

hydrolink

EXTREME FLOODING EVENTS



International Association
for Hydro-Environment
Engineering and Research

Hosted by
Spain Water and IWHR, China

IAHR.org

Angelos N. Findikakis
Hydrolink Editor

Alastair Barnett
Guest Editor

EDITORIAL



The present issue of Hydrolink focuses on some of the catastrophic extreme floods in different parts of the world earlier this year. Even though it is not possible to attribute any specific event to climate change, the number, magnitude and frequency of such events point to the logical conclusion that we have entered an era of higher flooding risks. According to the United Nations Office for Disaster Risk Reduction, the number of major floods in the period 2000–2019 has more than doubled compared to the previous twenty years (1980–1999)¹. The most recent report on the physical science basis of climate change released last August by the Intergovernmental Panel on Climate Change (IPCC) concluded that the intensity and frequency of heavy precipitation over land is expected to increase under all Shared Socio-economic Pathways (SSPs) considered in this report, being more severe for the SSPs resulting in higher global temperature rise.

This issue of Hydrolink includes four articles on heavy precipitation events and the flooding they caused in different parts of the world in mid-July of this year. The first two of these articles discuss the catastrophic flooding in Germany and Belgium caused by the extreme rainfall of a low-pressure system that passed over Central Europe. The article by Daniel Bung examines the flooding in the western part of Germany along the Rivers Ahr and Erft which caused a large number of fatalities. It discusses this event in the context of historical information and comments on uncertainty in the estimation of return periods due to the length and in some cases the accuracy of the historic record, emphasizing that hydrologic analyses must be revisited routinely and design floods for protection measures and structures must be updated as new data are added to the record. As sustainable solutions for future flood protection of the affected areas are sought, it is imperative to revisit the assessment of hazards and risks.

Benjamin Dewals, Sébastien Erpicum, Michel Piroton and Pierre Archambeau discuss the extreme floods in the Belgian part of the River Meuse basin caused by the same mid-July weather system. They point out that even though the rainfall intensity over short durations was not exceptionally high, the average intensity over one to two days far exceeded what was previously thought to be the design intensity for these durations. They also notice that even though peak discharges in the Meuse were not extreme, in some of the tributaries peak discharges were very high, in one case exceeding what was thought to be the 100-year flow by a factor of three. This event made it clear that the present flood hazard maps are inadequate, and they must be revised, and that there is a need to improve reservoir management to provide greater flood protection.

Just two days after the major flooding events in Europe, very heavy rainfall poured over Henan province in China, with the city of Zhengzhou receiving in one day close to its historic annual precipitation. Xiaotao Cheng and Jindong Cai describe the flooding caused by this event and comment on evolving flood risks in the area resulting from the combination of climate change and land use changes due to economic development and rapid urbanization. They also discuss ongoing efforts and proposals in China to strengthen the capacity building for identifying flood risks, accurate weather forecasting and information sharing, emergency rescue and resilient reconstruction.

In between these closely spaced events, very heavy precipitation in the Marlborough Region of the South Island in New Zealand caused near-record flows in the Wairau River, which tested the existing flood protection scheme to the limit. Geoff Dick, Mike Ede, Duc Nguyen and Val Wadsworth discuss how the flood protection scheme for the Wairau River basin performed well with relatively minimal damage to houses and roads, and key highway and railway bridges survived with only minor damage. There were three localized stopbank (dyke) failures, but modern upgraded stopbanks stood up very well, withstanding significant overtopping in places. Effective response to future major flooding events depends in part on the ability to forecast peak flows. Because currently available forecasting models underpredicted the size of the July flood, an effort is under way to improve these models and collect more data for their calibration. As part of this effort velocity data were collected during the July event using different techniques including Acoustic Doppler Current Profilers (ADCP) and Space Time Image Velocity (STIV) gauging.

Considering the events discussed in these four articles and many similar disastrous floods around the world the IAHR Technical Committee on Flood Risk Management is working on a White Paper summarizing the state of knowledge and practice on flood protection and mitigation. This paper will focus on practical flood risk assessment for development projects and is scheduled for release in the second half of 2022. A draft version will be peer reviewed during a special session in the 39th IAHR World Congress in Granada, Spain in June 2022.

1 | UNDRR, 2020: "The human cost of disasters: an overview of the last 20 years (2000–2019), United Nations Office for Disaster Risk Reduction"



IAHR HYDROLINK 4 | 2021

IAHR International Association for Hydro-Environment Engineering and Research

IAHR Global Secretariat

Madrid Office

Paseo Bajo Virgen del Puerto, 3
28005 Madrid, SPAIN
T +34 91 335 7908 | F +34 91 335 7935

Beijing Office

A-1 Fuxing Road, Haidian District
100038 Beijing, CHINA
T +86 10 6878 1128 | F +86 10 6878 1890

iahr@iahr.org

www.iahr.org

Editor

Angelos Findikakis

Bechtel, USA | anfindik@bechtel.com

Technical Editors

Joe Shuttleworth

Cardiff University

Sean Mulligan

National University of Ireland Galway

Editorial Assistant

Estibaliz Serrano

IAHR Publications Manager | publications@iahr.org

Guest Editor

Alastair Barnett

Hydrolink Advisory Board

Luis Balairon

CEDEX | Ministry Public Works, Spain

Jean Paul Chabard

EDF Research & Development, France

Jaap C.J. Kwadijk

Deltares, Netherlands

Henrik Madsen

DHI, Denmark

Rafaela Matos

Laboratório Nacional de Engenharia Civil, Portugal

Yasuo Nihei

Tokyo University of Science, Japan

Jing Peng

China Institute of Water Resources and Hydropower
Research, China

Patrick Sauvaget

Artelia Eau & Environnement, France

James Sutherland

HR Wallingford, UK

Karla González Novion

Instituto Nacional de Hidráulica, Chile

Cover picture: Aerial view of River Meuse basin flooding
close to Liege. ©Christophe Breuer, University of Liege

ISSN: 1388-3445



100

IAHR > END OF YEAR MESSAGE

IAHR from 2021 towards the future

By Joseph Hun-wei Lee and Tom Soo



104

IN DEPTH > EXTREME FLOODING EVENTS

Extreme floods in Belgium

By Benjamin Dewals, Sébastien Erpicum, Michel Pirotton
and Pierre Archambeau



108

Extreme flooding in Western Germany: Some thoughts on hazards, return periods and risk

By Daniel B. Bunge



114

Challenges of extreme rainstorm events and countermeasures in China

By Cheng Xiaotao and Cai Jindong



118

The Wairau River Flood of July 2021

By Geoff Dick, Mike Ede, Duc Nguyen and Val Wadsworth



122

Developing chinese fish passage: testing and simulation technology

By Xiaogang Wang, Yun Li and Nanbo Tang



125

STRENGTHENING DIVERSITY AND GENDER EQUITY

Famous women in hydraulics Pelageya Yakovlevna Kochina



126

IAHR PEOPLE

In-memoriam Peter Ackers

By John Ackers and Graham Thompson



GUEST EDITOR

Alastair Barnett

Dr Barnett has long experience of modelling water infrastructure projects worldwide, and in 2019 he provided technical reviews of international modelling in the WWDR 2020 "Water and Climate Change" report to the United Nations.

He has been commissioned for international feasibility modelling reviews by institutions such as the World Bank, the Asian Development Bank and the European Investment Bank.

He currently chairs the IAHR technical committee on Flood Risk Management.

An aerial photograph of a large industrial port or refinery complex, featuring numerous storage tanks, processing units, and shipping docks along a waterfront. The image is overlaid with a futuristic network of white lines and glowing nodes, suggesting a digital or interconnected theme. The sky is overcast, and the water is a deep blue.

IAHR_FROM 2021 TOWARDS THE FUTURE

By Joseph Hun-wei Lee and Tom Soo

IAHR FROM 2021 TOWARDS THE FUTURE

Joseph Hun-wei Lee
President

Tom Soo
Executive Director



The Earth's hydro-environment is central to global sustainable development and ecological well-being. Economic growth, social progress and environmental protection are all driven by the improved understanding and management of our water resources and aquatic ecosystems.

The world faces increasing challenges – including a world population that is likely to reach 9 billion within the next 30 years, more urbanized and prosperous and placing ever greater demands on our resources. This recent COP26 climate declaration calls to keep 1.5 °C within reach, whilst at the same time recognising the difficulties that countries shall face to combat the increasing risks and intensities of extreme events such as floods, droughts or changed precipitation regimes. Other key global challenges for the hydro-environment community include food security, energy production as well as putting biodiversity back onto a path of recovery¹.

The science and engineering of water and related infrastructure in harmony with our environment –from local to system wide scales– is essential to identifying and optimising our approaches to combat these challenges. IAHR must continually improve by galvanising the latest research and innovation, practical knowledge, and experience to make a distinct mark. Our association has a long and proud history of doing so by bringing together the world's community of engineers, experts, researchers and organisations to accelerate solutions and knowledge discovery. 2021 was a crucial year at the mid-point of the implementation of IAHR's four-year strategic plan. The 2020-2023 strategic plan sets out an ambitious agenda to:

- Provide a world class networking platform for hydro-environment experts, researchers and practitioners.
- Inspire, disseminate and catalyse state of the art knowledge and thinking.
- Convene events that set agendas and amplifies our collective knowledge.
- Act as a global voice for the hydro-environment community on the most pressing challenges of our times.

The promise of new knowledge and technologies gives rise to fresh perspectives and game-changing ways to address global hydro-environment problems. The acceleration in the adoption of sensors and remote information gathering has contributed to a global and exponential increase in data generation. When combined with the rapid advances in computing power and connectivity, this availability of Big Data gives rise to opportunities in digital water futures – a trend which will increasingly influence the management of the hydro-environment via static and real time data, modelling, hydro-informatics and artificial intelligence.

In the first two thirds of the twentieth century, the solution to all water problems was perceived to be through infrastructure projects and the harnessing of perceived unlimited and renewable water resources. This traditional "grey" approach has long been replaced by the science and practice of engineering our global solutions in harmony with nature. The fast-emerging field of ecohydraulics and nature based solutions is playing a crucial role to improve our understanding of the complex interface between human activities and the aquatic environment and the subsequent suite of solutions and best practices.

This year's United Nations World Water Development Report² explicitly affirms that "the value of water to society is underpinned by hydraulic infrastructure, which serves to store or move water, thus delivering substantial social and economic benefits" and that "Socioeconomic development is curtailed in countries that have insufficient infrastructure to manage water". Hydraulics for sustainable development now gives new life to technical feats for which IAHR members are uniquely qualified. Holistic water solutions of the future require us to consider infrastructure and water flow interactions that take into consideration social and economic influences whilst leveraging state of the art knowledge, technological advances and digitalisation. Hydraulic engineering and research directly contributes to several of the United Nation's Sustainable Development Goals (SDG's) extending beyond water supply and sanitation to also include global energy needs, food security, urban management, coastal protection amongst other complex interconnected systems³.

The improved science behind the latest major report of the Intergovernmental Panel on Climate Change⁴ re-affirms and clarifies the long-anticipated changes in precipitation regimes – even if we are able to keep global warming to the 1.5 °C target as set in the Paris Agreement of 2015. This estimates that heavy precipitation events over land will occur with 1.5 times more likelihood and with an intensity that is more than 10% greater on average than in a climate without human influence. With estimates that up to 10% of the global greenhouse gas emissions are derived from the water sector⁵, IAHR communities have a critical role to play in mitigation efforts as countries seek hydro-environment pathways to carbon neutrality; as well as measures to improve climate change adaptation and resilience building.

Over the past year, the world has been obliged to continue to face the constraints of a one-in-a-hundred year global pandemic. IAHR has emerged by maintaining a strong rhythm of activity – no doubt thanks to the incredible energy of its members and innovating new ways of working together. Highlights have included the development

of new digital platforms and numerous online events such as the inaugural IAHR Online Forum in July, which was attended by major institutions, companies and influential experts from around the world. Throughout 2021, these and other events mobilised successfully the participation of the IAHR Technical Committees, Regional Divisions and specialist Working Groups. Building on the successful revamp of the IAHR online system last year, the IAHR knowledge expertise in the form of hundreds of presentations can now be tapped at any time online on-demand. Webpage visits to these sessions have extended well into the tens of thousands – this is indeed a testimony to the vibrancy of the IAHR hydro-environment community and its knowledge sharing and networking platforms.

High quality publications are a vital part of our association's DNA, and with the recent completion of a major comprehensive review into the entire portfolio of IAHR publications and knowledge products.

This will pave the way for a renewed approach to IAHR's academic journals, Hydrolink's renewed focus on linkage with practitioners and industry, and a new series of IAHR monographs.

Further globalising IAHR's outreach shall be another focus in the coming years. IAHR currently has members from countries all around the world and a rich history of interaction via our regional divisions. The past year saw successful hybrid and online Regional events in Europe and Latin America hosted by Warsaw, Poland and Mexico, as well the IAHR-APD conference in late 2020 hosted

in Sapporo in Fall 2020. We will continue to invigorate the strategic direction of engagement with the African continent - where still only 30% of the sub-Saharan population have access to safe drinking water⁶, where irrigation potential is still largely under-developed, and with large untapped hydropower potential (11% currently utilised⁷). There exist many opportunities for IAHR to meet the substantial needs to exchange knowledge, build expert capacity and strengthen professional development by working with local partners in Africa.

IAHR's commitment to a strong and vibrant technical community is underpinned by the belief that the association's future can only be strengthened by diversity. The association's Task Force on Strengthening Diversity and Gender Equity has set concrete objectives to encourage the participation of women in engineering and ensure diversity in terms of gender, interests, age and background. A strategic priority is to further institutionalise the participation of women and different groups in IAHR communities. IAHR now also has some 51 Young Professional Networks around the world. The IAHR Young Professional Congress is now a signature IAHR activity, as are new initiatives that recognise and award the talent of young hydro-environment professionals. Meaningful engagement with the hydro-environment community is a cornerstone to a successful future for our association. Indeed, good governance is a foundation of IAHR's strength and this year saw the implementation of a revitalised Constitution and Bylaws approved at the Panama Congress.



The new Council which met for the first time in November includes the Chairs of all of the association's Regional Divisions and Technical Committees, the Editors of our publications as well as regional youth representatives. Bringing together diverse perspectives of an intellectual powerhouse boosts IAHR's capacity to contribute to hydro-environment solutions.

