Editorial

Environmental issues have been addressed in various fields of hydro-environmental science and engineering for several decades already. The Rio Declaration (1992) accepted the concept of sustainable development and the Kyoto Protocol (1997) provided specific targets to improve global environmental conditions. Since then, a sequence of UN summits, international conferences and world water events, have all contributed to raising awareness and suggesting solutions for present and future world water problems, stimulating the political will to address regional and global environmental issues. Hydro- and eco-environmental scientists and engineers will have pivotal roles to play in providing fundamental knowledge as well as practical technologies to facilitate decision making processes. We are entering a new era of complex sensor networks capable of monitoring the environment at unprecedented spatial and temporal scales, which is likely to improve our understanding of environmental processes. The explosion of available data will require new developments in data mining to convert raw data to useful knowledge, as well as to facilitate a quantum step forward in our ability to model complex ecological systems.

The European Water Framework Directive provides clear environmental objectives for all EU membership countries to be met in 2015 at the expense of legal sanctions and/or financial consequences. Both in North and South America, as well as in Asia, environmental awareness is rapidly increasing and becoming of public concern. The need for imposing measures to ensure environmental safety and sustainable development is becoming commonly accepted. However, understanding effects and consequences of proposed measures is often a matter of intense legal and scientific debate. Indeed, predicting the response of complex eco-environmental systems that are not fully understood, to measures that may contain a considerable degree of uncertainty, is not a simple matter at all. Moreover, socio-economic and political considerations often play an important role in environmental issues. Multi-stakeholder involvement, multi-objective criteria, multi-cultural considerations, and multi-national agreements all require proper tools and (socio)technologies to facilitate discussion and to support decision making. Environmental Hydroinformatics is all about contributing to these processes.

One example of how hydroinformatics can support implementation of environmental and ecological measures, concerns the European Water Framework Directive for River Basin Management, as elaborated by Van Griensven *et al.* in their opening article of this Special Issue. It demonstrates how research and development in hydroinfomatics can play an important role in environmental impact assessment by integrating physically-based models with data-driven approaches and information and communication tools (ICT). An illustration is given describing the Soil and Water Assessment Tool (SWAT) which operates on the river basin scale and includes features to assess diffuse pollution. Its open-source software allows for site-specific modifications to the source and easy linkage to other hydroinformatics tools. The integration of SWAT into a GIS environment has led to its rapidly increasing popularity and world-wide applicability. User defined modules and model analysis tools can easily be integrated to assist in the tedious tasks of model calibration and parameter optimisation. Sensitivity and uncertainty analyses can be carried out in order to allow better understanding of the model performance before addressing scientific and societal questions.

Environmental impacts of large-scale hydropower development have been a contentious issue for considerable time. Transferring lessons from past projects into a proposed strategy for Chile is the subject of the paper by Goodwin and co-workers. They recognise that large dams have provided extensive benefits during the past 60 years, but have also had considerable eco-environmental and social consequences. The environmental management of

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large dams is still a relatively new scientific field of research, compared to the time frame necessary to detect and understand all consequences occurring at the watershed scale. Unforeseen or unanticipated environmental consequences of large dam projects could well have ramifications for the original project scope. The value of a central knowledge base and the importance of a system-wide monitoring program to assess pre- and post-implementation conditions can have immediate consequences for adapting operational rules. Knowledge obtained from other basins can be used to develop future strategies, as outlined here for Chile. Chile has a strong economy, but a looming energy crisis is facing it to balance the long-term value of a renowned natural landscape with unique ecology and the largest salmon aquaculture industry in the world, against the prospect of low-cost hydropower to drive other sectors of the economy. Hydroinformatics technologies and scientifically-based management approaches are essential instruments for supporting decision-making in this complex issue.

