typical analytical method is the use of silicone stripes. The parallel application of both approaches also provided us with initial insights into the appropriateness of passive samplers to act as evidence for increased bioaccumulation. This technique, partly combined with biota monitoring, is planned to become more widely used in the coastal and inland areas to monitor the performance of sediment management activities and enhance the risk assessment of dredging operations.

Contact:
Dr Sabine Schäfer
(sabine.schaefer@bafg.de)
Benjamin Becker
(benjamin.becker@bafg.de)

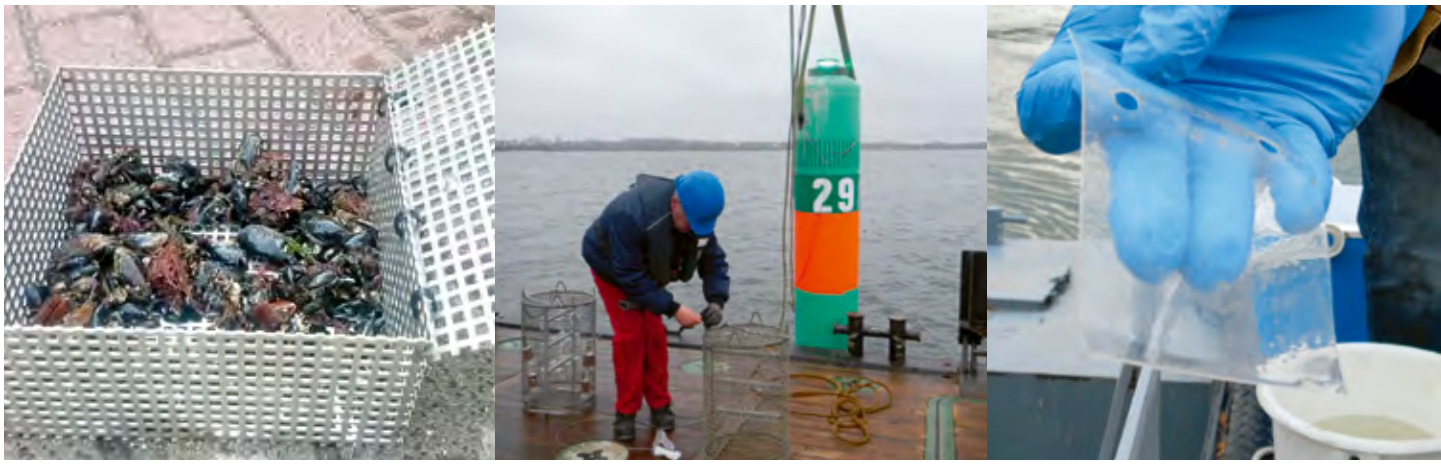


Fig. 2: Blue mussels in a stainless steel cage for water exposure (left), installation of passive samplers in a shipping lane (centre), silicone foil used for passive sampling in the aqueous phase (right). *(Photos: BfG)*

Measuring suspended sediments in federal waterways – the nationwide monitoring network

Understanding suspended sediment load is of significant importance for sediment management activities along federal waterways. Making up the largest part of the sediment load in major river systems, suspended sediments have considerable impacts on hydromorphology, water quality and watercourse ecology. Concepts for a sustainable sediment management require a representative monitoring of suspended sediment load, which is, however, rather difficult to measure since suspended matter is characterised by high temporal and spatial variability.

Against this backdrop, the Federal Waterways and Shipping Administration (WSV) operates an extensive monitoring network comprising around 70 sampling stations to measure suspended sediments. Their work is supported by BfG's continuous improvement of the measuring procedures. The current practice is to take samples at the monitoring stations every work day followed by filtration and gravimetric analysis to determine the suspended sediments concentration. This labour, time and cost intensive exercise will be gradually replaced by automated turbidity measurements in the six years to come. While those measurements provide high temporal resolution data on turbidity, they need to be calibrated to calculate the suspended sediments concentration because turbidity depends on several factors, such as the particles' grain size distribution. The underlying water samples are taken by WSV staff at the measuring stations on a weekly basis before being filtered in our sediment laboratory to determine the suspended sediments concentration (fig. 3).

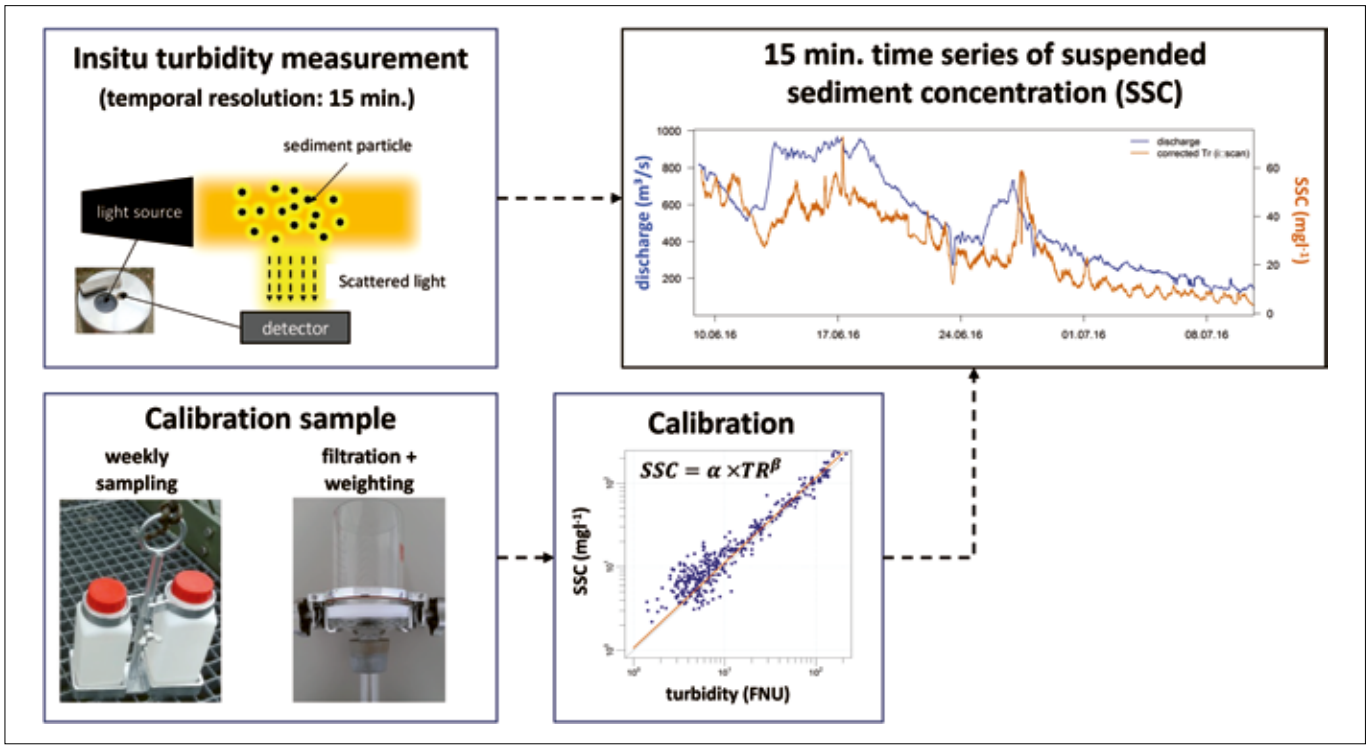


Fig. 3: Overview of the measuring tools, sample processing and analysis within the modernised suspended sediments monitoring network

The modernisation plan for the monitoring network that we developed over the past years (Hillebrand et al. 2015) is being implemented on the rivers Rhine and Neckar in 2021 in cooperation with the WSV.

The high resolution recording of the suspended sediments concentration by means of turbidity sensors allows for a precise attribution of the suspended loads to specific flood events, which is illustrated by the Plittersdorf station on the Rhine (km 340.2) where around 54% of the annual load (0.57 Mt) in 2018 was recorded during the two successive floods from 30 December 2017 to 8 February 2018 – a period of 41 days (i.e. 11% of the year) only. This relationship should be even more pronounced in the smaller subcatchments of the Rhine tributaries.

Contact:
Dr Felix Op de Hipt
(opdehipt@bafg.de)
Dr Thomas Hoffmann
(thomas.hoffmann@bafg.de)

References:

Hoffmann, T., G. Hillebrand, J. Schmegg, S. Vollmer (2017): Monitoring long-term suspended sediment yields in Germany: Quality controls on changing sediment sampling strategies, IAHR: HydroSenSoft, International Symposium and Exhibition on Hydro-Environment Sensors and Software., Madrid, pp. 1-7

Hillebrand, G., W. Otto, J. Schmegg, S. Vollmer, N. Gehres (2015): Neuausrichtung des WSV-Messstellennetzes Schwebstoffmonitoring. Bericht BfG-1799, Bundesanstalt für Gewässerkunde, Koblenz

The BfG GNSS monitoring network – Quality-assured heights of gauging stations to study sea level behaviour

Reliable water level data are a key prerequisite to answer water engineering, water management and hydrological questions. Conclusions on fundamental hydrological characteristics, such as parameters to evaluate sea level behaviour, require analysis of long-term water level time series. The oldest historical water level records available in Germany date back from the 17th century. Of particular importance for data quality is to put any gauge observation into relation with the adjoining land. Vertical land motion, caused by tectonic or anthropogenic effects (e.g. through mining), has a direct impact on gauges, resulting in supposed water level changes that tend to overlap with real variations in the water level. For example, natural gas extraction works that have taken place near the Dutch city of Groningen since 1957 cause the earth's surface in some coastal areas of the "German Bight" (*Deutsche Bucht*) to fall by 1-2 mm/a. Time-series analyses to study sea level behaviour require the height of the gauging stations during the entire observation period to be known and comparable. This is ensured by Global Navigation Satellite Systems (GNSS) being on permanent duty. Since 2008, we have been equipping major gauging stations in the German Bight area with GNSS antennae (fig. 4). The 39 GNSS stations in production mode on the German North and Baltic Seas form

Fig. 4: Permanent GNSS antenna at the Borkum Fischerbalje gauging station *(Photo: BfG)*

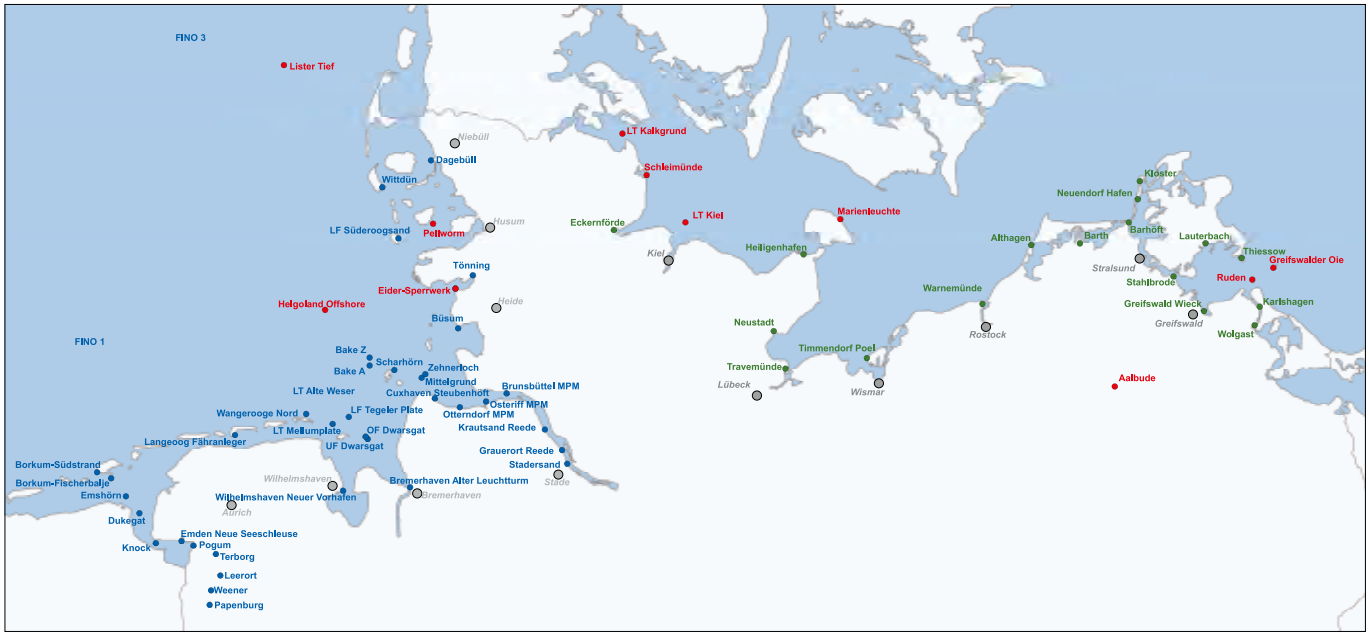


Fig. 5: Overview of BfG's GNSS stations on the North and Baltic Seas: permanent GNSS stations (blue), planned permanent GNSS stations (red) and WSV tide gauges (green)

the main constituent of the nationwide BfG GNSS monitoring network (fig. 5). We are currently expanding the network with four additional stations on the North Sea and seven more sites on the Baltic Sea coast, that are expected to deliver quality-assured height level data by 2021/2022. The latest height levels are submitted to the WSV at yearly intervals enabling a separate consideration of the two distinct effects of *vertical land motion* and *water level change* at each gauge. This approach allows for a robust monitoring of the sea level behaviour on a continuous basis. In the future, BfG's knowledge will be integrated into the core service "Climate and Water" established within the German Strategy for Adaptation to Climate Change (DAS) and will then form an integral component of the maritime module "Landbewegung@BfG" (*landmotion@BfG*) (see p. 45).

Contact:
Dr Christina Esch
(esch@bafg.de)

Monitoring environmental radioactivity

Our statutory responsibilities under the German Radiation Protection Act (StrlSchG) include the continuous monitoring of radioactivity in Germany's major rivers. The investigations aim to record changes in radioactivity within the waters and to estimate potential impacts on humans and the environment. Our activities are based on a total of 69 monitoring stations across Germany, operated with the support of the WSV, the *Deutscher Wetterdienst* (German Meteorological Service, DWD) and several *Länder* (state level) institu-

tions. The network comprises radiological warning stations, samplers for riverine water and suspended matter as well as precipitation collectors (fig. 6).

At the warning stations, total gamma activity concentration is monitored continuously as a reference parameter. In addition to these online measurements, we regularly collect water, suspended particulate matter and sediment samples for analysis in our two radiochemical laboratories, where they are analysed for naturally-occurring and artificial radionuclides. One example of an artificial radionuclide is tritium (^{3}H) that is continuously produced in nuclear power plants and is discharged into rivers via the cooling water. However, we also increasingly detect novel radionuclides originating from medical treatments, for example. Since mid-2021, the data measured on-site have been recorded in the new control centre of BfG's radioactivity monitoring network, which is equipped with a process control system to supervise the functioning of the monitoring network.

In our role as a federal coordinating office, we are in charge of the quality assurance of the inland water monitoring results, comprising not only our own data, but also the measurement results submitted by the Länder. After being reviewed and checked for plausibility, the data are transmitted to the federal *Integrated Measuring and Information System for the Surveillance of Environmental Radioactivity* (IMIS).