By accelerating the discovery of knowledge, IAHR and the global hydro-environment community has more to contribute than ever to the major development challenges of our times! As we move

towards 2022, the IAHR World Congress which shall take place from 19-24 June in Granada, Spain will hopefully become the long awaited opportunity for many of us to re-connect face-to-face. There are new digital possibilities to exchange knowledge; and a renewed energy and focus on important topics such as climate change adaptation and carbon neutral pathways, digital water futures and artificial intelligence, or engineering solutions in harmony with nature, or hydraulics for sustainable development.

We look forward to working with you in 2022!

-
- 2 | 2021 Kunming Declaration, <https://www.cbd.int/doc/c/99c8/9426/1537e277fa5f846e9245a706/kunmingdeclaration-en.pdf>
 - 2 | The United Nations World Water Development Report 2021: valuing water, <https://unesdoc.unesco.org/ark:/48223/pf0000375724>
 - 3 | IAHR White Paper. Hydraulic Structures at a Crossroads Towards the SDGs, <https://www.iahr.org/library/download-paper-file?code=LbBkQe03ps>
 - 4 | AR6 Climate Change 2021: the Physical Science Basis, <https://www.ipcc.ch/report/ar6/wg1/>
 - 5 | Global Water Report 2020, <https://www.cdp.net/en/research/global-reports/global-water-report-2020>
 - 6 | <https://sdg6data.org/region/Sub-Saharan%20Africa>
 - 7 | 2020 Hydropower Status Report, https://hydropower-assets.s3.eu-west-2.amazonaws.com/publications-docs/2020_hydropower_status_report.pdf



Extreme floods in Belgium

The July 2021 extreme floods in the Belgian part of the Meuse basin

By Benjamin Dewals, Sébastien Erpicum, Michel Piroton and Pierre Archambeau

The floods which occurred in July 2021 in the Belgian part of the Meuse basin were the highest on record along many tributaries. The combination of such extreme flows with a floodplain vulnerability comparable to the current one is unprecedented. This led to a high number of casualties, partly due to substantial surprise effects. In this article, the exceptional nature of the floods is highlighted, and some implications for flood risk management are discussed.



Credit: J. M. Lambotte, University of Liege

Context and impacts

The Meuse is a transboundary river, which flows from south to north across parts of France, Belgium, and Netherlands¹. Exceptional rainfall which affected several European regions in July 2021 led to disastrous floods along a number of tributaries of river Meuse, including river Ourthe, Amblève and, above all, river Vesdre (**Figure 1**).

The flood-induced impacts in Belgium led to 39 fatalities due to drowning, more than 20 of them in the Vesdre catchment alone. Hundreds of buildings were either washed away or faced so extensive structural damage that they need to be demolished. Thousands more residential buildings were substantially damaged, leading to extensive intangible damages, especially for younger people. Not only the housing sector, but also companies and public infrastructures faced unprecedented damages. More than 200 bridges need repair, many railway tracks were disrupted and kilometres of gas, drinking water and electricity supply networks were destroyed. This leads to indirect impacts which extent far beyond the affected valleys and will last for months until reconstruction of infrastructures is over. Damages to infrastructures can be related to a great extent to bank failures, scour, and other morphodynamic effects.

In this article, we quantify the event in terms of rainfall intensity and river discharge, and we reflect on the causes of such record-high impacts as well as on some implications for improved flood risk management.

Extreme long duration of high intensity rainfall

In the South East part of Belgium, the maximum cumulated precipitation volumes over 24 hours between 13 and July 16 July reached almost 200 mm at some locations. This value corresponds roughly to twice the monthly precipitation. Return periods estimated by the Belgian meteorological institute exceed by far 200 years in the upper part of the Vesdre catchment. Precipitation volume cumulated over 48 hours was slightly below 300 mm, and it was record-high not only in the Vesdre catchment, but also further south-west in the Amblève and Ourthe catchments (**Figure 1**).

Figure 2 shows Quantity – Duration – Frequency curves corresponding to the location of one of the rain gauges in the upper part of the Vesdre catchment. The circle symbols represent the cumulated volumes during the July 2021 flood event. They reveal that precipitations cumulated over relatively short durations, such as 10 min, 20 min... up to about one hour, did not lead to exceptional quantities. Most of these markers do not even reach the curve corresponding to a two-year return period (**Figure 2**). In contrast, for precipitation volumes cumulated over one to two days, the values skyrocket, and they greatly exceed the 200-year return period. This unprecedented long duration of high rainfall intensities is what made the July 2021 meteorological event extreme and exceptional.

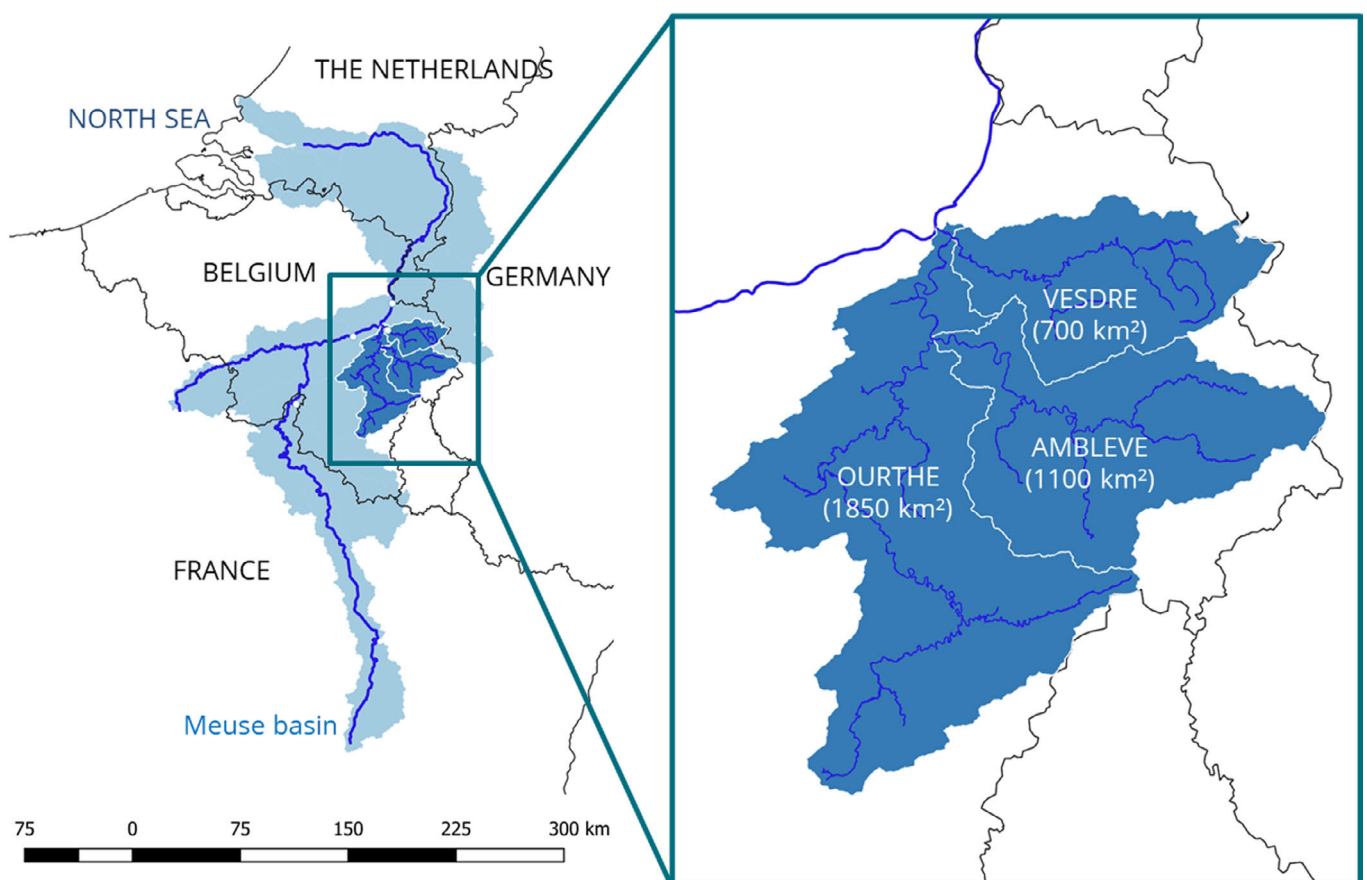


Figure 1 | Transboundary Meuse basin, and details of three of the most affected catchments: Ourthe, Amblève and Vesdre (data: European Environment Agency, Eurostat).

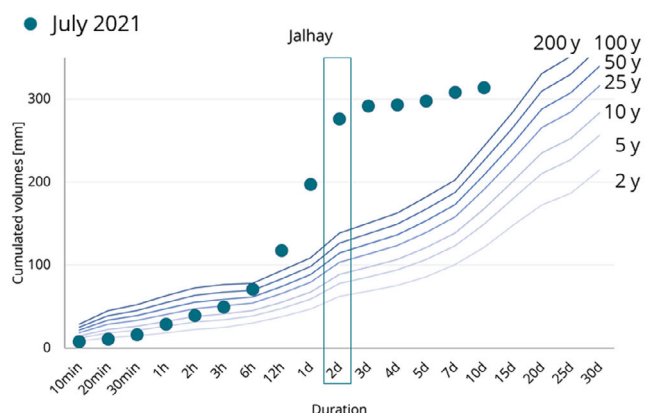


Figure 2 | Quantity-duration-frequency curves at the rain gauge “Jalhay” in the upper part of the Vesdre catchment, and cumulated volumes (circle markers) observed during the flood event in July 2021 (data: Service Public de Wallonie SPW-MI, Belgian Royal Meteorological Institute).

Extreme flows in the tributaries

In the upper part of the Meuse basin (southern part in [Figure 1](#)), the flood wave was not exceptional. For instance, at the French-Belgian border, the peak discharge was about half of that during another major flood event in 1993, which corresponds roughly to a 100-year flood. In contrast, further downstream, the peak discharges observed in July this year are comparable to those of 1993. At the Belgian-Dutch border, the currently estimated 100-year flood was even exceeded. These patterns are perfectly consistent with the spatial distribution of rainfall, which lead to higher rainfall volumes over the catchments of the tributaries situated in the middle part of the Meuse.

While the peak discharges in the Meuse were not extreme, the flow gradient over time was exceptional. During the summer flood in 2021, the discharge in the Meuse rose by 3000 m³/s in just two days. In contrast, in winter 1993, the rise was 2000 m³/s in about three days.

In the river Ourthe, which is the main tributary of the river Meuse, the observed peak discharge upstream of the Vesdre river confluence was by far the highest on record. The observed peak is estimated to have exceeded 1,100 m³/s, which is about a quarter more than the currently estimated 100-year discharge, and it is 50 % above the second highest observed peak discharge (1993). Such extreme flood peaks were also recorded along nine other rivers in the Belgian part of the Meuse basin, for which the observed peak discharges in July this year were the highest on record at virtually all gauging stations.

Along the river Vesdre, which was most affected, all four existing gauging stations were either washed away by the flood, or failed for another reason (e.g., loss of power supply).

Nonetheless, the partially available time series suggest also a very extreme flood wave. This is also confirmed by ongoing hydrological assessment of the event which suggests that the currently estimated 100-year flood may have been exceeded by a factor of three at some locations along this river. Similarly to the situation on the Meuse river, flow gradients were also exceptional compared to what was already measured on this river. These elements certainly led to surprise effects at various levels.

Surprise effects and implications for flood risk management

Available flood hazard maps display four levels of hazard, ranging from very low to high hazard². These levels of hazard are defined based on a combination of estimated submersion depths and frequency of occurrence of floods. In many floodplains, the flood extent displayed on the existing flood hazard maps matches well the inundated areas observed in the field. However, there are also remarkable exceptions, particularly in a town (Verviers) of roughly 50,000 inhabitants situated along river Vesdre. This town is currently not mapped as a flood-prone area, not even in the category “very low” hazard; but on 14-15 July, the centre of the town was terribly devastated, with flow depths above 2 m, and significant flow velocities, leading to the entrainment of tens of vehicles. This acted as a surprise, not only for the citizens who were not aware of the risk, but also for a number of authorities, including those in charge of deciding and organizing emergency evacuations from the floodplains. This may have contributed to the increase in the death toll in this area.

There are several explanations for the mismatch between the flooded extent and the hazard maps. First, the hydrometeorological event was indeed extreme. It was far beyond all the scenarios considered in the current flood hazard mapping procedures. This hints at the possible need for a revision of current flood hazard maps, considering more extreme scenarios as they are becoming more frequent, as well as for improved communication about the true meaning of scenario-based flood hazard maps and about inevitable uncertainties affecting these maps. This may foster substantial gains in risk awareness.

Another aspect may be related to the effect of dams located further upstream³, and particularly how these effects are incorporated in flood frequency analyses delivering inputs for inundation mapping. The effects of dam operation are known to differ significantly between relatively frequent floods and extreme events. The flood control capability of the dams is reduced when events become more extreme. This may lead to strongly nonlinear effects in the flood frequency distributions, which need to be accounted for to enable reliable estimation of extreme discharges in river reaches located downstream of large reservoirs.

In terms of crisis management, there is also room for improvement in the management of large reservoirs, to maximize the chance that these reservoirs succeed in reducing the peak flows, delaying flood waves to avoid superposition of the peaks, and reducing the flow gradients to facilitate evacuation and the setting up of precautionary measures. In the current configuration of the Vesdre valley, pre-releases at the dams one or two days before an event are likely to cause substantial damages in the downstream valley. At the time of reconstruction, rethinking the spatial planning in this valley so that emergency releases from the dams are made possible without damage may help avoiding another disaster. In the case of reservoirs aimed primarily for drinking water supply, widely accepted tools for balancing flood risk and risk of water scarcity are needed to achieve more objective decision-making during an event.



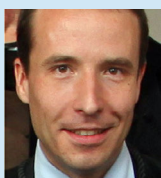
Figure 3 | Role of debris in damming part of the river section, affecting flow depths upstream and leading to flow contraction, scour, and high local damages (river Vesdre, upstream of Verviers). Credit: J. Mawet

This highlights the need to integrate flood and drought risk management.

Evidence from the field shows that debris and floating objects played a major role in damming a portion of the river section upstream of many bridges, which affected flow depths upstream and caused damage through severe scour at many nearby bridges (Figure 3). How to properly account for these effects in hazard mapping and risk assessment is another important question raised by the recent events. Similarly, hundreds

of cars and fuel tanks were washed out by the flood, leading to pollution of large agricultural areas... Progress is needed on how to predict and model such widespread contamination.

