SPECIAL ISSUE ON WATER

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WMO Water Ways

WMO held a photography competition with the theme “Water Ways” in December 2017. Photographers were encouraged to explore how this vital resource impacts our lives. With global population growth spurring both water demand and exposure to extreme events like floods and droughts, water issues are high on the global agenda.

WMO received over 250 submissions, which it narrowed down to 30 finalists. Its social media followers were invited to select their favourite from these. A WMO jury selected the top 12 photographs based on social media votes, artistic quality and geographical balance.

These winning photographs are featured in this special Water issue of the WMO Bulletin and will also be included in an exhibition during the WMO Global Conference on Prosperity through Hydrological Services in May 2018.

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Creative side of rain in O Barco de Valdeorras, Spain. (Photographer: Arsenio Blanco Gayoso)
Preface

Water is one of the essential elements to human life. It is indispensable to our social and economic well-being. However, more than 780 million people – about 11% of the world’s population – do not have access to clean, safe water. Even more worrisome is the estimate that about half of the world’s hospital beds are filled with people suffering from a water-related disease. Furthermore, 70% of global freshwater resources goes to agriculture and irrigation, and only 10% to domestic uses. It is therefore not surprising that international agreements are focusing attention on the availability and sustainable management of clean and secure water resources. Such agreements include the United Nations 2030 Agenda for Sustainable Development and the Sendai Framework for Disaster Risk Reduction.

WMO is the authoritative technical voice on weather, climate and water within the United Nations system. In addition to supporting various international frameworks, it is the lead technical agency for operational hydrology. The WMO Commission for Hydrology supports the National Hydrological Services of its Member States and Territories to develop and strengthen capabilities and services across the entire hydrological value chain, from monitoring to service delivery. Included within the Commission’s portfolio is the provision of guidance and assistance in real-time water data collection and data sharing, hydrological modelling and forecasting, flood early warning dissemination and water resources decision-support services. Although its various activities have traditionally focused on creating standards and capacity development, the Commission is increasingly emphasizing the need for sustaining operational capabilities. This shift in emphasis will hopefully provide National Hydrological Services of limited capacity with sustainable technological tools for long-term delivery of water information and services.

It is fitting that this special water edition of the WMO Bulletin draws attention to the programmes and activities of WMO in helping Member States and Territories to find solutions to the problems they face across the entire water resources value chain. It is particularly appropriate that this edition is being published on 22 March 2018, World Water Day, which marks the launch of the International Decade (2018–2028) for Action – Water for Sustainable Development. On this occasion, the eyes of the world are focused on this essential human need. It is my hope that the contents will provide the reader with an appreciation of the depth of commitment being made by WMO hydrological and meteorological communities in moving towards a world where all people are safe in face of increasing water-related hazards and have access to clean water.

Harry F. Lins  
President, WMO Commission for Hydrology

Petteri Taalas  
WMO Secretary-General
Water Security in a Changing Climate

By Michael H. Glantz, Director, Consortium for Capacity Building, University of Colorado, USA

The notion of “the water world we want” is a spin-off of the United Nations campaign *The World We Want*. It is open to subjective interpretation, as people have different perceptions of a desired future. Each person or organization is likely to identify their own set of key concerns: food, clean (uncontaminated) water, sustained agricultural productivity, sustainable use of land and ocean resources, healthy lives and secure livelihoods. But whatever utopian world view one creates, it cannot be achieved without adequate sustained water supplies.

In 2009, the then United Nations Secretary-General Ban Ki-Moon noted:

> It is well known that water is life; what this Report shows is that water also means livelihoods. It is the route out of poverty for individuals and communities. Managing water is essential if the world is to achieve sustainable development.

> This challenge is even more pressing as the world confronts the triple threats of climate change, rising food and energy costs, and the global economic crisis. All three are exacerbating poverty, inequality and underdevelopment.

Foreword to UNESCO (2009) report on *Water in a Changing Climate*

It is apparent that climate, water and weather-related concerns are mounting. Societies are becoming increasingly aware that impacts of extreme hydro-meteorological events expected to occur in, say, the 2050s are starting to appear decades earlier. These extreme events – related to climate change – are likely to increase in frequency, intensity and severity.

The world we have

Many people believe that clean water is in endless supply. After all, the global ocean makes up 71% of the Earth’s surface and contains the largest share of the planet’s water supply. The expectation is that scientists will one day devise ways to make the ocean’s saltwater potable. However, freshwater is, and will remain in the next few decades, a critical resource worldwide.

Over 1 billion people still lack access to safe water supplies, while 2.6 billion people lack adequate sanitation. Lack of sanitation leads to widespread microbial contamination of drinking water (http://www.who.int/globalchange/ecosystems/water/en/).

Summary of the planet’s supply of water availability and use (published in 2010)

Water metrics

The world’s 6.7 billion people consume about 4,500 km³ (4.5 teralitres) of freshwater annually. Approximately 10% is for domestic use, 70% is for food production and 20% is for industrial purposes. Freshwater precipitation makes up 2.5% of the available resource and much of that falls in remote areas, leaving only 10% of the total continental precipitation input as easily available for human use (about 9,000–12,000 km³).


Getting to the world we want: “connecting the dots”

“The water world we want” is a motivational notion to stimulate thinking and action to reduce water insecurity, with the well-being of future generations in mind. It is therefore a social invention that can be defined as an idea or a slogan that motivates large numbers of people to take action. Successful social inventions can have as great an effect on humanity as new scientific or engineering breakthroughs.

Thinking about water in a world we want generates an image of a child’s game called Connect the Dots. The picture that appears after connecting the numbered dots is often surprising. This may be a way of raising awareness of the interdependencies among climate, water, food, health and energy activities. The diagram below provides an overview of connecting the dots. It is one perspective of a multifaceted process to move towards the world we want that has water for all.

The world we want

There are many reports about “water affairs” that span different disciplines. Some of these are on the growing scarcity of water, competing demands for and access to water, water conflicts and hot spots, water pollution, human health and so forth. New water-related issues and conflicts are occurring around the globe daily.

Demands for access to water, which is essential for meeting basic human needs – drinking, cooking and hygiene – can create conflict among stakeholders with various needs, wants and demands:

1. The world we have
2. The world we want
3. We cannot have world we want, without the water we want.
4. We cannot have the water we want, without the climate we want.
5. We cannot have the climate we want, without the policies we need.
6. Without the climate policies we need, we are back to the world we had.

Source: R. J. Ross, CCB. 2018
• for development-related socioeconomic activities (e.g. factories versus food production);
• for irrigation of commercial crops or biofuels crops as opposed to meeting the public need for food and water security;
• for the protection of wetlands and other ecosystems versus commercial exploitation; and
• for growing food locally versus for export (e.g. exporting “virtual water”).

It is difficult for those in water-fortunate situations to relate directly to people who spend hours every day searching for water. Water quantity cannot be viewed by itself, because its availability and societal access, as well as increasing demands, are highly variable in both time and place. Gaps that exist between “water haves” and “water have-nots” must be addressed. Throughout history, societies have found reasons and devised means to move water from places of excess to places in need. These methods include using viaducts, surface and underground irrigation schemes, river diversions, rainfall harvesting techniques, water impoundment in dams, reservoirs, and artificial ponds and lakes.

The health, food or energy we want

Water is crucial for human and ecosystem well-being, agriculture, energy and public health. No one can deny that water is vital to life and is increasingly difficult to access, especially for poor people and communities that survive at margins of society with few resources and no political influence. However, it is extremely important to note that water crises are appearing in industrialized and emerging societies with regard to water quality for human consumption (e.g. Flint, Michigan, USA) and with regard to water quantity (e.g. Cape Town, South Africa).

Without clean water, communities cannot practice healthy hygiene, wash or prepare foods, nor help people to replenish fluids. Approximately 842 000 people die each year from diarrhoeal disease associated with drinking unsafe water – almost half are children under the age of five (WHO, 2018).

The figure below defines the water footprint needed to produce a specific amount of grain crops and meat items. Food supply is dependent on the timely availability of water in adequate amounts, and varies among crops. Some (e.g. rice) thrive only with an abundance of water. Others (e.g. sorghum) fare well under dry conditions. Still others need both conditions to occur at various phases of their growth cycle. With a warmer global climate, the uncertainties that have surrounded agricultural activities in the past are likely to increase.

We cannot have the water we want, without the climate we want

What might be considered a great climate for one region may not suit the needs of another region. Even within a region, there are different climate conditions that are favoured, depending on climate-dependent livelihood activities.

The impacts of climate change are not just about record-setting climate, water or weather extremes. There are always high-impact events that affect societies, especially highly vulnerable, at-risk populations. As global to local climate temperatures increase, researchers anticipate an increase in the frequency, intensity and severity of hydrometeorological extremes.

To summarize, without the climate we want, we cannot have the water we need to produce the food we need for the well-being of people in the future.

We cannot have the climate we want, without the climate policies we need

International negotiations have taken place since the late 1980s on climate change science, impacts and policy, right up to the third session of the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change in Kyoto, Japan. Since the signing of the Kyoto Protocol in 1997, governments around the world have increasingly taken a serious interest in the causes and possible impacts of global warming on their countries' economies and policies, and the well-being of their populations and ecosystems.

Deliberations have heightened since then, taking on increased urgency nearly every year until the Paris Agreement was adopted at the twenty-first session of the COP in 2016. This Agreement is proof that a large majority of nations are serious about finding a pathway to prepare for this century's uncertain variable and changing climate, water and weather future. Succinctly capturing this hopeful, if not optimistic view, Rahgav (2017) noted “The Paris Agreement is the most inclusive global agreement on climate change to date... Paris... set a global goal to which every country has agreed to contribute. While it does not bind any one country to any one solution, it focuses all players on the same challenge.”

Without the climate policies we need, we are back to the world we had

By signing the Paris Agreement, countries have agreed that global warming is a threat to well-being and there is a need to prepare for a new climate normal. This normal will continue to increase from decade to decade in the absence of effective limits on greenhouse gas emissions. Many governments are beginning to assess approaches to adjust activities of civil society to a new climate normal. But what about the water?

Are countries preparing for a new water normal?

It seems that most environmental problems in which humans are involved are taking place imperceptibly because they are low grade, incremental and cumulative over the long term. Seemingly insignificant problems from one year to the next become environmental crises in several years or decades. These problems...
include, but are not limited to, tropical deforestation, soil erosion, ozone depletion, greenhouse gas emissions, air pollution and water pollution.

Many water and water-related problems are due to creeping environmental changes. They appear most often at the subnational to regional levels. Societies have difficulties recognizing and coping with slow-onset, incremental, imperceptible but cumulative changes in the environment, so there is a tendency to deal with it later.

Water quality is an example of a creeping environmental problem. Today’s water quality in a given location is not much different from yesterday’s, and tomorrow’s is likely to be not much different from today’s. This thinking is replicated daily, so there appears to be no need to take action. However, after a few years, the degradation of water quality will have become noticeable, significant, harmful and possibly at a costlier crisis stage. It would likely have been easier and cheaper to resolve the water quality contamination earlier.

Water demand is also a creeping change, because of societal factors such as population increase, expansion of water-intensive industrial processes, increasing affluence, migration and the likely increase in variability in extreme hydrometeorological events as the global climate varies and changes. Related extremes – droughts, floods, flash floods, tropical cyclones and others – will not only appear in the currently identified vulnerable regions, but will also occur in unsuspected new regions.

While countries on opposite sides of the planet may be struggling with similar water issues, they are generally most concerned about resolving their own crises. Perhaps a social invention could be devised that would bring together spatially disparate groups with varied interests to work together to resolve the planet’s range of water crises and to work towards the water world we want.

Conclusions

The issues outlined above are being addressed globally, and many ideas have been proposed on how to prepare for the foreseeable scarcity of freshwater resources in many countries, as climate change continues unabated (http://www.circleofblue.org/2010/). Though good ideas abound, actions are not keeping pace. Actions are usually stimulated by an unexpected or rare climate, water or weather disaster. However, societies do not have to wait for their own hydrometeorological disasters to learn lessons that have been learned by countries already experienced in such disasters.

In the 1970s, the United Nations convened several awareness-raising conferences on the human environment, food, population, water, habitat, desertification, climate and technology. Now may be a good time to re-visit the concerns and action-oriented lessons and recommendations. This article could serve as a moment for reflection about where we have been on water issues, where we are now and where we need to go to have the future “water world we want.”
Water in the International Framework

By Tommaso Abrate, WMO Secretariat

In 2015 Members of the United Nations adopted the seventeen Sustainable Development Goals (SDGs) to end poverty, protect the planet and ensure prosperity for all as part of a new agenda to be achieved by 2030. The SDGs and their related targets are based on the achievements and successes of the Millennium Development Goals (MDG) but broaden their scope and include a wider array of topics that are so closely interrelated that no one can succeed alone.

Among these new goals, the sixth – “SDG-6 Ensure availability and sustainable management of water and sanitation for all” – specifically addresses water issues. It highlights the pivotal role that the availability, and quality, of water represents for sustainable development. In a world where it is estimated that by 2050 at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water, the sustainable management of this resource is a key to the achievement of almost all goals. Water issues are relevant also in SDG-11 on urban development and cities, especially when addressing the reduction of risks of death and damages by disasters, including water-related disasters.

SDG-6 addresses the multifaceted complexity of the role of water in human community and activities through six targets. Two address water supply and sanitation and follow on two of the most successfully implemented MDG targets. Four new ones address improving water quality, increasing water use efficiency, promoting integrated water resources management, including in transboundary contexts, and protecting and restoring water-related ecosystems.

The Sendai Framework for Disaster Risk Reduction more comprehensively addresses disasters, including floods and droughts. It aims to achieve a substantial reduction in the loss of lives and assets in disasters by promoting a better understanding of disaster risk, by strengthening disaster risk governance, and by investments in disaster risk reduction for resilience and improved disaster preparedness.

Many of the objectives included in the SDGs and in the Sendai Framework can only be achieved if timely and reliable hydrological data, information, products and services are available. The monitoring of progress in the implementation of SDGs also equally requires hydrological data and information.

Integrated water resources assessment is a goal per se, and the continuous flow of information for adjusting management practices to changing situation is its foundation stone. Indicators developed for measuring progress toward targets, such as the protection of ecosystem or improving water use efficiency, cannot be calculated without data on water flowing or stored in surface bodies, groundwater and reservoirs. Effective flood and drought policies can be implemented only with data and models for assessing the frequency and magnitude of foreseeable events. The role of National Hydrological Services is to provide the essential basic knowledge on the status and trends of water resources as well as the tools for interpreting them, which are required by the international community and the national authorities to achieve the goals that they set to themselves. To do so, it is essential to ensure that data monitoring and information production receive the necessary resources. An open dialogue is required between the parties to ensure that possibilities offered by science and technique are matched with the knowledge requirement of policy and decision-makers.

The World Meteorological Organization has actively participated in the UN-Water framework for the development of the methodologies to be used for monitoring progress in the implementation of the SDG. However, the Organization’s greatest contribution to achieving the SDGs will come through its practical work directly with its Members, supporting and developing their capacity to collect and process data and to produce actionable information and knowledge for decision-making.
Access to clean water sources brings new life to a community in the village of Mcuba, Swaziland. (Photographer: Luke Romick)

“Water has been recognized as fundamental human right, but hundreds of millions or even billions are denied this right.” – Michel Jarraud
Celebrating 25 Years of WHYCOS

By Michel Jarraud, WMO Secretary-General Emeritus, Former Chairperson UN-Water

Anniversaries are a good opportunity to reflect upon the past, look at successes and failures, and project into the future. 2018 will mark the 25th anniversary of the World Hydrological Cycle Observing System (WHYCOS), and follows the anniversaries in 2017 of two key water-related developments for WMO:

• The 70th anniversary of the first session of the International Meteorological Organization (the predecessor of WMO) Hydrological Commission, which called for close collaboration between meteorological and hydrological services and for regional cooperation in hydrology, especially in the area of standardization and exchange of hydrological observations.

• The 40th anniversary of the adoption of the Mar del Plata Action Plan at the UN-Water conference in 1977.

It further marked the 30th anniversary of the 3rd joint WMO/United Nations Educational, Scientific and Cultural Organization conference on hydrology.

These conferences, as well as successive sessions of the WMO Commission for Hydrology, highlighted the significant decline in hydrological observation networks and stressed the importance of addressing this situation.

It is in this context that the original concept for a global hydrological network was proposed in an article by Rodda et al. (1993). This explained that, over previous decades, many countries had reduced financial support for operation and maintenance of hydrological networks, which resulted in serious deterioration of the number and quality of associated observations.

A worrying consequence was the dramatic weakening of knowledge with respect to water resources in many parts of the developing world, especially Africa. At the same time, demand for such resources was increasing rapidly because of economic and demographic development, and pollution was reducing the available quantity of usable water.

The issues were further complicated by the fact that hundreds of river basins and aquifers are shared among two or more countries. So the need for an internationally coordinated action was clear. The 12th World Meteorological Congress in 1995 approved the concept and implementation strategy for WHYCOS. The key principle was to develop a number of networks (HYCOS), on basin, subregional or regional scales, within an overarching framework. Special attention was to be paid to addressing the deficiencies identified. These included the differing procedures for collecting data, variations in quality assurance procedures and standards, unreliable telecommunication systems, and outdated, inadequate or even non-existent information management systems.

Implementation

Based on the WMO World Weather Watch Programme, the WHYCOS concept had two components: a support component to strengthen cooperative links among participating countries, and a flexible and adaptive operational implementation component.

In 1999, the 13th World Meteorological Congress reviewed implementation of WHYCOS and adopted a governance mechanism (the WHYCOS International Advisory Group) associating the various partners. The advisory board of the Global Hydrometry Support Facility, also known as HydroHub, has now replaced this mechanism. The 13th Congress also adopted Resolution 25 (Cg-XIII) on the exchange of hydrological data and products, the hydrological counterpart to

Resolution 40 (Cg-XII) for meteorological data and products.