In addition to our statutory mandate and our close cooperation with the institutions involved, such as the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the Federal Office for Radiation Protection (BfS), we maintain active collaboration with national and international partners, e.g. the International Atomic Energy Agency (IAEA). The use of radioactive substances to answer numerous research questions is of major scientific interest.

Fig. 6: BfG's measuring network for the monitoring of radioactivity

Several federal coordinating offices have been established to take care of the official monitoring of environmental radioactivity in Germany, each being in charge of specific environmental media. Under the Integrated Measuring and Information System for the Surveillance of Environmental Radioactivity (IMIS) the offices continuously review and summarise data delivered by federal and Länder agencies.
The results are released in annual reports on "Environmental radioactivity and radiation exposure" (*Umweltradioaktivität und Strahlenbelastung* – available in German only), published by the BMUV and BfS.

https://www.bfs.de/EN/media/reports/environmental-radioactivity/environmental-radioactivity_node.html

Contact:
Dr Axel Schmidt
(axel.schmidt@bafg.de)
Dr Jan Wiederhold
(wiederhold@bafg.de)

Monitoring ecosystems in transboundary rivers and estuaries

Ecosystems are complex and evolve over time scales varying from hours to thousands of years. For a better understanding of this variability we need to observe ecosystems, or parts of them, over long periods of time. These monitoring activities serve to identify long-term trends as well as natural fluctuations allowing for a correct interpretation and evaluation of the results. In transboundary rivers and estuaries[3], we monitor the development of the macrozoobenthos, fish and phytoplankton within our monitoring programmes. In 2020, major publications were released providing analysis of the collected data (IKSR 2020 a, b; Landwüst et al. 2020). The insights gained support the efforts of the international river basin commissions, amongst others.

Long-term monitoring of the macrozoobenthos population[4]

Since 1986 (for the Rhine from Rheinfelden to Emmerich) and 1992 (for the Elbe from Schmilka to Geesthacht), respectively, we have been taking annual/bi-annual river bottom samples in both the long and cross profiles to conduct qualitative and quantitative studies of the macrozoobenthos biocenoses. By way of example, figure 7 illustrates long-term fluctuations in the number of species in the Rhine as a function of oxygen concentration.

From 1995 onwards, we have also been monitoring the macrozoobenthos in the estuaries of the German North Sea coast within the joint North Sea and Baltic Sea marine environment monitoring programme of the Federal Government and the Länder. Sample collection is carried out at six points in the Ems, Weser and Elbe estuaries, five points in the Jade embayment and three in the Eider estuary with the data

3 **Estuary:** funnel shaped river mouth on a tide-dominated coast

4 **Macrozoobenthos:** invertebrates visible to the naked eye that live on the river bottom

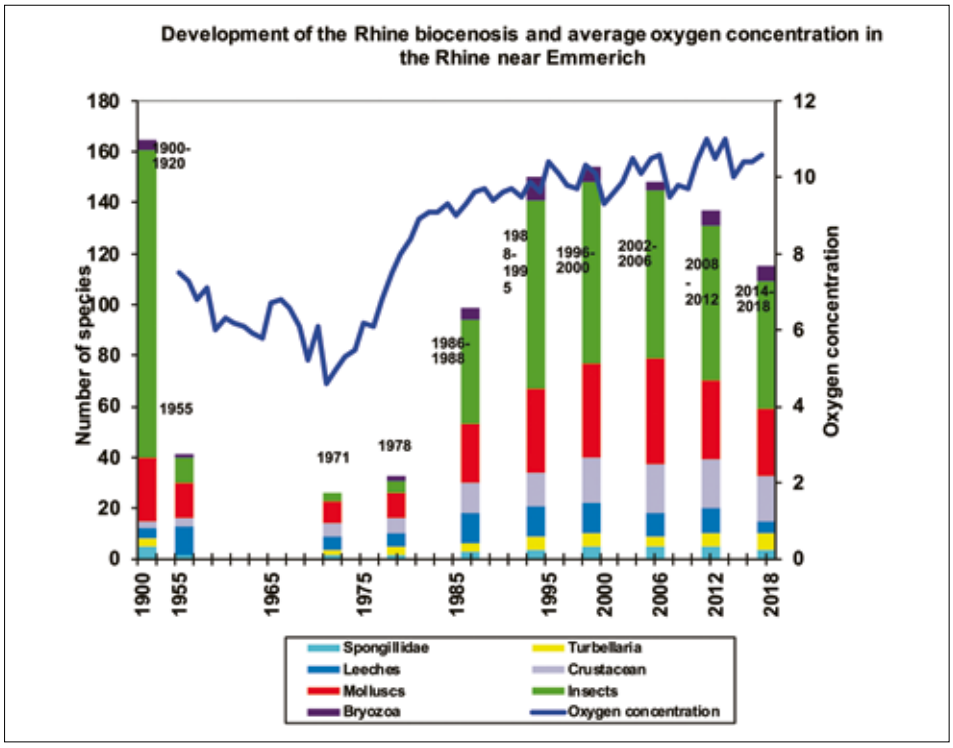


Fig. 7: Long-term fluctuations in the macrofauna of the Rhine's river bottom

gathered serving as reference samples for studies assessing the impact of dredged material disposal.

Long-term monitoring of the fish fauna

Since 2015, we have been investigating the fish fauna at representative sampling points in the Middle Rhine, the Moselle and the Lahn on an annual basis. The data collected serve to document the development of the fish fauna, for example as a function of changes in river connectivity, climate and the spread of alien fish species, such as the round goby (fig. 8).

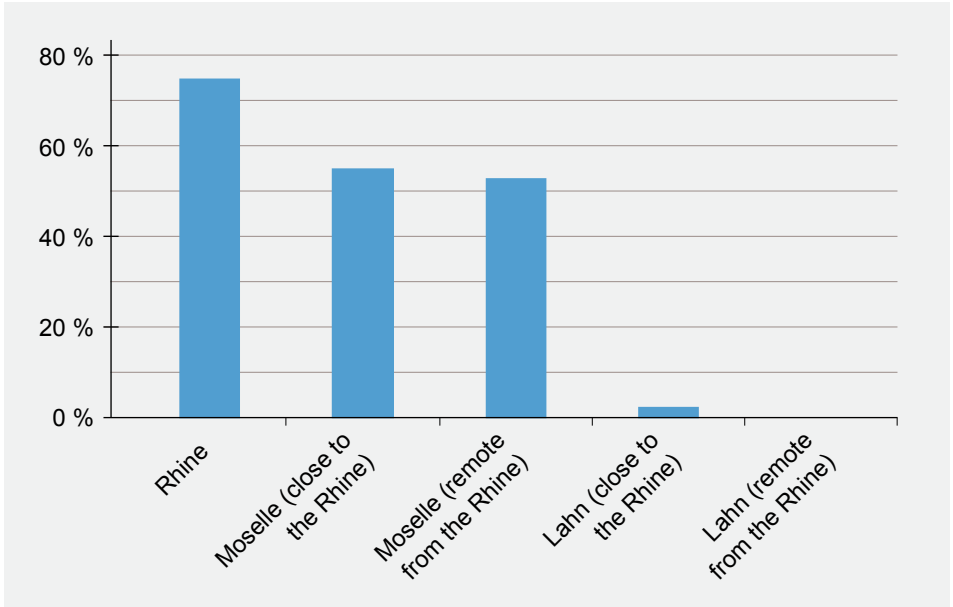


Fig. 8: Share of the non-native round goby in total number of fish caught in the Rhine, Moselle and Lahn from 2015–2018. Being an invasive species, the round goby poses a threat to native species and thus to biodiversity. *(Photo: BfG)*

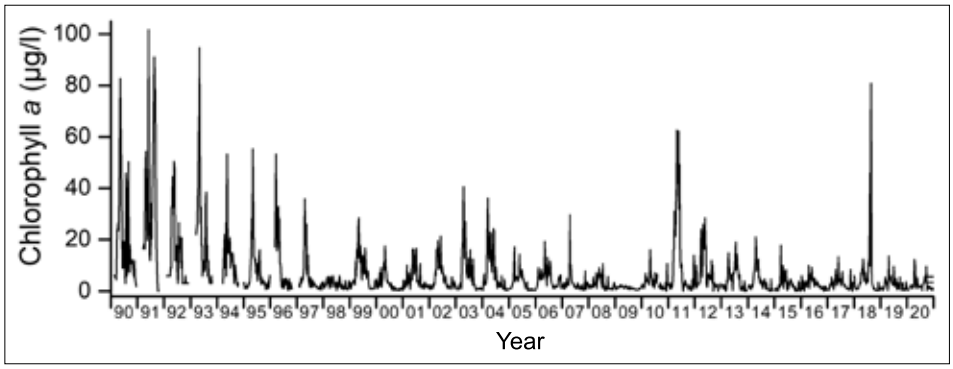


Fig. 9: Long-term dynamics of the phytoplankton in the Rhine from 1990–2020, shown as Chlorophyll a concentration

Long-term monitoring of the phytoplankton population[5]

Since the early 1990s, we have been conducting regular phytoplankton studies on the rivers Moselle and Rhine in Koblenz. Our monitoring revealed long-term trends related to the reduction in nutrient loads, the arrival of invasive mussel species and characteristics of, and changes in, the discharge dynamics over the annual cycle. The overall intensity of algal blooms diminished over the long term. In the dry year of 2018, however, the Rhine was once again affected by summer blooms of phytoplankton during low-flow periods (fig. 9). On the Moselle, cyanobacteria (blue-green algae) growth was observed in every late summer since 2017.

Contact:
Dr Franz Schöll
(schoell@bafg.de)
Dr Markus Wetzel
(markus.wetzel@bafg.de)
Christian von Landwüst
(landwuest@bafg.de)
Dr Helmut Fischer
(helmut.fischer@bafg.de)

References:

IKSR – Internationale Kommission zum Schutz des Rheins (2020 a): Das Makrozoobenthos des Rheins 2018. Federführende Bearbeitung F. Schöll. IKSR-Bericht 276, 46 S.

IKSR – Internationale Kommission zum Schutz des Rheins (2020 b): Das Phytoplankton des Rheins 2018. Federführende Bearbeitung H. Fischer. IKSR-Bericht 273, 17 S.

https://www.iksr.org/en/public-relations/documents/archive/technical-reports

Landwüst, C., W. von Heimann, S. Wieland (2020): Fischereibiologische Untersuchungen an Dauerprobestellen der Bundeswasserstraßen Rhein, Mosel und Lahn – Untersuchungsjahre 2015 bis 2017, Bericht BfG-2017, Bundesanstalt für Gewässerkunde, Koblenz, 320 S.

Re-equipment of BfG's lysimeter facility

Since 1986, we have been operating a lysimeter station on the Rhine island of Niederwerth near Koblenz to continuously monitor the soil water balance. In 2020, the whole facility underwent extensive refurbishment. The station comprises four lysimeter[6] couples, each consisting of a weighable (fig. 10) and a non-weighable lysimeter, all equipped with an outflow for seepage water at the lower bottom. Each of them is filled with intact soil cores (i.e. soil in natural condition) of 1 m² in surface and 2 m in height from three riverine locations in the surroundings and one higher site within the Neuwied Basin (*Neuwieder Becken*). The sampled soil substrates *alluvial clay*, *loess loam*, *high flood sand* and *loamy pumice* are representative of the particular hydrological situation of riparian locations along many reaches of Central Europe's major rivers.

The devices employed in the meteorological measurement field (fig. 11) were upgraded in liaison with the DWD in order to keep up with the

5 **Phytoplankton:** plankton consisting of plants and plant-like organisms

6 **Lysimeters** are tanks of fixed dimensions filled with a column of soil that is covered by vegetation. The containers are sunken into the ground and reach as high as the receiving surface. Lysimeters serve to examine various properties of the water balance, including through measuring percolating water volumes.

Fig. 10: Basement accommodating the four weighable lysimeters *(Photo: BfG)*

latest state of technology. Our determination of the precipitation, percolation and evapotranspiration conditions is based on more than 40 different parameters measured at least once every ten minutes. The results are saved in a database offering convenient features for visual analysis. A particular challenge was to integrate the existing data series spanning more than 30 years into the new database, since they were of different formats and in some cases incorrect or incomplete. Therefore, they were made comparable to the quality of the new data, thus enabling robust analysis. The data obtained from the lysimeter station help us to explore various questions, including – as a topical example – a comparative consideration of soil moisture data derived from the lysimeters and from satellite imagery.

Contact:
Jens Wilhelmi
(wilhelmi@bafg.de)

Fig. 11: View on the meteorological measurement field with its basement entrance *(Photo: BfG)*

The chemical monitoring station of the future

Monitoring chemical parameters is of crucial importance to the surveillance and assessment of water quality. Currently, certain water parameters are measured directly and on an ongoing basis, while others rely on laboratory analysis of mixed and random samples, which involves time delays. This is why, in 2019, we started to build the monitoring station of the future (in German: ***MON****itoringstation* ***DE****r Zukunft* – in short: *MONDE*) at BfG's premises on the Rhine in Koblenz. Within the research & development (R&D) project MONDE 1 we develop and test innovative sampling, treatment, analysis and data interpretation approaches. The station helps us to test prototypes and assess the comparability of different analysis techniques. After passing appropriate robustness checks the methods can be rolled out in further monitoring sites.

Especially in the case of smaller waters, high temporal resolution data provide for a more precise characterisation of the waters' chemical status. This, in turn, requires a near real-time assessment of the data collected. Following the installation of the station's basic infrastructure (fig. 12) we have already made our first comparisons covering strategies to measure nutrients and dissolved organic matter (e.g. online ion chromatography [2] for anions vs. optical sensors [8]). At present, a Ferrybox – an automated monitoring system – is tested within the station to measure basic parameters, such as temperature, pH, conductivity, turbidity, dissolved CO_2 and classification of algae [5], including colorimetric detection techniques for nutrients [6]. Three devices are currently being supplied with Rhine water by the filtering system [3]: a liquid chromatography with a mass spectrometer for the non-target analysis

Fig. 12: Overview of the monitoring station of the future with its different analytical instruments *(Photo: Arndt, BfG)*

1 ICP-QMS: metals/metalloids
2 IC: anions
3 Filtering system
4 QToF: organic pollutants
5 Ferrybox
6 Colorimetric methods (nutrients)
7 Sampler
8 Flow through basin with sensors
9 Radioactivity
10 Control cabinet

of organic substances (LC-QToF-MS [4]), a mass spectrometer for metals and metalloids (ICP-QMS [1])[7] and a self-constructed freezing sampler for small sample volumes [7]. Data analysis in the station will be completely automated. Given the enormous data volumes and the multitude of tasks carried out manually so far, the analysis of the non-target data is particularly challenging. In addition to analytical data, we also collect process data of the station providing insights into its "health status".

Within the project we organised the virtual symposium "The Chemical Monitoring Station of the Future" in April 2021, where participants presented and discussed pioneering technologies serving different needs, including analytical procedures, mobile monitoring activities and data analysis. Around 200 attendees from 15 countries followed BfG's invitation (*https://t1p.de/ChemSymposiumEN*).