Overall, exceptional floods should act as an agent of change. They give a unique opportunity for improvement at multiple levels, including in crisis management and flood-resilient urban planning. This will require considerable means so that reconstruction moves indeed in the direction of less vulnerable and more resilient floodplains.



Benjamin Dewals

Prof. Benjamin Dewals is a Professor in Hydraulic Engineering and Water Resources Management at the University of Liege where he received his PhD in 2006. His main research interests cover flood risk management, fluvial hydraulics and reservoir sedimentation. He conducted research in several leading European institutions, including at EPFL (Switzerland) and in Germany. He is a member of the IAHR Flood Risk Management Committee.



Pierre Archambeau

Dr Pierre Archambeau obtained his PhD from the University of Liege in 2006, for several new contributions to physically based hydrological modelling and flood hazard modelling. He is continuously working on several hydraulic and hydrological modelling projects and is currently the main developer of the WOLF modelling system, which simulates hydrological flow, fluvial processes and flow on hydraulic structures



Sébastien Erpicum

Dr Sébastien Erpicum is Associate Professor at Liege University, Belgium, where he obtained his PhD in 2006. He is also in charge of the Engineering Hydraulics Laboratory, a large experimental facility in which research activities related to hydraulics and hydraulic structures engineering are developed by means of composite modelling. He is past chair of the IAHR Hydraulic Structures Committee and Belgian representative at the Hydraulics for dams Technical Committee of ICOLD.



Michel Pirotton

Prof. Michel Pirotton obtained his PhD from the University of Liege in 1994. He is currently Full Professor and coordinates a group of about 15 researchers contributing to the development of the modelling system WOLF and to experimental research in hydraulic engineering and fluvial hydraulics.

References

- 1 | Kitsikoudis, V., Becker, B. P., Huismans, Y., Archambeau, P., Erpicum, S., Pirotton, M., & Dewals, B. (2020). Discrepancies in Flood Modelling Approaches in Transboundary River Systems: Legacy of the Past or Well-grounded Choices?. *Water Resources Management*, 34(11), 3465-3478.
- 2 | Mustafa, A., Bruwier, M., Archambeau, P., Erpicum, S., Pirotton, M., Dewals, B., & Teller, J. (2018). Effects of spatial planning on future flood risks in urban environments. *Journal of environmental management*, 225, 193-204.
- 3 | Bruwier, M., Erpicum, S., Pirotton, M., Archambeau, P., & Dewals, B. J. (2015). Assessing the operation rules of a reservoir system based on a detailed modelling chain. *Natural Hazards and Earth System Sciences*, 15(3), 365-379.

Acknowledgement

The authors gratefully acknowledge Service Public de Wallonie (SPW) for the provided data.

Extreme flooding in Western Germany: Some thoughts on hazards, return periods and risk

By Daniel B. Bung

The low-pressure system Bernd involved extreme rainfalls in the Western part of Germany in July 2021, resulting in major floods, severe damages and a tremendous number of casualties. Such extreme events are rare and full flood protection can never be ensured with reasonable financial means. But still, this event must be starting point to reconsider current design concepts. This article aims at sharing some thoughts on potential hazards, the selection of return periods and remaining risk with the focus on Germany.

Background

The low-pressure system "Bernd", which passed Central Europe on 12-15 July 2021, involved persistent and extreme rainfalls focused over the Western part of Germany. In large parts of the affected area, the 72-hour-accumulated precipitation exceeded the total average precipitation for July by a factor of about 1.5 to 2². An overview of rainfall totals, averaged over individual municipalities, is illustrated in [Figure 1](#). The reader may note that maximum rainfall of up to 180 mm was locally noted on Wednesday 14 July 2021 (e. g. 179 mm in Euskirchen-Steinbach). However, the severity of this event was compounded by earlier long-duration low-intensity rainfalls that resulted in the pre-saturation of soils, with an average soil water storage capacity of 10 to 75 mm. Under these conditions, the catastrophic storm resulted in flash floods in smaller water courses and larger rivers experienced major flooding with a tremendous number of fatali-

ties (more than 180 dead in Germany) and severe damages to infrastructure, particularly along the rivers Ahr (Rhineland-Palatinate) and Erft (North Rhine-Westphalia) in the East Eifel area.

Although more damaging floods in continental Europe have occurred in the past 20 years, people and experts worldwide were astonished at the pictures in the media. It is commonly accepted that the probability of this and similar events is extremely low and that significant flooding results in significant damages and corresponding financial losses. However, many questions still remain unanswered. How could these heavy losses occur in a technologically advanced country like Germany? Why have there been so many casualties? Is the level of flood protection in the region insufficient? Why was there no properly functioning early warning system?

The most significant failure that led to this incredible number of casualties was most likely caused by a malfunctioning

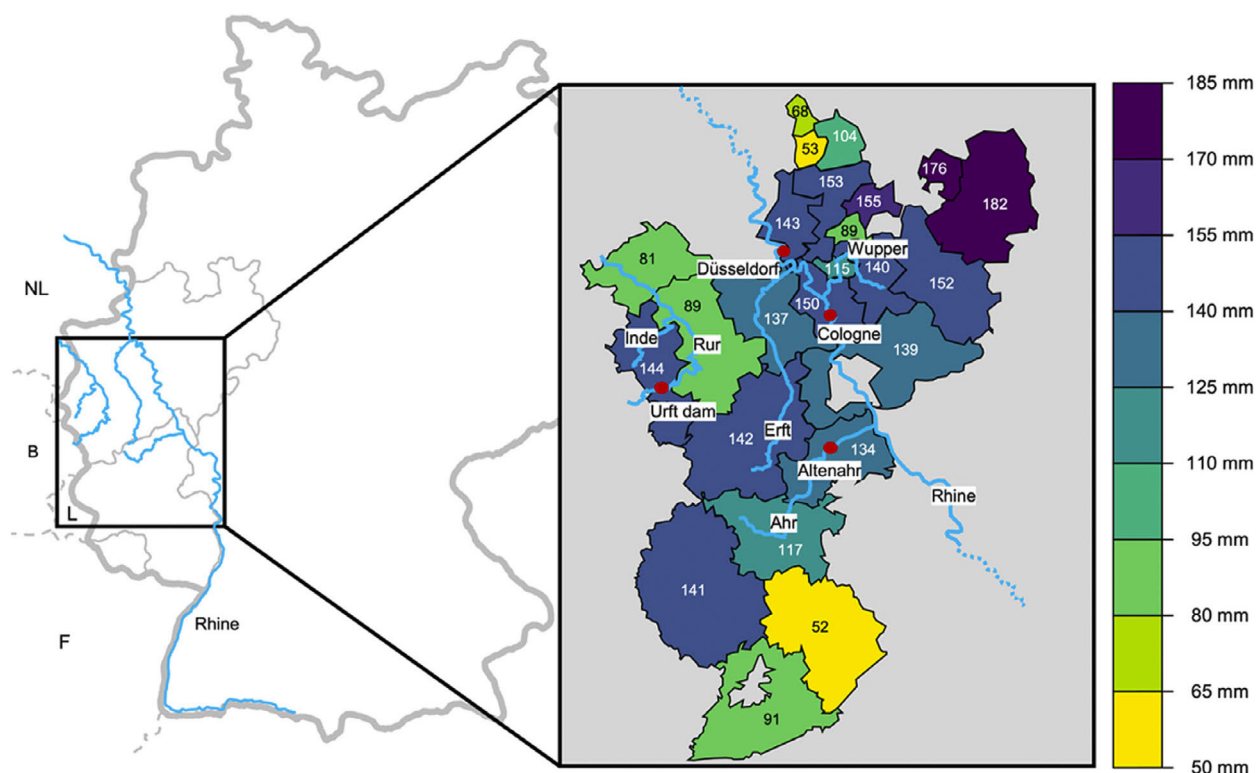


Figure 1 | Overview on areas in Western Germany affected by low-pressure system "Bernd" and 72-hour precipitation totals for individual municipalities³.

warning system and insufficient preparation of rescue services. Timely evacuation can make all of the difference when a significant flood strikes an area, such as the case of Edenville Dam collapse in Michigan, USA. At this stage, improper design or insufficient maintenance of flood protection systems have not been reported. However, from a technical point of view, this flood may be a starting point to reevaluate protection and warning systems and design strategies in the region in anticipation of increasing demands.

Floods induced by extreme rainfalls

In the Federal Republic of Germany, the Federal States are responsible for water management and legislation in their respective territories. In order to harmonize and develop national solutions, the Working Group on Water Issues (LAWA) has been established. After several flash floods in the last decade, LAWA presented a strategic paper in 2018 to develop an effective risk management plan for flooding induced by extreme rainfalls⁴. Flash floods, by definition, are locally restricted events that may be difficult to forecast and which may also occur away from water courses as pluvial flash floods.

The flood event in July, thus, cannot be generalized as a flash flood nor as a not forecasted or surprise event (but still, the LAWA paper emphasizes that extreme rainfalls have been identified as potential hazards in Germany). Indeed, on 12 July different models from German, European and US services forecasted maximum rainfalls of up to 200 mm in a region which covers quite precisely the areas illustrated in [Fig 1](#). However, a forecast is only part of the equation for flood safety managers as they make critical decisions regarding emergency action plans.

Hazards

A key component to any flood system and corresponding management schemes is identifying the hazards and corresponding risks that may be induced by extreme rainfalls. According to LAWA, individual municipalities should identify these areas at small scales by employing approaches of different complexity. The resulting inundation and hazard maps are available on the platforms or webpages of individual municipalities (depending on the State). However, these studies and risk estimates pertain to the specific extreme events that were modeled, which may differ from a pending forecast. Therefore, an advanced approach being implemented by various owners throughout the globe is a real-time platform, meaning that inundation areas and risks are able to be refined or updated immediately before a forecasted event occurs. In reality many municipalities, not just within Germany, have limited resources and may or may not have studies and maps with data gaps let alone the ability to make case-specific estimates. Thus, extreme events such as those equal to a specified fraction of the probable maximum flood may be required in the hope that the resulting estimates are conservative enough to bound real-life events. Also, in the past experts believed that evacuating more people than necessary might lead to traffic accidents and loss of life, but during recent flood events social scientists and flood experts have concluded that under such stresses, the general public is well behaved,

respectful, and probabilities of loss of life from traffic accidents is extremely low.

In the author's opinion, a basic risk-informed study should be conducted for a region, considering historic information, to first identify the areas at highest risks. With this portfolio, resources can be allocated where the most improvement in public safety and flood protection can be made. For example, areas which are known to be at risk from earlier recorded flood events or eventually from historic data (as highlighted below) merit action before areas of low risk (i.e., low probability of occurrence, low estimated hazards). For the river Ahr, for instance, a recent event on 2 June 2016 demonstrated the river basin's sensitivity to extreme rainfalls: In Altenahr (catchment: 746 km²), a municipality which was massively affected by the flood, the water level increased from roughly 90 cm to 371 cm within less than one day, corresponding to a peak discharge of 236 m³/s which was later identified to be in the order of a 100-year flood (mean discharge of 6.9 m³/s). In many urbanized areas and metropolitan cities, protection against the 100-year return period event is a minimum standard. However, the situation in much of Europe and other areas around the globe with longer histories of civilization is that past extreme floods may be forgotten as populations continue to grow and urbanization has expanded over the past 200 years.

Selection of return periods

When considering extreme hydrologic events, in Germany, design discharges and water levels for hydraulic structures are determined for a storm representing a specific return period. Flood protection works on rivers are designed according to the German standard DIN 19712, proposing certain return periods depending on the vulnerability in affected areas. If exposure and vulnerability are high, the design return period is commonly chosen as 100 years; while for several minor categories, shorter return periods are proposed. However, indicated return periods provide guidance values only and may be adapted to different locations with varying demands.

Yet, it may be a question of design philosophy if the deterministic methods to predict such return period events are limited by not considering site specific conditions and the latest data. Furthermore, would such a return period concept provide an adequate level of flood protection, or a risk-based analysis could conclude that higher protection is needed? For example, would it be concluded that a hydrologic event of 1,000 years return period is sufficient or an even more extreme, the site-specific Probable Maximum Precipitation (PMP) and corresponding Probable Maximum Flood (PMF) may be required? Indeed, in other countries the PMP and PMF design events prescribed by regulations have been, at times, replaced with an incremental risk-based approach that considers many return period storm events and corresponding hazards but then balances this information with public safety and finite resources for rehabilitation projects.

According to IPCC, it is commonly distinguished between "risk", "hazard", "exposure" and "vulnerability".

The selection of a return period on the basis of the exposure / vulnerability as the only criterion inevitably involves different safety or risk levels at different locations and careful consideration of the uncertainty linked to those metrics. For steep and narrow catchments, such as those along the river Ahr, the hazard is certainly high due to short and peaky hydrographs with deep flood waters and high flow velocities when compared to floods in the plain areas. Could we in Germany try to provide safety levels as a function of both, hazard and exposure / vulnerability, particularly for comparable catchments and historically flooded areas? The implementation of such approach will surely be challenging and as is the case with many civic projects, lessons learned from the events in July 2021 will take time to implement. However, any temporary or permanent increase of flood protection measures could help to increase available evacuation times and to save lives. In the case of Bernd event, the media reported that many fatalities were a result of unevacuated persons trapped in their homes that collapsed during the flood.

A common flood control structure is the simple weir. For the hydraulic design of weirs, the related German standard DIN 19700-13 was recently revised and now implements the aforementioned suggestion: A return period of up to 1,000 years is proposed depending on the exposure / vulnerability of the surrounding area and the head as a variable representing the hazard arising from the collapse of the structure. For larger dams, in contrast the return period is still a function of storage volume and dam height only and thus it may be as large as 10,000 years.

Operation of Hydraulic Structures

The operation of hydraulic structures during an extreme event is filled with uncertainty and potential consequences. How much water is coming? How much must be released in advance? What flooding downstream will the releases cause? Do I have time and will I be able to operate the dam effectively if I delay my decision?

During the flood in July 2021, spillways of several dams were set in operation. Fortunately, no major damages or dam failure took place (although a few dams were close to collapse). **Figure 2** shows a photograph of the stepped spillway (width of 91 m) at the Urft dam in the area of Aachen, which was built in the early 1900s. The design discharge of 289 m³/s for the presumed 10,000-years flood was exceeded (exact discharge measurements were not possible; the discharge was estimated to be approximately 320 m³/s by the depth-capacity curve of the Rur reservoir located downstream of the Urft dam) and the water was close to overtopping the dam. Major efforts will be needed to review hydrological conditions and resulting design discharges (profiting from the data of July 2021) and, eventually, adapt any deficient spillways and outlets. Besides the use of measured data, DIN 19700 also suggests the consideration of historic data for validation of extreme design discharges. Certainly, for large dams such historic data is absolutely rare. However, if available, this data could be included to extend the available time series rather than for validation purposes only.