The first project, implemented from 1997 to 2001, in cooperation with the World Bank, was regional, covering the Mediterranean Basin: Med-HYCOS. So far, 12 projects have been implemented, the most recent being IGAD-HYCOS, which just completed phase 2. These projects cover basins or regions around the world, including Africa, Asia, the Caribbean, the Arctic region and Pacific Islands. They take into account the local context and have different elements. For example, in the case of island States, the focus is on sharing of competencies and expertise, rather than exchange of data, while the sharing of information remains a key priority (and challenge) in other parts of the world.

WHYCOS, together with the WMO Hydrological Observing System (which aims to support preservation of and access to global hydrological data) and the Global Innovation Hub, is now a pillar of HydroHub. This is an integrated initiative to promote and develop further hydrometry activities, by reinforcing human and technical capacities, technical innovation and data exchange. It will ensure better sustainability of hydrological investments.

Achievements and challenges

After 25 years, it is now possible to reflect on the main WHYCOS achievements, but also on some challenges or weaknesses:

- About 500 hydrological observing stations have been installed, and databases modernized. Training and capacity development have been central to WHYCOS implementation. This has led to the launch of a number of new hydrological products and services.
- Within WMO, WHYCOS has contributed to increasing the visibility of hydrological issues, and the synergies with other elements of the WMO mandate, in particular weather and climate issues. It also contributed to improving the perception of WMO as an important actor for water-related issues, from hydrometry to prediction of water-related extreme events, through to data management and data exchange.
- The products and services adapted to user needs are still insufficient. One of the important lessons learned concerns the challenge of sustainability. A few years after completion of some of the projects, a significant number of observing stations were no longer operating, due to lack of financial or human resources, or inadequate training. This highlights the need to include sustainability in the project design and implementation plans, and to foresee technical support interventions beyond the lifetime of projects. HydroHub will address this aspect.
- There is sometimes insufficient appropriation of WHYCOS project outcomes by beneficiary countries, which contributes to the sustainability challenge identified above.

Concluding remarks

Water has been recognized as a fundamental human right, and it has been assigned a dedicated Sustainable Development Goal (SDG-6 - Ensure availability and sustainable management of water and sanitation for all) by UN Members in 2015. Knowledge on the qualitative and quantitative aspects of water cycle are crucial for the achievement of this goal.

One of the main objectives of WHYCOS was to address the deterioration of hydrological observing networks. After 25 years, it is possible to say that without WHYCOS, the situation would be significantly worse. However, there is still a long way to go, and in many countries (including developed ones), the reduction in the density of observation networks is still a serious source of concern.

During the same period, the number of people living in water-stressed regions has grown considerably and is predicted to increase even further. The number and intensity of extreme water events are both increasing, as a result of human-induced climate change and because growing numbers of people are living in vulnerable areas. Therefore, the need for better information on water resources and better management is more critical than ever.

There is no doubt that WMO, in particular through WHYCOS and the development of hydrological services, can make an invaluable contribution to the main hydrological challenges of this century!
Management of Hydrological Information and Sustainable Development

By Frédéric Maurel, Water Resources Expert, French Development Agency

Human activities are exerting pressure on the environment with consequences such as global climate change, disruption of the hydrological cycle and impacts on water catchments. In addition, demand for energy and food – water intensive activities – is increasing with population growth. An improved knowledge of water resources and related risks is essential in order to optimize the allocation of water for various uses.

Towards this objective, the French Development Agency has been working closely with transboundary basin bodies on the management of hydrological information for years. Programmes of the WMO Hydrological Cycle Observing System (HYCOS) have benefited from this close cooperation, namely in the basins of Niger (with the Niger Basin Authority - NBA), Congo (with the international Congo – Oubangui – Sangha Commission – CICOS) and Mékong (with the Mekong River Commission).

The use of water for the production of hydroelectric power still has great potential in many equatorial rivers, including the Congo River. There is similar potential for agricultural production, for instance, in the Senegal and Niger basins. However, investments in crucial infrastructure and equipment to meet these needs fall short if they are not based on reliable hydrological information and on models, the quality of which depend on data series accumulated over time. Knowledge of hydrological regimes is a linchpin of integrated water resources management and the foundation of any climate adaptation policy.

For donors like the French Development Agency such information is essential for the design and adequate implementation of any water-related project, whether it concerns irrigation, drinking-water supply, sanitation, hydroelectric power, or flood control. Knowledge of hydrological regimes is thus essential for any project to meet the Agency’s climate adaptation criterion – one of the Agency’s objectives is that 100% of its contributions are compliant with the Paris climate agreement¹. Such knowledge also ensures the sustainable use of water resources, and that environmental reserve flows are maintained.

Unfortunately, hydrometric stations in many river basins worldwide are in a state of neglect as the authorities responsible for their exploitation and maintenance lack resources. Activities within the framework of the HYCOS programmes have to overcome considerable obstacles. Some pertain to having stations scattered over vast territories, others to the increasing scarcity of the required skills to set up stream gauging, which is not done frequently enough, and still others to the need to optimize tools to provide reliable measurements of water height and the regular transmission of this data.

Further, the division of tasks and the allocation of financial and human resources between transboundary institutions and national hydrological services need to be improved. This is necessary to optimize data collection, transmission, processing and integration in models for the statistical description of regimes, forecasting, design and management of infrastructure for regulating and sharing water resources.

¹ Outcome of the 21 Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC)
Outlook for implementing technological innovation

The last session of the WMO Commission for Hydrology placed its World Hydrological Cycle Observing System (WHYCOS) within the framework of the Global Hydrometry Support Facility (HydroHub), while the WHYCOS International Advisory Group became part of the HydroHub Advisory Council. These developments within WMO have a technological innovation component that should allow WHYCOS to assist hydrological services in the field with simple but robust technologies. Such technologies should be complemented by information provided by satellite observation systems, including detailed altimetry measurements. Applications of these data, tested in the projects supported by the Agency in the Congo River basin, are very promising.

“People manage well only what they know well.” This saying implies that long-term commitment and adequate means and competencies are essential. These can be strengthened through public-private partnerships and by providing access to recognized experts and utilities familiar with the management of measuring networks and modelling tools. The challenge is to wholly manage technical requirements and innovations, and to ensure the accuracy of hydrological information systems for applications that can assure their sustainability by the collection of fees for services provided.

Technical and institutional solutions already exist and must be adapted to each context. The joint efforts of WMO and its partners within HydroHub will contribute to meeting the Sustainable Development Goals (SDGs) that we are all committed to achieve, particularly those concerning integrated water resources management at all levels, including transboundary (SDG 6.5), and a rational use of water resources (SDG 6.4).
Case Study: Implementation of the IGAD-HYCOS Project in Uganda

By Nebert Wobusobozi and Leodinous Mwebembezi, Uganda Ministry of Water and Environment, Directorate of Water Resources Management

About 60% of the East and the Horn of Africa – the region covered by the Intergovernmental Authority on Development (IGAD) – is arid or semi-arid. The availability of water resources is uneven and irregular, both in space and time, notwithstanding the presence of the River Nile and several lakes. The IGAD-HYCOS (Hydrological Cycle Observation System) project, launched in 2011, aimed to develop a sustainable and integrated water resources management system in the region.

IGAD member States – Burundi, Djibouti, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan and Uganda – have experienced periodic droughts over the last few decades with dramatic human, economic and ecological consequences. On the other hand, the characteristic high-intensity rainfall of the region’s short wet season leads to major flooding, the impacts of which have aggravated due to climate change, and the absence of appropriate adaptation strategies. In the last two decades, some 5 000 lives have been lost in 96 major floods that affected approximately 12.5 million people and left 2 million homeless.

The IGAD-HYCOS project would address these issues by enhancing regional cooperation and collaboration in the collection, analysis, dissemination and exchange of hydrological and hydrometeorological data and information for water resources assessment, monitoring and management. Specifically, the project would provide adequate infrastructure for hydrological observations and data receiving platforms, including databases and web-based data and information dissemination capabilities. These activities would strengthen regional and national capacities for more-efficient, cost-effective and sustainable water management by of National Hydrological Services (NHSs).

Project implementation

The entire IGAD region participated in the project, which ran from July 2011 to March 2017 with funding from the European Union and with WMO as the implementing agency. In each country, the project was placed under the ministries/departments or agencies responsible for water resources management, and a steering committee member, acting as overall supervisor, was assisted by a national focal point responsible for day-to-day operation. The Project Steering Committee – which included the steering committee member and national focal point of each country as well as the implementing and funding agencies – provided overall policy guidance. The Project Management Unit acted as the secretariat.

In this article, Uganda is used to exemplify the implementation and achievements of IGAD-HYCOS in each of the nine participating states. In Uganda, the IGAD-HYCOS project was anchored in the Directorate of Water Resources Management (of the Ministry of Water and Environment), and supported its NHS.

Main achievements

- Strengthening infrastructure for data collection, processing and dissemination

The project has assisted countries to design a strategic, and optimum, monitoring network of surface water and groundwater stations. Each of these networks includes a mix of upgraded old manual stations and entirely new stations that have all been equipped with telemetry systems and now support real-time data delivery to national and regional databases.
In Uganda, 12 surface water and 26 groundwater stations were installed by NHS technicians with support from the project’s field hydrologist. In the entire region, 199 stations were installed – 123 surface water and 76 groundwater stations. Operation and maintenance for the new stations has been gradually streamlined into the national networks at varying levels for individual countries.

In addition to the stations, the project provided equipment to monitor water resources. This included an acoustic Doppler current profiler, current meters, boats and outboard engines for conducting discharge measurements and survey equipment for use in the benchmarking and setting up of stations. The equipment has enabled countries to develop rating curves for new stations and to recalibrate gauged sections on old networks.

- **Developing a regional database and enhancing national databases**

  The project has supported the strengthening of national databases that will, in turn, feed into the newly established regional database. This has enabled countries to process data and information, and to generate useful information for decision-making on water-related issues to support sustainable economic developments.

  The Project Management Unit has worked with countries to design data management systems that meet their hydrological requirements. First, the country’s existing systems were assessed – most had near-obsolete databases (e.g. HYDATA), decades old and no longer supported by their original suppliers. Hence, it was necessary to upgrade many of them. New hardware and data management software were recommended, resulting in more-effective systems.

- **Increasing visibility by development of the IGAD-HYCOS web page**

  The Project Management Unit created a website for posting all information related to implementation. This was replicated by NHSs who posted similar information on the national web pages. Thus, the project had visibility at regional and national levels.

- **Strengthening regional and national capabilities for water resources management**

  To fully manage water resources in the implementing countries, it was necessary to have well-trained technical staff within NHSs. The project’s regional and national training programmes enhanced the skills of technical personnel in various aspects of water resources management (see Regional/National (Uganda) training programmes tables).

  The first training sessions were at the regional level, and targeted resources persons responsible for national training. These resource persons then replicated the sessions at the national level, thus, many national staff have benefited from the workshops.

- **Managing the IGAD regional centre for water management**

  The IGAD regional centre manages the regional water information system/database, including generation and dissemination of useful hydrological products. The centre plays a coordination role and promotes cooperation among member States. The regional database, currently under the care of the IGAD Climate Prediction and Applications Centre (ICPAC), receives data transmitted directly from observing stations in member States. ICPAC is expected to operationalize the centre and work with member States to ensure sustainability of the IGAD water information system.

- **Experiences and challenges during implementation**

  Coordinating multidisciplinary, multicultural, multi-linguistic and politically diverse teams to implement the regional project was a challenge. A mechanism for harmonized work methods and procedures was
adopted by steering committee members to address variances.

Nine countries with differing law regimes, operating procedures and standards for allowing free flow and sharing of data for joint purposes were involved in the project. Confidence-building had to take place step-by-step. It started with the compilation of a draft manual on harmonized data sharing for technical review and approval by individual countries. This was followed by the development of a binding data-sharing protocol to be ratified at the governmental level. At every stage, countries were reminded of their existing data-sharing obligations under other arrangements.

Some of the countries had poor Internet network connections and data transmission was not well covered by the networks of mobile service providers. Conversion to satellite transmission was recommended. For other Internet-supported hydrological or communication operations at the NHSs or in the data centres, bandwidth or bundles for Internet connections from service providers were enhanced.

There was a requirement for re-configuration of stations to a regional file transfer protocol as some NHSs initially had poor Internet connections. As assets are gradually transferred from regional project databases to ICPAC, there is a need for further support on data

### Regional training programmes

<table>
<thead>
<tr>
<th>No</th>
<th>Course name</th>
<th>Date</th>
<th>Venue</th>
<th>Number of participants</th>
<th>Number of facilitators</th>
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<tr>
<td>1</td>
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<td>Nairobi, Kenya</td>
<td>20</td>
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<td>1–5/09/14</td>
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<tr>
<td>3</td>
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<td>20–25/10/14</td>
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<td>Hydrological modelling Arch-GIS application</td>
<td>15–19/12/14</td>
<td>Addis Ababa, Ethiopia</td>
<td>25</td>
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<tr>
<td>5</td>
<td>Hydrological forecasting &amp; times series analysis</td>
<td>11–15/01/15</td>
<td>Wad Medani, Sudan</td>
<td>21</td>
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<tr>
<td>6</td>
<td>Database management &amp; website/portal design</td>
<td>20–25/07/15</td>
<td>Nairobi, Kenya</td>
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### National training programmes in Uganda

<table>
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<th>Course name</th>
<th>Date</th>
<th>Venue</th>
<th>Number of participants</th>
<th>Number of facilitators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Installation, operation &amp; maintenance of telemetry stations/ equipment</td>
<td>16–31/06/15</td>
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<tr>
<td>2</td>
<td>Integrated flood management</td>
<td>25–30/06/16</td>
<td>Kampala</td>
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<tr>
<td>3</td>
<td>Hydrological modelling &amp; Arch-GIS application</td>
<td>1–5/07/16</td>
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<tr>
<td>4</td>
<td>Database management &amp; website/portal design</td>
<td>20–25/07/16</td>
<td>Entebbe</td>
<td>11</td>
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</tr>
<tr>
<td>5</td>
<td>Installation, operation &amp; maintenance of groundwater stations</td>
<td>16–24/01/17</td>
<td>Entebbe</td>
<td>16</td>
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</table>
integration to ensure that data are received at national level, then transmitted to the regional database.

There is still a need for integration of incoming data from observing stations into the existing database. For every new project, the observing stations come with a separate computer server as the data-receiving platform. However, data are gradually being integrated into a common database. In the case of the IGAD project, data from the field were transmitted directly to the regional database in Nairobi pending twinned transmission to the national and regional databases.

Vandalism of equipment has lead to large data gaps. During installation and testing, solar panels were temporarily used to power small, but long-lasting, batteries. However, the power sources – both solar panels and batteries – are often stolen or vandalized. The longer-term solution to minimize disruptions caused by vandalism is to connect all stations within a 1-km radius to the national hydropower grid.

For after-sales service/support by suppliers beyond the project lifetime, there is online communication with the manufacturer whenever there is a problem. The suppliers have also created local counterparts and outlets to handle after-sales support and to provide access to spare parts. This is the result of a policy to encourage local content in all procurements.

**Measures being adopted for sustainability**

There is a need to create political goodwill to support the above initiatives. Politicians need to be brought on board, as they control national and state resources. Governments in the region do not give priority to water resources management, thus maintenance of the newly created infrastructure may pose challenges.

In Uganda, the NHS has prepared a paper on the importance of water resources management to the socioeconomic development of the country. This will assist the ministry to lobby for more financial allocations from national funds for operation and maintenance and further expansion of the monitoring network.

The establishment of a balanced team of dedicated staff – hydrologists, technicians, data management experts and information technology specialists – will ensure the sustainability of the new infrastructure. A Water Resources Institute is in the final stages of being established in Uganda. It will provide continuous capacity-building of ministry staff in the specialized areas of data management, information technology for data transmission, flood modelling, and more. The Institute will also serve as an induction vehicle for fresh graduates joining the NHS to narrow the gap between theory and practice. Further capacity-building to keep staff abreast of advances in technology will also contribute to the sustainability of systems.

There is a need for community support for the data-collection infrastructure. Most gauging stations in Uganda are remotely located from human settlements, which makes them subject to vandalism. Sensitization of communities to the use of the equipment and benefits to them, and the involvement of local artisans as observers on manual stations and for simple repairs, has reduced incidents of vandalism.

The planning model, based on the hydrological catchment adopted in Uganda, is also increasing the appreciation of local communities for the facilities. The model engages all stakeholders, through their catchment management organizations, in deliberations on allocations of water for various competing uses. In this way, the value of the observing stations in providing base data for developing the catchment management plans becomes apparent to the community.

In Uganda, the NHS has prepared a business plan for its operation. The Government will provide half of the required financial resources. The NHS is advocating for the creation of an environment fund for activities related to water resources management to generate revenues to cover the rest of its budget. Contributions to the fund would be by way of a small tax levy on revenue from data sales and from permits for water abstraction and effluent discharge.
Innovations for Sustainable Planning and Management of Watersheds

Wholesaling the paradigm of decision support with open access data & tools

By Nagaraja Rao Harshadeep¹, Global Lead (Watersheds), The World Bank Group

The dramatic technological advances of recent decades offer opportunities to modernize the way in which water and other natural resources are planned and managed. New high-quality datasets covering topics like water resources, disasters, climate change, trade and general development are being collected and made public as online data and mapping services by institutions and governments around the world. Earth observation from an increasingly powerful fleet of public and private satellites provides unbiased, synoptic views of the globe.

But many of these datasets – especially those from in-situ monitoring, even when digital – are fragmented, come in various formats, and are not well-known or easily accessible or viewable when scattered among thousands of websites. Communities, governments, regional organizations, development professionals, and others need easy, reliable, and useful access to these diverse datasets to support decisions at all levels, especially when it comes to managing watersheds. There is a need for a new paradigm to support decisions with open access data and tools that can leverage recent technological advances.