Research project at BfG:
Project on behalf of the Federal Ministry of Transport and Digital Infrastructure (BMVI, now renamed Federal Ministry for Digital and Transport): "MONDE 1 – The chemical monitoring station of the future" *(MONDE 1 – Die chemische Monitoring-Station der Zukunft)*, May 2019 – April 2023

Contact:
Dr Julia Arndt
(arndt@bafg.de)
Dr Julia Kirchner
(kirchner@bafg.de)

7 By means of a **non-target analysis** numerous organic substances can be established within one single measurement thanks to high resolution mass spectrometry. This approach provides extensive information on the chemical pollution of water samples, analysing both known and unknown substances.
LC-QToF-MS: liquid chromatography (LC) coupled to a quadrupole time of flight mass spectrometer
ICP-QMS: inductively coupled plasma coupled to a quadrupole mass spectrometer

Management of waterways and watercourses – BfG's contributions

Devastating precipitation events combined with river floods in July 2021 made us aware of how vulnerable existing transport infrastructures and society as a whole are. In general, climate research findings suggest that hydrological extreme events might become ever more frequent. This makes it even more important to pool responsibilities of federal and Länder (state) authorities and to maintain close cooperation, in particular with regard to the future management of federal waterways and rivers.

BfG's current product portfolio is aligned to the advisory needs of our partners, the Federal Ministry for Digital and Transport (BMDV), the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Länder and the Federal Waterways and Shipping Administration (WSV) as well as national and international river basin commissions. Our offering covers a broad range of services

related to both inland waters and estuaries, including ready-to-use data and data-based products. We deploy models to allow for integrated impact assessments of flood protection efforts on large German rivers and to deliver water level forecasts for transport providers operating on major federal waterways. Other modelling tools are used to infer recommendations regarding management activities on federal waterways and help identify future management options. We develop comprehensive monitoring frameworks, e.g. for hydromorphological issues, and evaluate dredging measures in estuaries using an impact prediction. In particular, we support the WSV's development activities by taking on data processing and product design tasks. The outcomes will be drawn together in user-friendly map applications and arranged in a clear way to serve as a basis for planning procedures.

The national flood protection programme and its effects

The devastating floods on the Danube and Elbe Rivers in summer 2013 are still engraved in many people's minds. In a bid to better protect inhabitants and mitigate potential damage from future flood events, the German Federal Government initiated a national flood protection programme (NHWSP), aiming to support the Länder in accelerating the implementation of large-scale flood protection measures having cross-regional effects. The question, though, is how well these measures are performing.

Within a five-year research project, we investigated the effectiveness of the measures planned for the Danube, Elbe and Rhine under the NHWSP. Collaborating with the Länder, we set up extensive hydraulic-hydrological model systems for the Danube, Elbe and Rhine basins (fig. 13). This enabled us to systematically examine the effects of the planned NHWSP measures in the catchments on various flood wave propagations and events with different probabilities of occurrence. The results – available since late 2020 – confirm the feasibility of an enhanced cross-regional flood protection scheme. According to the findings, the protection efforts might reduce water levels along large river stretches during future flood events by 10 to 50 cm or even substantially more in certain circumstances. Altogether, the NHWSP projects exhibit significant cross-regional effectiveness in all three river basins. Nearly 70 measures were studied, including levee setbacks, flood-control reservoirs and polders. These solutions give rivers room to expand, with some of them being able to receive and retain significant volumes of the flood wave.

BfG research and development projects

Project "Studies to determine the effects of preventative flood protection measures under the NHWSP" (*Untersuchungen zur Ermittlung der Wirkung von präventiven Hochwasserschutzmaßnahmen im Rahmen des NHWSP*) on behalf of the German Environment Agency (UBA) (October 2015 – December 2020)

Fig. 13: Overview of flood protection measures registered under the NHWSP across Germany (red squares, green dots) and illustration of large-scale model systems in the Danube, Elbe and Rhine river basins (coloured lines)

Even after completion of the project we continue providing expert advice to the NHWSP under a mandate of the BMUV, covering general guidance on flood-related issues, continuation of our model-based impact analyses, enhancement of the study approach as well as maintenance and updating of the underlying data and model infrastructure.

Further information (in German):
https://t1p.de/NHWSP

Contact:
Carina Schuh
(schuh@bafg.de)

References:

Hatz, M., C. Schuh, D. Q. Duong, T. Maurer (2021): Untersuchungen zur Ermittlung der Wirkungen von präventiven Hochwasserschutzmaßnahmen im Rahmen des Nationalen Hochwasserschutzprogramms – Abschlussbericht der Bundesanstalt für Gewässerkunde im Auftrag des Umweltbundesamts. UBA-Texte 70/2021. Umweltbundesamt, Dessau-Roßlau *https://www.umweltbundesamt.de/publikationen/untersuchungen-zur-ermittlung-der-wirkungen-von*

10-day Rhine water level forecast: a service well received by users

On the occasion of a visit at BfG in December 2019, the then Federal Minister of Transport and Digital Infrastructure Andreas Scheuer kicked-off our new probabilistic 10-day water level forecast for the Rhine. Since then, the new forecasting product has been accessed around 800,000 times via the WSV's Electronic Waterways Information Service ELWIS, amounting to a daily average of about 1,400 visits. In peak periods the forecast recorded up to 15,000 accesses per day (as of 1 August 2021). Our 10-day water level forecast is an important contribution to the "Low water on the Rhine" (*Niedrigwasser Rhein*) action plan aiming to improve transport conditions on Europe's most important inland waterway and to tackle climate change-related challenges. The strong dependence of inland navigation on hydrological conditions is also reflected in the 10-day water level forecast's user statistics: Water levels dropping well below the mean water level or moving towards high water mark II, being the threshold for the waterway's closure, clearly entail a rise in user numbers (fig. 14).

The 10-day forecast is based on real-time measurements at around 50 gauges and more than 900 weather stations and on an "ensemble" consisting of 72 different meteorological forecasts. Our hydrological and hydrodynamic models are complemented by statistical procedures to quantify uncertainties resulting from the weather forecast, the meteorological and hydrological measurement data as

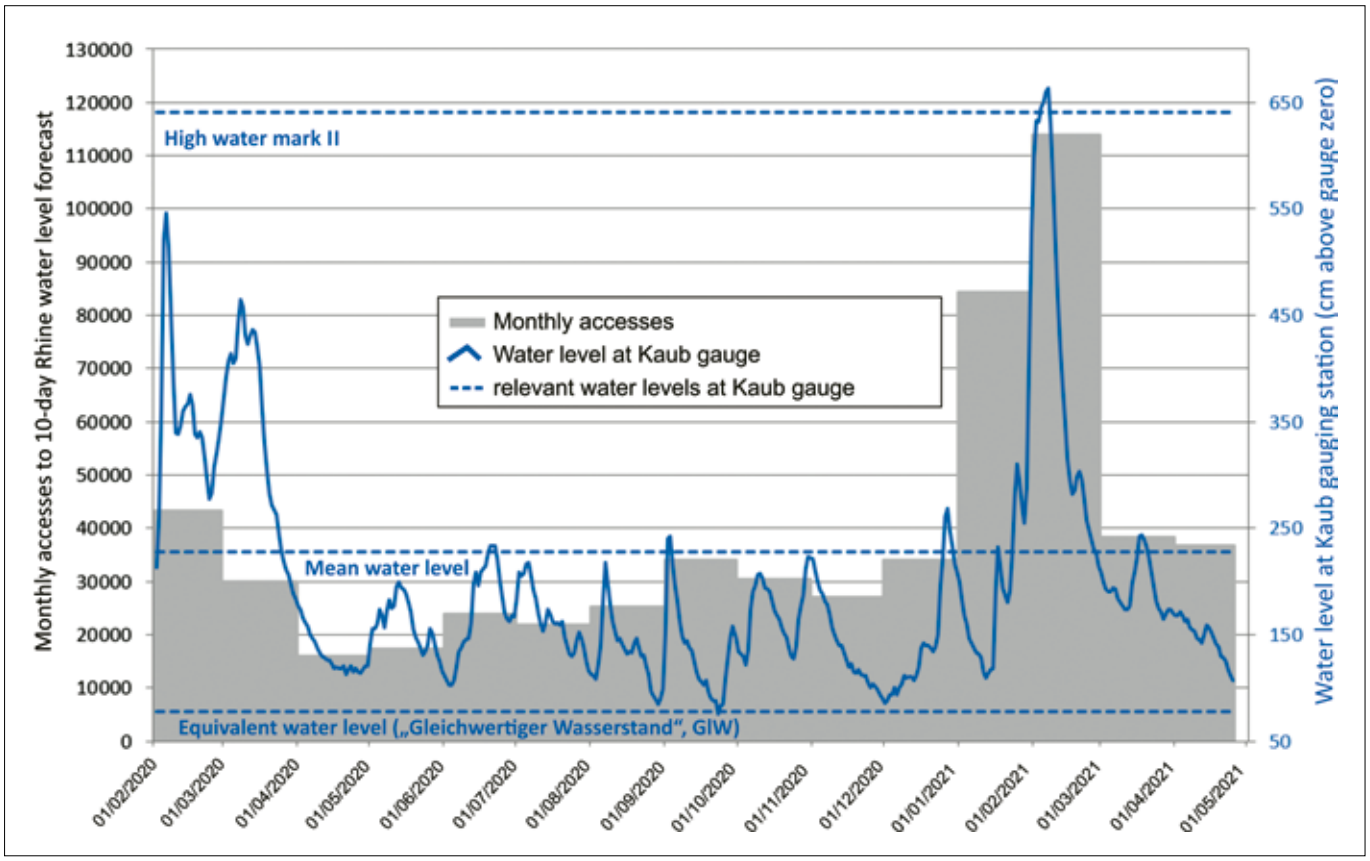


Fig. 14: Monthly accesses to BfG's 10-day forecast against the backdrop of water levels recorded at Kaub gauging station from February 2020 through April 2021

well as the forecasting models, with the results confirming the service's overall high degree of reliability. The predicted probabilities of occurrence are in good agreement with the actual frequency of occurrence observed. Even ten days in advance, 75% of all forecasts show a deviation of 40 cm maximum, and in about 50% of all cases, actual levels do not deviate by more than 20 cm from the forecast values. The above access figures and quality levels reflect the practical use of our new forecasting product brought to maturity with intensive research and development efforts over recent years.

Further information (in German):
Action plan "Low water on the Rhine" (Niedrigwasser Rhein)*https://t1p.de/8PunktePlan*
Transport-related water level forecast
https://www.bafg.de/vorhersage

Contact:
Dennis Meißner
(meissner@bafg.de)

Improving navigation conditions on the Middle Rhine – a map application to inform the public

The Rhine is one of Europe's most important waterways. Local shoals in the Middle Rhine limit the maximum transport capacity of inland navigation fleets, in particular in low-flow situations. This is why the project "Optimisation of load draughts in the Middle Rhine navigation channels" (*Abladeoptimierung der Fahrrinnen am Mittelrhein*) is now part of the BMDV's "Federal Transport Infrastructure Plan 2030" (*Bundesverkehrswegeplan* 2030) (BMVI 2016). Current project plans provide for a deepening of the navigation channel on the stretch from St. Goar to Wiesbaden in order to reach 2.10 m in height instead of 1.90 m with reference to the "equivalent water level 20" (GlW20) (low water). Therefore, the main focus of the project is on measures sustaining the water levels and on moderate riverbed modifications (WSA Rhein 2022) with different eligible options being under scrutiny (see fig. 15 for examples).

Public consultation on subsection 2, the first of three subsections, started in March 2021 with the following preliminary work provided by BfG: We homogenised and processed sounding data from the past two decades, laying the foundation for change analysis regarding the Rhine's riverbed evolution. Teaming up with the project group, we also developed specific products and data sets supporting their work. The resulting portfolio includes, among others, terrain models with a range of resolutions and modelling approaches, synoptic cross profiles for change analysis, various cartographic products serving as a basis for visualisation purposes and project works as well as local GIS projects and volume calculations.

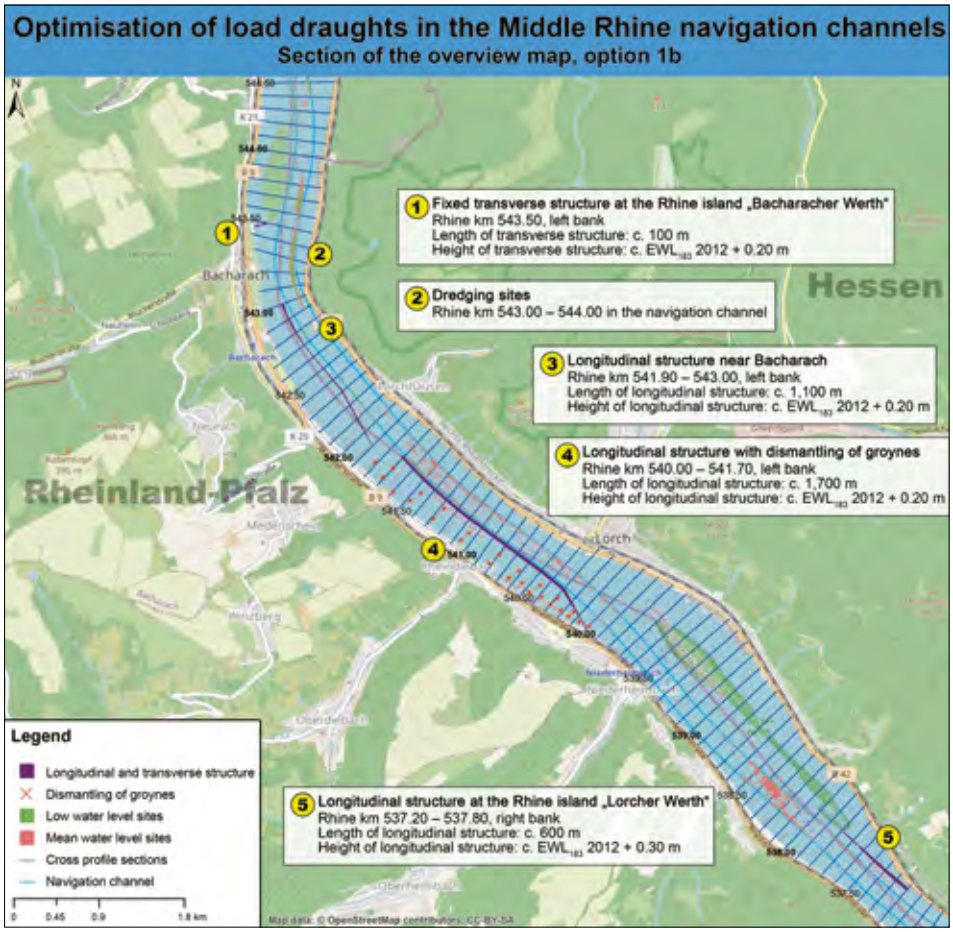


Fig. 15: Improving navigation conditions on the Middle Rhine

On behalf of the Rhine Waterways and Shipping Office (WSA Rhine), we used the data described above to develop a clear and interactive online map application providing the interested public with a source of information in the form of a map-based overall picture of the four options developed under subsection 2. Each of these options is a combination of individual measures consisting of transverse and longitudinal structures along with moderate riverbed modifications and highlights existing nature conservation study areas as well as the state of the riverbed. Users can customise their settings according to the information and map section needed. The selection menu on the map also allows to display additional objects, such as cross profile illustrations and pictures of the riverbed.