Figure 2 | Flood discharge (specific discharge approximately 3.5 m³/s) at Urft dam in the morning of 15 July 2021, the design discharge of 3.17 m³/s for a 10,000 year flood was exceeded, leading to significant overtopping of spillway sidewalls.

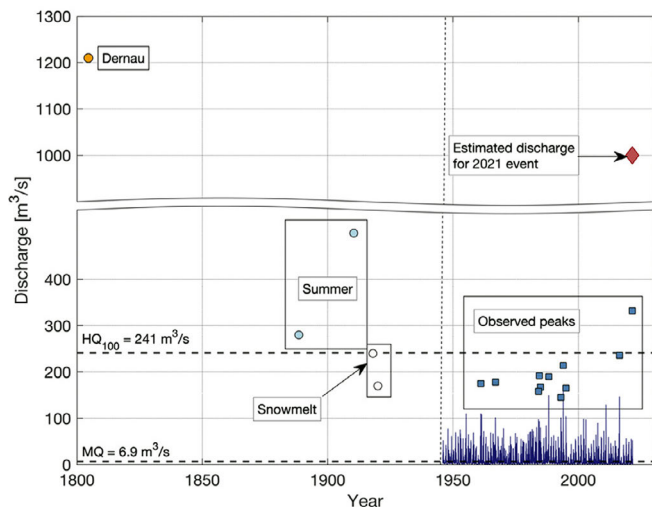


Figure 3 | Measured daily discharges (1945 to 2021), ten highest peak discharges (square markers), estimated discharge for 2021 event and reconstructed historic discharges (round markers, note that the historic floods include two events caused by snowmelt and one event in Dernau, located further downstream from Altenahr).

The flood in historical context: determination of design discharges

According to the European Floods Directive (FD), flood hazard and risk maps shall cover inundation areas and potential consequences for flood events with different return periods, among which extreme event scenarios must be considered. However, the return period of such an extreme event is not further specified and related discharges (HQ_{extreme}) in Germany are commonly estimated by a multiple of HQ_{100} , i. e. the 100-years flood, with consideration of a scaling factor in the range of 1.3 to 1.4. Obviously, the effective return period and, thus, the underlying safety level may again significantly differ for different catchments and locations⁶. The motivation for this very simplified method may be due to the statistical uncertainty for extreme value estimations, particularly due to the relatively short time series being available. Acceptable uncertainty is commonly expected for estimation of extreme values if the available systematic (measured) time series is stationary and of a length of at least 1/3 of the required return period. For instance, estimation of a 200-years flood peak discharge, which is mostly assumed to roughly represent HQ_{extreme} , requires a time series of at least 67 years. The German manual DWA-M 552 ("Determination of flood probability") recommends the consideration of historical observations if the length of available time series is insufficient. For sure, historical data is rare and the uncertainty of any statistical analysis depends on their accuracy while potential trends, e. g. due to climate change, are difficult to identify. This is why in some areas, hydrologic analyses are routinely revisited, flow gauging stations scrutinized for accuracy, and design floods are updated as each year is a new period of record.

The effect of including historical data is demonstrated hereinafter for the river gauge of Altenahr, which has been installed in 1945. After the major flood event in 2016, HQ_{100} was updated from 220 m³/s to 241 m³/s. Following the recommendations, estimation of a 200-years flood is possible with

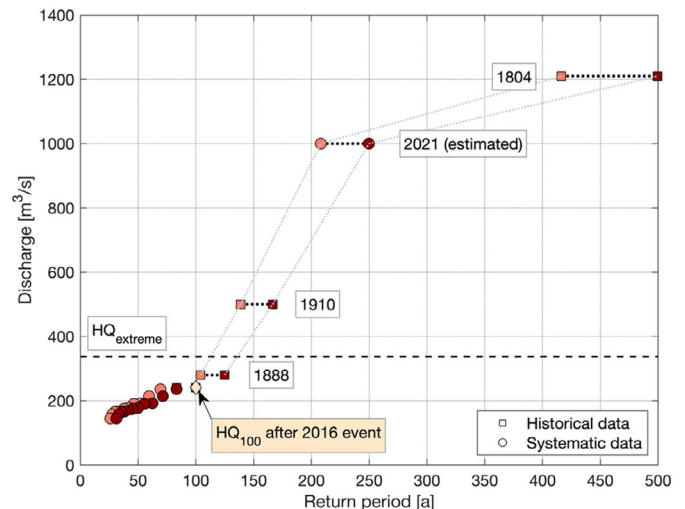


Figure 4 | Empirical return periods (Weibull plotting positions) for historic flood events, ten highest measured floods from systematic data since 1945 and current flood event (as estimated), salmon: threshold of 250 m³/s, dark red: threshold of 800 m³/s.

Note: the presented return periods are based on the subjective choice of threshold values and the results aim at highlighting the effect of including historic events only.

acceptable uncertainty without consideration of historical data. Accordingly, historical data has not been included for estimation of HQ_{100} and HQ_{extreme} , respectively. However, in 2014, a noteworthy study depicted historical flood events from floodmarks and old photographs in the Ahr catchment to estimate peak discharges⁵. It is emphasized that the estimated discharges are based on very simplified assumptions and the accuracy of their results may be questionable to hydraulic engineers. But still, such data is informative and indeed a whole branch of hydrology exists (paleohydrology) that tries to glean significant events from the distant past. In this context, it must be noted that the accuracy of reconstructed discharges is commonly regarded less significant than the definition of a reasonable threshold discharge, which needs to be selected in a way that it is exceeded by some historical extreme events only. When including historical data, systematic data is related to a longer time series, yielding generally lower return periods.

Figure 3 illustrates the systematic time series of daily discharges (collected since December 1945) in Altenahr together with the reconstructed data (assuming average roughness coefficients) for different historic flood events⁵ in the Ahr catchment. Additionally, the ten highest measured peak discharges (1946 to 2016) are included. The reader may note that the river gauge in Altenahr was destroyed in the evening of 14 July 2021 when measuring a discharge of 332 m³/s (flow depth of 5.05 m). Based on a maximum observed flow depth of about 7 m, an early report estimates the peak discharge in July 2021 to range between 400 and 700 m³/s¹; while a more recent and deeper analysis gives an estimate of 1,000 m³/s⁷ (thus, being slightly lower than an earlier event in 1804 (see **Fig. 3**). Such challenges with gauging stations during extreme events are common (i.e., the gauge is damaged, is out of commission, or estimates are grossly inaccurate for that range).

For the present article, Altenahr data was reanalyzed to obtain a rough estimate of return periods when considering

the historic data. For this purpose, a simple estimation of return periods by determining the Weibull plotting positions has been employed, considering the peak discharges from the systematic data together with the historic data. Data for the presumably most extreme flood in 1804 was available for Dernau, a municipality located next to Altenahr. The historic time series has been extended to 1688 (as no major floods have been reported in this period), leading to generally higher return periods. Fig. 4 illustrates the results, with consideration of two different threshold values (i. e. 250 m³/s and 800 m³/s) to obtain a range of potential return periods. Again, it is emphasized that no deeper analysis (e. g. application of the Maximum-Likelihood method) has been applied for this illustration and the results aim at demonstrating general effects of including historic floods rather than providing scientifically assured return periods. Apparently, with the employed simplified method, the presumed 100-year flood HQ_{100} may have a lower return period of only 75 years. The extreme flood $HQ_{\text{extreme}} = 1.4 HQ_{100}$ could have a return period of 120 years and the 2021 event could have a return period of only 200 to 250 years. It must be noted that preliminary results from a similar analysis have been reported⁷, leading to a return period of 500 years for the Ahr flood in July 2021. This supports a risk-based methodology focused on a range of extreme flows and corresponding hazards, as in truth we are selecting a critical discharge independent of the estimated return period.

For other affected flood areas, e.g. Erft and Wupper, reconstructed discharges are not available (to the author's knowledge). However, several historic events with severe damages and numerous casualties have been reported (e.g. in 1416, 1542, 1818 among others at upper Erft). In the author's eyes, reconstruction of these flood events may be insightful in the determination of design floods. Again, the author wishes to emphasize that indeed, a return period is the result of statistical analyses and available data and the selection of a design flood for hydraulic structures, mapping and planning, and emergency action plans should be based on more scientific rigor considering risks and critical thresholds in terms of flows.

Awareness

As demanded by the European Floods Directive (FD), flood hazard and risk maps are available for individual river basin districts and show the inundation areas for different flood scenarios. However, these maps are often generated under the assumption of steady flows using 1D models. In the context of current widely-used spatially distributed hydrologic models and 2D river models, reanalysis of critical areas with these more physics-based methods is emphasized.

So far, floods were known to be of higher relevance in large rivers with large catchments, where response times are long enough to evacuate people and to provide a certain level of additional flood protection by mobile systems. Along smaller rivers, people seem not to be aware of existing risks. The author noted during the flood event some confusion of individuals who did not know about the existence of hazard and risk maps, and others who felt safe due to the fact that they lived outside the

inundation area for HQ_{extreme} (arguing that "there can't be a more severe scenario than the extreme scenario"). Obviously, the communication of potential risks seizes up at some point in the information chain from the authorities to the citizens and technical information needs to be better translated to the citizens.

With the perspective of increasing intensity and frequency of extreme rainfalls in Central Europe, as predicted by the recent IPCC report (see also⁷), rescue services need to be better prepared as well. Regular practicing of different rescue services will be needed to better assess potential hazards and to improve decision processes.

Conclusions

The German flood in July 2021 was an extraordinarily extreme event which caused tremendous losses of billions of Euros and an incredible number of more than 180 fatalities. The question of guilt is difficult or even impossible to answer. Insufficient awareness of people and authorities may have been a key issue, which, however, may be surprising given the experience from historical floods in some of the affected areas. Most likely, people in a technologically developed country like Germany trust in the provided protection systems and services.

It is emphasized that from the hydraulic engineering and water management perspectives, no improper design or operation was reported. But still, a rethinking is required. We will never achieve providing full flood protection and this should not be our goal. But we must strive to avoid as many fatalities as possible in future events. In order to reach this goal, a more flexible interpretation of design standards is necessary. Why don't we generally consider historic data when it is available? Should we increase the considered return periods in areas which we know to be at more risk than others to reach consistent safety levels? The answer to these questions requires higher financial investments and efforts. But, most likely, we all agree that these efforts are negligible compared to what this country has to deal with now in response to extreme flood events.

At this stage, we need to find a sustainable solution to improve our approach to flood protection in future, bringing together stakeholders from all relevant disciplines. We have to make sure that this flood will not sink into oblivion as many extreme flood events did before. Obviously, this is not a short-term task and affected people need immediate help. But does it make sense to rebuild all destroyed houses, except a number of 34 as decided in Rhineland-Palatinate for the river Ahr, at their original places? If this is meant to be a sustainable solution, a change of hydraulic design concepts will be mandatory.

Acknowledgements

The author is grateful for the valuable discussion with Brian M. Crookston (Utah State University), shared his thoughts on flood protection from an international perspective.

**Daniel B. Bung**

Daniel B. Bung is a professor of Hydraulic Engineering at FH Aachen University of Applied Sciences, Germany. His research mainly focuses on the design of hydraulic structures as well as on the development and application of innovative measuring technique. He served in the IAHR Hydraulic Structures Technical Committee from 2011 to 2021 (as chair from 2017 to 2019) and is currently a member of the IAHR Technical Committee on Experimental Methods and Instrumentation.

References

- 1 | CEDIM (2021): Hochwasser Mitteleuropa, Juli 2021 (Deutschland), Center for Disaster Management and Risk Reduction Technology (Forensic Disaster Group), doi: 10.5445/IR/1000135730.
- 2 | DWD (2021): Hydro-klimatologische Einordnung der Stark- und Dauerniederschläge in Teilen Deutschlands im Zusammenhang mit dem Tiefdruckgebiet "Bernd" vom 12. bis 19. Juli 2021, Deutscher Wetterdienst
- 3 | GDV (2021): Naturgefahrenreport 2021, Gesamtverband der Deutschen Versicherungswirtschaft e. V..
- 4 | LAWA (2018): LAWA-Strategie für ein effektives Starkregenrisikomanagement, Bund-/Länderarbeitsgemeinschaft Wasser (LAWA).
- 5 | Roggenkamp, T.; Herget, J. (2014): Reconstructing peak discharges of historic floods of the river Ahr, Germany. *Erdkunde* 68(1), pp. 49-59.
- 6 | Schumann, A. (2012): What is the return period of an extreme flood event if it is estimated to be many times higher than the HQ_{100} ?, *Hydrologie und Wasserbewirtschaftung* 56(2), pp. 78-82.
- 7 | WWA (2021), Rapid attribution of heavy rainfall events in Western Europe July 2021, World Weather Attribution.

IAHR White Paper Series

2021_02

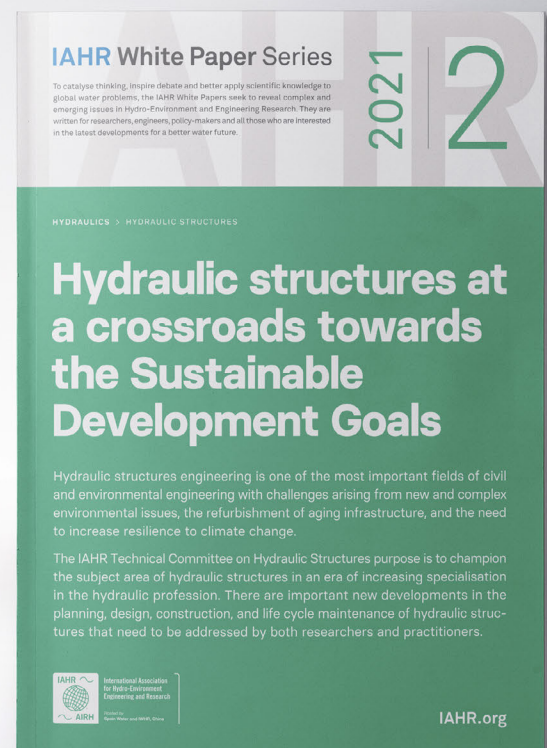
IAHR White Paper Series is our new publication series launched to inspire debate and better apply scientific knowledge to global water problems.