Need for a decision focus

Every day decisions are made – or not made (which also have impact) – relating to hydrometeorology. These can include decisions related to short-to-long term planning and daily operations:

- How can my country be better prepared for adapting to historical climate variability and ongoing climate change? Who do we warn (and when) about the impending flood? Which stakeholders need to be compensated this year for drought losses? When do we release water from this dam to help cushion the impact of incoming floods? Will I have enough water to sustain my crop? How much groundwater to pump today for this field? How could land use and climate change impact the services of this watershed? Where could the water required for an urbanizing landscape come from? Do I need an umbrella today?

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All these decisions can be taken in a manner that includes both meaningful analytical and stakeholder inputs – with the analysis providing the information and stakeholders providing the opinions.

**The data value chain**

Often, we get stuck at the level of data, seeking the decision nails that a shiny new data hammer can support. It is useful to change that paradigm by exploring the needs of the decision and how the data value chain can be developed to convert data to information to knowledge to support decisions.

For example, flood management decisions require good flood early warnings generated by forecasts (weather, hydrologic, and flood inundation) that require a range of data and analysis as shown.

**Data, data, everywhere**

There is an increasing amount of innovative equipment for monitoring and collecting data on all aspects of the hydrologic cycle – weather, surface and ground water hydrology, water quality, disaster risks, land cover, water use, and other water stocks, fluxes, and trends – in any watershed. The way these are transmitted to data repositories is also changing – moving from manual observations to automated digital systems. All of this is resulting in a deluge of petabytes of data, with just one Himawari meteorological satellite generating over 3 Terabytes every day.

Modelling tools help to convert these data into information – these can range from forecasting (e.g. short-term to seasonal), to water balance and systems simulation, optimization, and multi-criteria models that provide a more holistic systems perspective. Innovations in modelling tools are also making these more widely available.

**What’s broken today?**

However, many countries today rely on very distributed, “retail” level approaches to support administrative, watershed/basin decisions at a sub-national level. The data collected in this way (often still done manually on paper in less developed countries) has many challenges – primarily that they are not usually comprehensive in space and time, of uncertain quality, and not available or accessible in a timely
manner in useful formats to support analysis and decision-making.

Analytical tools, if used, are often also at a “retail” level, coming at great cost for a small area of interest (e.g. a single watershed or river basin), based on expensive proprietary software that only a few donor-financed programs can afford, and are so complex only a few PhDs in the country can use them. Clients are often confused on which tools to use and the innovations are difficult to keep track of, leading to further confusion. Access to the tools and underlying data is often restricted by policies and cost/knowledge of the software requirements, making them usable by only a small team that has little incentive to change the status quo. It is difficult for clients in the developing world to effectively participate in developing, sustaining, and improving these tools or to integrate them into a decision-making framework that often has a legacy culture of “data-free analysis and analysis-free decision-making.”

The resulting institutional complexity has resulted in a fragmented approach that tends to encourage disintegrated water resources management – with high transaction costs for exchanging data even among government agencies. Multiple, fragmented observation networks blossom with poor access or efficiency of use of the data from these networks.

Emerging wholesale approaches

A range of more “wholesale” platforms that provide a glimpse into the future are emerging. These are often enabled by a few innovations:

- **Data to online data services:** The conversion of traditional databases to online data services is one of the most under-appreciated advances in water resources planning and management. The serving of data through open application programming interfaces and using harmonized standards for data and mapping services, especially based on Open Geospatial Consortium (OGC) formats, has enabled ingestion of such data for interactive, real-time visualization and online analysis. Using this approach, institutions can retain the right to serve and update the data that they are responsible for, while benefitting from other data services.

- **Analysis to online analytical services:** Similarly, a move to online analytical services is promising to revolutionize the toolkits for water managers and users even in the poorest of nations. These tools are not only using the power of online data services to ingest in-situ and earth observation products in real-time, but also providing their outputs using the same types of online data platforms.

- **Get ahead in the Cloud:** The emergence of high-speed cloud services has enabled a new paradigm for storing, analyzing, and accessing data. These tend to be a combination of commercial subscription services (e.g. cloud storage and cloud computing platforms) and experimental somewhat free storage/analytical platforms (e.g. Google Earth Engine), with a promise of artificial intelligence making these systems even smarter in the coming years. There is significant scope for development partners to work with information technology foundations to develop a free global cloud framework for hydromet and water data that could completely revolutionize water resources management in a compressed timeframe.

- **Wholesale platforms:** A particularly exciting innovation that has been developing is to move to more “wholesale” platforms that can help access data and analytical services across platforms at low cost. An example of such a platform from the World Bank Group is the Spatial Agent App (see page 22), that provides easy access to a growing world of free, public-domain data and analytical services on mobile devices.

Looking ahead

An exciting future – with a range of increasingly powerful “wholesale” data, analytical, and knowledge services and platforms that can be applied at any “retail” level of decision support – lies ahead. Many of these will consist of free online services that can be packaged, augmented, and used in a new generation of customized portals, apps, and interactive e-books.

The level of connectivity in many parts of the world, especially Africa, does not permit easy access to this new world of data and analysis. However, the recent dramatic growth and projections for further growth in smartphone use and data connectivity worldwide and the amazing advances in disruptive
Spatial Agent App

A world of free, public domain data and analytical services

The Spatial Agent App from the World Bank (iOS, Android and web versions are available) puts a world of insights at the user’s fingertips by enabling easy and highly interactive access to a burgeoning group of free, public domain multi-sectoral datasets – including near real-time data – at the global, regional, and national levels.

The Spatial Agent platform brings together a wide range of development-related datasets from thousands of web services from several institutions around the world. Users can seamlessly search, visualize and compare data related to development issues through interactive maps and charts at different scales and time ranges around the world.

The system is being updated regularly with new data and analytical services, functionality, partnerships (including the use of data catalogs from the Group on Earth Observations), and user platforms. The aim is to improve awareness of free data services not only on hydromet aspects but also on other development aspects to give a more holistic multi-sectoral spatial perspective.

Such platforms could help showcase and leverage a rapidly exploding world of relevant free online data and analytical services on convenient mobile devices. They could also help institutions develop their own customized versions of Portals and Apps for their targeted clients.

In addition to what will inevitably be a plethora of free data and tools for the digital earth, there will be a range of value-added, analytical, alerts, and knowledge subscription or other services provided by the private sector and customized to various stakeholders. This will usher in a new era of cooperation across the “wholesale” and “retail” levels. Much operational work done at a local “retail” level can better leverage global and regional “wholesale” platforms and partnerships. “Retail” work can also benefit “wholesale” services by providing data for better calibration and validation and helping to shape better services and customization based on demand.

What do we need to do today other than wait for this new world? The answer lies in shaping mindsets to use the power of individuals and institutions to meaningfully “liberate” data in free, open, real-time, and analysis-ready service formats. Today, you would be hard-pressed to find a single hydrologic gauge that meets this criterion in many developing countries. And also in shaping mindsets that proactively try to learn from, leverage, and contribute to global good practice. Local leadership with open, curious minds are essential to undertake the difficult task of changing entrenched institutional inertia. These are the conditions that will enable a paradigm shift for resources management and climate resilience in watersheds around the world.
The Rio Mourinho bridge in Alentejo, Portugal was submerged by the waters of Pego do Altar dam for 2 decades, but re-emerged with the dam only at 8% of its capacity. (Photographer: António Francisco Ribeiro de Oliveira)

The Hindu Kush mountain range in the Central Highlands of Bamyan province, Afghanistan. (Photographer: Najeeullah Azad)
Supporting Development of International Data Exchange Policies
Experiences from the Sava River Basin

By Harry Dixon¹, Samo Grošelj² and Mirza Sarač²

In 2014, WMO assisted the International Sava River Basin Commission in establishing a ground-breaking hydrological data exchange policy across five Balkan countries, enhancing data sharing to underpin sustainable transboundary water management.

Access to high-quality and up-to-date hydrometric data is the foundation for effective water management. The famous management adage, “you can’t manage what you don’t measure” applies just as much to hydrology as it does to other areas. National Meteorological and Hydrological Services (NMHSs), environmental regulators, researchers and the public routinely rely on river discharge, precipitation, lake/reservoir levels and other hydrometric data to underpin their provision of flood warnings, water resource assessments, riverine transport information, management of aquatic ecosystems and much more.

However, rivers do not respect administrative boundaries. In many cases, they flow through multiple local and national jurisdictions on their journey from source to sea. All catchment managers face the challenges of maintaining hydrometric monitoring networks, ensuring systems are in place to maximize utility of data and modernizing infrastructure to take advantage of ongoing information technology (IT) developments. Transboundary river systems have the added dimension of needing to share data among organizations at operational timescales.

The World Meteorological Congress adopted a resolution recognizing the importance of hydrometric information sharing and the benefits to its Members with shared river basins in 1999. In doing so, WMO Members committed to broadening and enhancing, whenever possible, the free and unrestricted international exchange of hydrological data products. While the resolution provides a clear framework for data exchange, hydrometric information is both complex and expansive, and its implementation raises questions such as:

- What variables need to be exchanged?
- What monitoring points should be included?
- How should the data be transferred and how often should they be updated?

These were the questions that those trying to establish a data-sharing policy for one of the most important rivers of South-east Europe had to answer.

Sava River Basin

The Sava River Basin covers a total area of approximately 97 700 km² and represents one of the most-significant sub-basins of the River Danube. It is a very important transboundary river basin that is shared among six countries – Bosnia and Herzegovina,

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3 Resolution 25 (Cg-XIII)
Croatia, Montenegro, Serbia and Slovenia, while a negligible part extends also to Albania – with 18 million inhabitants. The Sava River is nearly 1 000 km long, and the average discharge at the confluence with the Danube River in Belgrade (Serbia) is about 1 700 m³/s.

Distinct hydroclimatic variations exist across the basin, with a mountainous alpine climate in the north-west and moderate continental (mid-European) climate in the lower parts of the basin. Long-term average annual precipitation ranges between 600 and 2 300 mm, and long-term evapotranspiration between 320 and 710 mm/year. As a result, spatial distribution of runoff varies from 150 mm/year up to 1 200 mm/year, with a long-term average of about 580 mm/year. In general, the right bank (southern) tributaries of the Sava River are characterized by a much higher water yield than the tributaries to the north.

In 2002, a Framework Agreement on the Sava River Basin was signed by the riparian countries. The agreement led to the formation of the International Sava River Basin Commission (Sava Commission). Its mission is to support navigation on the river, promote cooperation in sustainable water management and undertake measures to reduce water-related hazards.

In an internationally shared basin, the exchange of quality-controlled data and information is an essential element for undertaking basin-wide activities ranging from flood protection to water resources management. Under the Framework Agreement, the Parties – Bosnia and Herzegovina, Croatia, Serbia and Slovenia – are obliged to exchange information on the water regime on a regular basis. However, the technical details of data exchange and interoperability were still to be agreed.

In May 2012, the United Nations Office for Disaster Risk Reduction (UNISDR) and WMO started joint implementation of a project on Building Resilience to Disaster in the Western Balkans and Turkey, with the support of the European Commission. Among its many strands, the project provided an opportunity for WMO to work with the Sava Commission to enhance hydrological data management and exchange procedures. Workshops were convened, bringing together representatives of the NMHS and other related organizations (such as watershed and environmental agencies) to discuss requirements for data sharing and agree principles for a new policy. This would detail what would be shared, how, when and by whom.

The resulting Policy on the Exchange of Hydrological and Meteorological Data and Information in the Sava River Basin (2014), signed by hydrometeorological services and water agencies, was developed to be fully consistent with World Meteorological Resolutions 25 (Cg-XIII) and 40 (Cg-XII). The policy also supports the data- and information-sharing elements of the United Nations Watercourses Convention. At a European level, it is consistent with the United Nations Economic Commission for Europe Water Convention (Article 13) – which encourages riparian Parties to exchange data on the environmental conditions of transboundary waters.

The policy was structured to provide:

- A framework for sharing any hydrological (or meteorological) data that the signatories want to exchange under their own arrangements
- A minimum level of “core”, regular data exchange

This two-strand approach allows the signatory organizations to continue, and expand, ad hoc data sharing on a project-by-project basis, while also securing a minimum amount of core data exchange. This was seen as being vital for effective management of the basin.

The ever-changing requirements of hydrometric data users and the evolution of monitoring capabilities mean that the data which can or needs to be exchanged under such policies is never static. Importantly, the Sava Policy was written to allow the details to be regularly updated (for example, details of exactly which stations and data types are included). While an initial set of data types and monitoring stations was agreed in annexes to the policy, these were specified in such a way as to allow future modifications of the agreement. This ensures that it continues to meet the needs of signatories, while preventing the need to re-open negotiations on the policy as a whole.

The details of the policy were established by experts on water management issues that work in the basin.
They were driven by pressing practical needs and informed by in-depth local knowledge of the monitoring networks and data availability. The development of the policy represents just one step of the ongoing successful cooperation in the Sava River Basin. WMO support to the Sava Commission provided an independent source of advice and help, thus rapid progress was made. The entire process of policy development and signatory took less than 18 months.

Since its signing in 2014, the Sava Commission, in cooperation with relevant national institutions, has taken forward projects that directly build upon the new data and information exchange policy. A Hydrological Information System (Sava HIS), as a component of a Geographical Information System (Sava GIS), has been developed as a tool for collecting, storing, analysing and reporting high-quality hydrological and meteorological data. These data are used in decision-making systems in all aspects of water resources management.

The Sava countries are in the process of establishing a Flood Forecasting and Warning System for the Sava River Basin (Sava FFWS), which will be finalized in 2018. It will be implemented as an open-shell platform for managing the forecasting process, allowing a wide range of external data and models to be integrated. Sava FFWS will integrate Sava HIS (www.savahis.org) as a data hub for collection of real-time hydrological and meteorological data, along with integration of Sava GIS (www.savagis.org) for presentation of spatial layers. Together with various outputs from numerical weather prediction models, available weather radar and satellite imagery, existing national forecasting systems, and different meteorological, hydrological and hydraulic models, these data will be easily “plugged” into a common platform.

Through these and other ongoing developments, the Sava Basin organizations are reaping the benefits of international data exchange. As the demands for hydrometric information grow, the global need for WMO Members to collaborate in exchanging data to support operational activities and services becomes ever more acute. Resolutions 25 (Cg-XIII) and 40 (Cg-XII) provide an overarching policy framework for such sharing, and the capabilities of modern sensors and IT systems provide the tools needed.

Experiences from the Balkans suggest that big steps forward in collaboration are often driven by local needs and local agreements. The Sava Policy demonstrates how WMO can support the development of consensus-based data-sharing agreements as a foundation for integrated management of the world’s transboundary river basins.

Acknowledgements: The Policy on the Exchange of Hydrological and Meteorological Data and Information in the Sava River Basin was developed by ISRBC and Parties to the Framework Agreement, with the support of the WMO Secretariat and the Centre for Ecology & Hydrology in the United Kingdom. The development formed part of the multibeneficiary IPA/2012/290552 project “Building Resilience to Disasters in Western Balkans and Turkey”, implemented by WMO and UNISDR with funding from the European Union. The Sava HIS platform, subsequently developed as a platform implementing the data policy, was developed with financial support from the International Commission for the Protection of the Danube River and the Finnish Meteorological Institute.

References


A woman walks through the wetland ecosystem on her journey home in low-lying Sunamganj District, Bangladesh. (Photographer: Lydia Cumiskey)

Frozen lake in Iceland
(Photographer: Ignacio Carmona)
Hydrometeorological Integration in the La Plata Basin

By Silvana Alcoz, Hydrological Adviser of Uruguay

The 1969 Treaty of the La Plata Basin, the first instance of Southern South American integration, yielded important infrastructure development – in particular bridges and reservoirs – and became the framework for the sustainable management of water resources across the region. The Treaty was drawn up between 1967 and 1969, more than 20 years before the creation of MERCOSUR1, when the International Hydrological Decade was under way. It brought a global hydrological approach to a basin of more than 3 million square kilometres, which is home to more than 100 million people belonging to 5 countries: Argentina, Bolivia, Brazil, Paraguay and Uruguay.

The Treaty established the Intergovernmental Coordinating Committee of the La Plata Basin Countries (CIC). At the time, a pluviometric and hydrometric monitoring network, which dated back to the beginning of the twentieth century, covered a large part of the La Plata Basin. Therefore, conditions were already in place to facilitate the vision of WMO and the International Hydrological Decade of a system’s approach of water resources. Increasing food and energy production and the presence of populations at risk of flooding also require a better knowledge of the Basin’s hydrometeorological regime. Nevertheless, the constant coordination among the many national institutions responsible for the Basin’s natural resources was and is a challenge, but they all seek to ensure sustainable development.

Integration of communities

Weather forecasting and climate characterization are global activities that require access to observations well beyond the borders of countries, continents and oceans. Very early on in its history, WMO and its members understood the importance of observation and data exchange, and their integration in models, to strengthen weather predictions and forecasts at the global, national and community levels. A milestone in the integration of the meteorological community was the establishment of the WMO World Weather Watch Programme in 1963, which developed into the WMO Integrated Global Observing System (WIGOS). Modelling also became more complex and sophisticated to the point where climate models, for example, now integrate key components such as atmosphere, oceans, land masses and the interaction between them.

However, the situation is different in hydrology. Hydrological information has a productive value, unlike data on precipitation which can only be monitored but not managed. For example, hydrological data is essential to water management for hydroelectric plants and irrigation facilities (direct intakes and reservoirs). Because of this value, producers of hydrometric data have, historically, been very reluctant to share information. Nevertheless, integration in a basin of various water uses is leading to the integration of the databases developed by different users to meet their own needs.

In the La Plata Basin hydrological knowledge and data are currently dispersed and not always easily accessible. One of the challenges is in bringing the working groups on hydrology, in particular operational hydrologists, together. It is operational hydrologists who make decisions every day concerning, for example, water supply to a population, production of hydroelectric energy and food, and protection of people’s life and belongings.

1 Mercado Común del Sur (Southern Cone Common Market (Argentina, Brazil, Paraguay and Uruguay))
need to inculcate in both communities the advantages of thinking and working together – meteorologists are not simply providers of information for the hydrologists.