The map application is available online (in German): *https://geoportal.bafg.de/karten/AOMR*.
Our well-proven collaboration with the WSA Rhine will be continued during the public consultation phase for the upcoming subsections.

Project "Optimisation of load draughts in the Middle Rhine navigation channels"
(Abladeoptimierung der Fahrrinnen am Mittelrhein)
The project is managed by the Rhine Waterways and Shipping Office (WSA Rhine), with the Federal Waterways Engineering and Research Institute (BAW) and BfG both providing extensive assistance and advice.

The project's stretch is divided into three sections of the Middle Rhine:
Subsection 1: „Oestrich" and „Kemptener Fahrwasser", Rhine km 508.0 – 528.0
Subsection 2: „Lorcher Werth" and „Bacharacher Werth", Rhine km 528.0 – 547.5
Subsection 3: „Jungferngrund" and „Geisenrücken", Rhine km 547.5 – 557.0
Project website (in German):
https://www.abladeoptimierung-mittelrhein.wsv.de/

Contact:
Torsten Fay
(fay@bafg.de)
Dr Robert Weiß
(weiss@bafg.de)

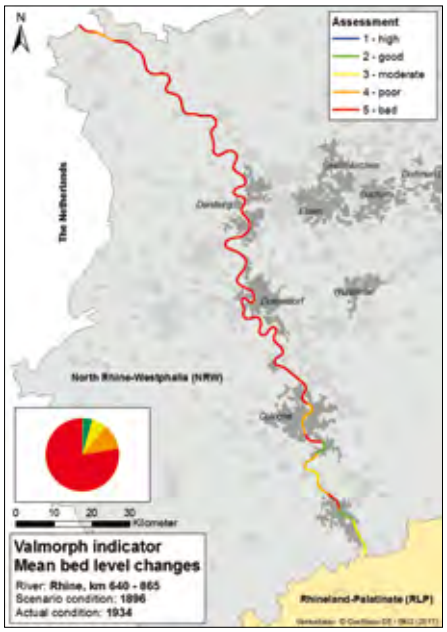
References:
BMVI (2016): Bundesverkehrswegeplan 2030. *https://www.bvwp-projekte.de/wasserstrasse/w25/w25.html* (in German)
WSA Rhein (2022): Website of the project "Optimisation of load draughts in the Middle Rhine" (in German).

Hydromorphological monitoring

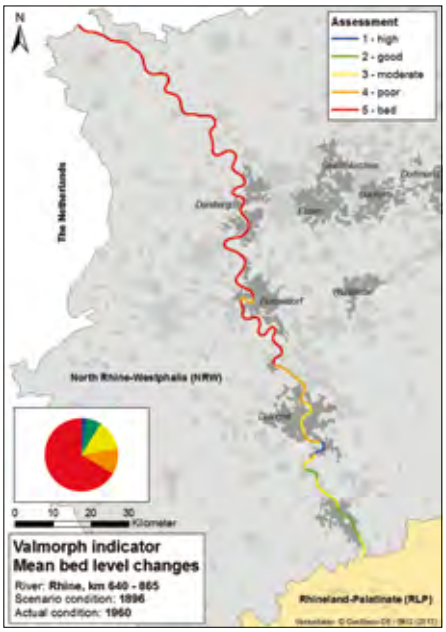
For many years already, we have been using hydromorphological monitoring to analyse short-, medium- and long-term changes in the federal waterways, aiming to record, document and assess hydromorphological effectiveness on the surface waters, their river banks and adjacent floodplains. This information is needed when it comes to the implementation of measures related to water maintenance, river training works, new constructions of waterways, compensatory actions (compensation and replacement measures) as well as reactivation and restoration. In a targeted approach, we monitor the abiotic watercourse development of the surface waters before, during and after implementation of any measures, thus making sure that we obtain valid data. However, longer-term studies are also part of our work, e.g. environmental monitoring of sustainable river restoration developments based on the type-specific dynamics of surface waters and observations over long time scales.

Hydromorphological monitoring helps us gain fundamental insights into a type-specific structural quality of surface water ecosystems and fosters our systemic understanding. This knowledge is a prerequisite to pursue a nature-based development of water bodies, which is of essential importance to increase their resilience to the impacts of climate change and promote biodiversity. Our practitioner-focused methodological standard (Quick et al. 2019, Quick & König 2021) provides operational guidance for monitoring

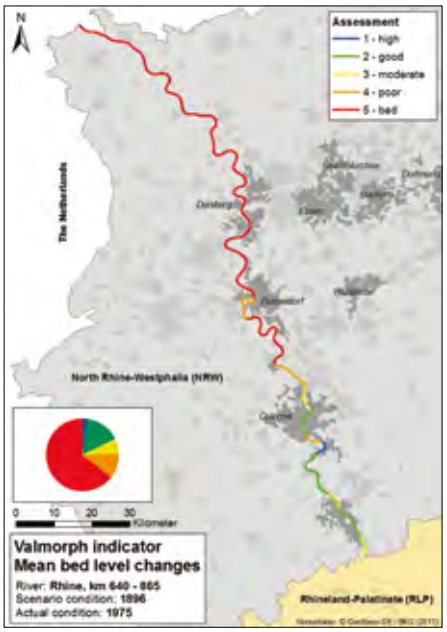
1896 – 1934



1896 – 1960



1896 – 1975



Mean bed level changes Class		Mean bed level changes percentage deviation from the comparative condition	Mean bed level changes range [cm/year]	Assessment
high	accumulation / no erosion	0 %	up to -0,25	1
good	minor erosion	> 0 % – 15 %	< -0,25 to -0,64	2
moderate	moderate erosion	> 15 % – 30 %	< -0,64 to -1,04	3
poor	major erosion	> 30 % – 60 %	< -1,04 to -1,84	4
bad	very major erosion	> 60 %	< -1,84	5

hydromorphological watercourse development in federal waterways including their banks, floodplains and tidal marshes. It also contains a complete set of requirements for a professional approach in design, planning, implementation, analysis, evaluation and documentation of hydromorphological effectiveness checks, making it an essential component of waterway management. Another key foundation in this field is our "Valmorph" tool, a proprietary survey, calculation and assessment procedure for navigable surface waters (Quick et al. 2017).

It is used in performance reviews of the model projects carried out under the Federal Government's "Germany's Blue Belt" programme (*Blaues Band Deutschland*) (see p. 41 for more information) (Gintz et al. 2020). Valmorph was also employed for the long-term monitoring of depth erosion and the effectiveness of sediment management efforts to combat these deepening tendencies of the riverbed (Quick et al. 2020), as shown in fig. 16. Deepening riverbeds have detrimental effects, such as a reduction in groundwater and river water

Fig. 16: Hydromorphological classifications and shifts observed: Excerpt from the long-term depth erosion monitoring on the Lower Rhine, carried out with the Valmorph procedure, example given here: period from 1896 to 1975 *(Quick et al. 2020; Daten Jasmund 1896, WSA Duisburg-Rhein, WSA Köln)*

levels, causing side channel systems, side branches of rivers and oxbow lakes in the bank and floodplain areas to become disconnected. As a consequence, the fish fauna is confronted with declining spawning and breeding grounds.

The insights gained through hydromorphological monitoring are useful to various kinds of contracting authorities and committee activities concerned with improved water resources management and support the management of our federal waterways. Beneficiaries include Germany's federal ministries of transport and environment, the WSV, river basin communities, international river basin commissions, the LAWA (German Working Group on water issues of the Federal Government and the *Länder*) as well as European expert committees. In addition, the assessment on whether management activities on surface waters comply with the provisions of the EC Water Framework Directive requires evaluating the hydromorphological development of surface waters.

Research projects at BfG:

- "Sediment continuity in the Elbe catchment area and facilitation of a balanced sediment budget of the Elbe" (*Sedimentdurchgängigkeit im Elbe-Einzugsgebiet und Förderung eines ausgeglichenen Sedimenthaushaltes der Elbe*) and "Calculation and assessment of quantitative and hydromorphological aspects of exemplary side waters in the Elbe catchment area" (*Erfassung und Bewertung quantitativer und hydromorphologischer Aspekte beispielhafter Nebengewässer im Elbe-Einzugsgebiet*), cooperation project with the River Basin Community Elbe (FGG Elbe), June 2019 – March 2021 (FGG Elbe 2021: Abschlussbericht Konzeptionelle Analyse, Bearbeitung Kathöfer et al. 2021)
- mDRONES4rivers: "Modern sensors and airborne remote sensing for the mapping of vegetation and hydromorphology along federal waterways" (*Moderne Sensorik und luftgestützte Fernerkundung für vegetationskundliche und hydromorphologische Anwendungen an Wasserstraßen*), joint project under the BMDV's mFUND research initiative, November 2019 – October 2021 (including, among others, two practitioner workshops and the presentation of the Kühkopf as one of the study areas, for example when the model project "Bank restoration Kühkopf-Knoblochsaue" (*Uferrenaturierung Kühkopf-Knoblochsaue*) carried out within "Germany's Blue Belt" programme was awarded the status of an official project of the UN Decade on Biodiversity in September 2020).

Further information (in German):
https://t1p.de/Hydromorphologie

Contact:
Dr Ina Quick
(quick@bafg.de)

References:

Gintz, D., M. Lütz, I. Quick, S. Schriever, Y. Baulig, S. Kranz, F. König (2020): Monitoring Hydromorphologie im Rahmen der Erfolgskontrolle des Modellprojekts „Uferrenaturierung Kühkopf-Knoblochsaue" des Bundesprogramms „Blaues Band Deutschland" – Erfassung des Ist-Zustands vor Maßnahmenumsetzung. Bericht BfG-2033, Bundesanstalt für Gewässerkunde, Koblenz

Quick, I. & F. König (2021): Methodenstandard zum hydromorphologischen Monitoring der Gewässerentwicklung schiffbarer Gewässer, ihrer Ufer und Auen. In: KW Korrespondenz Wasserwirtschaft 2021 (14) Nr. 6., 369-374. DWA, Hennef

Quick, I., F. König, T. Sauer, D. Gintz, M. Lütz, S. Kranz, C. Borgsmüller, S. Schriever, S. Wick (2019): Hydromorphologisches Monitoring zur Gewässerentwicklung bei Maßnahmen in und an Bundeswasserstraßen. Bericht BfG-1911, Bundesanstalt für Gewässerkunde, Koblenz

Quick, I., F. König, Y. Baulig, Y., C. Borgsmüller, S. Schriever (2017): Das hydromorphologische Erfassungs- und Bewertungsverfahren Valmorph 2 für schiffbare Oberflächengewässer. Bericht BfG-1910, Bundesanstalt für Gewässerkunde, Koblenz

Quick, I., F. König, Y. Baulig, S. Schriever, S. Vollmer (2020): Evaluation of depth erosion as a major issue along regulated rivers using the classification tool Valmorph for the case study of the Lower Rhine. In Habersack, H.; Liedermann, M.; Tritthart, M.; Eder, M. (editors): International Journal of River Basin Management, Volume 18, 2020, Issue 2: Major Issues in Large River Basin Management, pages 191-206

Key fundamentals for managing the Kiel Canal and the Eider

The German Land of Schleswig-Holstein is the home of the Kiel Canal and the Eider River, with the latter being the Land's largest natural receiving body of water while also providing a long navigable stretch. In the late 19th century, the construction of the Kiel Canal – now the world's busiest artificial waterway – split the Eider into two separate drainage basins (fig. 17). The Inner Eider and the Tidal Eider empty into the North Sea through the Eider Barrier operated since 1973 to control tidal influences. The Upper Eider is situated in the eastern part of the Kiel Canal's catchment area. Sluice systems allow for drainage into the North Sea and the Baltic Sea provided that outer water levels are sufficiently low.

Both catchments are marked by a typical Northern German landscape, such as vast plains at low altitude with gentle slopes. On the side facing the North Sea, agricultural use is enabled by dewatering through sluice systems and pumping stations as well as a dense network of ditches. Human activities have modified this landscape over the centuries. Today, it is of high relevance for tourism and nature conservation, too.

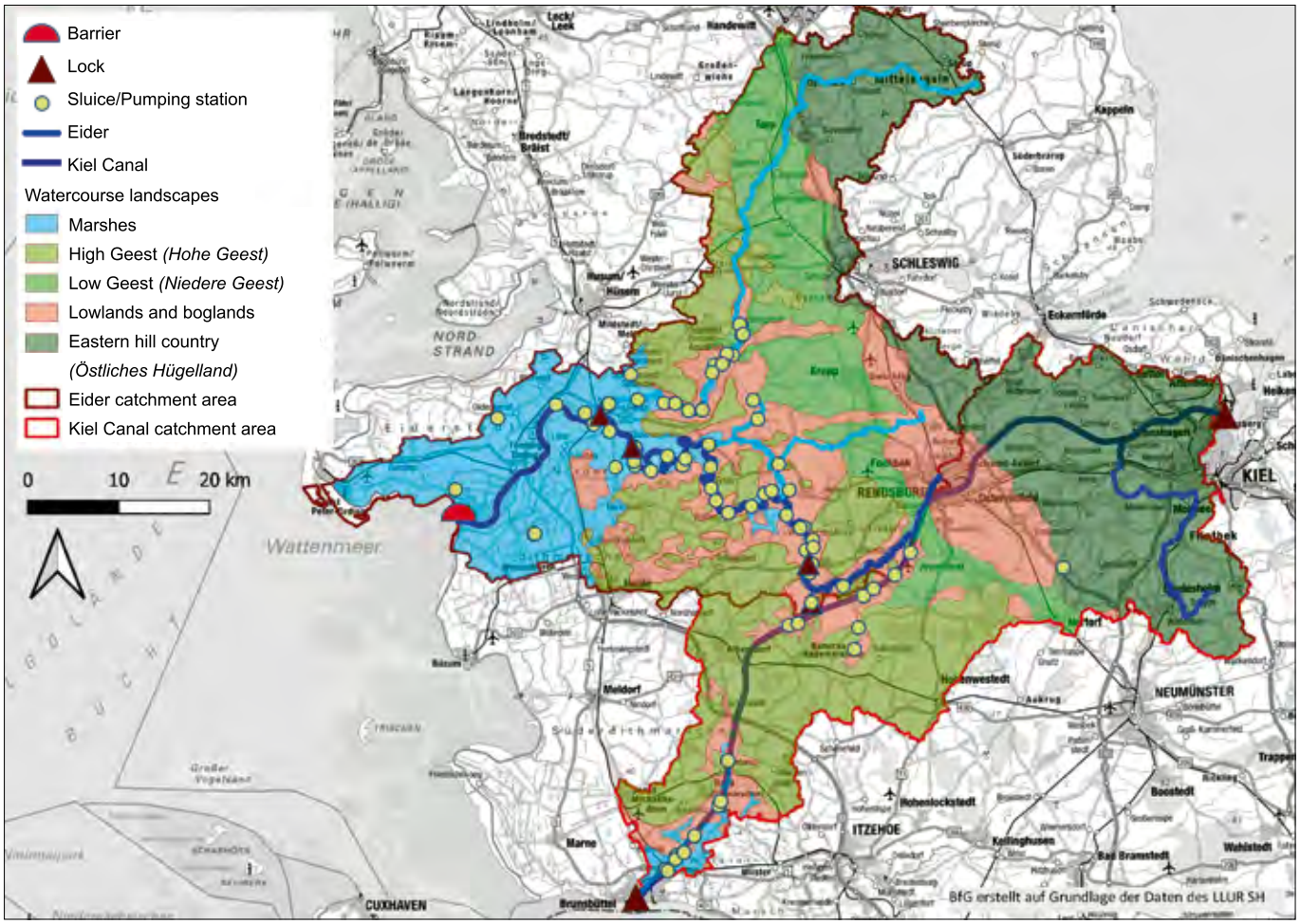


Fig. 17: Eider and Kiel Canal catchments and the watercourse landscapes (BfG, based on data of the State Office for Agriculture, Environment and Rural Areas of Schleswig Holstein (LLUR))

The diverse functions of this cultural landscape must be investigated to make them future-proof. This includes tourism and nature conservation as well as agriculture and shipping. These are impacted by the effects of rising sea levels, increasing air temperatures and changing precipitation patterns as well as land losses/uplift and subsidence. This is necessary in order to lay the foundations for forward-looking management activities.