IAHR White Paper Series are written for researchers, engineers, policy-makers and all those who are interested in the latest for a better water future.

IAHR's latest **White Paper** on *Hydraulic structures at a crossroads towards the Sustainable Development Goals* is now available online for free.

IAHR Members are welcomed to submit suggestions for topics to be covered in the next **IAHR White Paper Series**. For this purpose please contact with Estibaliz Serrano at: publications@iahr.org

Access, read and share from www.iahr.org



Challenges of extreme rainstorm events and countermeasures in China

By Cheng Xiaotao and Cai Jindong

China Institute of Water Resources and Hydropower Research

In recent years, extreme rainstorms in local areas have caused many flood events beyond the flood control standards in China. Under the combined influence of rapid economic development and unprecedented urbanization process, the characteristics of flood risk have undergone significant changes. In order to effectively deal with the adverse effects of excessive floods and safeguard the economic and social development, it is urgent to improve the flood control and disaster reduction system and comprehensively strengthen the capacity building of emergency response. This article uses the extreme rainstorm flood event in Henan, in July 2021 (referred to as "21.7") as an example to analyze the changing characteristics of flood risks under the new socio-economic and climate conditions and discuss the direction of adjustment countermeasures.

Basic characteristics of "21.7" extreme rainstorm in Henan, China in 2021

In 2021, the global weather system is out of whack, with record-breaking storms and floods occurring one after another, and China is not immune. From 17 to 22 July, under the combined influence of abnormally strong Western Pacific subtropical high, continental high and Typhoon In-Fa, rare and extremely heavy rain was witnessed in Henan province. Rainfall over 400 mm, 250 mm and 100 mm poured down onto an area of 18,300 km², 46,300 km² and 96,200 km², respectively. The rainfall distribution is shown in Figure 1(a). The coverage area of this heavy rainfall is roughly equivalent to that of the heavy rainstorm in Henan from August 4 to 8, 1975 (referred to as "75.8"). However, the rainstorm center of "75.8" was in the hilly area of Luohe and Zhumadian in southern Henan, as shown in Figure 1(b), whereas the rainstorm center of "21.7" was in the north of Henan. Daily rainfall registered at nearly one sixth of

all the national meteorological stations in Henan province exceeded the maximum record in history, covering Zhengzhou, the provincial capital city, with population of 12 million, and some major cities of Jiaozuo, Xinxiang, Hebi and Anyang. The average rainfall of the whole province was 222.9 mm, significantly higher than 176.8mm of "75.8". The area covered by torrential rains of more than 250 mm was also larger than that of "75.8", the latter being 38,700 km². From 16:00 to 17:00 on 20 July, Zhengzhou received 201.9 mm of rainfall in one hour, breaking the highest record of 198.5 mm in "75.8" in the Chinese mainland. The maximum daily rainfall registered at Zhengzhou station was 624.1 mm, which was close to the total annual rainfall of 641 mm for the station, and 3.39 times of the maximum daily rainfall since the establishment of the station (184.1mm, July 1, 1978). In addition, the accumulated rainfall of 10 national meteorological stations during the rainstorm in five days exceeded the local average annual rainfall, among which the accumulated

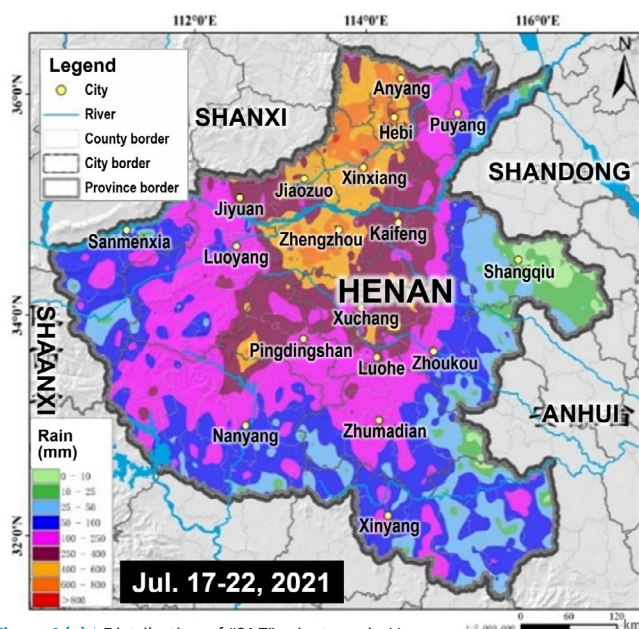


Figure 1 (a) | Distribution of "21.7" rainstorm in Henan

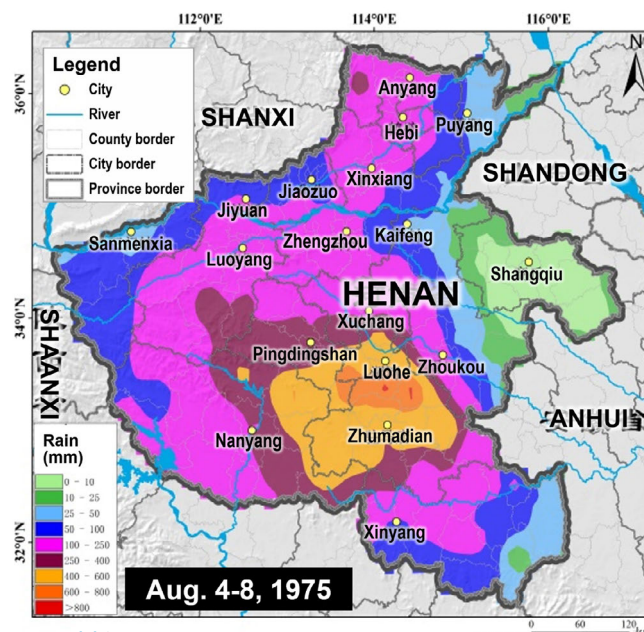


Figure 1 (b) | Distribution of "75.8" rainstorm in Henan

Figure 1 | Comparison of rainstorm distribution between "21.7" and "75.8" in Henan.

Source: <http://www.weather.com.cn/>

River basin	River name	Station name	Max. flow (m ³ /s)	Flood peak appearance time	Highest water level (m)	Occurrence time	Max. flow in history (m ³ /s)	Highest level in history (m)
Huaihe	Jialu	Zhongmou	600	July 21, 14:00	79.40	July 21, 14:00	245	77.69
Haihe	Weihe	Jixian	265	July 24, 08:00	72.76	July 24, 08:00	260	70.77
		Qimen	460	July 23, 00:00	68.03	July 22, 18:30	824	67.45
	Dasha	Xiuwu	343	July 22, 17:00	83.65	July 22, 19:00	203	83.02
	Gongqu	Hehe	1,320	July 22, 22:00	76.77	July 23, 11:00	1,710	75.90
		Huangtugang	1,140	July 23, 12:00	73.67	July 24, 00:00	1,290	71.48
	Anyang	Henshui	607	July 22, 07:00	6.94	July 22, 05:00	1,140	6.8

Table 1 | Record-breaking floods occurred in some section of rivers due to “21.7” rainstorm | <http://www.hnssw.com.cn/primaryservice/index.jhtml>

rainfall of Zhengzhou National Meteorological Station was 820.5 mm, 1.27 times of the average annual rainfall of Zhengzhou Station (641 mm). Continuous heavy rains caused widespread flooding in rivers in Henan. A total of more than ten rivers in the province, including the Shaying, Shuangji, Honghe, Huiji, Yihe, and Qinhe rivers, were flooded over the warning level. Among them, some sections of the Jialu, Dasha, Anyang, Gongqu, and Weihe rivers experienced the highest level of flooding in history (Table 1). In the table, Qimen station on Weihe River, Hehe and Huangtugang stations on Gongqu River, and Hengshui station on Anyang River, show the phenomenon of lower flow but higher water level, which reflects the adverse effect of river channel changes.

As of 8:00 on 23 July 2021, the total amount of water stored in 24 large reservoirs and 102 medium-sized reservoirs in Henan province reached 5.74 billion m³ and 1.23 billion m³ respectively, 2.558 billion m³ and 497 million m³ more than the annual average of the same period (3.82 billion m³, 733 million m³). Among them, the highest water level of 14 reservoirs, including Panshitou, Xiaonanhai, Jiangang, Wuxing, etc., exceeded the all-time high since the reservoirs were built. Affected by a variety of factors, flood discharge in the Weihe River basin was not smooth. From 21 to 30 July, eight out of the nine flood storage and detention areas in the Weihe River basin were successively put into use, with a maximum flood storage capacity of 859 million m³, effectively lowering the water level of the Weihe River and its tributaries.

The scale of floods caused by the “21.7” heavy rainstorm in Henan far exceeded the local standards of flood control and drainage systems. Severe flash floods occurred in mountainous areas, some parts of the rivers overflowed and burst the dikes in the plain region, flooding large areas of farmland. Many urban areas in cities such as Zhengzhou, Xinxiang, Anyang, Hebi and Jiaozuo suffered serious flooding. Railway and civil aviation operations were affected, and lifeline systems such as power supply, water supply, gas supply, transportation, and communications were paralyzed for a time.

More than 16 million people in the province were affected by the disaster, resulting in direct economic loss of about 120 billion Chinese yuan. Fortunately, the meteorological department issued nine red early warnings during the rainstorm process,

and the local government promptly evacuated and properly re-located the residents from high-risk areas. The affected areas were in good order, and there were no heavy casualties as had been seen in the “75.8” flood.

Evolution characteristics of flood risk under changing environment

The “21.7” extraordinary rainstorm and flood disaster in Henan province, on the one hand, reflects the disrupted weather system associated with global warming, which is more likely to cause extreme weather events. On the other hand, it also reflects the impact of rapid economic development and urbanization on flood risk characteristics. When the super heavy rain falls on a huge and rapidly expanding city with a population of more than ten million, its threat object, disaster mechanism, disaster mode and loss composition change dramatically, and flood risk presents the characteristics of linkage, mutation and transmissibility.

Due to the increasing dependence of the normal operation of modern society on transportation, communication, power supply, water supply and other lifeline network systems, and closer and wider industrial chains formed with economic development, in the event of excessive flooding, the chain reaction within and between the affected systems causes a sudden increase in disaster losses, and its influence range can be transmitted far beyond the flooded area along with the lifeline system and the industrial chain. Therefore, the indirect loss can be amplified to an extent even more than the direct loss.

Zhengzhou covers an area of 7,567 km², is located on the south bank of the Yellow River and straddles the Yellow River and Huaihe River basins, with 27% and 73% respectively of Zhengzhou being in these two basins. It straddles Songshan Mountain, low mountains and hills and Huang-Huai Plain, with the overall terrain higher in the west and lower in the east. Plains, hills and mountains account for about 70%, 24.9% and 4.7% respectively (Figure 2). There are 29 tributaries to the Yellow and Huaihe Rivers with a catchment area of more than 100 km² in the region, among which Jialu River, Shuangji River, Yinghe River and Yiluo River are important flood discharge channels in Zhengzhou (Figure 3).

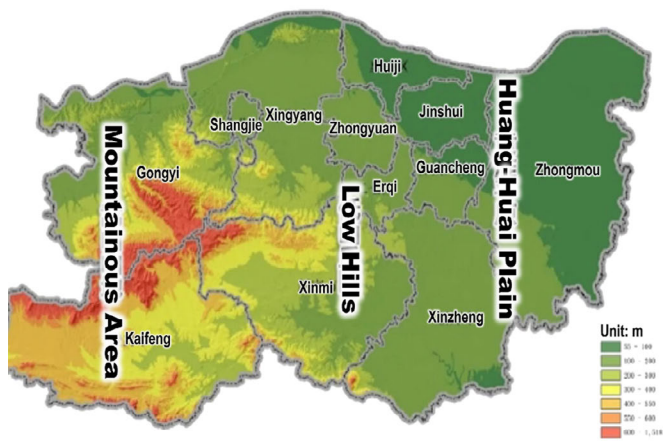


Figure 2 | Topography and landform of Zhengzhou.

Since the beginning of the new century, development in Zhengzhou has been accelerated. By 2018, the total urbanized area had increased by 702 km², and the area of water and wetland decreased by about 30%. With the expansion of the urban area, some flood channels outside the city have become the city's internal rivers. That increases the risk of flash flood entering the city from the southwest mountainous and hilly areas, which could occupy the river channel making it difficult to discharge rainwater from local urban areas in time. By 2020, the permanent resident population of Zhengzhou had reached 12.6 million, increasing by 3.97 million just in 10 years.

After the huge flood disaster, Zhengzhou faced a very difficult task of disaster relief and reconstruction. With the efficient organization by governments at all levels and the great support from all over the country, power supply had been basically restored for 1,194 residential areas by 30 July; water supply completely restored in 1,864 residential areas by 1 August; and gas supply restored in 111 residential areas by 2 August. All five subway lines in the city resumed their operation in two phases on 12 and 15 September.

Discussion on countermeasures against extreme flood under the new situation

In recent years, extreme disaster events have occurred frequently and uncertainty has increased, which warns us that the trend of flood risks in the context of climate warming and rapid urbanization should be recognized and that we should coordinate development and security, improve risk prevention and emergency response system, and strengthen the resilience of urban centers and other residential areas to adapt to and withstand catastrophes. After the occurrence of the "21.7" huge flood disaster in Henan province, widespread concern was expressed about how to prevent and deal with extreme rainstorm flood [1-2]. Discussions began in some cities, such as Beijing, Fuzhou and Kunming [3-5], on what kind of disaster scenario would occur if the heavy rain of 201.9 mm per hour in Zhengzhou fell there, and actions were proposed for risk prevention and emergency response, such as:



Figure 3 | Distribution of rivers in Zhengzhou.

1 | To strengthen the capacity building of risk identification.

It is required that the most likely and the most unfavorable disaster-causing scenarios be considered, identifying not only the high-risk points in the region, but also the weak links in the lifeline system, so as to formulate emergency plans and draw flood disaster risk maps that can be made available to the public. Flood risk assessment should be strengthened for construction projects that change land use patterns to avoid artificially aggravating disaster risks.

2 | To strengthen the capacity building of danger perception.

It is necessary to strengthen meteorological and hydrological monitoring, forecast and early warning systems, improve the forecasting accuracy and timeliness of the spatial and temporal distribution of rainstorm and flood, and improve the level of information sharing.

3 | To strengthen the ability to deal with dangerous situations.

It is necessary to establish a stricter and regularly implemented engineering safety evaluation system for flood control and drainage engineering systems and lifeline systems, and to attach importance to the classification, grade, urgency, consultation, and rapid evaluation of risk disposal plans, and make any necessary adjustments in time according to the real case.

