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EDITORIAL

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Digitalization and hydroinformatics

In early 2022, within the framework of Singapore International Water Week (SIWW), we wanted to find out what well-established senior water professionals from all over the world considered to be the main likely water-related megatrends of the future. Toward this end, Peter Joo Hee Ng, the then Chief Executive of PUB, Singapore's National Water Agency, and one of the world's most forward-looking heads of water utilities we have ever met, and us, sent a request to over 200 leading water experts from all over the world, requesting them to let us know what in their views were the three most important water megatrends of the post-2025 world. This was an open-ended request: the participants were not providing a possible list of megatrends from which they could select only three: they were to identify three without any prompting. Nearly 30% of the people contacted responded to our request.

SIWW Secretariat thereafter consolidated all these responses under some broad categories. Not surprisingly, climate change, adaptation, and mitigation headed the list. It was followed by digitalization, urbanization, water reuse, and resource circulatory/circular economy.

We selected the top three megatrends and had a special session during SIWW 2022 to discuss the implications of these megatrends to water resources management. To this end, leading world experts were invited to discuss the implications of the identified megatrends. The longer term plan is to consider specific regions of the world and assess how the selected megatrends are likely to affect water resources management during the post-2025 era in a synergistic way.

Some people may have been surprised that digitalization was considered by the participants to be the second most important megatrend of the future. However, on reflection, this result should not be surprising, especially when rapid advances in knowledge and technology during the past two decades are considered. Consider only the following few facts:

- Nearly 90% of data in the world has been generated during the past 2 years. With the extensive use of sensors and robots in the water sector, data generated in the coming years will increase exponentially.
- Until 1900, human knowledge doubled approximately every century. By the end of the Second World War, knowledge was doubling every 25 years. Doubling time was reduced to 13 months by 2013 (Schilling, 2013). It is likely to double soon every 12 h, or even less.
- Storage cost per gigabyte of data was over $1 million in 1980. Now it is a fraction of one cent (Schwab, 2016). It is likely to be almost free in the future with new technological breakthroughs, which are on the horizon.
- In 2017, the cost of translating one million words, from Chinese to English, was nearly $1 million. Currently, it is approaching zero (Callanan, 2019). Instantaneous, near-zero-cost translation will facilitate significant knowledge sharing and use across languages in the coming years. This will, for the first time in centuries, challenge the pre-eminence of the English language as the preferred medium of knowledge dissemination and use.

While knowledge and technology have advanced tremendously during the past two decades, the water profession is still giving too much attention to the experience and paradigms of the past, many of which have become increasingly ineffective, and some even completely obsolete. However, the comfort of the status quo and/or vested interests have kept in use at least 70+ years old paradigms like integrated water resources management and integrated river basin management, even though, for the most part, they have been ineffective for decades for nearly all countries (Biswas, 2004, 2008).

During the current era of rapid advances in knowledge and technology, many water professionals and water institutions are often being overwhelmed by the magnitude and extent of the rapid advances in water-related developments. Many are often ignorant of the potential use of new knowledge and information to improve nearly all aspects of water management.

Digitalization is one of several important changes in recent years to which a large number of water professionals and institutions have not given adequate attention, often because of sheer ignorance of its potential use to significantly improve existing water planning and management practices and processes. This is partly due to the fact that they are not familiar, or comfortable, with using these rapidly evolving developments.

1 | DIGITALIZATION AND HYDROINFORMATICS

As water management becomes increasingly more complex with time, the use of digitalization and hydroinformatics will become important means to make it progressively more rational, efficient, and equitable. Sensors, robots, and other means of data generation are already producing massive amounts of data, which then need to be promptly analyzed and applied, to improve overall water governance. Modern technology and big data analytics are already helping water managers in numerous institutions, in many developed and a few developing countries to understand, appreciate, and use the information contained in large amounts of data, which then could be meaningfully deployed to find more appropriate solutions. To be really effective, the entire process needs to be complemented by good, transparent, and steadily improving policy frameworks. Equally, the water institutions must train, recruit, and retain experienced personnel to distill and translate the knowledge that may come out of big data analytics so that the knowledge can be promptly used.

Water management is inherently a mixture of social, economic, technical, environmental and political considerations. Digitalization and hydroinformatics should feed information generated, and knowledge obtained, from all of these activities to make the decision-making processes more timely, relevant, efficient, and cost-effective. Water institutions should also formulate effective and implementable information and communication strategies to engage all appropriate stakeholders.

Data-driven management and operational models are already contributing to new ways of finding more effective solutions to old problems by obtaining new knowledge and insights from the massive quantities of data collected and their speedy analyses. Rapid advances in sensors, computing powers, and artificial intelligence, as well as their steadily decreasing costs, are contributing to increasing more rational and efficient use of water, including resource conservation, reducing overall costs, and generally contributing to positive impacts on the environment, ecosystems, and societal welfare.

As water management becomes increasingly more data-driven, as it will undoubtedly become in the future, the availability of reliable and high-speed internet infrastructure becomes an essential prerequisite so that managers can take full advantage of the process. This will also require, in addition to good, reliable and up-to-date digital infrastructure, compatible platforms where collected data can be stored and transmitted to wherever such data could be beneficially analyzed and used. It is equally important that decision makers have the capacity, knowledge, and inclination to use such new types of information.

Our own first large-scale appreciation of the benefits of digitalization and hydroinformatics occurred when we visited, some two decades ago, hydropower plants in the far north of Finland. These were located in inhospitable terrains where normal facilities and services are generally scarce.

When we first expressed our desire to visit these plants, we were informed that it can be organized only one day each week, and we must make an appointment so that an expert may be available to guide us. Having visited numerous such plants all over the world, we felt these requirements were, to put politely, somewhat strange!

When we arrived in Rovaniemi, the capital of Lapland and a city of some 60,000 people, we found that the hydropower dams in northern Finland are managed and operated from this medium-sized city. Data and pictures from all the dams were transmitted to a control centre in Rovaniemi. This is manned by trained and experienced personnel 24 h a day and 365 days a year. If the experts in the control room feel there is any sign of trouble, at any hydropower plant, a team of specialists is promptly dispatched to check out the nature of the problems and find and implement promptly appropriate solutions.

The hydropower plants are open only 1 day a week for visual inspection and cleaning. On the other 6 days, they remain closed but all essential information is instantaneously transmitted to Rovaniemi where it is carefully monitored. The system has been working successfully for decades.

2 | DADU RIVER HYDROPOWER AUTHORITY: AN EXCELLENT EXAMPLE

Based on our current global knowledge of the operation and management of dams, there is no question that the Dadu River Hydropower Authority is probably one of the most advanced institutions in the world in terms of managing its entire hydraulic infrastructure through extensive use of sensors, robots, big data analytics, and artificial intelligence. They are probably 5 years ahead of their nearest competitor in China or the rest of the world. This issue contains an important paper (Tu et al., 2023) from this Authority on intelligent operation and management of the Dadu River Basin.

The Authority is developing a cascade of 28 dams in the mountainous region of Sichuan province, including the 312 m high Shuangjiangkou Dam. When completed, it will be the tallest dam in the world.

The Authority is extensively using sensors, robots, high-definition pictures and sound, big data analytics, Internet of Things, and mobile internet, to collect, transmit, store, and analyze data constantly. High-definition photos and sound systems, backed by data collected, successfully enable remote site monitoring and scene understanding. Such developments can now effectively simulate physical on-site inspections. As of 2021, the Authority had 22,948 risk sensing points on the bank slopes of dams and reservoirs and hundreds of thousands of points monitoring more than 350 types of equipment. The Authority has successfully developed 128 common fault monitoring indexes for turbines, generator rotors, and transformers.

Results of extensive digitalization and management reforms have been impressive. Between 2014 and 2021, the number of hydropower plants in operation under the Authority increased from 5 to 9, and the installed capacity more than doubled, from 5.6 to 12 GW. This was achieved with a reduction in employments, from 2498 to 2148. This means even though its installed capacity more than doubled, the number of employees was reduced by 14% and the productivity of its workforce increased by 75%. All these developments contributed to a profit increase of 35%.

Such developments require fresh talents, with special expertise in new areas like data analysts and decision managers. More than 300 employees have been retrained and transferred to digitalization-related work. The Authority has established a big data service company, with new jobs, which provides needed services with regular data analyses, which are at the core of all intelligent units. The staff are continually innovating. This is contributing to the development of new knowledge management practices, including the creation of new operational algorithms, as well as continually improving existing algorithms and management practices. Sensors, robots, and artificial intelligence have given the Authority unprecedented new skills for problem-solving and helping it to continually improve operational and management practices.

3 | FUTURE OF DIGITALIZATION AND HYDROINFORMATICS

Not only Dadu River Hydropower Authority but also numerous other water-related institutions, both public and private, in several developed countries and a few developing countries, especially China, have made remarkable progress in recent years in terms of increased use of digitalization, hydroinformatics, artificial intelligence, and information technology, to significantly improve water management. There is no question that in the coming years, their use will increase very significantly.

Like all major developments, such advances will have both benefits and costs. The nature of beneficiaries will be different, and, unless carefully managed, there will be winners and losers. Thus, it is essential that this transition process is managed carefully. Otherwise, there could be significant job losses.

Technological innovations often have the potential to reduce overall employment in older areas, even though they invariably create additional employment in many new areas. For example, in the United States, at the beginning of the 19th century, nearly 90% of workers were employed or earned their living from agriculture-related activities. Today, this percentage is less than 2%.

Such developments, of course, are not new. Nearly a century ago, the well-known economist, John Maynard Keynes (2010), warned that "due to our discovery of means of economizing the use of labour outrunning the pace at which we can find new uses of labour." Fortunately, up to now, society has managed this transition process reasonably well as a result of which the results have been overwhelmingly beneficial to the society as a whole.

Furthermore, what has been observed thus far in the case of Dadu River Hydropower Authority is that water institutions will have to give considerable attention to ensure that likely redundant workers can be retrained in areas where new types of jobs may be available in the future where they could be gainfully employed. Institutions also have to provide a good working environment where people could be retrained and new talents could be attracted and retained. To the extent possible, all the negative impacts of digitalization need to be kept to a minimum for societal good.

There is no question that digitalization has the potential to improve significantly how water is being managed at present in different water institutions. Once implemented, it is likely to radically transform how water will be managed in the future, and perhaps the very nature of individual water management components. Effective digitalization across any water institution will be one of the prerequisites if water security is to be achieved.

While the benefits of digitalization are many, challenges faced by water institutions to operationalize it successfully are also significant.

Currently, in most water institutions around the world, the different departments of any institution are responsible for collecting, storing, and analyzing the data on various items. The data are generally available on different platforms, in different formats, and stored differently. The reliability of data collected by different departments could vary. In addition, the various platforms may organize the data collected and stored differently so that their use can be constrained in the institution as a whole. It is not unusual that some departments of the same water institution may see others as rivals and there could be historical mistrust between them. This could mean consolidating all the data collected and storing them in a compatible platform may prove to be a complex, time-consuming, and difficult task.

Furthermore, appropriate algorithms have to be developed for the platform software, which needs to effectively integrate data with pictures and sound. This would enable managers to diagnose emerging problems remotely and find solutions before they become serious.

A few water institutions, like PUB, Singapore's National Water Agency, have already made a good beginning. Its previous Chief Executive created a high-level position, the Chief Information Officer, whose tasks include: ensuring all data and information collected and stored are available to everyone in the institution and are in a compatible form so that they can be used by all. For most water institutions, in different parts of the world, this will not be an easy task but one that has to be accomplished if the full benefits of digitalization have to be harnessed for more effective water management.

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