As early as 2014, we started to set up appropriate model tools for the Kiel Canal: a water balance model, a hydronumerical model as well as a balance and control model for water management purposes, helping us, on the one hand, to make recommendations for the short-term management of the canal's water resources in the upcoming days. On the other hand, this toolkit also serves to identify long-term management options covering the 21st century, ensuring the reliable operation of the canal even when taking into account the impacts of climate change. Since October 2019, we have been conducting test operations with four daily forecasts of the canal's water levels assuming different drainage strategies. Previous climate impact analysis has revealed that in the absence of adaptation measures a significant increase in critical management situations is likely to occur, depending on the extent of sea level rise. Timely efforts to develop an adaptation strategy are therefore crucial. We will inform this process by conducting further in-depth research and tackling ancillary questions of ecology.

Likewise, we have been developing appropriate products under the "Future of the Eider" project (*Zukunft Eider*), a joint initiative of the WSV, the Land of Schleswig-Holstein and regional associations.

Further information (in German):
Forecast:
https://www.bafg.de/vorhersage
"Future of the Eider" project (*Zukunft Eider*):
https://t1p.de/Eider

Contact:
Dr Anna-Dorothea Ebner von Eschenbach
(ebnervoneschenbach@bafg.de)
Peter Krahe
(krahe@bafg.de)
Dennis Meißner
(meissner@bafg.de)

References:
Ebner von Eschenbach, A.-D., J. Hohenrainer (2020): Wassermengenbewirtschaftung des Nord-Ostsee-Kanals unter Klimawandel. Bericht BfG-2009, Bundesanstalt für Gewässerkunde, Koblenz

Contributions to sediment management in estuaries

Estuaries are unique natural landscapes while also serving as access routes to major German seaports. Their tidal currents transport large volumes of sediments, depositing in well-known sections of the navigation channel and ports. In order to maintain the navigation channel depth, the WSV has to dredge many millions of cubic metres of sediments, which may partly be polluted. Dredging and – in particular – the disposal of dredged material in the water body may impact the valuable ecosys-

Fig. 18: Dredging vessel on the tidally influenced section of the Weser *(Photo: J. Visscher, Ludwig Franzius Institute)*

tems in estuaries. In a bid to assess the effects and minimise potential impacts we are assigned by the WSV – and in case of the Elbe River also by the Hamburg Port Authority – to elaborate so-called GÜBAK impact assessments and studies on sediment management.

GÜBAK is the acronym for "Joint transitional arrangements for the handling of dredged material in coastal waters" (*Gemeinsame Übergangsbestimmungen zum Umgang mit Baggergut in den Küstengewässern*). These guidelines have been agreed upon by the Federal Government and Germany's coastal Länder and serve as a basis for assessing the impacts of maintenance dredging operations in coastal areas. BfG is currently involved into the revision of those arrangements.

Drawing up the impact assessment and keeping it up to date requires specific data acquisition and analysis works – either conducted by ourselves or by contractors – to determine grain size distributions, contaminant and nutrient concentrations, ecotoxicological effects and the oxygen consumption of the dredged material. Where appropriate, investigations also cover the macrozoobenthos populating the dredging and dredging disposal sites as well as potential impacts on other animal groups and vegetation. Model investigations carried out by the Federal Waterways Engineering and Research Institute (BAW) and relevant outcomes thereof are increasingly used as input in our impact assessments. In 2020, BfG finalised GÜBAK impact assessments regarding the WSV's placement sites in the Jade and Outer Weser areas (BfG 2020 a, b). Current work focuses on placement sites in the tidally influenced area of the Elbe (*Tideelbe*), including the stretch around the "Neuer Luechtergrund" downstream of Cuxhaven.

Further information (in German):
https://www.bafg.de/DE/Home/sedimentmanagement_aestuare.html
https://www.bafg.de/Baggergut/Home/homepage_node.html

Contact:
Mailin Eberle
(eberle@bafg.de)
Dr Axel Winterscheid
(winterscheid@bafg.de)
Dr Carmen Kleisinger
(kleisinger@bafg.de)

References:

BfG (2020 a): Unterbringung von Baggergut aus der Unterhaltungsbaggerung auf die Unterbringungsstellen in der Jade. Im Auftrag des WSA Weser-Jade-Nordsee. Bericht BfG-2019, Bundesanstalt für Gewässerkunde, Koblenz

BfG (2020 b): Umlagerung von Baggergut aus dem Bereich Weser-km 40 bis Weser-km 130 auf die Umlagerungsflächen K1 bis K6, K01 sowie T1 bis T3 in der Außenweser – Untersuchung nach GÜBAK. Im Auftrag des WSA Weser-Jade-Nordsee. Bericht BfG-2029, Bundesanstalt für Gewässerkunde, Koblenz

Environmentally-focused development of the federal waterways

Watercourses and their adjacent floodplains are multifunctional areas where diverse interests meet. Not only do they serve navigation, agriculture and forestry purposes, but they also provide spaces for settlement, industrial facilities and recreation. At the same time, they are refuges for plants and animals that have become rare or are even endangered and have adapted to a life between the extremes of flood and low-flow events. Contrary to the targets set by the EU Water Framework Directive, the ecological status or ecological potential of waters has not yet improved sufficiently, which is due to overuse of waters and their adjoining areas.

Given the increase in environmental awareness and the acknowledgement of the beneficial contributions of intact ecosystems, society attaches major importance to the ecological development of water bodies, which is also reflected in current legislation. Since 2009, the Federal Waterways

and Shipping Administration (WSV) has already been in charge of the water management-related maintenance of federal waterways. In June 2021, its portfolio was complemented by the responsibility for their water management-related development. Both tasks are aligned with the green targets of the EU Water Framework Directive. We therefore provide continuous guidance to the WSV regarding ecologically optimised waterway maintenance and development works on federal waterways.

Knowledge in a nutshell: fact sheets on relevant species

Waterway maintenance can contribute considerably to improving the general status of water bodies. As a tool for the WSV's tasks, we compiled fact sheets providing a quick and eye-catching reference guide to species that typically inhabit specific water bodies and floodplains and are relevant to maintenance planning.

Regular updates, made available on www.bafg.de, ensure that the current state of scientific knowledge and applicable legal requirements are properly reflected.

- **Fact sheets on protected animal and plant species on federal waterways**
  More than 120 protected animal and plant species can be found in and along federal waterways in Germany. The fact sheets provide the WSV with information on a specific species, its life cycle and habitat and potential mitigation and compensation measures (fig. 19) to be considered in development and maintenance works.

- **Fact sheets on invasive neophytes[8] on federal waterways**
  Waterways and their floodplains provide major pathways for invasive species to spread. These species may be detrimental not only to native plants and animals and thus to biodiversity, but also to human

8 **Neophyte:** Non-native plants are species that have been introduced into geographical regions outside their natural habitat through human influence (whether intentionally or not), living in the wild in their new territories. The term "invasive species" is used for neophytes posing a threat to the indigenous biocenosis.

Fig. 19: Fact sheet "Common Noctule" (available in German only) as an example of a protected species

Fig. 20: Fact sheet “Giant Hogweed” (available in German only) as an example of an invasive neophyte. Handling this plant is particularly problematic because of its harmful phototoxic effects to health. Furthermore, it is likely to be confused with the native species of common hogweed and garden angelica.

Fig. 21: Cover of the brochure “Fact sheets on woody plants for the maintenance of federal waterways” (available in German only)

health. We advise the WSV in this respect. Our fact sheets on invasive plant species provide concise recommendations on the identification of the relevant species as well as on measures for spread prevention, control and protection (fig. 20).

- **Fact sheets on woody plants**
  In collaboration with the Rhine Waterways and Shipping Office (WSA Rhine) and the WSV Education and Training Centre in Hanover, we created fact sheets on wooden plants published as a brochure in December 2020 (fig. 21). 60 typical woody plants of the floodplains and their key identifying features are described in a simple and concise form, illustrated by representative photos, enabling users to recognise plants based on characteristics like habit, trunk, leaf, bud or habitat and to assign them to a specific floodplain vegetation zone[9]. Regular training sessions are held with the WSV to deepen knowledge on this issue.

Further information (in German):
https://t1p.de/Artensteckbriefe
https://t1p.de/Neophyten
https://t1p.de/Gehoelze

Contact:
Detlef Wahl
(wahl@bafg.de)

9 Floodplain vegetation zones: Depending on the flood regime and the resulting vegetation cover, floodplains can be divided into different zones. Woody plants are found in softwood-floodplain forests (e.g. willows, black poplars) and hardwood-floodplain forests (e.g. common oaks, ash trees, elms).

Ecological connectivity

On many federal waterways, barrage systems built or operated by the WSV enable safe and smooth navigation. At the same time, they typically present impassable barriers to fish and other aquatic organisms. This is why fishways are installed to make unimpeded fish migration in rivers possible again. Since 2010, the restoration of the federal waterways' ecological connectivity has been one of the WSV's statutory responsibilities in order to implement the provisions of the EU Water Framework Directive. Given the multitude of locations, a prioritisation of potential actions is needed at the national level – a task assumed by the Federal Waterways and Shipping Agency (GDWS) on a regular basis. We support this process by assessing the current status of ecological connectivity and recommending urgent measures from a fish ecology perspective. Within the scope of the current prioritisation concept 2021, we have therefore revaluated more than 80 locations as to their specific required actions.

Together with the Federal Waterways Engineering and Research Institute (BAW), we advise the WSV in planning, designing, constructing and operating fishways. This work is based on the BfG/BAW "Guidance on fishways on German federal waterways" (*Arbeitshilfe Fischaufstiegsanlagen an Bundeswasserstraßen* – available in German only) (BfG/BAW 2015), which is currently being developed further in a collaborative process under the auspices of the GDWS to become a manual on ecological connectivity. So far, we have been reviewing draft designs for more than 50 locations for quality assurance purposes. Where necessary, completed projects undergo a biological performance check, which will soon be underpinned by a methodological standard developed in one of our ongoing research and development (R&D) projects. To this end, we tested different methods at the stations in Malliß (Müritz-Elde waterway) and Rothenfels on the Main, such as our proprietary standard fish trap (fig. 22), in 2019/2020.

Although specific policies summarising the current state of technology for the design of fishways do exist, there are still knowledge gaps when it comes their application along the federal waterways. These are addressed in an extensive collaborative R&D programme with the BAW, whose outcomes will directly feed into our advisory practice. This programme includes field and pilot plant research, the use of models and analysis of fish behaviour under different hydraulic conditions in the BAW's experimental flume.

Fig. 22: Standard fish trap to check the performance of the fishway in Malliß on the Müritz-Elde waterway *(Photo: BfG)*

Installing downstream migration facilities in cases of weir replacement is becoming a new focus of our scientific advice. Our first step in this context was to summarise key issues in an expert paper illustrating the steps required to identify any existing needs. This procedure is supported by a statistical model tool for downstream fish migration, enabling a comparative analysis of different weir design options in terms of their respective implications for downstream passage at a specific location (BAW/BfG 2021). Since there is no state of technology for appropriate downstream fish migration facilities yet, we develop and test potential solutions together with the BAW.

Further information:
https://www.bafg.de/EN/Home/durchgaengigkeit.html

Contact:
Dr Matthias Scholten
(scholten@bafg.de; durchgaengigkeit@bafg.de)

BfG research and development projects

- Fish biological performance checks of fishways (*Fischbiologische Funktionskontrolle von Fischaufstiegsanlagen*), January 2018 – December 2022
- Etho-hydraulic tests with fish (*Ethohydraulische Versuche mit Fischen*), January 2015 – December 2023
- Fish migration corridors in impounded federal waterways (*Wanderkorridore von Fischen in stauregulierten Bundeswasserstraßen*), January 2012 – December 2030
- Classification of migration corridors for downstream fish migration (*Klassifizierung der Wanderwege für den Fischabstieg*), January 2014 – December 2030
- Weir type-related implications on downstream fish migration (*Auswirkung verschiedener Wehrtypen auf den Fischabstieg*), January 2014 – December 2030

(each carried out on behalf of the Federal Ministry of Transport and Infrastructure (now: Federal Ministry for Digital and Transport, BMDV) and in cooperation with the BAW)

References:

BAW/BfG (2015): Arbeitshilfe Fischaufstiegsanlagen an Bundeswasserstraßen (AH FAA), Bundesanstalt für Wasserbau (BAW) und Bundesanstalt für Gewässerkunde (BfG), Version 2.0, *http://doi.bafg.de/BfG/2015/AH-FAA_2.0_2015.pdf*

BAW/BfG (2021): Bewertung der Auswirkung baulicher und betrieblicher Maßnahmen an Stauanlagen auf den Fischabstieg. In: BAW-Empfehlung, Ausgabe 2021, Hrsg.: BAW, Karlsruhe

‘Germany’s Blue Belt’ – A Federal Government programme

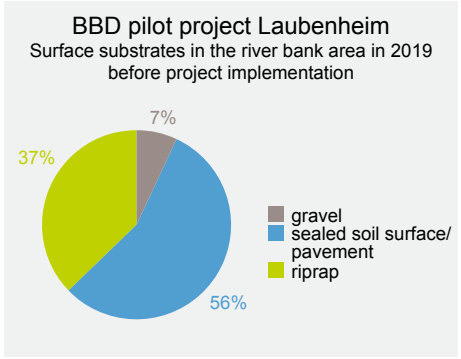
The “Germany’s Blue Belt” programme (*Blaues Band Deutschland* – BBD), initiated by the Federal Ministries of Transport and Environment, is aimed at the near-natural restoration of the federal waterways, promotion of biodiversity and creation of a national biotope network. Furthermore, the programme is designed to meet recreational needs by enhancing the experience of nature offered by rivers, banks and floodplains.