4 | To strengthen capacity building for emergency rescue.

Make clear the scope, way, and vulnerable groups in need of help in various scales of danger situations, and organize training and rescue exercises to strengthen capacity building for self-protection, mutual rescue, relocation, and resettlement.

5 | To strengthen capacity building for resilient reconstruction.

For all lifeline systems, water resources projects, roads, and other flood-damaged projects, when formulating recovery and reconstruction plans, it is necessary to reflect on their shortcomings exposed in the occurrence of catastrophic disasters, and use post-disaster reconstruction as an opportunity to improve the resilience level of national security.

**Cheng Xiaotao**

Cheng Xiaotao, professor, former director of the Research Department of Water Hazards and former deputy chief engineer of the China Institute of Water Resources and Hydropower Research (IWHR). He is now a member of the expert team of the China National Disaster Reduction Committee, the Chief Editor of Journal of Hydraulic Engineering (CHES, IWHR & CHINCOLD), the director of the Urban Water Management Committee of CHES and leadership team member of the Flood Risk Management Committee of IAHR.

**Cai Jindong**

Cai Jindong, translator of the Division of International Cooperation of the China Institute of Water Resources and Hydropower Research (IWHR), is now also the deputy office manager of the IAHR Global Secretariat (Beijing).

References

- 1 | ZHANG Weijun, LIAO Qingtao, YANG Sen, et al. Thoughts and inspirations: Urban flood risk management inferred from Zhengzhou flood model [J]. China Flood & Drought Management, 2021(9): 1-4.
- 2 | LIU Yuanyuan, ZHENG Jingwei, LIU Hongwei, et al. Warning and thoughts of extreme rainstorm on urban flood prevention [J]. China Flood & Drought Management, 2021(9): 21-24.
- 3 | ZHANG Shuhan, ZHENG Fandong, DI Shuchuang, et al. Thoughts on urban waterlogging control in Beijing from the rainstorm and flood of "2021.7.20" in Zhengzhou [J]. China Flood & Drought Management, 2021(9): 5-11.
- 4 | XU Zongxue, YE Chenglei. Simulation and risk analysis of flood and waterlogging process in Fuzhou City under extreme rainstorm scenarios [J]. China Flood & Drought Management, 2021(9): 12-20.
- 5 | BAI Ping, LIU Yesen, LIU Shu, et al. Warning and thoughts of extreme rainstorm on urban flood prevention in Kunming [J]. China Flood & Drought Management, 2021(9): 25-29.



ARISTOTLE
UNIVERSITY OF
THESSALONIKI



KENTRO OIKOKHPOIMENHS DIAKEPTEHS YAATON AIO
CENTER FOR INTEGRATED WATER MANAGEMENT AUTH



Intergovernmental
Hydrological Programme



Young
Professionals
Network

Hosted by
Spain Water and IWHR, China



YOUTH
DELEGATES
of the World Water Council

Youth in the forefront

Online Youth Water Congress "Emerging water challenges since COVID-19"

6-8 APRIL 2022

www.keody.auth.gr/youthcongress

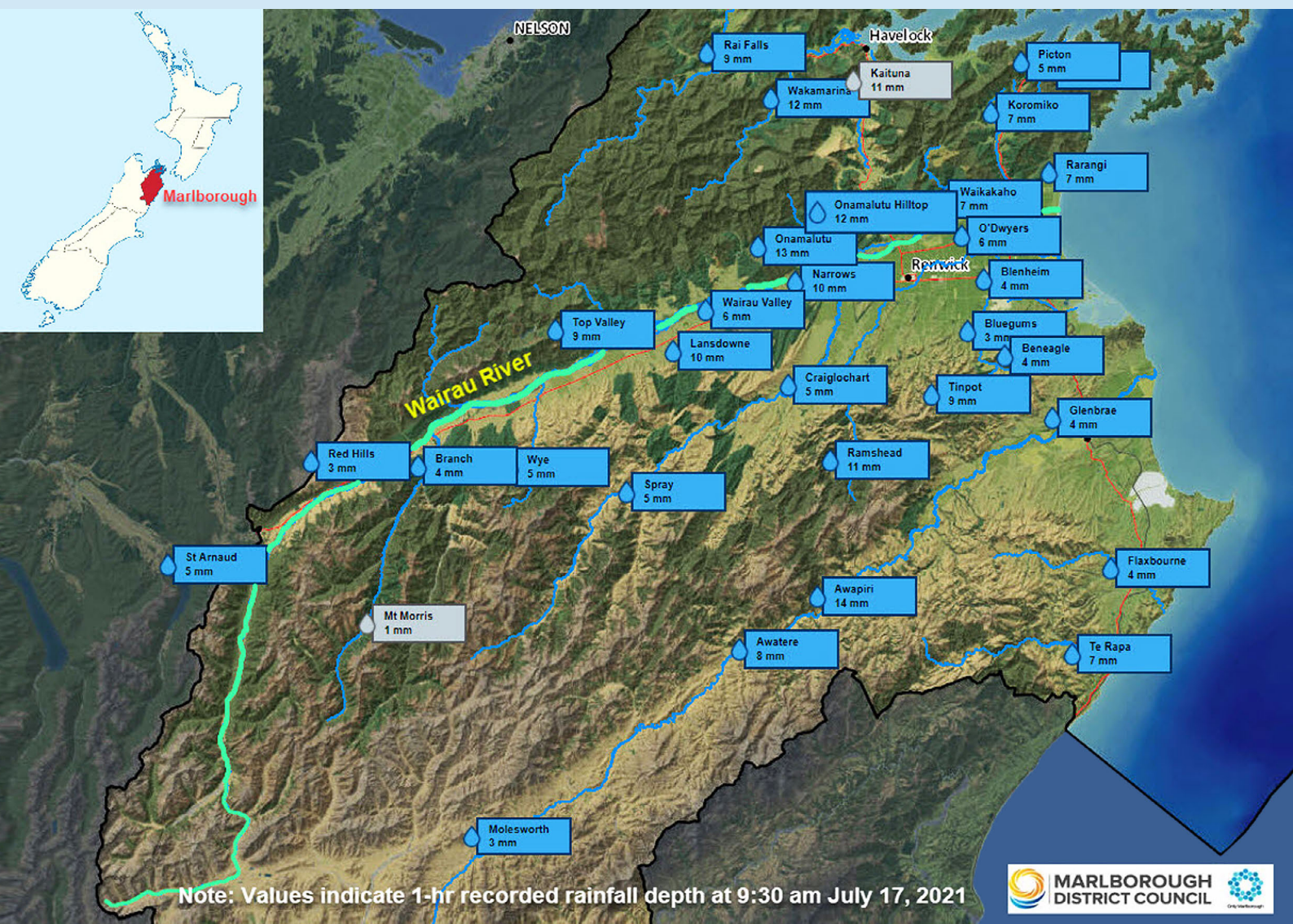
#YouthWaterCongress

The Wairau River Flood of July 2021

By Geoff Dick, Mike Ede, Duc Nguyen and Val Wadsworth

The Wairau River, in the Marlborough Region at the north end of the South Island, is subject to some of the largest floods in New Zealand. In July 2021, the river flooded sharply, with peak flows well over 5,000 m³/s near its mouth. This was the second highest Wairau discharge observed in some 70 years of systematic records. However, New Zealand is a mountainous country, so the catchment is relatively short and steep, and the time above average annual flow was a little over 24 hours. This foreshortened time scale requires adaptation of forecasting and civil defence procedures so that evacuation of threatened areas can be activated at short notice. In recent years, the Marlborough District Council has been building up technical capability in the flood risk management team, and this was the first test of their response to the challenge of a major event. Figure 1 shows the location of rainfall stations in the Wairau River basin and the amount of one-hour rainfall recorded at 9:30 am of 17 July 2021.

Figure 1 | The Wairau River and Marlborough District rain recorders (Inset: Location in New Zealand).



	3 hour max	3 hr ARI	6 hour max	6 hr ARI	12 hour max	12 hr ARI	24 hour max	24 hr ARI	2 day total
Tunakino							240 mm	4 yr	255mm
Kenepuru			71 mm	3 yr	137 mm	10 yr	196 mm	15 yr	271mm
Onamalutu	61 mm	20 yr	112 mm	60 yr	201 mm	215 yr*	291 mm	290 yr*	320mm
Top Valley	57 mm	24 yr	108 mm	88 yr	194 mm	395 yr*	282 mm	510 yr*	308mm
Branch	28 mm	2 yr	50 mm	3 yr	87 mm	6 yr	127 mm	11 yr	142mm
Wye	23 mm	1.5 yr	39 mm	2 yr	69 mm	3 yr	96 mm	5 yr	108mm
Spray	23 mm	2 yr	40 mm	3 yr	75 mm	14 yr	102 mm	23 yr	112mm
Tinpot			30 mm	1.6 yr	50 mm	1.8 yr	71 mm	2 yr	76 mm
Awapiri	41 mm	13 yr	73 mm	28 yr	131 mm	94 yr*	181 mm	125 yr*	188mm

Table 1 | Selected rainfall statistics for the storm of 16-17 July 2021.

Hydrology

The meteorological context of the July 2021 event was a classic Wairau flood situation, with a deep low approaching the West Coast, a blocking high to the east of New Zealand, and a NNW front crossing Marlborough. As the forecasts progressed it became apparent that this had the potential to be a significant event, and monitoring staff were placed on standby on Friday afternoon for flood monitoring through the weekend. Over the previous months there had been frequent rainfall in northern Marlborough. Therefore, the catchments were well saturated, resulting in high runoff. The main rainfall event was centred on the Richmond Range, which has mountain peaks over 1700 m high near the Onamalutu Stream (see box centre top in [Figure 1](#)). There, with 24-hour rainfall up to 291 mm, an indicative annual recurrence interval (ARI) of 290 years was estimated (see [Table 1](#)). A very similar 24-hour rainfall in a site at Top Valley with less extreme exposure rated an estimated ARI of 510 years. The lesser runoff from the southern tributaries was interesting, as usually major Wairau floods have significant contribution from those catchments as well. [Table 1](#) presents rainfall statistics at selected stations within the Wairau River basin.



Figure 2 | Flood peak against a key stopbank (dyke) with emergency work to limit overtopping.

Flood narrative

The storm affected much of Marlborough, with associated flooding and roading damage. However, the key Wairau flood protection scheme is considered to have performed well and consequently saved an enormous amount of associated flood damage across the lower Wairau plains ([Figure 2](#)). There were three stopbank failures and a number of sections of stopbank overtopping, causing flooding above the floor level of a small number of houses as well as restricting road access.

Of the three key stopbank failures, preliminary assessment suggests two were due to a combination of overtopping and poor to variable stopbank quality, and one due to piping under the bank via an underlying fine sand layer. As expected on a large, powerful fast flowing river like the Wairau there are now numerous areas suffering erosion, bank slumping, and silting of some drainage outlets.

On the positive side, modern upgraded stopbanks stood up very well, withstanding significant overtopping in places. Also, the highway and railway bridges are the only links connecting the South Island to the North Island via the interisland ferry, and both appear to be undamaged ([Figure 3](#)).



Figure 3 | Key transport links survived peak flows.

Flood prediction modelling

Considerable effort has been put into numerical modelling of Wairau floods, so that forecasting and flood protection design can be improved. Current forecasting models have been fairly successful for prediction of medium floods, but they underpredicted this flood size. Part of the problem was the unusually low proportion of precipitation south of the river, and part was the lack of calibration data at the high stages encountered during this flood. The rating curves then required significant extrapolation, and confidence in the results was correspondingly lower.

Gauging techniques

As well as traditional mechanical current meters, the Marlborough District Council has progressively been introducing Acoustic Doppler Current Profilers (ADCP) since 2007. Figure 4 shows an example of gauging using an ADCP unit installed on a small boat, which may be either remotely controlled or tethered to a structure such as a bridge. The use of ADCPs greatly speeds up the sampling of current velocities over an entire cross-section.

Space Time Image Velocity (STIV) gauging was then purchased, and was tried during the July flood, sometimes with simultaneous ADCP as a control. The equipment can be used from a fixed site on the river bank, or from a drone or helicopter, to track current velocity by recognizing and following visual features on the surface.

For discharge measurements, the STIV method requires correction from surface velocity to depth averaged velocity, but there are promising signs that a systematic correction will be developed from the analysis of large quantities of ADCP profiles.

Figure 5 shows the STIV surface velocities (blue line markers) measured across the standard cross-section at "Barnetts Bank", some 500 m upstream (to the right) of the bridges shown in Figure 3. These velocities are compared with depth averaged velocities obtained by modelling. 2D modelling provides depth averaged velocities by dividing specific discharge (m^3/s per m) by depth, after which the chosen correction factor is applied to recognise that surface velocities are expected to be greater than depth averaged velocities. In this case a good fit (brown line) was obtained by dividing by 0.95 the model depth averaged velocities corresponding with a total discharge of $5,280 \text{ m}^3/\text{s}$.

Summary

The current Wairau peak flow assessment of the July 2021 flood is $5,280 \text{ m}^3/\text{s}$. The uncertainties involved in making high flow assessments must be recognized, and further work will be done which may refine this figure further. The design flood for the Wairau River is $5,500 \text{ m}^3/\text{s}$. This near-design peak flow tested existing flood protections to their limit.