During a visit to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), Colombia, the advantages of meteorologists and hydrologists working together in an integrated manner were highlighted. Here are a few:

- The geographic (spatial) aspect of an event is key, and how the hydrologist and the meteorologist see that phenomenon geographically
- Model outputs are not enough: the opinion of the meteorologist is needed in order to validate them for a period of time, or to adjust the model as needed
- A joint analysis helps to validate data and widens early warning coverage.

Hydroelectric reservoirs, due to their own needs and economic value, usually have teams of meteorologists and hydrologists working together. This could be an interesting example to follow. In the La Plata Basin the coordination of the three binational reservoirs is, therefore, strategically important.

WMO Regional Association III (South America) has been a pioneer in promoting the integration of the meteorological and hydrological communities. It has already organized two joint meetings of its three working groups: that on infrastructure (which includes weather forecasting), that on climate, and that on hydrology and water resources. The Association is also promoting joint monitoring of drought in the Region, through the integration of meteorological and hydrological indicators, and joint forums on hydro-climate in addition to those of climate forecasting.

A new opportunity

Despite these efforts, in the past 15 years, various initiatives to coordinate meteorology and hydrology within the institutional framework of the Treaty of the La Plata Basin have been left incomplete. In 2014, for example, the CIC Secretary-General attended the WMO Regional Association III session that considered the development of the WIGOS-Southern South America-Plata Basin (WIGOS-SAS-CP) programme. The main objective was to create a homogeneous hydrometeorological network in southern South America, particularly in the La Plata Basin, through WIGOS. A prototype was developed but the programme was not implemented.

Use of the WIGOS framework is essential for the integration of hydrometeorological information. The objective of integration is to make hydrological and meteorological data and products available to both communities. To achieve effective regional integration it is important that the conceptual basis of WIGOS is established in each country and that daily coordinated work is encouraged.

The CIC La Plata Basin Framework Programme (2011–2016) adopted a development methodology that is strongly based on the participation of institutions, together with their decision-makers and technical experts. Those who took part in the project learned the value of regional integration and of speaking with one voice. The advantages were also clear to USAID, which will contribute to the final implementation of the WIGOS-SAS-CP system during 2018–2019 through WMO. There will be benefits, principal among them, the possibility of extending the flood early warning system to the entire La Plata Basin.

The attempt at integration of the meteorological and hydrological communities stemming from the CIC La Plata Basin Framework Programme has not yet been institutionalized. It is expected that the continuation of technical collaboration projects will form the basis of major institutional agreements in Basin bodies such as CIC, in coordination with WMO.

Acknowledgements: I would like to thank Eng. José Luis Genta, CIC Secretary-General (2011–2015) for his contribution to this article.
Hydrology Distance-learning Courses for Indian and International Professionals

By Dattakumar Chaskar, Director, National Water Academy, Pune, India

India’s Hydrology Project phases I (1996–2002) and II (2006–2012) augmented the infrastructure and institutional network necessary for the hydrological information system and hydrological services. The project also supported training institutions, such as the National Water Academy in Pune, in capacity-building efforts. This led the National Water Academy to conduct numerous classroom programmes in training of trainers for hydrologists. However, the geographical spread of those to be trained and budgetary constraints were major issues in organizing face-to-face classroom programmes. Distance learning was identified as the way forward.

There were other challenges: There was room for further improvements in hydrological services, particularly in terms of geographical coverage, quality and lead time for forecast products. Further capacity-building and training efforts were required for ensemble forecasting, hydrological modelling, hydraulic modelling and addressing the impacts of climate change. High turnover in staff, meant that basic training had to be offered on a continuous basis, while also offering more advanced training on new and emerging technologies.

It is also important for hydrologists to work consistently and to improve their knowledge and skills in order to provide accurate models, predictions, and impact and risk assessments. Capacity-building and training of hydrological services personnel is a continuous process aimed at creating a pool of competent officers – professionals from federal and state agencies, hydrologists, academics, etc. The advent of information technology and the Internet offered an effective and economical way of reaching out to a large target audience in the form of distance learning.

The National Water Academy, which is a part of India’s Central Water Commission (CWC), started making efforts in this direction. However, the pedagogy of distance learning is vastly different from that of classroom learning, and the Academy had little experience in the area. The Academy, with support from WMO, built its distance-learning capacity, domain knowledge and developed online training materials on hydrology.

WMO trained the staff of National Water Academy through train the trainer courses, conducted by distance-learning as well as classroom training conducted at COMET in Boulder, United States of America. The comprehensive training and skill development at Boulder gave NWA the necessary confidence to deliver its own distance learning courses.

Academy distance-learning courses

■ Basic course in hydrology

The Academy delivered its first distance learning course in March 2012. Guidance provided by WMO during this pilot programme was crucial to its success.

The basic course was designed to meet the needs of hydrological forecasters who work with hydrological data, particularly on flood forecasting and design flood analysis. The course was structured to provide understanding of the elements of the hydrological cycle, description of rainfall runoff processes, learning of river discharge measurement techniques, discharge computation by the velocity area method, streamflow routing, derivation and use of a unit hydrograph, etc. By the end of the course, the participants acquired knowledge and skills for application of various hydrological modelling methods and different methods to
assess flood risks. There were mandatory and optional modules, catering to the regional requirements and the priorities of participants.

The first two programmes for Indian participants were immensely successful. Thereafter, two international courses were conducted, which were also very well received.

The WMO Executive Council Panel on Education and Training visited the Academy when the first course was being held and took note of the advancements. This led soon thereafter to recognition of the Academy as a WMO Regional Training Centre. This established formal linkages with WMO and COMET and gave wider visibility to the Academy. It also resulted in further take-up of DL courses, not only for the Indian participants, but also for participants from WMO Regional Association II (Asia) Members.

■ Advanced course in hydrology

After the basic course, an advanced course was developed to further enrich the knowledge of participants. The first such course, designed to meet the needs of hydrological forecasters who require more-advanced training in selected hydraulic and hydrological modelling topics, was conducted in 2015.

It was structured for participants who had successfully completed the basic course or who already had the requisite knowledge on the subject. The focus areas:

- Distributed hydrological models for flow forecasting
- Methods and techniques used in ensemble streamflow prediction
- Features of dam failure modelling processes
- Various aspects of tropical meteorology, including rainfall analysis and forecasting
- Forecast verification

■ Course materials

In distance-learning, it is crucial that training material be self-explanatory, easy to understand and interactive, with plenty of audio-visual elements, so that participants remain engaged during the self-learning process. COMET modules provided the main basis for the distance learning activities. Quizzes were structured to generate interest and make participants explore issues that they may otherwise have missed. This encourages them to re-take modules to achieve maximum score, and thus gain deeper learning.

The Academy developed additional modules on measurement of river discharge, derivation of the unit hydrograph, flood forecasting techniques and flood frequency analysis. These modules were prepared with regional requirements in mind and covered best practices being followed in Indian and Asian regions.
Water Resources in India

India is a vast country with varying climatic conditions and uneven spatial and temporal distribution of rainfall. The country is home to some of the largest river basins of the world – the Indus, Ganges and Brahmaputra. It has wide-ranging climatic and physiographic zones that experience all kinds of hydrological events. There are numerous perennial as well as seasonal rivers, some of them carrying huge loads of sediments. Devastating floods every year are as common as droughts. Flash floods and cloud bursts are regular events in mountainous regions. This situation is similar across the whole of Asia.

In such scenarios, the hydrological services are crucial. Hydrological products, like observations and forecasts, play a pivotal role in framing responses to water-related hazards and in decision-making for risk analysis and mitigation.

Data from hydrological networks are vital for preparation and distribution of flood forecasts and warnings aimed at protecting lives and property. They are an essential input for planning, designing, operating and maintaining multi-purpose water management systems by public and private sectors. The hydrological data are also a prerequisite for: design of critical structures like spillways, highways, bridges and culverts; floodplain mapping; determining and monitoring environmental or ecological flows; managing water rights and transboundary water issues; education and research; and protecting water quality and regulating pollutant discharges.

Webinars

Webinars play an important role in distance learning courses as they provide a platform for everyone to come together and interact. Normally, Academy courses start with a webinar giving an overview and a description of the structure and the various activity components. About 50% of candidates participate in the first webinar. The concluding webinar is usually well attended, and the performances of participants are analysed and names of successful participants declared.

Feedback

Every Academy distance-learning course was comprehensively evaluated every week, as well as at the end of the course. Feedback was taken from the participants on various aspects of the programme including course content, format and administration. It has been very encouraging, and the popularity of the courses is increasing. There is also demand for more distance-learning courses.

Challenges and lessons learned

Distance learning is a challenging medium of instruction as participants are not directly in front of instructors. There is limited scope for interaction among the participants and with the instructors. The only means of guiding students is through course forums, messages, emails, telephone calls, WhatsApp, Skype, etc. As the courses are self-paced and self-learning, participants can become isolated.

The course structure should be explained at the beginning of the programme. For many participants, it was their first experience of distance-learning courses and the majority of them faced difficulties. The coordinator needs to get in touch and guide them properly to diminish the likelihood of their losing interest.

It is also important to identify the participants that are lagging behind and to try to find out why. There may be various reasons, such as other pressing office engagements, difficulty in understanding or insufficient access to the Internet. Sometimes, participants can become stuck while reading a module and cannot go further unless they understand that particular part. If the instructor is analysing the performance of every participant, it is easy to identify such participants and
pay attention to them. Personal communication from the course instructors can motivate participants in re-engaging in course activities.

Some participants are very vocal on the course forum, whereas some can be reluctant to propose their views. However, it is not necessary that every participant be very active on the course forum. From the feedback, it was observed that although a few of them may not have posted anything on the course forum, they were comfortable in their self-study, performed well in quizzes and did not feel any need to post.

In its last three programmes, the Academy set up a WhatsApp group to facilitate communication among participants and instructors. This was not as a replacement of the course forum, but was to facilitate easy registration. It was really useful, particularly at the beginning, when participants experienced difficulties logging into the course website and understanding the overall course structure.

It was observed that about 10%–15% of participants required a good deal of persuasion from the instructor to complete the course. Such participants were contacted by telephone to persuade them to complete the activities, so that they could become eligible for a course completion certificate. This practice of calling participants individually may not be suitable in other regions of the world, due to cultural practice. In India, participants do not mind if instructors are persistent, whereas in other countries, this might be taken as interference in personal space.

Success of the Distance-Learning Programmes

To date, the Academy has conducted ten distance-learning courses, eight on Basic Hydrological Sciences and two on Advanced topics in Hydraulics and Hydrological Sciences. The courses are very popular among hydrometeorologists, private organizations and academics. Each programme is oversubscribed by a factor of 1.5–2 and there are many queries about future schedules. Upon completion of the basic course, many participants have also undertaken the advanced course. Below are a few testimonials from participants.

Pravin Kolhe – Executive Engineer, Water Resources Department, Government of Maharashtra – Basic course 2013 and advanced course 2015:
As a dam manager, my duty is to regulate releases from reservoirs in such a way that the entire flood impinging upon the reservoir can be safely routed without involving any risk to the structure itself or any damage to life and property downstream. Flood forecasting techniques learned during the courses proved to be very important tools in efficient operation of reservoirs, and helped in taking further steps to reduce damage due to floods.

T. Siva Prathap – Assistant Professor, Department of Earth Sciences, Yogi Vemana University – Basic course 2017:
The course added a new dimension to my career, as my background is geography and my students were from Earth Sciences, Yogi Vemana University, Kadapa, Andhra Pradesh, India. The DL course quenched my thirst for updating my skills and knowledge.

I am satisfied that my students were inspired by my lectures and became active in projects for the improvement of hydrological services in neighbourhoods.

Vaseem Ashraf – Director, CWC – Basic course 2014 and advanced course 2015
Both the courses were useful as far as my job activities were concerned. The topics covered in the basic course were very much contemporary and relevant to my area of work.

Since I was involved in collection and dissemination of hydro-meteorological data of 22 hydrological sites in southern India, the final assignment relating to this was very helpful in gaining further insights on automation of such process.

In the advanced version of the course, the assignment on ENSO, MJO and the Indian Monsoon was instrumental in gaining insights about the various weather phenomena; this is intrinsically linked with the area of activities that our organization CWC is involved with.
MCH Database Management System

An invitation to join a community developing and customizing a freely available database management system

By WMO Secretariat

The WMO Meteorological, Climatological and Hydrological database management system, known as MCH, manages observational data from its three namesake areas – meteorology, climatology and hydrology – under a single platform. By doing so, MCH facilitates data exchange among National Meteorological and Hydrological Services (NMHSs) and the gathering, in a unique system, of all the data needed for cross-cutting analysis of climate, weather and water phenomena. MCH offers a solution for NMHSs that are looking for a simple, customizable and license-free solution to store, analyse and visualize data. The system permits them to manage and generate reports on large amount of observed data.

The PROMMA (Programa de Modernización del Manejo del Agua, which ran from 1996–2005) technical cooperation project developed MCH to provide a water and climate database management system tailored to the needs of the Mexican National Water Commission. At the end of the project, Mexico made the system available to PROHIMET, the WMO-supported Ibero-American Programme for Cooperation of NMHSs. PROHIMET then added a meteorological component to MCH and adapted it to serve a broader audience, thanks to a Trust Fund established by Spain at WMO to support its activities.

In 2011, MCH ownership was transferred to WMO, where the software was translated into English and

Example of a graphic of daily water level observations from 01.01.2004 to 12.12.2015

A comparative graphic for precipitation at two stations

A comparative graphic for air temperature and precipitation at one station
French and made freely available to all WMO Members. The user manual is now available in all three languages. An online User Community platform was created to permit users support and to share customized modules (functionalities). The group is very active and thanks to their feedbacks, contributions and support, MCH is constantly evolving. Every year new functionalities are added in the three domains – meteorology, climate and hydrology – allowing all users to improve their services and products they provide to national authorities and the public.

MCH offers NMHSs a simple tool to manage data without their having to purchase licenses. It can be used to gather data from measuring stations and to digitize in a standardized format years of backlog observational data records on paper and/or in other centralized data sources (MS Excel or Access, for example). As of 2018, some 24 WMO Members have expressed an interest and been provided with the MCH software and appropriate training, and more and more Members are using it operationally. In a coming issue, the Bulletin will publish case studies from MCH users.

Those NMHSs that would like to know more and join the community are encouraged to contact WMO through their Permanent Representative.
Built centuries ago, the traditional stone spouts in the Kathmandu Valley, Nepal are connected to underground water channels with a small shrine attached to the top. Due to excessive groundwater extraction and unplanned urbanization, these stone spouts have slowly started to dry up.

(Photographer: Palpasa Prajapati)

A water crisis in Tabriz, Iran.

(Photographer: Ali Rostamiiranagh)
Overview of the Global Flash Flood Guidance System and Its Application Worldwide

By Konstantine P. Georgakakos, Sc.D., Director, Hydrologic Research Center

The primary purpose of the Global Flash Flood Guidance (GFFG) system is to provide real-time guidance products to forecasters worldwide. These products pertain to the threat of potential small-scale flash flooding over large regions with high resolution. The system provides the necessary products to support development of warnings for precipitation-induced flash floods. It uses real-time in situ and remotely-sensed data, numerical spatially distributed land-surface hydrological models and mesoscale numerical weather prediction models.

The GFFG system consists of regional systems (referred to as Flash Flood Guidance Systems (FFGSs)) that allow incorporation of local information into system products and development of regional cooperation in hydrometeorological forecasting. Six regional FFGSs—Black Sea and Middle East, Central America, Central Asia Region, Mekong River Commission, South Africa Region and South East Europe—have been completed and have become fully operational, covering 41 countries. Four—Haiti and Dominican Republic, South Asia, South East Asia and Southeastern Asia-Oceania—are
under implementation, covering an additional 17 countries. Another two FFGSs are being designed. One is a stand-alone system for an individual country, while another is for Northwest South America (emanating from the Zarumilla River Basin pilot application), which will likely include three countries. The system has also been successfully implemented at a subnational scale.

Real-time information on precipitation is provided by gauge-adjusted, satellite-based rainfall estimates and, when available, radar-rainfall estimates. An extensive training programme – designed to allow forecaster to adjust system products in real time based on local experience and local up-to-the-minute information – complements the system. The design aims to reduce loss of life and human suffering from the devastation caused by flash floods, and is consistent with an end-to-end forecast response process.

To demonstrate use of products of the GFFG system, imagine a hypothetical situation in which an operational forecaster in Panama begins a shift at 1 p.m. local standard time on 21 November 2015. The forecaster is told that it has been raining in western Panama. The first question the forecaster is likely to ask is: “what is the rainfall forecast for the next 6 hours?” At that time, FFGS, based on the Weather Research and Forecast mesoscale numerical weather prediction model, indicates the precipitation forecast (Figure 1a) for the region.

The forecaster sees that the western mountainous region of Panama is forecast to have significant rainfall in the next 6 hours, exceeding 100 mm/6 hours in some areas. Observing from the operational forecaster logs that there has already been rainfall in that same region, the forecaster would like to know the current saturation level of the upper soils. The upper soil water deficit provides buffers against the production of surface runoff as flash flooding from future rainfall. Based on the GFFG system component that covers the region (the Central America Flash Flood Guidance (CAFFG) system), the forecaster sees saturation levels of 1 or close to 1 in the upper soils for a very significant portion of western Panama (Figure 1b). Consequently, there are very small buffers to absorb the forecast rainfall in the next 6 hours, which is a cause of concern.

The next likely question in the forecaster’s mind is: “which specific areas will experience flash floods?” Using the FFGS Flash Flood Threat (FFT) index (Figure 1c), the forecaster notes that several basins exhibit high FFT indices (values beyond what is considered a normal index variability range, appearing in the yellow part of the index scale).