We have been supporting this programme from its beginnings in 2017. In addition to coordinating

Fig. 23: River bank strip within the pilot project area Laubenheim on the Rhine, before (left) and after (right) implementation of the restoration works

the cross-departmental "BBD expert group" (*Fachgruppe BBD*), we make major contributions to the performance reviews of the five restoration pilot projects on the rivers Rhine and Weser. From the conceptual design to data collection, treatment and analysis to result interpretation, all of BfG's scientific divisions are involved in the programme. The performance reviews help to keep project changes documented and understandable. With the insights gained, we deepen our understanding of the river, bank and floodplain system. We also share our experiences so as to ensure best possible success of restoration works on federal waterways. Our work is based on close interaction with the *Länder* (state level) institutions involved and the Federal Waterways and Shipping Administration.

By way of example, we refer to the pilot project "River bank restoration Laubenheim" (*Uferrenaturierung Laubenheim*) on the river Rhine. In 2019, the connection between the river and the adjacent floodplain was improved by means of initial floodplain plantings and by upgrading a river bank strip of about 1 km length through destoning and revitalisation (fig. 23). Spatial digital recordings of the surface substrates in the Laubenheim river bank area evidence the progress achieved with regard to the substrate composition (fig. 24). The monitoring also included an evaluation of the "river bank structure" indicator, based on our proprietary "Valmorph" approach (see p. 31), enabling us to quantify and locate the advancements made. Previously, the Laubenheim Rhine section had been awarded the lowest-ranking evaluation grade 5. Following implementation of the measures, 67% of the river bank was ranked within the highest evaluation category 1. The fish population, too, has made some initial progress. Gravel spawners, in particular, are responding well to the new structures. In the years to come, the covered area will generate diverse



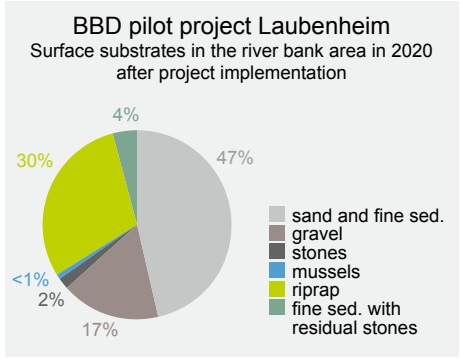


Fig. 24: Shares of the surface substrates in the river bank area covered by the BBD pilot project "River bank restoration Laubenheim" on the river Rhine (km 491.6 – 492.5) in 2019/2020, identified through digital analysis of aerial photographs and mappings

Fig. 25: BfG's remote control ArcBoat "Q" in action *(Photo: BfG)*

water type-specific habitats, whose evolution will be documented in additional performance reviews.

Further pilot projects, too, included broad reviews to monitor the effectiveness of restoration measures. For example, the effects of slotted groynes and the introduction of deadwood on hydraulic conditions were measured with a remote-control survey boat. Our new ArcBoat named "Q" saw its first use in 2021 (fig. 25). Besides discharge measurements, we are currently exploring ways to carry out waterside surveys of river bank structures with a camera installed on the boat.

Since the beginning of the "Funding Programme Floodplains" (*Förderprogramm Auen*) launched by the Federal Agency for Nature Conservation on 1 February 2019, we contribute our know-how by way of expert opinions for the evaluation and prioritisation of new BBD projects. Projects like "Wild Island of Pagensand" (*Wilde Insel Pagensand*) on the *Tideelbe*, the tidally influenced area of the Elbe, and "Revitalisation of the Havel floodplain near Bölkershof" (*Revitalisierung der Havelaue bei Bölkershof*) have already been approved, and implementation is in progress. Applications for further promising projects, such as "Middle Elbe floodplain restoration" (*Auenrenaturierung Mittlere Elbe*) and "Diversity on the Aller River in Verden" (*Aller Vielfalt Verden*), are in preparation. We expect further interesting BBD project proposals to be submitted in the future.

The BBD programme is closely linked with our new tasks in the context of water management-related development, since both are similar in terms of targets and potential projects in the field of waters, river banks and floodplains, which will create synergies in the future.

Further information:
https://www.blaues-band.bund.de/
(available in German only)

Contact:
Dr Andreas Anlauf and
Corinna Krempel
(blaues-band@bafg.de)

Ecosystem services

An appropriate approach to determine the value of the multiple functions of waters for humanity is the so-called ecosystem services (ES) concept, which looks at the benefits that people can obtain from the ecosystem's structures and processes. This concept implies both opportunities and challenges for the management of watercourses. On the one hand, opportunities arise because the ecosystem service approach takes account of the significance of waters and floodplains as multifunction areas and may facilitate an environmentally-focused development of the federal waterways. On the other hand, the concept also poses challenges since it aims to open up established evaluation systems for an integrated view of both environmental and economic benefits or costs. However, challenges in terms of methodologies and data technology have prevented the ES concept from being adopted in real-life planning exercises, so far.

We have been addressing the issue of ecosystem service evaluation for years. A recent inventory revealed that our portfolio included 40 ongoing or completed activities related to nearly all of the sections of the *Common International Classification of Ecosystem Services*: provisioning, regulating and cultural ES (BfG 2021). We can also draw on our experiences regarding overarching evaluation approaches incorporating multiple ES.

In order to merge and assess this know-how and to use it as a basis for the development of practical methods, we set up a cross-divisional panel, the "Coordinating panel on ecosystem services and environmental evaluation of socio-economic changes" (*Koordinierungsrunde Ökosystemleistungen und umweltbezogene Bewertung sozioökonomischer Änderungen – KR-ÖSUS)*) in March 2019. Following the inventory stage, these efforts will soon (from 2022 onwards) be supported by the R&D project "Approaches for a multi-criteria evaluation of measures on federal waterways" (*Ansätze einer multikriteriellen Bewertung von Maßnahmen an Bundeswasserstraßen*). A 'simulation game' will provide the framework for defining minimum requirements for data, expertise and resources to be fulfilled in real-life application of the ES concept. Our insights concerning the feasibility and benefits of ES integration into planning procedures will be depicted in collaboration with the BMDV, the GDWS and research representatives. This will serve as a basis to infer recommendations for action in the context of federal waterways management.

Further information:
Common International Classification of Ecosystem Services 5.1 – CICES, *https://cices.eu*
BfG (2021): BfG-Aktivitäten zum Themenkomplex „Ökosystemleistungen und umweltbezogene Bewertungen sozioökonomischer Änderungen" – eine Inventur. Bundesanstalt für Gewässerkunde, Bericht BfG-2073, Koblenz

Contact:
Dr Elmar Fuchs
(kroesus@bafg.de)

Adaptation to climate change – BfG's contributions

Climate change is a key challenge to humankind and the environment – a conclusion underpinned by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which was published in August 2021 and describes the state of scientific knowledge on climate change. BfG takes on this particular challenge by making multiple contributions.

We engage in the implementation of the DAS Core Service "Climate and Water" (*DAS-Basisdienst Klima und Wasser*) established under the German Strategy for Adaptation to Climate Change (*Deutsche Anpassungsstrategie an den Klimawandel* – DAS) for advisory and data provision purposes around the issues of inland and coastal hydrology, water quality, floodplain ecology, suspended matter, pollutants and trace elements as well as transport sector-related water management in times of climate change.

These same topics are also addressed

as part of our international activities, which comprise, amongst others, the operation of the Global Runoff Data Centre and the provision of discharge data in the context of global and climate change to the international research community. Located at BfG, the International Centre for Water Resources and Global Change (ICWRGC), carries out a variety of projects dealing with different aspects of climate change. Below, we describe our water quality monitoring and assessment activities around the globe and our contributions to the observation of the global water cycle under the Global Climate Observing System (GCOS).

DAS Core Service "Climate and Water" now in operation

DAS Basisdienst Klima und Wasser

Since its adoption by the German Federal Cabinet in 2008, the German Strategy for Adaptation to Climate Change has been under continuous development. A growing number of provisions, including relevant standards for watercourse-related action planning, call for consideration of climate change. Hence, demand for related consultation services and data is constantly on the rise.

As part of the network of higher federal agencies within the portfolio of the Federal Ministry for Digital and Transport (BMDV, formerly BMVI), we have set up modules of a comprehensive advisory service. Following the completion of preliminary works carried out within BMVI research programmes (KLIWAS from 2007 and Network of Experts from 2016 on) and a pilot phase (PROWAS from 2017 on), several modules of the newly established DAS Core Service "Climate and Water" have gone live in 2020/2021.

Coordinated by the *Deutscher Wetterdienst* (German Meteorological Service), this service includes, among others, information on various water-related aspects of climate change, delivered by BfG. Using historic and recent data as well as scenarios and models, we analyse changes in the water balance of river catchments, the physical and chemical water properties and ecological conditions around water bodies for the past (climate monitoring) and the future (climate projection until 2100). In partnership with the Federal Waterways Engineering and Research Institute (BAW) and the Federal Maritime and Hydrographic Agency (BSH), we also address the effects of rising sea levels on Germany's coasts. The current state of knowledge concerning these changes is disseminated in the form of flood, low water, tidal, water quality and sediment indicators and hazard notice maps, including personal advice, where needed. In the upcoming years, we will maintain, update and enlarge our data and information product range.

The PROWAS pilot phase and the first months of operational availability of the DAS Core Service have already revealed the enormous need for information (fig. 26). Users include staff members of the Federal Waterways and Shipping Administration (WSV), federal and *Länder* (state) agencies,

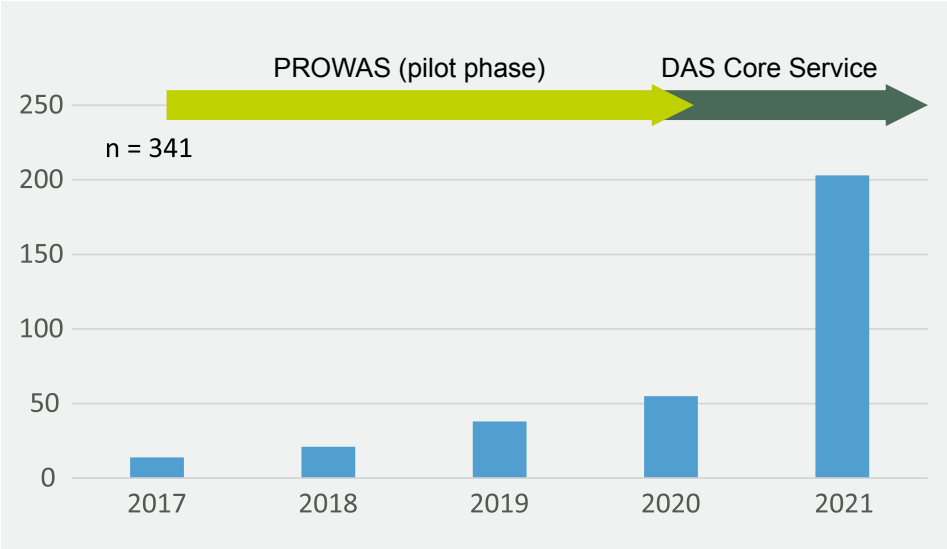


Fig. 26: Number of annual requests submitted to BfG's climate advisory services since the start of the PROWAS pilot phase. Usage statistics of BfG's DAS Core Service modules from July 2017 through August 2021: implementation of the service and reporting scheme still in progress.

businesses, media and individuals as well as climate researchers from other institutions who submit data requests to underpin their scientific works.

In summer 2021, the DAS Core Service web portal www.das-basisdienst.de (available in German only) was activated to provide an overview of the entire range of the DAS Core Service. Our services for the above-mentioned players from the water management and navigation sectors are accessible via the portal ws-klimaportal.bafg.de (English version under construction), which is part of the DAS Core Service. The offering includes analysis of an array of gauges, maps and background information and is constantly being expanded.

Contact:
Dr Enno Nilson *(nilson@bafg.de)* – general issues, transport-sector related water management; Dr Arnd Weber *(arnd.weber@bafg.de)* – floodplain ecology; Claudius Fleischer *(fleischer@bafg.de)* – hydrology; Dr Hartmut Hein *(hein@bafg.de)* – coastal hydrology; Dr Marieke Frassl *(frassl@bafg.de)* – water quality

Our global water data centres and their range of tasks

Sustainability and digitalisation are among the most significant topical items on Germany's and the United Nations' (UN) agenda. Major initiatives in this context are the UN's Sustainable Development Goals and the FAIR Data[10] principle requiring data to be findable, accessible, interoperable and reusable at all times. Many parts of the world, however, lack a free and open basis to share or co-use hydrological data systematically. The Global Runoff Data Centre (GRDC) at BfG and the GEMS/Water Data Centre (GWDC) at the International Centre for Water Resources and Global Change (ICWRGC) maintain

10 FAIR Data is the abbreviation for "Findable Accessible Interoperable Reusable Data" (where "interoperable" refers to a format allowing for exchange, interpretation and combination with other data sets).

a close collaboration in this respect. Together with ten more global water databases they form the Global Terrestrial Network – Hydrology (GTN-H). These activities foster the understanding of the global water cycle and the worldwide monitoring of water quality and promote achievement of the Sustainable Development Goals.

New GRDC portal offers faster access to global runoff data

With a few mouse clicks, international researchers engaged in the scientific study of global and climate change can access the discharge data stored in the Global Runoff Database. This is enabled by a GRDC data download portal released in June 2020, making time-consuming, semi-automated data provision procedures a thing of the past.

The data portal features web-based tools to select stations and time series for download (fig. 27). Map views, hoverboxes, filters, tables with configurable columns and the graphical presentation of the available time series complement well-known zoom functions and selection tools. The time series of the selected stations are available in different formats, including approved international standard formats for hydrological data exchange. Users who wish to download data must first accept GRDC's general terms stating that data use and exchange must serve purely scientific purposes.

Currently, the Global Runoff Database comprises quality-assured "historical" time series of daily and monthly discharge data provided by around 10,700 monitoring stations (up from nearly 10,000 at the end of 2019) across the globe. Data supplies by the Member States of the World Meteorological Organization (WMO) help keep the database continuously up-to-date, making this unique data set even more valuable.