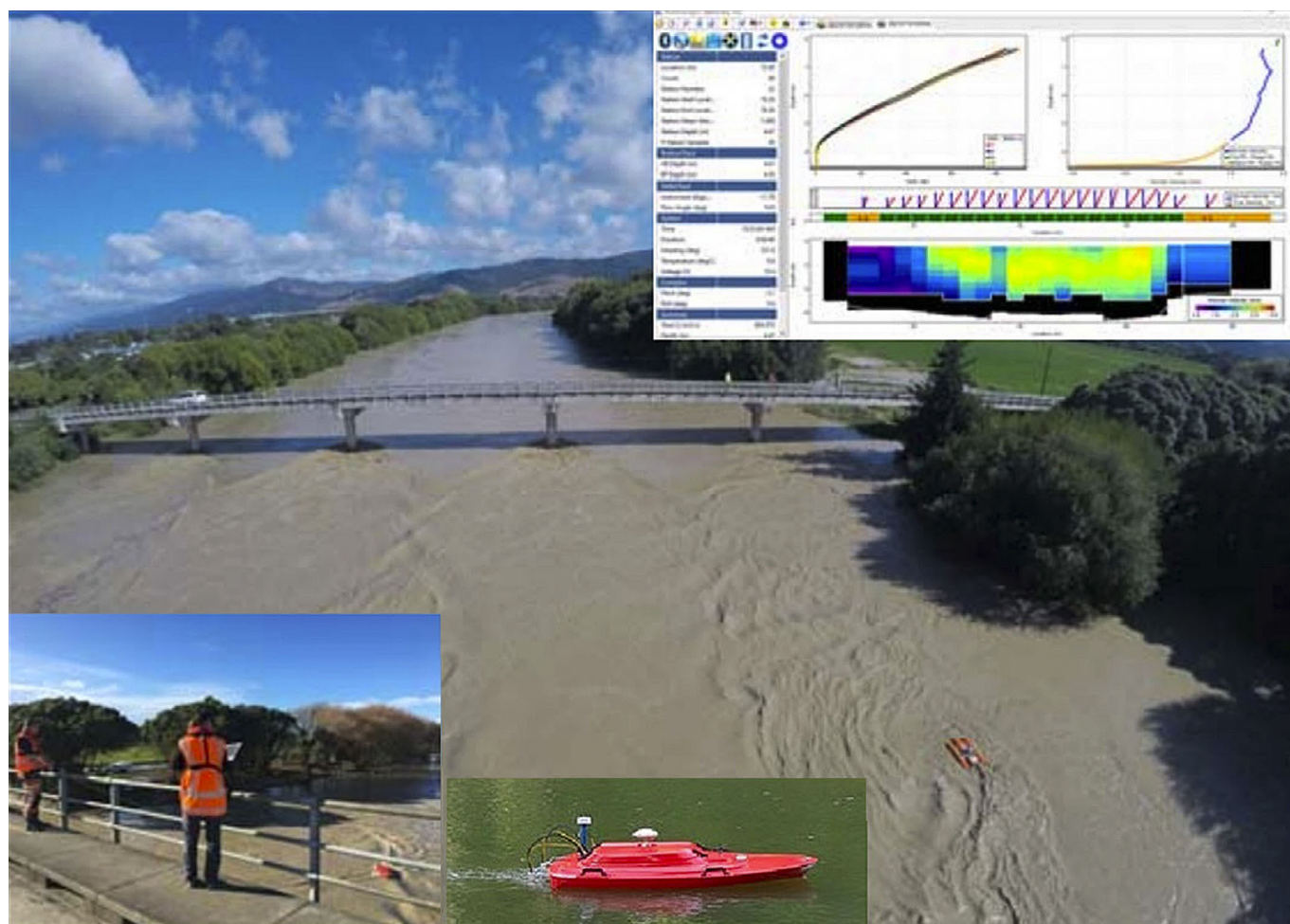


Figure 4 | ADCP gauging a major flood using a remote-controlled boat.

Surface velocity comparison between STIV measurement and modelling at Barnetts Bank for a $Q_{\text{peak}}=5,280 \text{ m}^3/\text{s}$

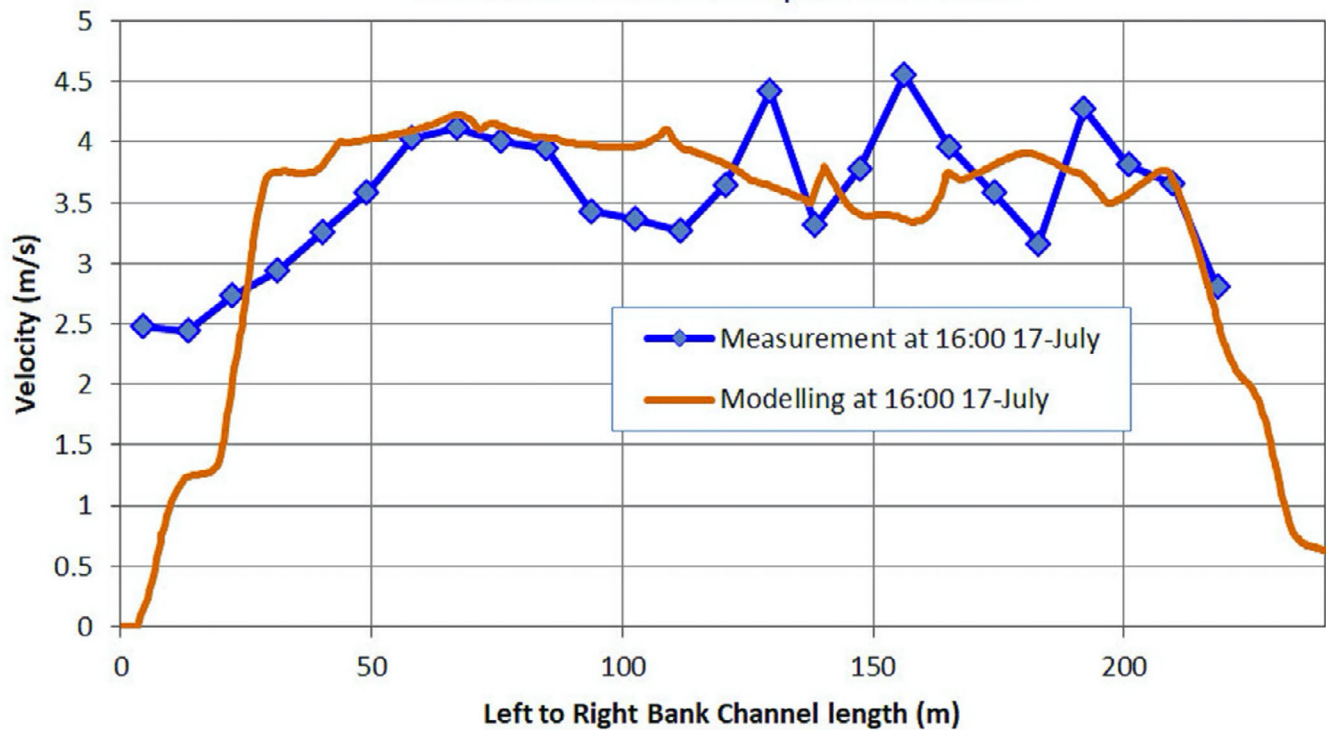


Figure 5 | Calibration of STIV velocity using model depth-averaged velocity.

Geoff Dick

Geoff Dick, Rivers & Drainage Engineering Manager, Marlborough District Council.

Mike Ede

Mike Ede leads the environmental monitoring team at the Marlborough District Council with thirty seven years of field hydrology experience principally in the Wellington and Marlborough regions and holds a New Zealand Diploma in Field Hydrology. He chairs the National Environmental Monitoring Standards Steering group who are responsible for the development of hydrology monitoring standards for New Zealand. Mike is also an executive member of the New Zealand Hydrological Society where he has led the establishment of annual technical workshops for the industry over the last ten years.

Duc Nguyen

Duc Nguyen is a rivers investigation engineer at the Marlborough District Council. Duc has been working in fields of river engineering and water resources management over the past nineteen years. He has participated in a number of water resources projects in Laos, Thailand, Vietnam, Japan, Netherlands, United State, and New Zealand taking responsibilities for the design of flood protection measures, river and stormwater modelling, estuarine sediment and salinity assessment, flood risk mapping and climate change projections.

Val Wadsworth

Val Wadsworth has been involved with Marlborough rivers for forty-seven years in engineering and hydrological roles. He is the Marlborough District Council's environmental scientist (Hydrology) responsible for analysis and dissemination of hydrological data.

Developing chinese fish passage: testing and simulation technology

By Xiaogang Wang, Yun Li and Nanbo Tang

To balance the environmental conservation and economic development, ecological issues have received the attention of the Chinese Government. In November 2012 the Chinese Government proposed the concept of "ecological civilization", which focused on the continued development of humankind in the future. The main idea behind ecological civilization is to respect and maintain the ecological environment, based on sustainable development. Subsequently, a series of acts and regulations on hydropower development and ecological and environmental protection were issued, where aquatic ecosystems conservation is important.

These acts and regulations include the notice on "Further Strengthening Environmental Protection in Hydropower Construction", which was issued by the Ministry of Environmental Protection in 2012 and restated that "hydropower projects must include fish passage construction".

The revised Fisheries Law of the People's Republic of China, issued in 2013 by the Standing Committee of the National People's Congress, stipulated that "fish passages must be provided on segments of rivers where dams, locks and other water-blocking structures have already been built".

The notice on "Deepening the Implementation of Eco-environmental Protection Measures for Hydropower Development" issued in 2014 by the Ministry of Environmental Protection and National Energy Administration, requires that hydropower development "fully demonstrate the fish-passing methods and earnestly implement fish-passing measures".

The opinions on strengthening the protection of aquatic life in the Yangtze River¹⁰ and on key watershed aquatic biodiversity conservation programs¹¹ set out requirements for both the construction of fish passages and the ecological protection of rivers and lakes.

The study of fish passages started in China in 1958, but stopped for approximately 20 years from 1980 to 2000. Since 2000, due to the gradual strengthening of environmental protection policies, the significance of fishways in restoring river connectivity has been emphasized, a group of new fishways have been planned and designed, and the construction of domestic fishways has entered a new stage. With the rapid progress in the evolution of measurement methods and devices, the base data on fish behavior and life cycle are growing significantly. Fishway physical models and numerical simulations have been developed over the years. This article focuses on the progress in the research on fish passage testing and simulation techniques in China.

The entrance layout is the most important segment in a fish passage, since the fish passage is a kind of needle-eye projection compared to the river width. The fish passage efficiency always is the key measure for the assessment of all fish passages built in China. The hydraulic characteristics around the entrance which affect fish behavior are studied using novel simulation technologies that reveal the details of water flow in this area.

Study on the layout of fishway entrance and exit

Fishways consist of an entrance, a chamber, a resting pool and an exit. The flow of water from the river towards the entrance allows the fish to find their way and guides them to the fishway, which is usually a smaller structure relative to a wide river, usually up to 5 m in width, with the characteristic of "needle-eye", especially obvious for the big river⁵. Therefore, it is of vital importance to locate the entrance of the fishway so that fish can easily find it and enter the channel. The flow outside the fishway exit should be smooth, preferably away from the power station discharge, the entrance of any diversion structures, the exit of diversion channels, and water quality pollution areas, while being able to adapt to changes in upstream water levels to ensure that a certain depth of water is maintained⁷ during the fish passing season.

The layout of the fishway entrance is optimized mainly on the model of the entire project, in combination with two-dimensional numerical modeling, which can be used to analyze the flow characteristics of the fishway entrance and exit during the main fish passing season, to get to know even the possible migration path of target fish populations.

Accumulation of energy in the pool and entrance flow conditions

The change in water depth between entrance and exit affects the flow rate distribution in different chambers of the fishway. If the water level of the entrance is lower than the design water level, then the water depth near the entrance will be shallower than normal and the amount of energy consumed by the pond will be insufficient, and will result to flow energy accumulation and excessive flow velocity in the lower depth pond. If the entrance water depths are higher than normal, then the velocities near the entrance will decline, which will make it hard for fish to find the entry⁹. In order to solve this problem, it is usually necessary to establish a model of part of the fishway (which was named 'quasi-whole' fishway model in China) with more than 100 stepped pools (if the number of pools is too large, the cost of the test increases, and otherwise it may be difficult to simulate the accumulation of insufficient energy dissipation effects). The model can be used to study the phenomenon of energy accumulation of the flow in the channel, and to analyze the quantity of water filling for higher flow around the entrance.

To address the effect of flow energy accumulation in the fishway pool and the changes of the water flow conditions at the fish entrance, the entire (or part of) fishway model is needed to study the overall hydraulic characteristics of the fishway under different water levels (flow rate, water surface line, velocity of flow through the orifice and the pool, water level difference between adjacent pools, etc.), verify the velocity of flow in the fishway pool, optimize the number and arrangement of fishway entrances and exits, the slope of the fishway, and pool size. Especially for fishways with large variation of the water level at the downstream end of the fishway, researchers need to adjust the number and layout of entrances to adapt to the water level, analyze the need for auxiliary water, and determine the size of appropriate auxiliary water systems, location of the water supply pipe, the flow rate and the layout of energy dissipation facilities, etc. The scope of an entire (or quasi-whole) fishway model simulation usually includes the entire length of the fishway, the plant fish attraction system, and fishway entrance and exit. The model scale can be selected between 1:10 and 1:40 depending on the specific local conditions⁷.

Flow conditions in fish passages channel

Flow conditions in the fish passage are mainly related to the arrangement of the partitions in the fish passage pond. The purpose of the baffle is to divide the total water head into segments with smaller water heads to control the flow velocity under the fish swimming speed and adjust the flow patterns to help the fish find the next exit and continue moving upstream. There are many factors that affect the flow conditions in the pool, including the water head in an adjacent pond and the volume of the pond⁸.

At present, the main methods for selecting the fishway baffle type are partial physical models and 3D numerical simulations. Researchers use 3D turbulence numerical models to determine the reasonable baffle (plate) arrangement, analyze the water flow characteristics in the pool. The recommended fishway baffle type can be used, and the hydraulic condition can be checked in quasi-whole fishway model tests.

The most commonly used numerical simulation approach for three-dimensional turbulence is the $k-\epsilon$ turbulence model. Large eddy simulation (LES) and the $k-\epsilon$ turbulence model have both been used by Chinese scholars^{2,4,8} to study the baffle type and hydraulic characteristics of flow in the pool. 15 to 20 typical pools of the fishway are usually modeled in partial physical tests. The scale of the model can be 1:3 to 1:10. In order to match the swimming characteristics of fish, the velocity, water head, turbulent energy and power dissipation per unit volume between the pools should be controlled.

Fish collection gallery around the tailwater

The hydraulic characteristics of fish collection systems downstream of turbines are also one of the main concerns. The Bonneville Dam fish passage, which was built on the Columbia River in 1938, included the design of a fish collection system downstream the plant, which was used later successfully all over the

world. The Hunan Yangtang Hydropower Station, which was built in 1980 in China, was equipped with a fish collection system on the tailwater platform. This fish collection system was also used successfully in China. The reasonable design of the fish collection gallery is significant for fish, as it can help them find their way to the entrance. It is a good example of the type of fish collection systems used in Chinese hydropower stations⁶.

Fish collection systems mainly include an inlet, a fish collection channel, and an auxiliary water system. The scale of a fish collection system model can be 1:3 to 1:10. In addition to controlling the flow rate, it is important to avoid reverse currents in the collector channel that can cause fish to swim in the opposite direction and delay access to the fishway.