Ranking alternative designs of a juvenile fish passage facility to overcome effects of the Wanapum Dam on the Columbia River in the United States is the subject of the paper by Weber *et al*. By introducing an Eulerian-Lagrangian-Agent-Method (ELAM) they couple three modelling approaches into a single, integrated simulation environment: (i) an Eulerian CFD model that solves the 3-D Reynolds-averaged Navier-Stokes (RANS) equations using a multi-block structured mesh, (ii) a Lagrangian particle-tracker used to interpolate information from the Eulerian mesh to point locations needed to track the trajectory of fish in three dimensions, and (iii) an agent-based model, called the Numerical Fish Surrogate (NFS), that simulates the movement decisions made by individual fish. Such ELAM environment proves particularly effective at decoding and simulating the motion dynamics of individual aquatic organisms, using the output from detailed computational fluid dynamics (CFD) calculations to represent complex flow fields. The good match between forecasted (virtual) and measured (observed) fish passage proportions demonstrates the benefit of using agent-based hydroinformatics models as part of common engineering practice for fish passage design and, more fundamentally, to simulate complex eco-environmental processes.

The same message is advocated by Chen and co-authors, who provide a range of applications of hydroinformatics techniques in eco-environmental modelling and management. Computer models in the hydrosciences demand a clear understanding of the processes involved, and are conventionally formulated in terms of mathematical equations based on the assumption of spatial homogeneity and conservation principles of mass, momentum and energy. However, these assumptions are easily violated when spatial heterogeneity, individual species behaviour and local interactions play a significant role in the system dynamics. In particular for eco-environmental systems, local interactions may determine the overall system behaviour. But knowledge on local behaviour is not always readily available. Also, high quality measurement data on ecosystems are still limited, which restricts the application of data mining methods to eco-environmental system modelling. In addition, no modelling – also not black-box modelling – can be undertaken without having at least some understanding of the basic processes and mechanisms involved. A case study on harmful algal bloom prediction shows how neural network trimming can be used to establish the dominant factors that determine local bloom conditions. By extending conventional mathematical/physical formulations with other paradigms such as cellular automata, fuzzy logic rule-based systems, and individual-based modelling concepts, a wide range of eco-environmental features can be addressed. Examples include eutrophication modelling in estuaries, competitive growth simulation and colonization of underwater macrophytes in lakes, coastal algal bloom prediction, and invading mussel species dynamics in rivers.

Clearly, having access to an adequate information infrastructure is a prerequisite for carrying out integrated ecohydraulic and water resources modelling and assessment, as elaborated by Wallace and co-workers in the closing article. Their arguments stem from the fact that watershed management practice increasingly requires ecohydraulic modeling and assessment on a basin-wide scale, rather than on a project-by-project basis. Such holistic modelling and assessment requires evaluation capabilities across multiple temporal and spatial scales. Hence, for researchers and practitioners alike, it is necessary be able to integrate modelling and assessment tools in a scientifically sound and computationally effective information infrastructure. Ongoing activities are summarised, related to establishing a comprehensive set of hydroinformatics modelling and assessment tools for ecohydraulic and water resources management applications, all based on a common data and information infrastructure. Attributes of this information infrastructure are elaborated for recent initiatives in the USA and compared with similar initiatives in the EU. Clearly developments in informatics technologies are important drivers for advancing hydro- and eco-environmental applications.

This Special Issue demonstrates that although numerical models are quite capable of simulating the abiotic aquatic environment including complicated fluid flow and transport mechanisms, when it comes to simulating eco-environmental system dynamics the interaction of individual species with their environment, as well as the interactions amongst species – including anthropogenic impacts – have to be taken into account. The future of ecohydraulics and eco-environmental modelling thus seems to lie in the integration of different computer-based simulation and data-analysis techniques, which is at the core of the hydroinformatics discipline. Hence, close collaboration between the environmental and hydroinformatics communities is called for. Forthcoming opportunities include the 7th International Conference on Hydroinformatics in Nice, France (September 2006), the 6th International Symposium on Ecohydraulics in Christchurch, New Zealand (February 2007) and the joint Hydroinformatics-Ecohydraulics Conference in Concepcion, Chile (2008/2009).

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