The forecaster then communicates with local contacts responsible for the high-threat areas (either the Panama weather service or the disaster management agencies of Panama) in order to validate the system.
estimates of soil saturation and antecedent rainfall. The forecaster also evaluates the rainfall forecasts to make adjustments to FFGS products before deciding whether to issue a warning for high-threat areas. In this case, if the hypothetical forecaster issued a warning, it would have been well verified by what actually happened).

Design fundamentals

WMO and the American Meteorological Society provide definitions of flash floods. These highlight that flash floods are characterized by short response times and small spatial scales. This implies that to gain a lead time allowing for effective response to this hazard, meteorological predictions of rainfall and hydrological predictions of soil water and stream bankfull deficits are needed (and in small scales at that). In addition, local and up-to-the-minute information and data are very useful for issuing a local flash flood warning.

The Global Initiative for Flash Floods was established in response to recognition that flash floods are prodigious killers and that no reliable warnings existed for them in many countries. Its goal was to support National Meteorological and Hydrological Services (NMHSs) worldwide to provide reliable and effective flash flood warnings and improve disaster management efficiency. With the participation of WMO, the United States Agency for International Development (USAID) Office of Foreign Disaster Assistance (OFDA), the National Oceanic and Atmospheric Administration (NOAA) and the Hydrologic Research Centre (HRC), the initiative focuses on flash flood prone regions worldwide, especially in countries with sparse real-time observations.

In each region, a regional centre with well-developed computational and communications capability is designated by participating countries. Data communication and computational facilities at the regional centres are used to host FFGS computers, which provide secure Internet sites to disseminate information and products to NMHSs of individual countries. Extensive online courses and hands-on training sessions conducted in the regions and at HRC enable country forecasters to use the system products effectively. They can also develop skills for making real-time adjustments as necessary. To achieve such system implementation for each region, computational and data handling components are involved at regional centres and at country forecast agencies. The design of these components is such that it can accommodate global data, regional data and local data through the computational system and can allow for in-country adjustments by forecasters prior to issuing warnings.

The key term “Flash Flood Guidance” (FFG), used for implementation of the GFFG system, refers to a rainfall threshold concept consistent with long-standing meteorological forecast concepts associated with severe rainfall events. According to such a traditional rainfall exceedance concept, a warning is issued when the forecast rainfall exceeds a certain fixed amount of heavy rainfall. The latter is selected from experience or past history to represent a lower bound to amounts that are likely to cause significant damage. The additional value of FFG stems from the fact that it is not a fixed rainfall threshold. Instead, it is a time-varying rainfall threshold based on time behaviour of the soil water deficit and the unfilled bankfull storage of the streams of the small flash flood prone basin of interest. Thus, for high saturation, even modest rainfall amounts can produce flash floods.

An FFG index is defined for each small drainage basin in the region as the amount of rainfall of a given duration and over the small basin that is just enough to cause bankfull flow at the outlet of the draining stream. It is a mean areal rainfall threshold over the basin of interest. If it is exceeded by forecast
rainfall, it signifies the onset of overbank flooding at the outlet of the basin draining stream. The concept is used only to signify the occurrence of potential flash flooding for a particular basin and not the magnitude of the overbank flow. The location of occurrence is at the outlet of the small basin.

The definition of FFG indicates that it is necessary to have soil water accounting (and in cold regions, snow accumulation and melt accounting) in each flash flood prone drainage basin. This is necessary for continuous production of this index. To estimate FFT out to 3–24 hours, it is also necessary to have mesoscale precipitation prediction capability with sufficient resolution (2–4 km$^2$) for the region.

There is a snow water accumulation and melt model, a soil water accounting model (soil moisture model), a model to estimate FFG using information from the soil water accounting model and a component that estimates stream storage deficit from bankfull (threshold runoff model). All of these models are running continuously for all the small basins in the region with varying temporal resolutions depending on the region and available input data. Most systems run with a 6-hourly update cycle, but there are some implementations in convective environments that use an hourly update cycle. The spatial resolution of the small basins delineated for each region depends mainly on the available precipitation data (satellite precipitation is associated with resolutions of order 100 km$^2$, while radar precipitation is associated with spatial resolutions down to tens of square kilometres).

There is input data quality control and, specifically for the remotely sensed precipitation data, there is bias adjustment effected in real time on the basis of the available automated on-site gauges. The adjustment has a climatological factor that is constant over a season and a time-varying, real-time component that uses an adaptive Kalman filter to process real-time gauge observations.

There is a mesoscale numerical weather prediction component, forced by global atmospheric model input that provides high-resolution gridded precipitation forecasts for the region with a maximum lead time of 48 hours. FFGS allows for precipitation forecasts

Figure 2a. Interactive forecaster interface for the GFFG system referring to the Southern Africa regional system
The development of performance metrics for evaluation and adjustments of the computational component and the development of warnings are recommended to be established for several of the regional systems at least once per year after the wet season. Metrics include the probability of detection of flash flood occurrence and the probability of false warning as well as the probability of a miss. The results obtained so far by the various systems and forecasters point to the value added by the forecasters in real-time operations and preparation of warnings, and the generally reliable seasonal performance of systems during the wet season. In most cases, the sources of highest uncertainty are the numerical weather prediction model forecasts.

**Advances and challenges**

Each regional component of the GFFG system includes the ability to use input from several mesoscale numerical weather prediction models to develop threat indices for each model for forecaster review. It is notable that forecasters requested that all such model input be distinctly preserved in the products series rather than combine these through the production of a statistical blend of such forecasts. The forecaster’s ability to choose in real time which model to use as input for a particular region underlies such a request and guided the design.

Advances of the basic GFFG system capability include the ability to produce real-time nowcasts of landslide occurrence based on precomputed high-resolution susceptibility maps and real-time estimated thresholds of the FFG-produced precipitation and soil water. This is currently under evaluation for one of the regional systems. Reports are positive, and indicate that this is being used effectively.

FFGSs are also being enhanced with riverine routing and reservoir simulation capabilities. They are now able to provide simulated and forecast hydrographs for pre-specified locations on large regulated rivers of a region. Such information, currently under evaluation in a few locations, is useful for large riverine flood warnings.
Another recent application of FFGS component models pertains to the seasonal ensemble forecasting of snow water equivalent, and combined runoff from snowmelt and rainfall with 6-hourly resolution. This was done for Tajikistan using the data and models of the Central Asia Flash Flood Guidance system (another regional implementation of the GFFG system) in collaboration with Tajik Hydromet.

The challenges experienced during implementation of FFGSs worldwide are listed below, with emphasis on data and information:

- **Data ingest.** This concerns the great variety of data formats, the availability of public versus private data, the reliability of data delivery to the system, the asynchronous arrival of data and a mix of space–time data resolutions.

- **Measurement/forecast uncertainty.** This refers to the uncertainty characterization as climatological versus time varying, and the uncertainty implications of the availability of only short records for fine-tuning of system reliability.

- **Timely product/warning generation.** The main issues here are the regional centre computers (and the related communication requirements and constraints) and the opportunity for timely forecaster adjustment and warning generation coupled with effective response. For example, decisions to not use ensemble prediction products in the initial implementations were made on the basis of these constraints in regional centres.

- **Products easily accessible and searchable by NMHSs.** This refers to the in-country interface and database requirements, the constraints in communications to access the system products in a timely fashion by certain developing countries, the use of local versus regional data storage, and the requirement to use free and open source software for developing countries (e.g. end-user geographic information system (GIS) software).

- **Education and training in product interpretation and communication with disaster management agencies.** The issues here arise because of diverse forecaster backgrounds, the necessary interdisciplinary and multidisciplinary nature of the assessment process that leads to the generation of warnings, and the cultural and socioeconomic diversity in the perceived value of and response to warnings by forecasters, disaster managers and the public.

The presence of the GFFG system worldwide and the experience being accumulated by its use in a variety of situations, constitute a catalyst to turn these challenges to opportunities to further improve the utility and reliability of the GFFG system and to enhance hydrometeorological information and collaboration worldwide.

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Operational Regional Flash Flood Guidance Systems

Case studies: Croatia and Zimbabwe

By Terek Borivoj, Hydrological Department, Meteorological and Hydrological Service, Croatia - Innocent Gibbon T. Masukwedza, Climate, Research and Training Division, Zimbabwe Meteorological Services Department, Zimbabwe

A lack of capacity to develop effective early warnings is one of biggest issues associated with flash floods. This article presents two case studies examining the usefulness of operational Flash Flood Guidance Systems (FFGSs) in predicting regions likely to be affected by flash floods. The case studies involve application of the South East Europe Flash Flood Guidance (SEEFFG) system in Croatia and the Southern Africa Regional Flash Flood Guidance (SARFFG) system in Zimbabwe. Both systems were implanted as part of a global project to address issues associated with flash floods.

It is important to note that in all instances, forecaster evaluation of FFGS output products is required prior to issuance of any early warnings that may potentially affect life and property. Therefore, the systems were designed and developed for interactive use by meteorological and hydrologic forecasters throughout the world, to provide real-time informational guidance products pertaining to the threat of small-scale flash flooding throughout a region. They provide the necessary products to support development of warnings for flash floods from rainfall events through use of satellite-based rainfall estimates and hydrologic models.

A memorandum of understanding between WMO and the United States America (US) – specifically USAID\(^1\), NOAA\(^2\) and the HRC\(^3\) – supports this cooperative initiative to implement FFGSs worldwide. The FFGS programme is a public benefit effort on behalf of its partners.

**Croatia case study**

Croatia is located in south-east Europe along the Adriatic Sea. It is not a large country (56 594 km\(^2\)), but its topography is impressive as it adjoins several large European relief forms. The three main ones are lowland Pannonian, mountainous Dinaric, and the Adriatic Sea with more than a thousand islands and islets. Because of its steep mountains and hilly areas with cascades and torrents as well as its wide valleys of lowland watercourses, the country and its numerous valuable assets are vulnerable to floods and flash floods.

In Croatia, the National Meteorological and Hydrological Service is the sole entity mandated to issue general warnings of hydrometeorological hazards through the media, on its Internet pages and through the European Meteoalarm system as well as directly to authorities. The Meteorological and Hydrological Service began operational forecasting and verification of flash flood events with the SEEFFG system. Because flash floods are truly hydrometeorological phenomena, flash flood warnings in Croatia are issued in common accord by weather and hydrological forecasters.

This case study examines an event that took place on 11 September 2017 in the cities of Zadar and Nin when about 190 mm of rain fell in less than 2 hours,
damaging property and leaving the two communities in difficulty.

**Weather situation:** A low surface pressure above Scandinavia was stretching its frontal system over western Europe. During the night of 9–10 September, a secondary low formed in the Gulf of Genoa and remained quasi-stationary over the Tyrrhenian Sea for most of the day. In the upper levels of the atmosphere, a deep trough with a cut-off low was visible at 500 hPa and 300 hPa, with a left jet stream exit region entering into the Adriatic. The trough axis extended from north to south and changed its direction to a NW–SE orientation.

The upper level trough was also visible at 850 hPa. On its leading side, a strong south-westerly flow brought warm, moist and unstable air towards Croatia. This flow, together with wind shear, caused intense convective processes on 11 September. The potential energy available and shear (between 0 and 6 km) showed mostly a moderate possibility for intense convection.

The airmass red–green–blue (RGB) composite image (below) from Meteosat 9 showed a mesoscale convective system over Croatia with a horizontal dimension greater than 400 km. It defined weather conditions not only on the Adriatic coast, but also in the inland mountainous and central regions of Croatia. The highest cloud top temperature was about −65 °C. This indicated deep moist convection and strong updrafts that brought water droplets to very high altitudes (about 12 km over the Zadar region).

**SEEFFG system analysis:** After assessing the weather situation, it was imperative to analyse the SEEFFG system products carefully. The system diagnostic products were analysed to find the hydrological responses of catchments. Products included the microwave-adjusted global hydroestimator for precipitation estimates, merged mean areal precipitation, average soil moisture and flash flood guidance.

**Conclusions:** On 11 September, stationary convective activity persisted over the cities of Zadar and Nin for several hours. This resulted in devastating flash flood events with extensive material damage, but without loss of human life. Out of the 276 mm of rainfall recorded by the Zemunik Meteorological Station, 265 mm fell in only 6 hours. Similarly, the Zadar Station measured 213 mm in 24 hours, while 188 mm was recorded in 6 hours.

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*Meteosat airmass RGB, 11 September at 0600 UTC (EUMETSAT)*

*Flash flood in the city of Zadar, 11 September 2017*
The effects of the flash flood events could have been even worse, but they were well forecasted, and warnings were issued in advance. The National Meteorological and Hydrological Service issued several flash flood warnings to the National Protection and Rescue Directorate and also via Meteoalarm to the public and media. The SEEFFG system was very precise, showing the exact locations of flash floods.

The hydrologic response of the small torrential streams to large precipitation amounts was very quick due to high soil saturation. Because flash floods mostly occur in urban areas, it is important to note that urbanization can have a significant effect on surface-runoff patterns.

The flash flood warning verification in Croatia revealed that the probability of occurrence of urban flash floods in its coastal region has increased appreciably in recent years. This makes flash flood forecasting not only more important, but also more challenging. Other countries that are using FFGSs should be advised to collect flash flood reports as much as possible. They should also conduct verification studies that can help to understand uncertainties in forecasting models and ways in which they could be improved.

The experience in operational work with the SEEFFG system proved valuable for disseminating warnings in Croatia. It also highlighted the potential for enhanced collaboration with response agencies in disaster risk reduction and for raising community awareness. As time is the most critical factor, collaboration and involvement is necessary for effective “end-to-end” flash flood and flood forecasting early warning systems.

Zimbabwe case study

Zimbabwe is a landlocked country, covering an area of 390,754 km², in southern Africa. It is geographically divided into 10 provinces. South Africa bounds the country to the south, Zambia edges it to the north-west, Botswana borders it to the south-west and
Mozambique edges it to the east. The country spans a large and elevated inland terrain that decreases in elevation to the north towards the Zambezi basin. This is the area where Zambia shares the boundary with Zimbabwe. The terrain elevations also decrease in the south towards the Limpopo River basin and the border with South Africa.

The Zimbabwe Meteorological Services Department has the national mandate of saving human life and property, which includes providing warnings for flash floods.

This case study focuses on a flash flood incident that occurred on 14 November 2016 in regions situated south of Manicaland province. It examines how the SARFFG system depicted regions of intense heavy rainfall as well as regions of saturated soils.

Weather situation: In the week that preceded the incident, there had been widespread rainfall activity over the country, with parts of Manicaland, Mashonaland East, Mashonaland West, Matabeleland South and eastern Midlands experiencing heavy precipitation. The automatic weather systems in the regions were down during this period. Such systems are important as they provide the time or rate of the greatest precipitation intensity and would have been very helpful for use in this study had they been available.

Significant rainfall totals reported in a 24-hour period were at Harare Airport (67 mm) and Mvuma (64 mm), on 11 November. Mukandi also had a significant precipitation total of 64 mm reported on 14 November.

It was deduced from weather charts that there was a trough situated in the Indian Ocean and extending inland onto Mozambique and Zimbabwe. As the region of flash flooding has a high relief and there was a lot of moisture as a result of the rains that had been received prior to this event, coupled with high temperatures, there was a good chance that the resulting thunderstorm activity could be due to a combination of all these factors. This thunderstorm activity was responsible for hail, which was reported in parts of these flash flood regions.

SARFFG system analysis: To gain a good understanding of the rainfall distribution since the start of the wet season, accumulated rainfall totals over the country were studied. This suggested that relative to other regions of the country, the regions that received the highest precipitation totals were likely to have had high levels of soil moisture. This result was supported by the SARFFG average soil moisture product, which demonstrated that some basins in the country, where incidences of flash flooding were reported, had upper soil saturation fractions of at least 75% (as a result of the accumulated precipitation noted previously).

The SARFFG product showed that at 1200 UTC, the eastern parts of the country only needed precipitation amounts in excess of 30 mm within the next 6 hours to reach bankfull. It was during this period that significant amounts of precipitation fell in these regions and flash flooding occurred.

Conclusion: As a result of its ability to predict (with reasonable accuracy) regions likely to be affected by flash floods, the SARFFG system is a useful tool to help the Zimbabwe Meteorological Services Department to meet its national mandate of saving human life and property.

Both studies show that FFGS builds capacity and results in effective early warnings for flash floods. The National Meteorological Services of other countries could use the FFGS. The FFGS partners—WMO, USAID, NOAA and HRC—aim to broaden its implementation worldwide.
Flood Forecasting and Warning in Bangladesh

By Md. Sazzad Hossain¹

Bangladesh is located downstream of three large river basins: the Ganges, Brahmaputra and Meghna river basins (Figure 1). The total catchment area of these basins is 1.72 million km², with almost 93% of the catchment area situated outside the territories of Bangladesh – in Bhutan, China, India and Nepal. The topography, location and discharge from each of these three basins shape the annual hydrological cycle of the country.

Over the course of a year, Bangladesh experiences periods of extreme water availability – too much and too little water. Monsoon precipitation from June to September is the main source of water, and the country has less water available outside of this season, termed the “dry period.” Heavy rainfall during the monsoon period is the main cause of flooding; this occurs almost every year, with a devastating flood every 5–8 years (FFWC, 2004). Such flooding causes severe damage to agriculture and infrastructure and the loss of human lives.

Bangladesh has implemented flood control and drainage projects since the 1960s. However, structural measures alone cannot totally protect the people and infrastructure from floods. Complete flood control in a country like Bangladesh is neither possible nor feasible. With this understanding, Bangladesh started developing flood forecasting and warning systems (non-structural measures) for flood management (Bhuiyan, 2006). The objectives were to enable and persuade people, communities, agencies and organizations to be prepared for floods and take action to increase safety and reduce damage. The goal was to alert people on the eve of a flood event.

Developing flood forecasting services

Bangladesh Water Development Board (the Board) is responsible for flood management through structural and non-structural measures. It also provides hydrological services in Bangladesh. As part of non-structural measures, the Board has been providing flood forecasting and warning services through its Flood Forecasting and Warning Centre (FFWC), established in 1972. Since then, the development of flood forecasting and warning services has made stepwise progress, which can be divided into three stages.

Initial stage (1972–1988) Initially, 11-gauge points were used for real-time flood monitoring and forecast purposes. In this early phase, gauge-to-gauge statistical correlation and Muskingum–Cunge methods were used for predicting water levels. In 1981, WMO and the United Nations Development Programme provided technical assistance for computerization of the hydrological database. Computer programs were also developed to carry out operations that had previously been performed manually. During devastating floods in 1987 and 1988, flood forecasts of the major river systems proved to be fairly accurate.

Second stage (1989–1999) After the 1987 and 1988 floods, an initiative was launched to develop a flood forecasting system based on a numerical model. WMO engaged the Danish Hydraulic Institute (DHI) to create a flood forecasting model for Bangladesh. During 1989–1991, the national flood forecasting model was developed using a MIKE 11 modelling system. From 1991, additional deterministic flood forecasting efforts were pursued, resulting in forecast lead times being increased to 48 hours. The number of real-time forecasting stations was increased to 16. From 1995 to 1999, the flood forecasting model was further upgraded to improve its forecast accuracy.

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under the Bangladesh Flood Action Plan. A geographic information system (GIS) module was added to the flood forecasting model, and the number of stations used to support forecast modelling was increased from 16 to 30.

Bangladesh again experienced severe flooding in 1998, for which the flood forecasting and warning services yielded productive and successful results. An internal analysis of the 1998 flood concluded that flood forecasting and warning services should be extended to all flood-prone areas of the country. In addition, the need for dissemination of flood information to vulnerable communities became very evident.

Third stage (2000 to date) Many lessons were learned from the 1998 floods. Foremost was that the people of vulnerable communities require flood information with a greater lead time. Further, they wish to know when their homesteads are going to be inundated and for how long. This showed that people were demanding area-specific flood forecasts. Moreover, field-level flood and water-related disaster managers also expressed their eagerness to receive timely flood forecasting information. In this third stage, FFWC received support to improve the accuracy and extend the lead time of flood forecasts, expand the provision of flood forecasting services to all flood-prone areas of the country, improve flood information dissemination at the vulnerable community level and build a sustainable institution.

FFWC efforts focused on improving the forecast lead time. It started to use ensemble precipitation forecasts from the European Centre for Medium-Range Weather Forecasts to provide medium-range flood forecasts. Since 2004, FFWC has provided deterministic flood forecasts to 3 days and medium-range probabilistic forecasts to 10 days. FFWC also started to develop its basin model in 2012.

Development of the basin model

The concept for the basin model was introduced under the Comprehensive Disaster Management Programme Phase-II to increase forecast lead time. As Bangladesh is located downstream of three big river basins, an integrated basin model was needed to effectively increase the forecast lead time for Bangladesh. Fundamental to this was using the advances that have been made in numerical weather modelling and ensemble forecasting.

FFWC uses the Weather Research Forecast (WRF) model for precipitation forecasting. A typical WRF over the region and the three basins is shown below. The basin model, which is currently used for flood forecasting purposes in Bangladesh, uses quantitative precipitation WRFs for establishing a deterministic flood forecast with a lead time extended from 3 to 5 days.

Flood forecasting and warning activities

Flood forecasting and warning activities run from April to October every year in Bangladesh. In this period, the field-level hydrological measurements division works closely with the flood forecasting centre to
provide observed data. FFWC remains open 24 hours a day, 7 days a week during this period.

**Data collection and transmission**

Today, the hydrology division of the Board has an extensive network of 60 rain gauges and 90 hydrological stations where water level, discharge, sediment or water quality are measured. Network design reflects the need for field data based on requirements of the flood forecasting model. Daily operational requirements of the flood forecast model are for real-time water level and rainfall data. Water level gauge readers for the 90 stations send data to FFWC twice daily. Data are usually collected from 6 a.m. to 6 p.m. at 3 hourly intervals every day. Rainfall records are available for 24 hour periods for the 60 gauges all over the country.

Data are now transmitted from the field using a mobile SMS system (see below). Prior to this development, hydrological data had been orally transmitted using landline telephones. The Board piloted automatic collection of water level data using a radar level sensor as part of another project.

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2 The HKH-HYCOS project, see [http://www.icimod.org/?q=264](http://www.icimod.org/?q=264)

**Operation of the flood forecast model**

The flood forecast basin model is based on the DHI MIKE 11 hydrodynamic modelling system. The computational core of the hydrological forecasting system is the DHI MIKE 11 software, which contains two modelling components: (i) a hydrodynamic model and (ii) a hydrological model (NAM; a rainfall-runoff model). The hydrodynamic module contains an implicit finite-difference computation of unsteady flows in the rivers based on St Venant equations. The flood forecasting model is customized with the Flood Watch database, which uses a GIS. The MIKE GIS module is also integrated with the digital elevation model (DEM) of Bangladesh to generate an inundation model.

Quality checked, processed data are used in the model to generate 5-day deterministic forecasts. The operational flood forecasting system is based on real-time data received from available stations in Bangladesh, relevant online data received from riparian countries (based on an existing data-sharing protocol), and quantitative precipitation forecasts from numerical weather prediction models provided by the Bangladesh Meteorological Department and the Indian Meteorological Department. FFWC also uses satellite-based observation data for flood forecasting purposes.

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![Data transmission through the SMS system](image.png)
Forecast products

- Daily water level and rainfall situation reports
- Flood conditions summary (provided both in Bangla and English)
- Forecast bulletins for 24, 48, 72, 96 and 120 hours
- Rainfall surface map
- Flood inundation map
- Interactive voice response (mobile voice message)
- Special outlook
- Press briefing

Flood warning dissemination

There is no doubt that effective early warning system can save lives and property. Early warning systems can also help disaster preparedness programmes to establish measures, such as emergency relief operations and evacuations, in advance. Flood forecasting and warning activities have proven very effective in recent years to combat the damaging effects of flooding. FFWC disseminates flood warning information through media and communication outlets using the Internet, fax, telephone, mobile SMS, etc., and uploads the forecasted information daily on its user-friendly website (www.ffwc.gov.bd).

Moreover, FFWC has also started to disseminate flood warning messages using an interactive voice response system. Anyone in the country can receive a short message regarding current flood information pertaining to Bangladesh’s major rivers by calling 1090. This novel system provides timely information to a variety of different users including government departments, agencies, disaster managers, non-governmental organizations, news, media, local government institutions and individuals.

Recommendations

The FFWC has a number of recommendations based on its experience with early warning systems for flood forecasting. The top three are below.

Area-specific forecasting: FWC provides flood forecasts based on predefined danger levels for the major rivers. It is essential to provide area-specific inundation-based flood forecasts for better flood management.

Flood inundation map: FFWC currently generates flood inundation maps using old DEM data. To increase the accuracy of the flood inundation maps,
it is recommended that updated high-resolution DEMs be used.

**Long-term and seasonal flood outlooks:** Long-term (greater than 10 days) flood forecasts are essential for agricultural planning. Due to improvement of numerical computational schemes, sub-seasonal to seasonal weather forecasts are increasingly available. However, effort is needed to apply these long-term forecasts to hydrological issues. FFWC has experimented with ensemble weather forecasts for flood forecasting in Bangladesh for the medium range (up to 10 days). Based on the available tools and long-range weather forecasts, FFWC can now develop sub-seasonal to seasonal flood outlooks.

**Coastal flood forecasting**

One third of Bangladesh is vulnerable to coastal-influenced flooding; this is expected to worsen due to the effects of climate change. The coastal area can experience flooding during astronomical high tides as well as due to tropical cyclones, or both combined. In addition, flood waters from the Ganges, Brahmaputra and Meghna rivers can be confronted with coastal saltwater intrusion, compounding the overland flooding of Bangladesh’s low-lying areas.

The WMO Coastal Inundation Forecasting Demonstration Project was carried out in Bangladesh from 2011 to 2017. Previously, this part of Bangladesh had not received operational flood forecasting services due to the complex interaction of coastal and overland flooding processes, including storm surges that may reach several metres at the coast. It is essential that additional efforts be undertaken to maintain and strengthen this new coastal inundation forecasting system, to enhance operationalization of such flood forecasting services delivering flood warnings for the coastal region of Bangladesh.

**References**


Building Hydrometeorological Early Warning Capacity in Developing Countries: Successes and Failures

By Curtis B. Barrett, Hydrometeorological Advisor, and Sezin Tokar, Senior Hydrometeorological Advisor

Hydrometeorological extremes account for more than 90% of all disasters caused by natural hazards recorded between 1994-2013. Floods, storms, droughts and extreme temperatures alone affected more than 3 billion people, claimed about 600,000 lives and caused about US$ 2 trillion in direct economic damages during the same period. According to Global Facility for Disaster Reduction (GFDR) of the World Bank, economic assessment of meteorological and hydrological services indicates that as many as 23,000 lives could be saved and up to US$ 65 billion in economic benefits could be realized if National Meteorological and Hydrological Services (NMHSs) were strengthened to produce better forecast, information and warning services.

Establishing and sustaining operational Early Warning Systems (EWSs) remain a challenge, despite the concerted and ongoing efforts of many partners and NMHSs to modernize delivery of hydrometeorological services. This article highlights some of the lessons learned from implementing and sustaining these projects. Results indicate that changes in project strategy are needed to increase the likelihood of sustainable delivery of services, along with capacity building of NMHSs, local commitments and strong partnership with users and private sector.

The United States Agency for International Development (USAID) Office of Foreign U.S. Disaster Assistance (OFDA) in partnership with the National Oceanic and Atmospheric Administration (NOAA) and the University of Colorado supported a research project to look into the hydrometeorological projects to understand if learning is taking place, and if not, why, and how to overcome some of the obstacles to improve sustainability of activities. Although lessons learned were identified in most of the projects, they were not completely learned and incorporated into the future projects.

The challenges

Lessons learned from implementation of these projects demonstrated that building weather, water and climate early warning services are not only about equipment. They also highlight the need to strengthen other elements of an end-to-end EWS and to ensure linkages among them in order to deliver the best available information to enable affected population and users to take action.

An end-to-end system consists of many interconnected components:

- data collection and transmission to a centre
- developing models, producing forecast products and analysis,
- dissemination and communication of the forecasts or warnings to users and public in order for them to take appropriate actions
- a feedback loop.

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1 Both from USAID Office of Foreign Disaster Assistance, Washington, DC
Failure of any one of these basic components or of the link between them will lead to reduced effectiveness if not the complete failure of the system. Interconnectivity is an essential attribute of a successful warning system as well as investment into delivering services. Therefore, when an NMHS is being strengthened, it is critical that attention be placed on assuring that these components are functioning, maintained and continually tested to guarantee their successful operation and integration. Feedback is important to address failures and gaps for effective end-to-end systems.

Many NMHSs can only acquire sufficient funding to modernize their services after a major hydrometeorological-related disaster hits their country or neighbouring countries. Disasters usually get media, political and public attention, which can lead to a rapid infusion of funding for modernization efforts. However, a modernization strategy must first identify gaps in the end-to-end system, then formulate a way forward to build an operational forecasting programme that meets user-demands. That can be a tall order in the usually short time period afforded by a donor or government funding cycle.

It is evident that many organizations need to participate in developing an end-to-end EWS process, including representatives from all levels of government, communities and other stakeholders. However, due to time limitation, coordination with and participation of all the above is difficult. Often, many donors are
implementing different components of the end-to-end system, installing technologies and systems that may not link well. The result is a fragmented EWS that cannot be operated or maintained with the limited human and financial resources available when the donors leave. In addition, many NMHSs have difficulty competing for scarce national resources as the disaster gets farther away in time and media attention diminishes, thus, they have limited budgets to maintain operational systems.

From 1992 to 2008, NOAA participated in many hydro-meteorological projects around the world. Many were launched after a major disaster. Lessons learned revealed significant barriers to sustainability:

- change in senior leadership (loosing support and advocacy)
- Limited NMHS’s budget for maintenance and operation
- difficulty to retain trained personnel
- lack of roadmap
- various competing and unconnected activities leading to limited use and high cost of maintenance.

In addition, building capacity to operate new systems in a short period of time is a challenge made more difficult as staff continue their normal duties so there is a lack of commitment or support for the new system(s).

It is difficult for governments to absorb the total financial burden of maintaining and operating new hydrometeorological systems. In addition, most finance ministers lack awareness of the value of services provided by NMHSs in saving lives, livelihoods and infrastructure and in building economies. Thus, limited funding is provided to NMHSs. Public-private partnership can be an important element in the sustainability of hydrometeorological projects, mobilizing resources for operational activities.

Another lesson learned includes the need for a champion – a technical forecaster or agent that understands the value of the system, is committed to the strategy and the needed care and support of the system and staff to continuous delivery of services. This person should also champion the role of the private sector in the sustainability of hydrometeorological projects.

Case studies: Successful flood forecasting and EWS projects

In 1998, Hurricane Mitch devastated Central America. About one metre of torrential rainfall caused catastrophic flooding and mudslides, killing over 20 000 people and setting-back development prospects 10 to 20 years in some countries. Following the event, the US Central American Rehabilitation project aimed to establish an end-to-end flood forecasting and warning system for rivers at high risk of flooding in El Salvador, Guatemala and Honduras. The project would strengthen weak components of the end-to-end system meteorological and hydrological observation network and establish a real-time communication system. The NOAA National Weather Service River Forecast System (NWSRFS) for main-stem river flooding and the Automated Local Evaluation in Real Time (ALERT) systems would be installed for selected high potential flash flood river basins.

A specific sub-project under this initiative was to build a regional flood forecasting system for the Rio Lempe River. Stream and rain gauges were set up throughout the basin. In order to promote sustainability, a public-private partnership was established between the NHMS of El Salvador and its energy company (CEL). The system, established in 2001, is still operational today. This project revealed the importance of public-private partnerships and of having a technical champion to assure proper system maintenance and operation.

Afghanistan is highly exposed to hydrometeorological hazards. In the period from 1980 to 2015, the country lost close to 15 000 lives and an estimated US$ 396 million in economic losses (CRED) in extreme hydrometeorological events. The Afghanistan Early Warning Project is a joint effort between the WMO and USAID/OFDA. The project has the elements of a technical champion, and coordination with donors – including the World Bank. In 2013, USAID/OFDA pledged financial support for the WMO to strengthening Early Warning Systems in Afghanistan in order to reduce loss of lives and the socio-economic impact of hydrometeorological hazards.

WMO and the Afghanistan Meteorological Department (AMD) worked closely to develop a strategy to build
in institutional capacity to produce severe weather forecasts and early warning services. Activities started a few years later: AMD infrastructure was enhanced to access and exchange data and products through the GTS by installing local and wide area networks, back-up power sources and security systems, updating IT equipment and rehabilitating the building with a new forecasting room. In 2016, 21 AMD staff received quality management and observer training, which was customized to the level of each forecasters to prepare them for reporting surface synoptic observations on the GTS. Through these efforts, Afghanistan’s data was made accessible to the international community in 2017 for the first time in 30 years.

The project also focused on long-term sustainability. Local champions were identified, including the director of AMD and forecasters. They were motivated to move forward following the roadmap developed at the beginning of the project, which provided a systematic and integrated process for modernization. Partnerships with NMHSs in the region, especially the Turkish State Meteorological service, enabled AMD to have continuous mentoring and operational training during the project. Female weather forecasters, knowledgeable about hydrometeorology and passionate about making a difference, were excited about the possibilities opened up by this project. AMD also received requested funding from the Ministry to continue to hire and train additional forecasters and observers to support these efforts.

A week after a meteorological satellite data reception, visualization and processing station was installed in the country through the project, AMD issued its first flood warning. The extensive capacity and infrastructure building undertaken made this milestone possible. By demonstrating their value through services, NMHS increase their public and political visibility, which is necessary to mobilize funding for sustained service delivery. All stakeholders should be brought on board early in the project to assure the end-to-end system functions properly and sustainably. Capacity building is essential to ensure that NMHS staff masters the operational use of new systems and are able to identify operational failures.

There is an urgent and timely need to change the way that projects are implemented in developing countries. Donors and their partners need to learn lessons from the past.

Learn from our successes

Last year’s hurricanes, floods, droughts and other hydrometeorological extremes show that vulnerability is increasing. Lessons learned from past projects demonstrate that there are common factors that contribute to the failure of hydrometeorological and forecasting modernization initiatives. Conversely, successful projects illustrate that effective warning systems can reduce losses and can be maintained for a number of years. The lessons learned need to be communicated in order to avoid same mistakes over and over again:

- think ahead and promote local motivation and ownership at the beginning of the project through technical champions
- develop a simple, clear roadmap with a phased approach to modernization and implementation in order to coordinate multiple partners and maximize resources and efforts to focus activities on the gaps
- public-private partnerships are essential to get additional resources support and to maintain systems while delivering services to private sector

References

Community-based Approaches to Flood Management in Thailand and Lao People’s Democratic Republic

By Ramesh Tripathi, WMO Secretariat

The project for Community-based Approaches to Flood Management in Thailand and Lao People’s Democratic Republic developed self-help capabilities in flood-prone communities in the two countries. The Associated Programme on Flood Management, a joint WMO/Global Water Partnership initiative, worked alongside the Asian Disaster Preparedness Centre and a range of country partners for the three years of the project – from June 2013 to March 2016. With funding from USAID through WMO, the Programme implemented flood risk assessments and preparedness measures using a participatory approach in four pilot communities prone to riverine and flash floods in Thailand and Lao People’s Democratic Republic.

Its community-centred approach aimed to reduce the negative impacts of floods while enhancing community preparedness and resilience to flood events. The Sendai Framework for Disaster Risk Reduction (2015–2030), adapted two years after the project launched, would underline the significant role of communities in disaster risk management activities. Thus, the project complements the community-based disaster risk management in the Sendai Framework, specially linking with priorities of action 1, 3 and 4.

Significance of the project

Flood risk has been a growing concern in the communities of Thailand and Lao People’s Democratic Republic. With every flood situation, community capabilities have been reduced and investments in development – such as houses, hard assets, livestock, food or security – severely affected within a short time period. But communities were not actively engaged in flood risk management activities, they were simply seen as its beneficiaries.

The first step in the pilot project was to familiarize them with flood/disaster management concepts. Then they were engaged in participatory risk assessments and preparedness measures for flooding. This would help them to undertake such activities independently in the future and also help neighbouring flood-prone communities to develop capacities in similar ways. The idea was to foster community project ownership so that long-term sustainability would be developed beyond the project duration. The project also brought the communities and local agencies together to work in a coordinated way to develop resilience to floods.

Four pilot communities of Thailand and Lao People’s Democratic Republic

<table>
<thead>
<tr>
<th></th>
<th>Riverline flood</th>
<th>Flash flood</th>
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<tbody>
<tr>
<td>Thailand</td>
<td>Talad Kao, Kabinbury district, Prachinburi province</td>
<td>Ban Buphram, Nadi district, Prachinburi province</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>Ban Suan Luang, Xieng Ngeun district, Luang Prabang province</td>
<td>Ban Keo Many, Nan district, Luang Prabang province</td>
</tr>
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</table>
**Main benefits of the project**

**Participatory risk assessments** – This proved to be an invaluable means of helping pilot communities and local authorities to develop an understanding of specific local risk factors to various hazards. As a participatory process, groups were engaged across each community to share their thoughts, reflect upon their needs and identify and design potential solutions which could minimize flood risk and increase preparedness and resilience. The process encompassed hazard, vulnerability and capacity assessments. People's perceptions of risk within a community were also considered. Risk assessment results were compiled and presented as community risk profiles and hazard maps, which were further used by the community to identify flood risk reduction solutions.

**Gender-inclusive participation** – The project helped to promote more-equal participation of men and women in disaster risk reduction activities and to encourage groups to understand each other's perspectives of disaster preparedness and response. The project activities encouraged participation of women, the elderly and those with disabilities for enhanced inclusivity in planning and management of disaster risk reduction measures.

**Formation of a Community-Based Flood Management Committee and a Village Disaster Prevention and Control Committee** – These committees played an important role in empowering community members through participation in planning efforts for disaster preparedness. Based on their skills, experience and areas of interest, committee members were trained and assigned to work under dedicated subteams – for early warning, search and rescue, evacuation, security, health and relief. This helped in assigning roles and responsibilities to committee members and guided them in performing tasks before, during and after flood events.

**Value of non-structural solutions** – Non-structural solutions were of significant importance in the project. If only a proportion of these measures were to work during severe flooding, it would still reduce flood damage. This is because people would, for example, have knowledge of safer places, awareness about vulnerable people, be able to provide search and rescue support to other people, have knowledge about access routes to evacuation centres and have knowledge on first aid. In contrast, structural solutions could be wiped out by the flood events. These non-structural solutions aimed to encourage better understanding of flood management and invited community participation in developing other localized solutions without involvement of additional resources and funding.

**Shift from a reactive to a proactive approach** – The historical way of dealing with flood disasters in the region has been to respond after the event has occurred, rather than being proactive ahead of flood events. It was important to change the mindset and the traditional way of working with external responders. The proactive approach of the community was visible during simulation exercises performed during the monsoon season of 2015, in which pilot-project communities proactively responded to flood events.

**Impacts of the project**

In theory, a community that comes up with its own ideas and work programmes to address its individual needs has a better chance of finding long-term solutions. With knowledge of the local geology, hazard context and resources available, local communities were involved in flood management programmes from the start. The support received was to develop the capacities and linkages that help overcome susceptibility to disasters. In this way, individual community members benefited from the project activities. The impact stories gathered below highlight some of these benefits.

**Post-project assessment**

The Associated Programme on Flood Management and the Asian Disaster Preparedness Centre recently conducted a post-project assessment in Thailand and Lao People's Democratic Republic. The objective was to determine the outcomes and long-term impacts of the project 15 months after its completion. This
Vulnerable households marked by green ribbons: Ms Wilailak Haritworn is physically challenged and owns a grocery shop in Talad Kao community. In the flooding of 2013, she did not receive any warning and had to wait for others to rescue her. Now, her house is marked as a vulnerable household due to the project. She is confident that the houses marked as vulnerable by green ribbons will be the first to receive response support from the search and rescue team during a flood situation. The vulnerable households ribbon offers an additional benefit: district health aid volunteers visit them on a regular basis to assess health conditions.

Early warning communication through a public announcement system: Ms Sukree Limchiw has been a pork meat seller in the Talad Kao community and nearby local market for more than 10 years. She uses a modified motorbike to carry and sell her meat product. During the project, she and her community friend agreed to become part of a public relations committee responsible for providing door-to-door early warning communication. Ms Limchiw felt that her daily work would help in early warning communication because she knew the people in the community and the access routes to their houses. Since then, she has communicated several other messages of the project committee, reaching every section of the community. She is proud to be doing this work, as it was previously difficult to reach out to every individual of the community with flood warnings.

Coordination and collaboration among hydrometeorological departments and local communities: Mr Likhit Sakrasae, employed at the Kabinburi district hydrometeorological station, collects daily readings from the raingauge and river-gauge devices installed at the meteorological station and nearby river. He agreed to join a line messenger group along with other members of the district and provincial hydrometeorological departments, irrigation and water resources, provincial disaster prevention and mitigation office and municipality as well as project members of Talad Kao. Mr Sakrasae provides daily line message information about the rainfall and water-level measurements at the river. In this way, the community receives information directly, instead of from the municipality. He participates in the Talad Kao community meetings, where he has developed good bonds. The project brought local agencies and communities together to proactively develop preparedness for riverine flood hazards.
included the relevance and fulfilment of objectives, the efficiency and effectiveness of managing flood risks, the impacts and the sustainability of the project. The assessment methodology used a participatory approach, fully engaging the primary beneficiaries (community members) and supporting entities (local/ regional/national agencies involved in the project) with significant roles in the project activities as the core constituents.

During the assessment visit to the pilot communities, it was observed that they have improved awareness and capacities for better response in emergency situations, particularly in community-based flood preparedness and early warning infrastructures/services. However, the sustainability of the project remains a challenge, as communities are not regularly practising the training and skills provided through the project. Mock drills or simulation exercises were not carried out after 2016, nor were pilot communities approached by local agencies to support simulation exercises. There has been a lack of participation and engagement from local agencies with the project communities, as a budget has not been allocated for performing post-project monitoring and evaluation of flood preparedness activities. The methodologies and expertise to perform periodic monitoring and assessment of project activities are not available, neither in Thailand nor in Lao People's Democratic Republic.

Next steps towards long-term sustainability

The pilot communities should utilize their structural and non-structural assets for building sustainable resilience. Communities should be supported with regular training practice sessions and toolkits, which will help keep them updated with flood preparedness knowledge and skills. A promotional calendar containing success stories and timelines for conducting simulation and training exercises should be developed and shared with the communities, emphasizing the importance of these activities and reminding communities about the need to have periodic simulation drills.

Communities also need additional investment to mainstream disaster risk reduction into development practices, plans and policies at local, provincial and national levels and to further gain economic benefits out of the investment. Flood prevention measures need to be actively pursued so as to further reduce the impacts from future flood events. These include planned construction of dams or reservoirs, land-use planning, avoiding construction of houses near rivers through flood zoning, flood proofing and providing flood awareness through school education. Other communities prone to flooding should perceive the pilot communities as a role model for attaining flood resilience, so that they can develop their capabilities in similar ways.

The Associated Programme on Flood Management

The Associated Programme on Flood Management is a joint initiative of the WMO and the Global Water Partnership. It promotes the concept of Integrated Flood Management (IFM) as a new approach to flood management. (http://www.floodmanagement.info/)

The Asian Disaster Preparedness Centre (ADPC) is an independent, non-profit foundation, serving as an international focal point for disaster preparedness and mitigation in the Asia and the Pacific regions, with the vision of “safer communities and sustainable development through disaster reduction” (http://www.adpc.net)
Integrated Drought Management in Central and Eastern Europe

By Sabina Bokal1 and Richard Müller2, both of the Global Water Partnership Central and Eastern Europe

Water scarcity and droughts are not just matters of concern for water managers. They have direct impacts on the citizens and economic sectors that use and depend on water, such as agriculture, tourism, industry, energy and transport. Water scarcity and droughts also have broader impacts on natural resources at large such as through biodiversity, water quality, increased risks of forest fires and soil impoverishment. But how can such a complex natural phenomena be managed?

Drought management is currently reactive, dealing mainly with losses and damages. Cooperation among key actors is missing, and formal legislation mostly does not exist. In 2013, at the High-Level Meeting on Drought Policies, the Global Water Partnership (GWP) and WMO launched a joint Integrated Drought Management Programme (IDMP). Its main mission is to move from reactive to proactive drought management, focusing on drought prevention, mitigation, vulnerability reduction, planning and preparedness. Shortly after, in February 2013, the GWP Central and Eastern Europe (CEE) office launched a regional implementation of the IDMP.

The IDMP CEE3 supports the Governments of Bulgaria, Czechia, Hungary, Lithuania, Poland, Republic of Moldova, Romania, Slovakia, Slovenia and Ukraine in the development of drought management policies and plans. It is structured to provide both policy advice and practical solutions in drought management, and focuses on an integrated approach rather than fragmented solutions. Over 40 organizations from the 10 countries are involved. This article highlights the main achievements of the first phase (2015–2017) of the regional implementation and shows the direction of the second phase (2017–2019).

Responding to drought

Over the past few decades, droughts have dramatically increased in number and intensity in the European Union (EU). Between 1976 and 2006, the areas and people affected increased by almost 20%. In the last 30 years, the total cost of droughts across the EU amounted to Euro 100 billion (European Commission, 2012). Water scarcity and droughts have hit the CEE region frequently, and have had large impacts on the economy and welfare of people. Despite this damage, drought is still not considered an issue of high priority, and people are not aware of the impacts.

It has become evident that CEE countries need to improve national drought monitoring and management policies with the goal of improving preparedness and reducing drought impacts. Although most CEE countries have well-developed meteorological and hydrological monitoring systems, these are not translated into concerted efforts to support decision-makers in various sectors of the national economy (such as agriculture and energy).

Drought episodes can have local, national and regional characteristics. Several river basins (e.g. Danube, Tisza and Sava) in the CEE region have a transboundary character. However, there is currently no suitable mechanism to share information and knowledge among countries, and regional integration of drought monitoring and early warning is not at the desired level.

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A transnational integrated approach is therefore needed for successful tracking of drought, comparing its impacts using a common methodology and assessing the vulnerability of various sectors to drought occurrence. Currently, all of the countries within the CEE region need to improve their responses across sectors to meteorological, agricultural and hydrological droughts.

Many people still consider drought to be a rare phenomenon in the region. In fact, it is becoming a regular feature of the climate. The year 2017 was just the latest in a series of major drought events, and significant parts of the CEE region (especially the Danube) were hit by drought, which affected different water-dependent economic sectors, vegetation and water resources. Even though drought events are becoming more frequent and intense, they still catch communities unprepared. People remain reactive in their actions, and carry out measures only when drought has already developed.

Managing drought in an integrated way

Drought management to enhance regional drought resilience and to improve capacities of target groups for integrated drought management is the central aim of IDMP CEE. In cooperation with national hydro-meteorological institutions, river basin authorities, ministries and research institutions, the programme addresses the following four main components:

- Investments in regional and national development: To advance regional/transboundary cooperation in drought management by integrating water security and drought resilience into national development planning and decision-making processes.
- Demonstration projects: To develop and implement several innovative solutions for addressing critical drought management challenges. Project implementation is driven by institutions working at the local level with support and technical assistance from regional and country teams.
- Knowledge and capacity development: To organize regional and national workshops, publish policy briefs, work with social media and implement other activities focusing on increasing awareness among water managers, farmers and other water users.
- Partnerships and sustainability: To ensure that the network facilitating IDMP CEE is strengthened as well as to enhance further fundraising of programmes promoting water security and drought resilience for sustainable development.

Producing step-by-step guidance

One of the cornerstones of proactive drought management is the establishment of a drought policy and a drought management plan. This should address the whole drought management cycle (monitoring–impact assessment–response–recovery–preparedness) and help to improve decision-making processes in drought management.

During the first phase of IDMP CEE, partners conducted a review of the current status of implementation of drought management plans and measures and integration of drought issues into the first river basin management plans (RBMPs). An overview in 10 CEE countries showed that most countries had not produced a drought management plan in accordance with EU general guidelines (European Commission, 2007). Furthermore, substantial shortcomings were found in the implementation of all key elements of drought management plans, such as indicators and thresholds establishing different drought stages, measures to be taken in each drought stage and the organizational framework for drought management. In addition, drought was not identified as a significant water management issue in several RBMPs. The problem areas identified by the review were deemed a good basis for developing guidance on how to produce a
The Guidelines for Preparation of the Drought Management Plans\footnote{www.gwp.org/globalassets/global/gwp-cee_files/idmp-cee/idmp-guidelines-final-pdf-small.pdf} aim to provide a better understanding of how to integrate drought management into RBMPs in CEE. They were developed specifically for EU countries. They are built on guiding principles derived from EU legislation and drought strategy as well as other water policy documents. They are also based on WMO/GWP guidelines, which provide a template for action that countries can use in the development of a national drought management policy and drought preparedness/mitigation plans.

The main obstacle in CEE in developing drought plans was identified as a lack of methodology. As the guidelines provide a detailed methodology for drought management plan development, describing basic steps in a very concise way, a lack of methodology should no longer be a problem. In addition, examples are presented for each step to increase the clarity on how any specific part of a drought management plan functions in practice.

Seven steps of how to integrate drought into planning processes for development of RBMPs

Monitoring and forecasting of drought

The first step in monitoring drought at international and regional levels is to establish communications with and among national authorities. Almost all countries in CEE have operational products used for drought monitoring. Some of the countries use many different data sources, while others rely on only one indicator.

Partners within IDMP CEE collected existing national data and any other indicators used in partner countries to identify or forecast drought, and made them available through the European Drought Observatory (EDO), operated by European Commission Joint Research Centre.

Similar to many continental and global monitoring platforms, EDO intensively uses modelling systems for drought status assessment. However, many meteorological variables, especially the amount of precipitation, are very difficult to accurately simulate using only remote-sensing and conventional measurements. Country drought products prepared
from local measurements are, therefore, crucial for drought status assessment. Moreover, the integration of existing national data increases data visibility of data and enables countries to justify requests for assistance in case of major natural disasters.

The implementation guide prepared during this activity can be used in similar future projects that involve integration of existing or new data into EDO.

Reducing drought impacts, vulnerabilities and risks

The IDMP CEE coordinated several demonstration projects, focusing on various aspects of drought management and covering different sectors (water, agriculture, forestry and meteorology).

One of the most successful was a demonstration project on natural small water retention measures. Small retention is an adaptive measure that serves to adjust to extreme climate variability. Specifically, it slows down flood waves during flood periods and helps retain water in the land during wet periods. This fits perfectly in the CEE region, which is faced with increased frequency of extreme weather events – one year floods, next year drought.

Natural small water retention measures focus on increasing the buffering capacity of the landscape to mitigate extreme events. The guidelines on Natural Small Water Retention Measures, which were developed during this activity, define small retention measures and their purpose. They are intended for individuals, civil society and policymakers, and are on how to plan and construct different kinds of small water retention measures that lower flood risk and store water for dry periods.

The guidelines complement the case studies, examples of different small retention measures already in action from the CEE region. To increase knowledge of these measures in the region and beyond, an online lecture was prepared for everyone who wants to understand the concept as part of the integrated water resource management. This demonstration project continues as a larger scale project with funding from the Interreg CENTRAL EUROPE programme FramWat – a framework for improving water balance and nutrient mitigation by applying small water retention measures. There are also other demonstration projects such as upgrading agricultural drought monitoring and forecasting in the Ukraine and Republic of Moldova.

Main achievements of the first phase of IDMP CEE (2015–2017)

- A concise overview of the situation regarding drought management in CEE
- A guidance document for preparation of a drought management plan in accordance with the EU Water Framework Directive and global conventions
- Communication links among experts and policymakers active in drought management at the country level
- Increased capacity of key actors to implement the entire process of preparing a drought management plan in their own countries
- Collection of existing drought monitoring indices, methods and approaches from the CEE region, and the establishment of a link and integration of data into the European database and monitoring service (the European Drought Observatory)
- Demonstration of innovative approaches in drought management
- Exchange of information and results with organizations in the region that deal with similar issues

Developing efficient and operative drought management

IDMP CEE partners developed a new three-year workplan (2017–2019) through which they will continue to build capacity in order to change ad hoc drought responses into proactive drought management. The main expected results of the next phase are:

- Establishment of efficient and operational drought management procedures, leading to improvement of drought monitoring and a unified analysis of drought impacts and risk assessments for the whole region
• Overcoming gaps in decision-making processes in drought management, improving dialogue among scientific and policymaking communities, and increasing knowledge about EU policy instruments and relevance to implementation of drought policy
• Increased knowledge and capacities regarding operational and strategic capacity to monitor, forecast, evaluate and respond during the onset of droughts, and improved capacity to analyse data faster and with higher accuracy
• Better access to information and products, and enhanced accessibility of IDMP CEE knowledge and outputs to all stakeholders across sectors

IDMP CEE played a catalytic role in the development of the DriDanube project (Drought Risk in the Danube Region) – the programme and the project benefit from mutual synergies. The project aims at helping all stakeholders involved in drought management become more efficient during drought emergency response and prepare better for the next drought. This fits well into the IDMP CEE overall goal.

The changes required with IDMP in the CEE region are to move from recovery to protection, from crisis management to risk management, from reactive to proactive actions. Practical tools are being developed to help everybody to be better prepared for future drought events.

Acknowledgements: All colleagues and experts who contributed to the IDMP CEE programme are acknowledged. Special thanks to Danka Thalmeinerova and Tomasz Okruszko, who made major contributions to preparing and initiating the programme, and to the peer review group: Janusz Kindler, Henny Van Lanen, Bob Stefanski and colleagues of GWP/WMO IDMP.

References


Environmental Flows in Sustainable Integrated Water Resources Management

By Martina Bussettin, Institute for Environmental Protection and Research, Italy

Modifications in water availability and quality over time and space – especially in the context of climate variation and change and growing water needs – call for adaptive management of water resources. The essential requirement for such an approach is detailed knowledge of the availability and usability of water resources in time and space. This implies knowledge of physical systems and their driving processes, and the availability of hydrological data in real time (precipitation, temperature, stream discharge and groundwater levels), together with data on water use and on environmental flows. With this information, it is possible to run water budget models and to know the availability of water for different objectives. These depend on the provision of ecosystem services.

Ecosystem services are the benefits people obtain from ecosystems that maintain the conditions for life on Earth. They include:

- Provisioning services such as food and water
- Regulating services such as flood control
- Cultural services such as spiritual, recreational and cultural benefits
- Supporting services, such as nutrient cycling

Water resources can therefore be considered as “ecosystem products” whose protection and sustainable management will, in turn, also protect and safeguard water resources.

Water bodies – rivers, lakes, groundwater, etc. – provide a wide range of services for ecosystems and human society to thrive on. Fluvial systems – rivers and associated lakes, wetlands, etc. – evidently provide the highest number of such services, for example, for food and agriculture, drinking, natural flood mitigation or energy.

In order to ensure such services, there has to be an appropriate level of functionality of fluvial processes, in terms of flow and sediment regime. This will promote heterogeneous habitats and connectivity and sustain the different biotic communities inside ecosystems. To support the complex task of determining the appropriate level of functionality, WMO is in the process of developing guidance on the estimation of environmental flows.

The establishment and maintenance of such flow and sediment regimes, namely environmental flows, is an essential element in preserving riverine ecosystems and the services they provide. They should be included as a constraint in water resource assessment and in national legislative frameworks.

Environmental flows currently refer to the typical seasonal and interannual variabilities of the natural flow regime, and not only to the minimum amount of water (low flows) to be maintained in a river. In addition to this pure hydrological assessment of natural flow variability, there is also the necessity to link environmental flow definition to related hydromorphological processes and local ecological objectives for the river.

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Environmental flows are fundamental to the management of water resources as a tool for ecosystem and biodiversity conservation and adaptation to climate change at a country scale. Additionally, environmental flows should be considered for large uses of water for agriculture and for the development of hydropower projects.

Historically, exploitation of water resources, particularly water, has occurred with no consideration of the sustainability of such management in the long term. For example, rivers have been considered as canals and severely engineered for socioeconomic development. Ecosystems have therefore been disconnected from once-related water bodies and deteriorated, often irreversibly, with a substantial loss of freshwater biodiversity.

River management not taking into account the dynamic nature of rivers has provoked undesired effects. These include incision processes and bank erosion undermining channel stability, sediment starvation, coastal erosion, disconnection with groundwater bodies and, ultimately, loss of habitat and ecosystem services.

A change of method is therefore required to ensure availability and sustainability of water resources. Together with real-time knowledge of water availability and quality, a different approach to river basin management has to be considered. This should be based on a systemic vision of catchments where rivers are seen as dynamic entities providing ecosystems services that have to be managed with these services in mind.
Rebuilding High River

An interview with Craig Snodgrass, Mayor of High River, Canada

Interview by Celine Novenario, WMO Secretariat

On 20 June 2013, the community of High River in Alberta, Canada, found itself under water. With an intense and slow-moving storm stalled over the Rocky Mountains, torrential rain poured down on saturated ground for three days and hastened mountain snowpack melt, leading to rapid swelling of surrounding rivers and creeks.1 Highwood River, a Bow River tributary originating in the Rockies and cutting through the town of High River, expanded to 35 times its usual width and peaked in 8.5 hours at approximately 1 850 cubic metres per second (cms) of flood discharge. By the time the flood waters began to recede, nearly all of High River’s 13 450 residents and 5 308 homes2 had been evacuated.3

Craig Snodgrass was a citizen of High River then, grappling with the onslaught and aftermath of the devastating flood like the rest of his community. In October 2013, he was elected Mayor of High River and faced with the colossal challenge of working out how to rebuild the town better: “Did I have a clear vision? Not at all. But I knew I had to figure it out. For whatever reason, [the people of High River] felt I was the one who would be able to take them the distance. So I stuck my hand up and went for it.”

The Snodgrass family had lived in High River for four generations but never experienced a flood of this magnitude. “High River is built on a flood plain, so there have been floods before, of course – but not even close to this,” Mayor Snodgrass said. High River had flood mitigation plans in place when Snodgrass took office, but the unprecedented nature of the 2013 flood left him in unchartered territory. “Previous floods we had experienced were 700 to 900 cms; those were the kinds of floods that we knew how to deal with. But because the flood of 2013 was 1 850 cms, we had to double all the programmes,” he said.

Together with the town council, Snodgrass examined a range of structural measures and evaluated which best served the needs of High River: “We did not want to dam up the Highwood River for flood protection. Dams can be a dangerous thing.” Dams can reduce the severity of downstream hazards by retaining floodwater during flood peaks, but they can also give a false sense of security when people fail to consider the potential for dam failure.4 Building against nature was also ruled out: “We did not want to do a massive and expensive diversion; we have natural waterways that already act as a diversion.”

“Our philosophy became getting out of the way of the river and making room for the river. We moved two neighbourhoods out of the way of the river,” Snodgrass said. An aggressive land-use strategy was pursued, including buying out and relocating about 150 homes to reclaim the river path. High River’s flood protection system of berms and dykes was also upgraded to protect the town from river flows exceeding that of the 2013 flood: “The berms and dykes were functionally in place by June 2014.

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1 Environment and Climate Change Canada, 2013: Canada’s Top Ten Weather Stories of 2013.
We’re 95% complete now; we just have one larger berm left to take care of.”

Non-structural measures were also put in place, such as establishing and regularly testing the High River Alert System. “As soon as we have any kind of threat perceived, two big sirens in High River go off. Those sirens notify people to look at their phones and our website to figure out what’s going on,” Snodgrass said. Residents can sign up on the website to receive emergency alerts through voice calls, text messages and emails. The community is expected to take an active role in disseminating emergency information: “As soon as you get the information, you make sure that all your neighbours know. You’ve got a radius around your house, around your business – wherever you’re at – it’s your responsibility to make sure that everyone around you knows what you know.”

Strong commitment from the government and the community were critical to better protecting High River from floods. “[The flood] was so catastrophic that the government committed the funds necessary to get this done very quickly... but at the end of the day, it’s your community that has to rally around your vision,” said Snodgrass. Making full use of and elevating community programmes using the additional resources provided by the government and the Red Cross were key to getting the High River community on the same page: “[The government and the Red Cross] funded a tonne of programmes to get this community back on its feet.” The programmes addressed a range of issues from post-traumatic stress to replacing sports equipment for the kids of High River. “Human beings are resilient. It’s not special just to High River. Wherever you are in the world, human beings are resilient. They’ll figure it out. But it takes money and you need government support behind it to make these things happen,” Snodgrass said.

More than four years have passed without a major flood event in High River, but Snodgrass remains vigilant: “We’ve been through what we have and learned a tonne. But human beings’ memories are very, very short. It’s very easy to get complacent when you haven’t had an event in four years. That’s the danger now: coming back to complacency. Don’t get complacent.” High River schedules regular drills and tests so that emergency personnel and the community at large are trained and aware of emergency...
protocols. Emergency information is accessible on a dedicated Web portal, including household emergency guides, evacuation information, and hazard, risk and vulnerability assessments. The month of May is designated Emergency Preparedness Month in High River, during which the town holds community cafés on safety and security, and provides neighbourhood block party starter kits, which include emergency preparedness information. Such events help to build and strengthen the community connections that are so critical for emergency preparedness.

As devastating as floods can be, Snodgrass views such events as an opportunity to better protect the community. He urges government officials to focus on the task at hand and not let this opportunity get sidelined by politics: “If your government is not committed to protecting the communities and putting the necessary pieces in place, knowing what’s coming ... you’re going to kill people – and a lot of them. You’ve got an opportunity. If you lose it, you won’t get it until that community is flooded again.”

Seizing the opportunity that came with the 2013 floods has paid off for High River. It has now been rebuilt to better withstand flood risks: “Our number one priority was to make sure that everybody was confident in the protection levels of High River. We succeeded because now we’re the most well-protected community from flood risk in Canada.”
Looking Ahead

By Harry Lins, President WMO Commission for Hydrology

WMO has continuously focused on promoting and facilitating the development of capabilities within National Hydrological Services in order to assist them in providing the best possible products and services for securing sound and sustainable water resources worldwide. This has been the Organization aim since it began working on issues in operational hydrology and water resources in 1961. Despite the numerous technological and computational advancements in hydrology, the focus has remained on the fundamental needs for robust water resources management and decision-making; that is, data and forecasting.

At its 15th Session in Rome in December 2016, the Commission for Hydrology reinforced this ongoing commitment by adopting two new initiatives that will significantly strengthen the capacity of National Hydrological Services to deliver hydrological data, forecast products and related services, particularly in developing countries. These initiatives are the WMO Global Hydrometry Support Facility (HydroHub) and the WMO Global Hydrological Status and Outlook System (HydroSOS).

The HydroHub

The HydroHub builds operational capacity in hydrometry and water monitoring, expands the base of hydrological data and exchange capabilities, and facilitates free and open data sharing. It does this through the development and application of innovative monitoring and database technologies, by supporting regional and local projects aimed at building sustainable hydrometeorological networks and freely accessible data, and by promoting the use of quality management principles.

The HydroHub consists of five main components:
- the World Hydrological Cycle Observing System (WHYCOS)
- the WMO Hydrological Observing System (WHOS),
- a technical Help Desk
- a Hydrological Services Information Platform.

WHYCOS, a pre-existing capacity-building mechanism, is being redesigned to increase the sustainability of the projects by building operational systems and capacity in water monitoring and information systems, while the Global Innovation Hub will facilitate the free and open exchange of observation data and information to support informed decisions and policy-making.

HydroHub has three main objectives: 1) To develop an efficient, innovative and sustainable framework to support operational systems in hydrometry around the world; 2) To enhance and sustain global integration of national and regional monitoring systems in support of data sharing; and 3) To facilitate the operational uptake of innovative technologies by national services.

Through its various activities, the HydroHub will contribute to projects that have identified a hydrological observation data challenge by making the full WMO portfolio of expertise – from science to technology to services – accessible to end-users of hydrological data and services from various economic sectors, as a tailored service. Bringing these different communities together will increase the base of hydrological data – particularly as catalyzed by innovative technologies and approaches. The HydroHub will also contribute to related WMO activities such as the Global Hydrological Status and Outlook System (HydroSOS).

The HydroHub’s initial four-year operational period is being financed by the Swiss Agency for Development and Cooperation (SDC). HydroHub will gradually increase its functionality in 2018 following a one-year preparation phase that was used to establish procedures, test new approaches and most importantly, weave the network of partners. Key highlights of the 2017 preparation phases included engagement with potential partners, contributions to a proposed...
Senegal-HYCOS project, and the co-organization of an innovation workshop together with the Measurements and Observations in the XXI Century (MOXXI) activity of the International Association of Hydrological Sciences (IAHS). The workshop focused on fostering discussion for future integration and implementation of innovative measurement approaches in operational hydrology.

The WMO HydroHub is governed by an Advisory Council that is chaired by the President of the Commission for Hydrology and comprised of members representing the World Bank, the SDC, a WHYCOS stakeholder, a Global Innovation Hub stakeholder, a member of the Association of Hydro-Meteorological Equipment Industry (HMEI), and two representatives from UN-system organizations with an interest in hydrometry.

In addition, the Advisory Council is supported by an Innovation Committee that focuses specifically on issues related to the review, endorsement, and periodic update of the Innovation strategy and Innovation areas; endorsement of the selection criteria for Innovation activities, such as impact on and benefits to the goals of the HydroHub; assessment, approval or rejection of proposals of Innovation activities to be funded by the Innovation Fund; and endorsement of resource allocation related to personnel and financial support of Innovation activities through the Innovation Fund. The Innovation Committee is chaired by a member of the Commission for Hydrology’s Advisory Working Group, with members from financial partners, experts in innovation, industry experts, and a representative of the IAHS.

HydroSOS

HydroSOS is being designed to address the vexing problem of global hydrological variability – an omnipresent threat to society. As population increase, so do the number of people at risk from water-related hazards and the rapidly growing demands on water resources. However, there is currently no global system capable of assessing the present status of surface and groundwater systems or predicting how they will change in the immediate future.

HydroSOS aims to develop a worldwide operational system at monthly timescales capable of providing:

1. An indication of the current global hydrological status (including: groundwater, river flow, soil moisture)
2. An appraisal of where this status is significantly different from ‘normal’ (for example, indicating drought and flood situations)
3. An assessment of where conditions are likely to improve or get worse over coming weeks and months.

HydroSOS will bring together existing tools and approaches to develop composite products of hydrological status and outlook.

It will be implemented through National Meteorological and Hydrological Services (NMHSs) and enabling them to offer simple, accessible hydrological information to users such as government agencies, basin managers, funding institutions, aid agencies, UN bodies, and the general public. It will be developed in phases, beginning with a pilot phase from the present through 2020. At an initial planning meeting held in Entebbe, Republic of Uganda, in September 2017, discussions focused on two candidate pilot studies: one in Africa (preferably a transboundary basin like the Lake Victoria Basin), and the other in the South Asia (also involving a transboundary basin).

A third candidate pilot study will focus on a global assessment to evaluate the added value of a coordinated global hydrological assessment; to assess the feasibility of such a project; and to verify the commitment of NMHSs. The benefits of such a global assessment are notable: First, it would provide inclusive, standardized and quality information, particularly for countries that do not have such information, and will focus primarily on medium to long-term (extended range) forecasting. This coverage will not replace the products of NMHS, but will leverage them. Second, the project will improve the awareness of potentially hazardous situations and increase the visibility of the NMHS through successful products and outcomes. Third, the project will provide a tool for comparison among areas using common standards.

This initiative is aligned with several WMO priorities such as disaster risk reduction, the Global Framework for Climate Services, the WMO Integrated Global Observing System, and capacity development. HydroSOS will be an important tool to help NMHSs deliver their services. In addition, HydroSOS will support the 2030 Agenda for Sustainable Development and, in particular, the broader global community in the area of water management.
The Global Conference for Prosperity through Hydrological Services (WMO HydroConference) aims to foster collaboration on improving the availability and use of hydrological services worldwide by:

- **Promoting collaboration** for new and ongoing initiatives, including the establishment of data exchange;
- **Leveraging the knowledge and expertise** of the full range of water stakeholders to coordinate efforts towards greater impact; and
- **Mobilizing public and private sector leaders** to leverage support for key initiatives.

**Approximately 150 participants** from a broad range of areas are expected to attend the conference, including Ministries of Foreign Affairs; Ministries responsible for Water, Meteorology, Disaster Risk Reduction, Finance, and Development Aid; National Meteorological and Hydrological Services; Donors; UN Agencies; Non-Governmental Organizations; Research/Academia; Private Sector; and Media.

To cover all the critical steps that lead to hydrological services with high positive impacts, discussions will focus on key segments of the **hydrological services value chain**:

- **Data Management**
- **Products**
- **Service/Product Delivery**

### Provisional Programme

The conference programme includes opening and closing plenary sessions, technical sessions, interactive roundtables, a water photo exhibition, an information area, and a welcome reception.

**7 May 2018**

- Opening Ceremony
- The Societal Benefits and Value of Hydrometeorological Services
- Segment 1: Hydrological Data Management
- Welcome Reception

**8 May 2018**

- Segment 2: Hydrological Products
- Segment 3: Hydrological Service/Product Delivery
- Breakout Group Discussions

**9 May 2018**

- High Level Segment: Hydrology for Sustainable Development
- Session 4: Conclusions and outcomes from technical sessions
- Summation and Closing Session

The Global Conference for Prosperity through Hydrological Services is co-organized by:

Find out more at [hydroconference.wmo.int](http://hydroconference.wmo.int)
The Global Conference for Prosperity through Hydrological Services (WMO HydroConference) aims to foster collaboration on improving the availability and use of hydrological services worldwide by:

- Promoting collaboration for new and ongoing initiatives, including the establishment of data exchange;
- Leveraging the knowledge and expertise of the full range of water stakeholders to coordinate efforts towards greater impact; and
- Mobilizing public and private sector leaders to leverage support for key initiatives.

Approximately 150 participants from a broad range of areas are expected to attend the conference, including Ministries of Foreign Affairs; Ministries responsible for Water, Meteorology, Disaster Risk Reduction, Finance, and Development Aid; National Meteorological and Hydrological Services; Donors; UN Agencies; Non-Governmental Organizations; Research/Academia; Private Sector; and Media.

To cover all the critical steps that lead to hydrological services with high positive impacts, discussions will focus on key segments of the hydrological services value chain:

**Provisional Programme**

The conference programme includes opening and closing plenary sessions, technical sessions, interactive roundtables, a water photo exhibition, an information area, and a welcome reception.

- **7 May 2018**
  - Opening Ceremony
  - The Societal Benefits and Value of Hydrometeorological Services

- **8 May 2018**
  - Segment 1: Hydrological Data Management
  - Segment 2: Hydrological Products
  - Segment 3: Hydrological Service/Product Delivery
  - Breakout Group Discussions

- **9 May 2018**
  - High Level Segment: Hydrology for Sustainable Development
  - Session 4: Conclusions and outcomes from technical sessions
  - Summation and Closing Session

The Global Conference for Prosperity through Hydrological Services is co-organized by:

WMO Headquarters, Geneva, Switzerland, 7 to 9 May 2018

**A man uses his canoe to ferry people and goods across a lake in Abuja, Nigeria.**
*(Photographer: Mohammed Alamin)*