Fish lift

Fish lifts have been developed at different levels in China and abroad, and their effects on fish protection vary. In some countries, fish lifts have been successfully used as a fish passage. In China, the construction of fish lifts has received renewed attention in the last 10 years³.

A fish lift may be the only type of fish passage that may be appropriate for high dams. Fish lifts are installed in many high dam projects such as the Laingjiangkou Hydropower Station, the Huangdeng Hydropower Station and the Dahuaqiao Hydropower Station in China. Fish trapping facilities are used to lure fish into a metal cage or flume carrier box, and then fish passing over the dam is achieved by a vertical or an inclined lift. The key to the successful operation of fish lifts is the efficient attraction of the target fish into the cage or box. At present, the injection of continuous attraction flows at entrance is often used. The attraction flow must be obvious and sufficient, and the speed of flow should be based on the swimming ability of different target fish.

Field observation and assessment of fish passage effectiveness

Due to the lack of sufficient fish behavior data, the design of fishways is not well adapted to fish habits and migratory patterns. As a result, the fish are unable to find the entrance or are prevented by unsuitable water flow conditions in the fishway pool. Field observations are perhaps the most direct and effective method to confirm the effectiveness of fish passages, despite their high costs.

Recently Chinese researchers have conducted a series of field observations and assessment of fish passage effectiveness, such as in the Cuijiaying fishway on Hanshui River, Xinglong fishway, Zangmu fishway on Yarlung Zangbo River, Guangxi Changzhou fishway, and Qinghai Lake fishway among others. **Figure 1** and **Figure 2** show these fishways.

Several previously unnoticed problems have been identified that could strongly improve fishway design. For example, after the operation of the turbines, the riverbed downstream of the dam is scoured severely, resulting in the original fish passage entrance elevation that is no longer optimal; water



Figure 1 | Stepped fishway of Shaliu River in Qinghai Lake, China.



Figure 2 | Distribution of rivers in Zhengzhou.

plants and floating objects can block parts of the entrance into the fish passage; fishermen below the dam set many fish nets to catch fish, and even electrocute fish near the tailwater of the power station. Operational management of fishways should be strengthened¹.

Conclusion

Fishway testing and simulation techniques are advancing in

China. The various target fish, hub layout, hydrometeorology, geography and other aspects affecting the design and operation of fishways have been considered. A relatively complete set of experimental simulation methods have been developed. The 2020 revision of the code titled "Guideline for Fishway in Water Conservancy and Hydropower Project" is also underway. More efficient and well-designed fishways are anticipated to be designed and constructed over the next decade.



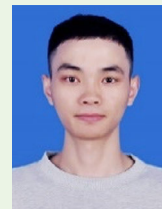
Xiaogang Wang

Xiaogang Wang is a professor in the Hydraulics Department of Nanjing Hydraulic Research Institute. He has strong interest in the many different aspects of eco-hydraulics.



Yun Li

Yun Li is the vice director of Nanjing Hydraulic Research Institute, his main Research interests are in the Hydraulics and river dynamics.



Nanbo Tang

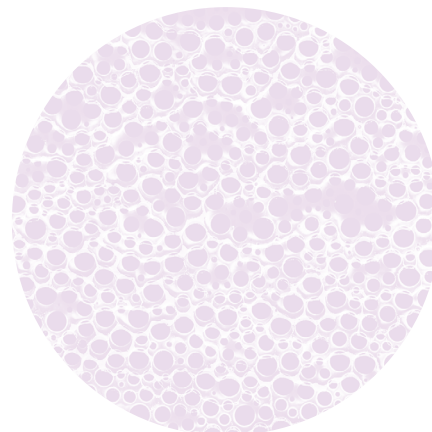
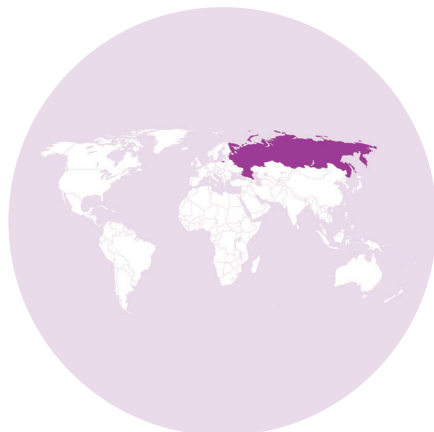
Nanbo Tang is a PhD in the Hydraulics Department of Nanjing Hydraulic Research Institute.

References

- 1 | Cao Na, Zhong Zhiguo, Cao Xiaohong, Zhang Sharon, Zhang Yichao (2016) Status of fishway construction in China and typical case analysis. *Water Resources Protection* 32, 156-162.
- 2 | Cao Qinglei, Yang Wenjun, Chen Hui (2010a) Numerical Simulation of Characteristics of Vertical Slot Fishway on Same One Side. *Journal of Yangtze River Scientific Research Institute* 27, 26-30.
- 3 | Chen Kaiqi, Chang Zhongnong, Cao Xiaohong, Ge Huaifeng (2012) Status and prospection of fish pass construction in China. *Journal of Hydraulic Engineering* 43, 182-188+197.
- 4 | Chao Liu, (2019) Model experiments and numerical simulation study of eel channel in southern China. *North China University of Water Resources and Hydropower*.
- 5 | Mao Xi (2017) Review of Fishway Entrance Research. *Civil Engineering* 6, 393-398.
- 6 | Nanjing Institute of Hydraulic Science, Ministry of Water Resources, Ministry of Transportation (1982) Yu Dao. Power Industry Press, Beijing.
- 7 | Guideline for Fishway in Water Conservancy and Hydropower Project, (2013).
- 8 | Tian Zhengye, Luo Hongying, Yang Haoliang (2018) 3D Numerical Simulation of Vertical Slot Fishways. *Journal of Plateau Agriculture* 2, 537-543+575.
- 9 | Xie Chunhang, An Ruidong, Li Jia, Yi Wenmin, Ma Weizhong (2017) Study on the Influence of Fishway Entrance Layout Mode on Hydraulic Characteristics of Fish Luring Flow. *Advanced Engineering Sciences* 49, 25-32.
- 10 | Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2018: "Strengthening the Protection of Aquatic Life in the Yangtze River", General Office of the State Council, No.95, http://www.moa.gov.cn/nybgg/2019/201905/201906/t20190625_6319268.htm
- 11 | Ministry of Ecology and Environment of the People's Republic of China, 2018: "Key Watershed Aquatic Biodiversity Conservation Program", no 3, http://www.mee.gov.cn/gkml/sthjbgw/sthjbjw/201804/t20180410_434172.htm

FAMOUS WOMEN IN HYDRAULICS

The IAHR task force on Strengthening Gender Equity intends to raise the profile and visibility of women who made major contributions to hydraulics.



Pelageya Yakovlevna Kochina

1899–1999, Russia

In 1921, Pelageya Yakovlevna Kochina (born Polubarinova) graduated at Petrograd University as a mathematician and started working at its geophysical observatory in 1919. From 1927 to 1934, she was a lecturer at Leningrad University and a staff member of the Institute of Civil Aviation Engineering. In 1935, she moved to Moscow's Steklov Mathematical Institute but left for the institute of mechanics of the USSR Academy of Sciences in 1938. Submitting a doctoral thesis in mathematical and physical sciences in 1940, she was an associate of that institute until 1957. From 1958 onwards, she directed the department of applied hydrodynamics at Novosibirsk. In 1970, she returned to Moscow to direct the section of mathematical methods in mechanics at Moscow University.

Kochina is known for her fundamental contributions to the theory of flows in porous media. She developed a general method for solving two-dimensional seepage problems in homogeneous soils. Kochina's research was characterized by a deep and well-organized link with practice, a subtle attention to the physical essence of the phenomena considered, an exact mathematical formulation of the relevant physical problem, and a brilliant mastery of mathematics.

She was awarded, among many others, the Stalin prize in 1946, member of the USSR Academy of Sciences in 1958, Hero of socialist labour in 1969, and the Order of the Friendship of Nations in 1979.

Anonymous (1959). Pelageya Y. Kochina. *Izvestija Nauk Moscow* (3): 6-14, with bibliography. P

Cooke, R. (2000). Pelageya Yakovlevna Polubarinova-Kochina. <http://www.physics.ucla.edu>. P

Kochina, P.Y. Polubarinova (1938). On an integral flow equation for tanks of constant depth. *Izvestiya Akademii Nauk* 2: 249-270 (in Russian).

Kochina, P.Y. Polubarinova (1938). Application of the theory of linear differential equations to some cases of motion of groundwater. *Izvestiya Akademii Nauk* 2: 371-398; 3: 329-350; 3: 579-602 (in Russian).

Kochina, P.Y. Polubarinova (1952). *Theory of groundwater flow*. Nauka: Moscow, translated by J.M. deWiest in 1962. University Press: Princeton.

Vronskaya, J. (1989). Kochina, P.I. *A biographical dictionary of the Soviet Union 1917-1988*: 187. K.G. Saur: London.

Prozorov, A.M. (1973). Kochina (Polybarinova) P.Y. *Bolshai Sovetskaya encyclopaedia* 13: 300.P

Biography extracted from the IAHR book *Hydraulicians in Europe 1800-2000*

A biographical dictionary of leaders in hydraulic engineering and fluid mechanics

by Willi H. Hager ISBN:90-805649-5-8, 788 pp. 2003.

Used with permission of the author.

IN-MEMORIAM



Peter Ackers (1924-2021)

IAHR Honorary Member

Peter was born in 1924 in Bootle, Merseyside (interestingly his future wife Margaret was born on the same day very close to where Peter was born). At school he excelled at physics and mathematics and won a place at Imperial College studying civil engineering. As this was during WW II his course was condensed into two years.

On graduation he worked for the National Physical Laboratory where he carried out research into composite steel and plastic struts. In 1946 he was transferred to Bristol Aeroplane Company, where he worked on designs of the Bristol Freighter and Brabazon aircraft. He subsequently worked in local government during which time he obtained an MSc(Eng) in Civil Engineering and became a Member of the Institution of Civil Engineers (later becoming a Fellow). He also became a member of, amongst others, ASCE and the Institution of Water Engineers.

In 1956 he joined the government's Hydraulics Research Station at Wallingford, where he spent the next 18 years rising to the position of Assistant Director. During that time, he carried out much work on practical engineering hydraulics including work on flumes and weirs, subsequently publishing the definitive book on the subject. He went on to develop the Wallingford tables, the ultimate set of hydraulic design tables for pipework. Furthermore, he developed, with Rodney White, the Ackers-White sediment transport equation. This took a novel approach and was based on similitude theory and was calibrated against a very large database. This equation still provides one of the best representations of the transport of non-cohesive materials. In 1974 he left HRS and joined Binnie & Partners as hydraulics consultant, where he was to remain for 12 years. He was supported by a small team of specialist engineers tackling a diverse range of hydraulic problems from across the globe. During this time, he was also appointed as visiting professor at Imperial College. He specialised in finding simple innovative solutions to complex issues. Examples are listed below:

- Design tables for the new Cairo sewers ranging from 1m to 10m diameter, designed on not only hydraulic capacity but also being able to transport the copious amount of sand that finds its ways into the sewers;
- The design of low head air-regulated syphons for the spillways at Plover Cove reservoir, Hong Kong;
- The use of dolosse as the anti typhoon sea defences at High Island reservoir, Hong Kong;
- The design of a stable artificial beach at Discovery bay, Hong Kong;
- The hydraulic feasibility of the Severn tidal power scheme which could have provided 7% of the UK's electricity generated as green predictable energy;

- Locating water supply intakes on seven estuaries on the Malaysian peninsula to minimise salt water incursion;
- Identifying a strategy to extend the life of Guanting reservoir, which was rapidly filling with sediment but was essential to the water supply to Beijing (on that visit he was amused when he was presented with a copy of his book on weirs and flumes, translated into Chinese which was a standard text in Chinese universities);
- Designing an innovative 100m deep vortex drop shaft for drainage at Ok Tedi gold mine in PNG;
- Developing anti-cavitation measures for the 200m high Shahid Abbaspour dam in Iran;
- Developing the theory to predict the hydraulic capacity of a rough-cut tunnel beneath the Andes from the Mantaro to the Rimac River to supply Lima and beyond (as a continuation of this he developed the theory to cover segmentally lined tunnels, both theories were published in CIRIA publications);
- Development of the rheological theory to pump for sewage sludges in Greater Manchester;
- He advised on the design of several major hydro projects in Pakistan including the 52km Ghazi Barotha power channel carrying a steady 1300 m³/s. The design requirements were to minimise the headloss along this concrete-lined channel, whilst avoiding progressive blockage when Tarbela reservoir was sluicing high quantities of sediment above the power canal intake. This is the largest canal of its type in the world and hence there were no prototype data to rely on.

Peter delighted in resolving these types of issues. He had an incisive mind that could quickly break down a complex problem into a number of smaller manageable issues each of which could be analysed then combined to understand the overall picture. For all of his intellect he was a quiet and very humble man. As a boss he was supportive and always had time to listen and advise in a paternal way. His calm supportive leadership style encouraged us to think that abnormally complex problems were just normal problems that we could readily resolve, with the right approach. This allowed us to confidently design successfully at the very limit of technical knowledge.

His passing leaves not only a gap in the engineering community but also deprives many of us of a mentor and close personal friend. His wife predeceased him by seven years and he is survived by two sons, John and David and a daughter Sheila, together with four grandsons and two great-grandchildren.

John Ackers and Graham Thompson



Prince Sultan Bin Abdulaziz
International Prize for Water

.....
Recognizing Innovation
.....

Invitation for Nominations

**11th Award
(2024)**



Creativity
Prize



Surface Water
Prize



Groundwater
Prize



Alternative Water
Resources Prize



Water Management &
Protection Prize

**Nominations open online
until 31 December 2023**

www.psipw.org
e-mail: info@psipw.org



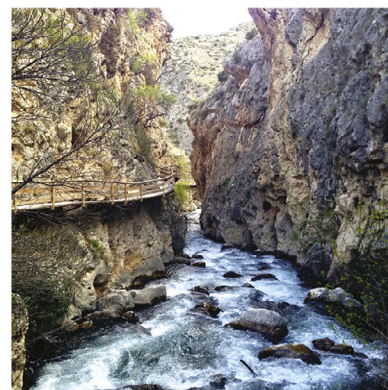
Hosted by
Spain Water
and IWHR, China

39th IAHR WORLD CONGRESS GRANADA, SPAIN 2022 From Snow to Sea



www.iahrworldcongress.org
19-24 June 2022

#FromSnowToSea



Organized by:



Congress Secretariat:

