8 Key Messages, Recommendations and Concluding Remarks

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In the following the key messages from the previous chapters are summarized and conclusions drawn. Based on our discussions, we, the Hydrology 2020 Working Group, have addressed what we feel are the key current and future hydrological and water-related issues, instead of attempting to cover all facets of hydrology. Our objective was to explore how the science of hydrology can evolve into an integrated discipline capable of meeting the world water challenges that already exist to a large extent today, and are expected to prevail by 2020, and indeed also in the time beyond that.

In almost every basin of the world, anthropogenic activities have disrupted the natural hydrological and ecological regimes. The societal and environmental challenges linked to water-related issues are absolutely staggering in many cases, thus “business as usual” is unacceptable. Noting that this is not new makes it an even more morally and ethically embarrassing situation for today’s policy and decision makers. The principal problems associated with water resources and their appropriate management have remained the same over the last decades. But the magnitude of the problems has increased in many cases and regional disparities have become more pronounced. Nevertheless, in contrast to the past, today there is at least a wider global recognition of world water problems as well as the greater availability of new tools, datasets and computer models. However, finding sustainable solutions is becoming increasingly difficult. This seems to be caused, on the one hand, by various global changes as well as politically driven processes that seem to make the world—and sustainable water management in its basins—more complex. On the other hand, the hydrological cycle seems to have accelerated, most likely causing increased extremes (floods and droughts or water quality problems), and aquatic ecosystems are being destroyed or are under enormous pressure partly as a result of global changes. The pressure on water resources from direct human impacts will continue to increase because of the world’s rising population (an additional three billion people by 2050, a 50% increase from today’s population) and the associated expected changes in consumption and production patterns.

As illustrated in Chapter 4, a lot of effort has been directed towards improving measurement of hydrological variables using new ground-based and remote sensing techniques. For the application of the latter, it is very important to have sufficient ground-truth information yet there are currently cutbacks to monitoring networks worldwide. Although there is a greater awareness of the related scale problems, an improved understanding of the often conflicting scales of the processes that are measured and modelled is particularly required. Resolution of scale mismatches is a key future research requirement in hydrology. Knowledge gaps also exist in hydrology, in particular in the interactions between coupled hydrological processes and other processes (e.g. atmospheric or biogeochemical processes). Additionally, observing hydrological (and other) processes in the subsurface, with its spatio-temporal variabilities and heterogeneities, is still a great challenge.

Hydrological modelling has certainly advanced in the last decades and is today a central component in integrated water resources management. However, it can be expected that modelling will continue to be a significant research topic, but with more emphasis on: model coupling across hydrological domains; greater incorporation of socio-economic models; coupling of hydrological and biogeochemical processes; better incorporation of physiographic data; uncertainty assessment; real model validation and inter-comparison as well as improvement in model parameterization and data assimilation approaches; and improved frameworks for incorporating indirect data such as from tracers, geophysical tools and remote sensing. Research on these themes will improve the potential for the current generation of models to become predictive tools, able to predict fluxes and processes at the relevant spatial and temporal scales and also under changed circumstances. However, to meet the necessity for robust and truly predictive tools, it may be that entirely new, conceptually different models are required that can provide novel descriptions of the physical and biogeochemical processes at the appropriate spatial and temporal scales.

The *great challenge for the scientific hydrological community* is to identify appropriate responses to these obstacles. The following five points are considered crucial:

– As discussed in Chapter 1, the central role of *hydrology as integrator* of knowledge of different water-related disciplines must be recognized. In order to holistically analyse the water system, integrated research within hydrology and between hydrology and its sibling disciplines must be encouraged.
– Several scientific and technical obstacles prohibit us from understanding, predicting, and ultimately guiding the management of water resources. As was described in Chapter 7, the scientific bottlenecks include *our lack of understanding of hydrological processes at the basin scale, and our inadequate understanding of the coupling between hydrological, ecological, and climate systems across scales.* Crosscutting problems were also identified that affect many natural science disciplines, including those associated with prediction, scaling and integration.
– We recognize the fragmentary nature of hydrological expertise. However, in order to secure the long-term resources required to tackle the complex global, regional and local water challenges, it is necessary to secure *community consensus* about what are the grand hydrological challenges that should be addressed, where *community* refers to water-related scientific disciplines. Then the next important step is to *prioritize the challenges* and to develop a framework for addressing them through integration of ongoing efforts or through development of new coordinated efforts.