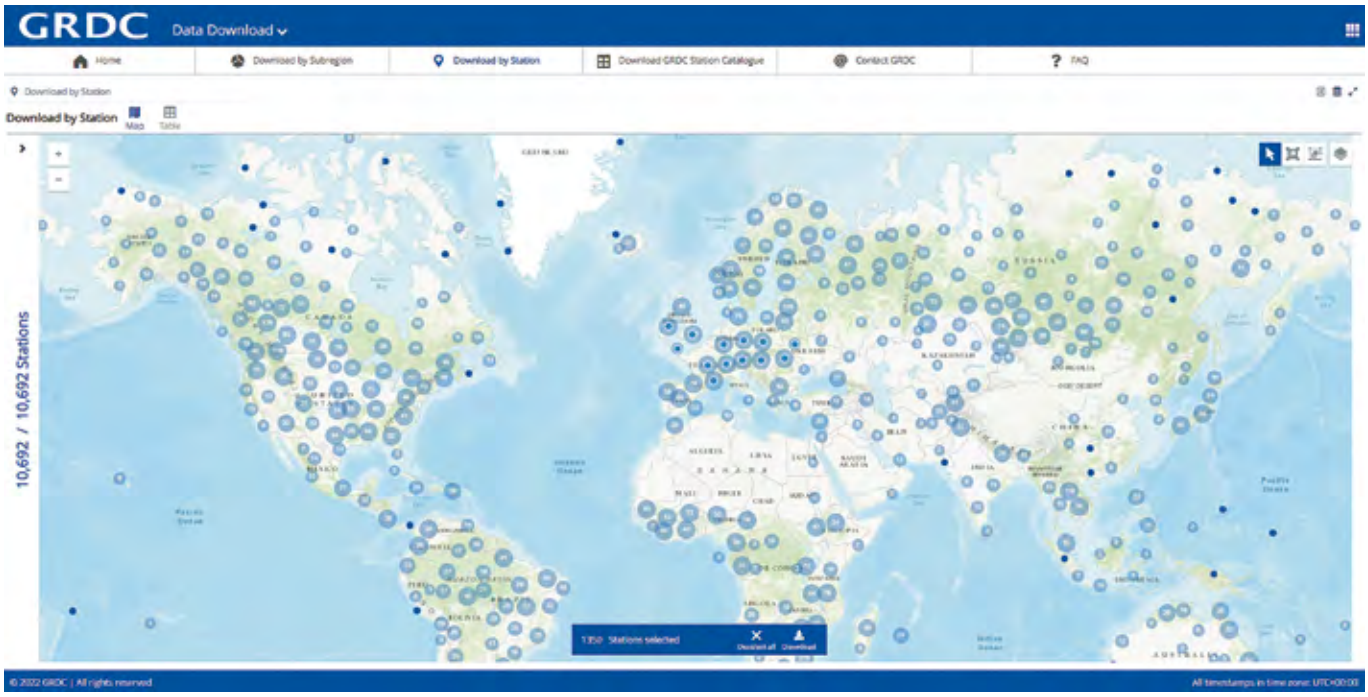


Fig. 27: User interface of the GRDC data download portal (*https://portal.grdc.bafg.de/*)

Since its implementation, GRDC has thus become the most comprehensive global runoff data archive supporting climate-related programmes and projects of the UN and its specialised agencies as well as research, development and education in the field of sustainable water resources management.

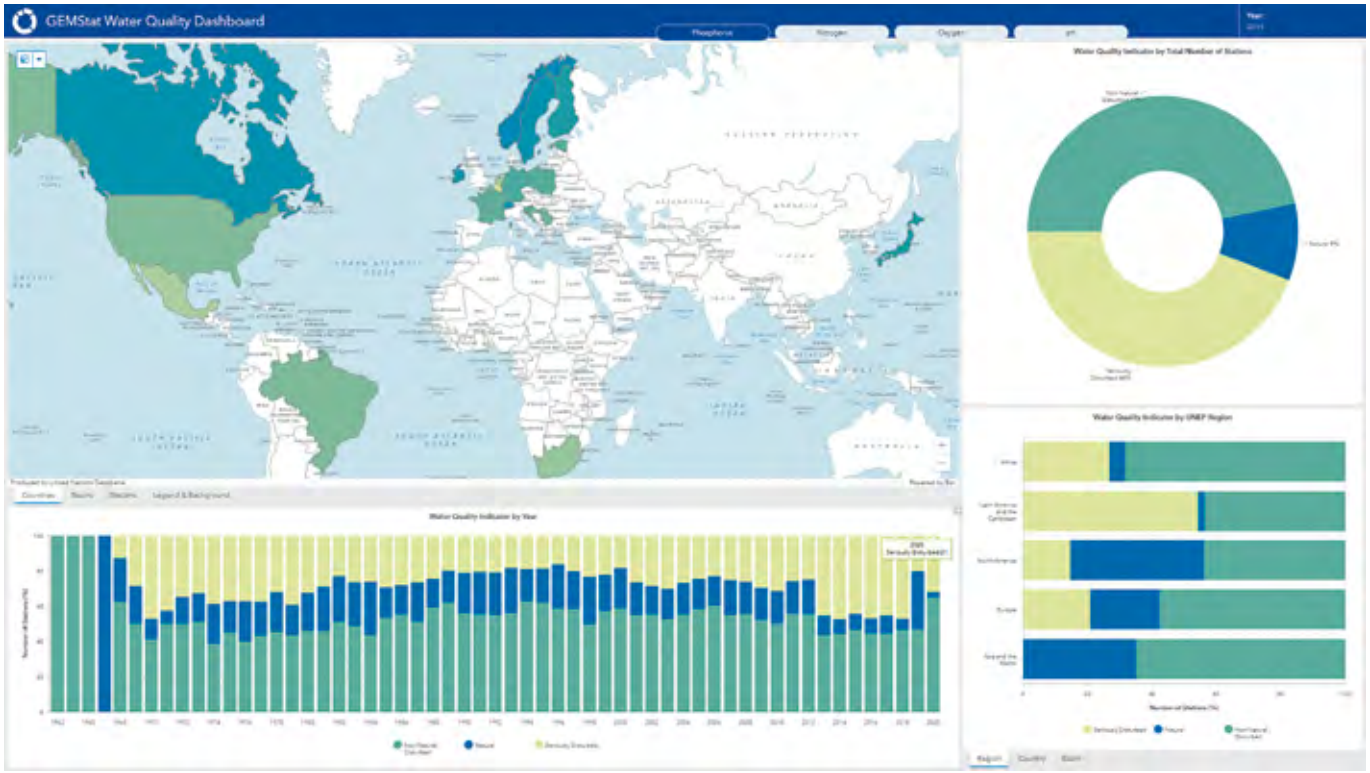
GRDC is an international data centre under the auspices of WMO and has been operated by BfG since its establishment in November 1988. Global discharge data are collected, standardised and made accessible in the Global Runoff Database. One of the key rationales behind this offer is to ensure the long-term provision of in situ data to the international research community. In situ discharge data collected by GRDC are used to calibrate hydrological models, analyse model-based findings and validate remote sensing data.

Further information:
https://grdc.bafg.de

Contact:
Ulrich Looser
(looser@bafg.de; grdc@bafg.de)

Monitoring and assessing global water quality

The GEMS/Water Data Centre (GWDC) is mandated by the Global Environment Monitoring System for Freshwater (GEMS/Water) of the United Nations Environment Programme (UNEP) to collect water quality monitoring data of all UN Member States. In 2020, its volume tripled to 11.7 million values collected at more than 8,500 monitoring stations in 35 countries, which was the largest data growth since the inception of GEMS/Water. Our latest tool is an interactive dashboard providing information on water quality in countries, river basins and on monitoring stations across the globe based on the indicators of phosphorus, nitrogen, dissolved oxygen and pH (fig. 28).
In 2020, the GWDC also collaborated with UNEP to contribute to the implementation of the second global reporting cycle on indicator 6.3.2 on water quality within the scope of the UN's Sustainable Development Goals. 89 of 193 Member States submitted their data on indicator 6.3.2 in that year with 60% of around 77,000 water bodies assessed being found to be of good ambient quality. The findings have been summarised in a progress report providing an update on the status of the different aspects of the Sustainable Development Goal "Clean Water and Sanitation" (SDG 6) in different parts of the world, on areas where the international community is not on track to achieve its targets and on the strategies needed to accelerate the achievement of SDG 6 (fig. 29).



Indicator 6.3.2 is calculated as the proportion of the surface of inland waters with good ambient water quality in relation to the total surface of a country's inland waters and assists countries in evaluating their efforts to improve water quality.

Contact:
Philipp Saile
(saile@bafg.de; icwrgc@bafg.de)

Fig. 28: The interactive dashboard allows to visualise water quality in terms of the indicators of phosphorus, nitrogen, oxygen and pH by country, river basin or station (*www.gemstat.org*).

Fig. 29: The Summary Progress Update 2021 on Sustainable Development Goal (SDG) 6 "Clean Water and Sanitation", including input of the GWDC in its role as implementation partner for indicator 6.3.2 on water quality (*https://t1p.de/UNwater*).

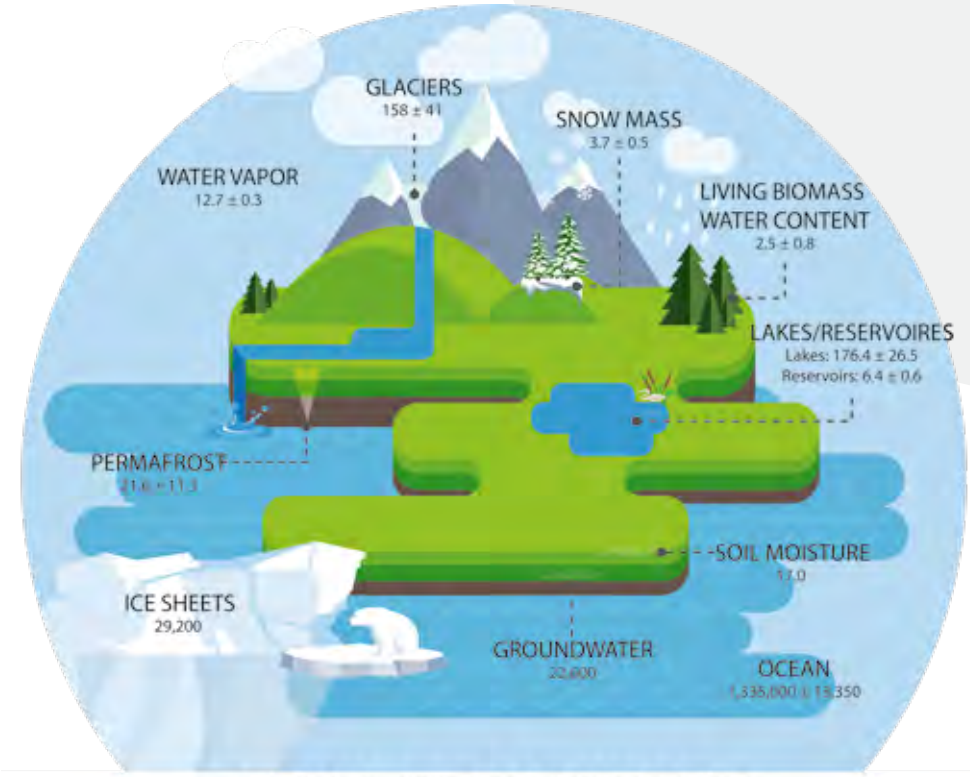
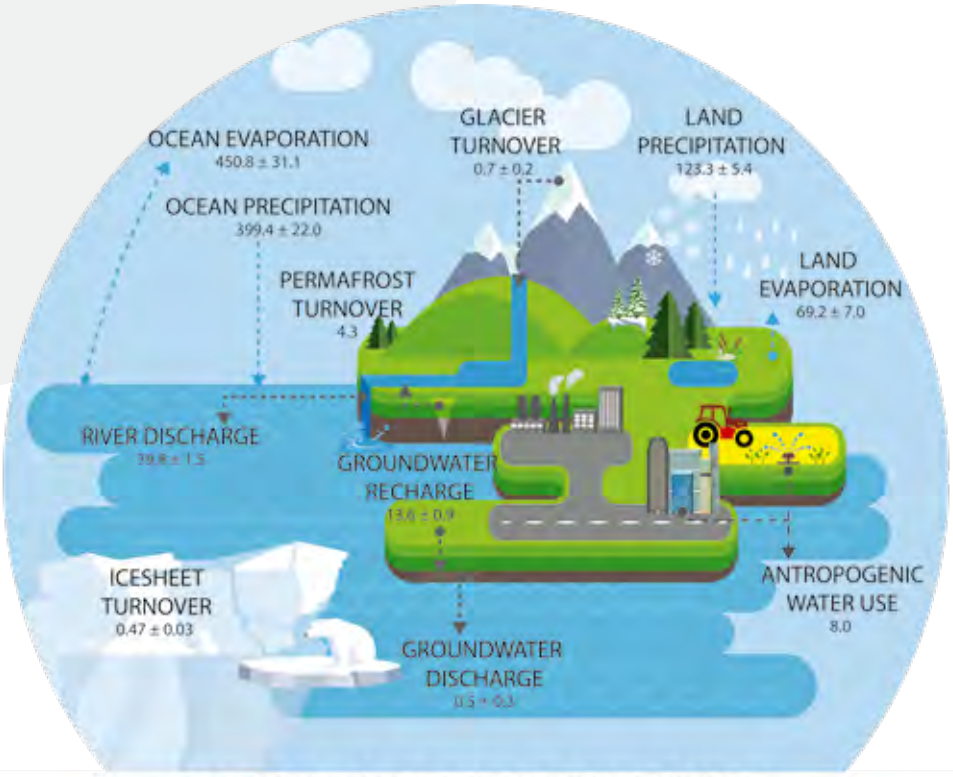


Fig. 30: Status of global water resources and the water cycle (Dorigo et al. 2021) Observed estimates of global water storages and their uncertainties (left) and observed estimates of annual global water cycle fluxes and their trends (right), in 10^3 km^3. *(© American Meteorological Society. Used with permission)*

Engaging in the observation of the global water cycle

The Global Terrestrial Network – Hydrology (GTN-H) is actively involved in the Global Climate Observing System (GCOS) and the support of the United Nations Framework Convention on Climate Change. In this role, the Network and its federated data centres contributed to the compilation of the recent GCOS Status Report (GCOS 2021), revealing a clear need for action regarding exchange and interoperability of hydrological data. With respect to water cycle observations, examples include the lack or non-implementation of standards for meta data and data transfer formats, insufficient data exchange between research institutions and agencies, faster delivery of observational data and a sustainable funding of monitoring networks and data centres or lack of political support to implement open data policies. As a basis for the GCOS status report, the observation status for the three climate cycles (water, energy and carbon) was evaluated. The article Dorigo et al. 2021 was coordinated by TU Wien and ICWRGC and includes input of a total of 32 international experts active in climate observations (in situ and satellite remote sensing) of the atmosphere, the oceans and land surfaces, providing an update on the status of global water cycle observations and suggesting ideas to enhance future monitoring activities. Nine researchers from the Global Runoff Data Centre (GRDC), the Global Precipitation Climatology Centre (GPCC) and the International Soil Moisture Network (ISMN) were involved, too. The publication provides the latest synopsis of the planet's water resources and water cycle (fig. 30).



GLOBAL WATER CYCLE FLUXES

Since 2017 we have been co-ordinating the Global Terrestrial Network – Hydrology (GTN-H) at ICWRGC. GTN-H was established in 2001 and is mandated by the World Meteorological Organization to bring together under one roof twelve global data centres, each in charge of different core parameters of water balance.
https://www.gtn-h.info/networks/

Contact:
Dr Stephan Dietrich
(dietrich@bafg.de; icwrgc@bafg.de)

References:

Dorigo, W., S. Dietrich, F. Aires, L. Brocca, S. Carter, J.-F. Cretaux, D. Dunkerley, H. Enomoto, R. Forsberg, A. Güntner, M. I. Hegglin, R. Hollmann, D. F. Hurst, J. A. Johannessen, C. Kummerow, T. Lee, K. Luojus, U. Looser, D. G. Miralles, V. Pellet, T. Recknagel, C. R. Vargas, U. Schneider, P. Schoeneich, M. Schröder, N. Tapper, V. Vuglinsky, W. Wagner, L. Yu, L. Zappa, M. Zemp, V. Aich (2021): Closing the water cycle from observations across scales: Where do we stand? – Bulletin of the American Meteorological Society 102, 10, DOI: *https://doi.org/10.1175/BAMS-D-19-0316.1*

GCOS (2021): The Global Climate Observing System 2021. The GCOS Status Report, GCOS-240

Research and Development at BfG

BfG is a departmental research institute and a higher federal authority within the portfolio of the Federal Ministry for Digital and Transport (BMDV). In this role, it is involved in research and development (R&D) activities that make substantial cross-departmental contributions to the Federal Government's objectives for the development of inland and coastal waters. The overall goal is to build an environmentally sound, sustainable and resilient infrastructure of waterways and their catchments. These efforts are key in order for our inland and coastal waters to meet the vast range of demands placed on them now and in the future.

Delivering scientifically sound, evidence-based information to the Federal Government is the core function of federal departmental research institutes – research establishments that are directly linked to certain federal ministries. At the Federal Institute of Hydrology, we identify the topical challenges in the field of federal waterways and conduct R&D projects to propose tailored solutions. Addressing and communicating new insights with a focus on practical application is of great importance to us.

BfG's growing R&D output for the interface of science and politics is reflected in its R&D budget increase: While in 2018, total volume amounted to €11.6 million, it is estimated to add up to around €16.2 million in 2022. This sum includes research for the federal waterways financed by the BMDV and cross-modal research within the BMDV Network of Experts as well as development and research activities on behalf of the Federal Ministry for the Environment and external funds for water research. Over the past years, we have consistently enhanced our R&D potential, in particular for the federal waterways – not least thanks to BMDV funding.

Key topics of our R&D activities included the multi-disciplinary development of inland and coastal waters as well as devising and optimising methods and procedures to analyse and evaluate water quality and quantity. Our projects deliver promising results, translating into practical actions. Findings are also disseminated on events, such as national and international conferences, practitioner workshops and other lecture series, and discussed with counterparts from other institutions. Emerging topics and/or related scientific insights are published in renowned peer review journals, practice-focused expert journals as well as proprietary BfG report types.

In order to ensure a high scientific quality of BfG's R&D works, all BMDV funded projects are subject to an expert review, requiring our scientists to engage in an internal competition, where they present their project proposals for discussion. The audience includes members of BfG's Scientific Advisory Board, who provide crucial support in selecting the projects to be sponsored.

Cross-modal research within the BMDV Network of Experts is a vital tool to further connect with the BMDV's other departmental research institutes and expert agencies involved – the Federal Maritime and Hydrographic Agency (BSH), the Federal Waterways Engineering and Research Institute (BAW), the German Centre for Rail Traffic Research (DZSF), the Federal Office for Goods Transport (BAG), the Federal Highway Research Institute (BASt) and the *Deutscher Wetterdienst* (German Meteorological Service, DWD). The second research phase kicked off in January 2020 and serves to continue the measures initiated in the first stage (2016 – 2019) and to promote the exploitation of previous findings. Our work focuses on designing adaptation options to climate change and developing the federal waterway transport infrastructure in an environmentally sound way. This also includes devising remote sensing and geodesy approaches for structure monitoring.

The International Centre for Water Resources and Global Change (ICWRGC), located at BfG, collaborates with partners from multiple regions around the world, which is also reflected in the Centre's R&D focus. ICWRGC's R&D activities are part of the implementation of UNESCO's "International Hydrological Programme" (IHP) and WMO's "Hydrology and Water Resources Programme" (HWRP). Again, these contributions rely on the indispensable guidance and assistance provided by ICWRGC's Scientific Advisory Board. Working in collaboration with the Board ensures a dynamic dialogue between Germany's water research landscape and the United Nations' water programmes.

Particular focus was on the evaluation of ICWRGC by an independent international scientist and UNESCO, actively supported by the Scientific Advisory Board. ICWRGC's work was highly valued, and in December 2020, UNESCO confirmed ICWRGC's acknowledgement as a globally operating UNESCO Category 2 Water Centre for another 6-year term (2021-2026). Recommendations from the evaluation will be incorporated into ICWRGC's ongoing strategy development.

In order to provide a coherent overview of BfG's research efforts, we launched a new biannual publication series, the "Research and development compendium" (*Kompendium Forschung und Entwicklung*, in German only) (fig. 31), in 2020. The strategic direction of our future R&D activities is outlined in the "Research and development approach of the Federal Institute of Hydrology – 2022 to 2030" (*Forschungs- und Entwicklungskonzept der Bundesanstalt für Gewässerkunde – 2022 bis 2030*, in German only). BfG's evaluation by the German Council of Science and Humanities (*Wissenschaftsrat*), scheduled in May 2023, will provide momentum, driving forward the governance and design of BfG's research and development activities.

Fig. 31: First issue of BfG's new publication series "Research and development compendium" (in German only)

Further information:
https://www.bafg.de/EN/01_Services/02_Research_Development/research_development_node.html
BMDV Network of Experts:
https://bmdv-expertennetzwerk.info/EN
ICWRGC:
https://www.waterandchange.org/en/

Contact:
Prof Dr Thomas Ternes,
BfG Head of Research
(ternes@bafg.de)

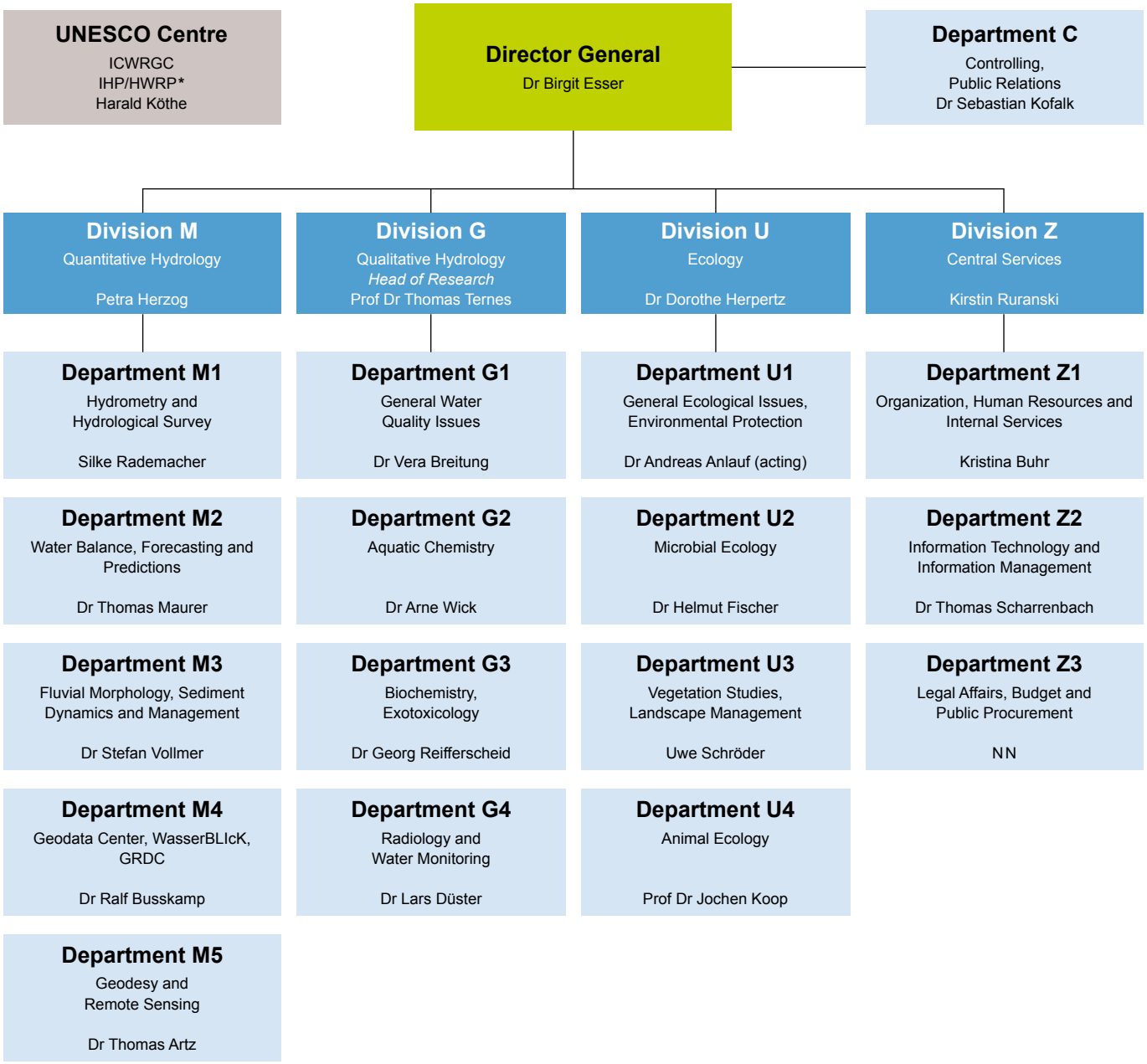
BfG's Scientific Advisory Board:

- Prof Dr Günter Blöschl (Chair), TU Wien, Hydraulic Engineering Department
- Dr Bernd Brügge, Federal Maritime and Hydrographic Agency
- Dr Norbert Salomon, BMDV, Directorate General "Waterways and Shipping"
- Dr Dirk Engelbart, BMDV, Division "Environmental Protection for the Waterways, Climate Change Adaptation, Hydrology, BfG"
- Sebastian Messing, GDWS, Directorate "Environment, other Waterways"
- Prof Dr Daniel Hering, University of Duisburg-Essen, Faculty of Biology/ Aquatic Ecology
- Prof Dr Kai Jensen, Universität Hamburg, Department of Biology, Applied Plant Ecology
- Dr Adriano Joss, Eawag, Department Process Engineering (CH)
- Dr Jan Kayser, Federal Waterways Engineering and Research Institute
- Prof Dr Heribert Nacken, RWTH Aachen, Department of Engineering Hydrology
- Prof Dr Rita Triebskorn, University of Tübingen, Institute of Evolution and Ecology

Scientific Advisory Board of the German National Committee for the International Centre for Water Resources and Global Change:

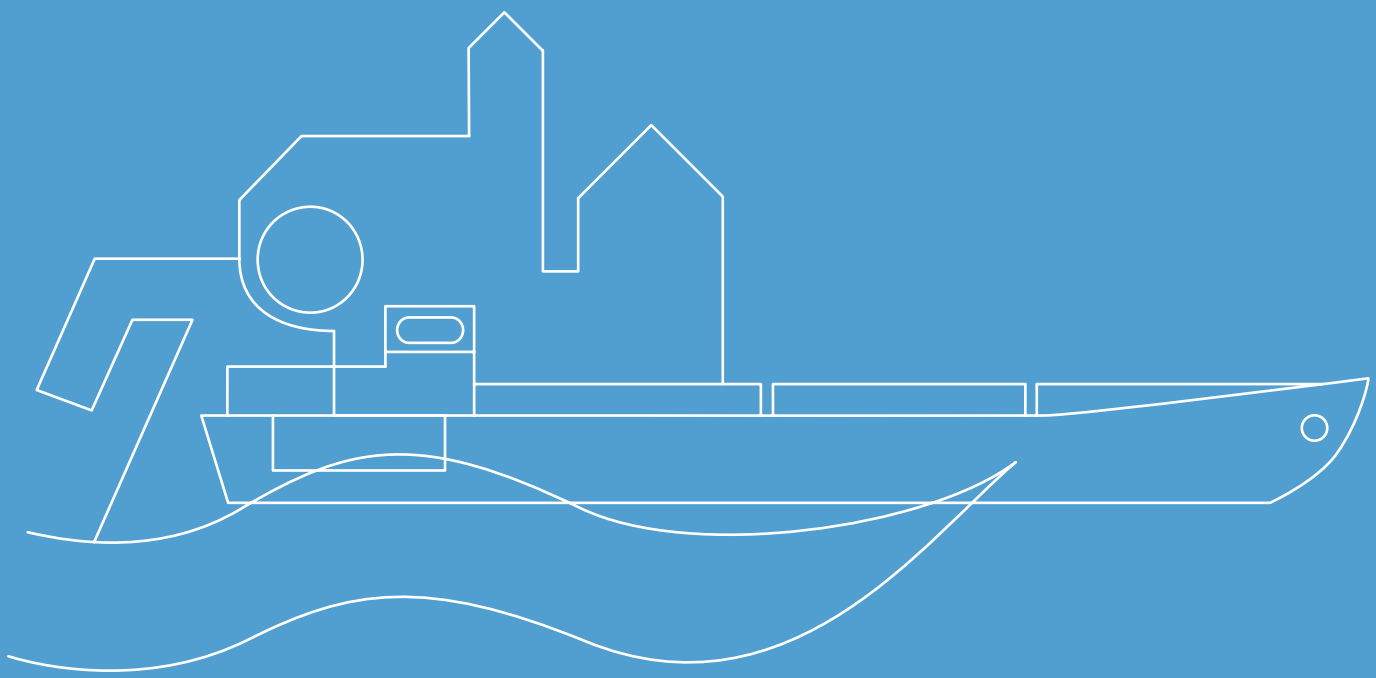
- Prof Dr Mariele Evers, University of Bonn, Department of Geography (Chair)
- Prof Dr Bodo Ahrens, Goethe University Frankfurt, Institute for Atmospheric and Environmental Sciences
- Prof Dr Dietrich Borchardt, Helmholtz-Centre for Environmental Research – UFZ, Department of Aquatic Ecosystem Analysis
- PD Dr Jörg Dietrich, Leibniz University Hannover, Institute of Hydrology and Water Resources Management
- Prof Dr Markus Disse, Technical University of Munich, Chair of Hydrology and River Basin Management
- Prof Dr Petra Döll, Goethe University Frankfurt, Institute of Physical Geography
- Prof Dr Nicola Fohrer, Kiel University, Ecology Centre, Department of Hydrology and Water Resources Management
- Prof Dr Elisabeth Imgard Meyer, University of Münster, Institute for Evolution and Biodiversity
- Prof Dr Heribert Nacken, RWTH Aachen, Department of Engineering Hydrology
- Prof Dr Stefan Wohnlich, Ruhr-Universität Bochum, Institute for Geology, Mineralogy and Geophysics
- Dr Helmut Löwe, Federal Ministry of Education and Research
- Dr Andreas Becker, Deutscher Wetterdienst
- Dr Claudia Heidecke, Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Coordination Unit Climate
- Petra Herzog, BfG
- Prof Dr Thomas Himmelsbach, Federal Institute for Geosciences and Natural Resources (BGR)
- Bernd Mehlig, North Rhine-Westphalia Office of Nature, Environment and Consumer Protection (LANUV)
- Mathias Weiland, Saxony-Anhalt State Office for Flood Protection and Water Management (LHW)

Organisational structure



* International Centre for Water Resources and Global Change and Secretariat for the IHP/HWRP National Commitee chaired by the Federal Foreign Office

Status as of 26 April 2022



Perceiving waterways as lifelines.
Harmonising economic and human activities with nature.
Within Germany and beyond. **www.bafg.de**