- The establishment of a *global hydrological intergovernmental organizing mechanism* is necessary. It is not realistic to consider the establishment of a single water agency as water is on the agenda of many UN agencies and many other global and regional associations. However, a wider coordination mechanism for water resources issues and the necessary development of the underpinning hydrological science would complement the existing UN-wide mechanism "UN Water". Such a global organization could play a key role in identifying and prioritizing the hydrological research challenges, and in helping to provide hydrological expertise and input to guide water policy and management.
- The involvement of *young scientists in hydrological research* is crucial. We recommend that the IAHS continues its efforts by supporting workshops of young hydrologists, granting awards for the best student papers at conferences, and facilitating the next forward-looking working group: Hydrology 2030.

The barrier analysis presented in Chapter 7 demonstrated that funding is always one of the key limiting factors to overcoming the existing scientific, technological or organizational bottlenecks. In particular, *funds that are committed over the long term* to technological development, research and monitoring, and with an emphasis on coupled, cross-disciplinary and integrated scientific approaches are needed. This would enable the hydrological community to establish interdisciplinary, coordinated field, experimental and modelling campaigns over a variety of spatial and temporal scales in different biomes. Various national groups are currently developing basin-scale hydrological observatories, which will help to better understand the complex and coupled systems, and ultimately improve our capabilities to manage our water resources. In such observatories, the necessary technological breakthroughs can be developed, e.g. "intelligent" microsensor networks, multi-satellite measurements and multi-technical field-based approaches using the latest geophysical, tracer and hydrometric techniques. However, to achieve a wider distribution of the knowledge gained with new technologies, it is essential that they become operational and are straightforward to apply in other regions of the world. In addition to these observatories, it is important that societal and organizational aspects of different regions are integrated with hydrological science. This includes the translation of scientific results, whenever possible, into action-oriented recommendations for decision makers.

As discussed in Chapter 3, the hydrological science community has to be more active in *transferring its knowledge to policy and decision makers*, ensuring that they make decisions based on the best available knowledge. In this regard, the interdisciplinarity of water-related problems needs to be acknowledged explicitly. Without incorporating knowledge from many disciplines, such as engineering, social and political sciences, biology, atmospheric sciences, geology, soil science, and ecology, the development of desperately needed holistic water management solutions is not possible. In addition, it is obvious that more generic and worldwide problems require improved political and organizational support through international processes and international institutions, including strengthening regional and global networks. Through these networks, data, knowledge and techniques can be distributed and, accordingly, water resources and the benefits that they generate can be shared in a more cooperative way. The development of such networks is crucial in particular for many developing countries, where international assistance in financial and human resources for capacity building needs to be enhanced. It is a sad fact that something so basic as hydrological data is still seen as a national security issue in many parts of the world!

To summarize, the demands for future development of the science of hydrology in order to meet the world water challenges in 2020 are high. In particular, better cooperation between hydrologists, sibling water science disciplines, and water policy specialists for improved integrated water resources management is not easy to attain. It might be argued that the lists of bottlenecks and our demands are extensive and the actions required for achieving sustainable solutions would be costly to implement. *However, the repercussions of not attacking these obstacles now may be much more costly for future generations.* Finally, it cannot be stressed often enough that water can also be a source of peace. In particular, hydrological understanding is the basis for sustainable integrated management of water resources in conflict regions, paving the way for cooperative efforts in other areas. There are many such examples: the Nile, the Middle East, the Zambezi, or the Mekong. Thus, the further improvement of the science of hydrology contributes to sustainable development from all perspectives, and for the entire global population. *The further development of hydrology should be seen as a critical investment opportunity for global welfare.*