Szylkarski, Stefan; Van Kalken, Terry

Murrumbidgee River Computer aided river management (CARM)

Hydrolink

EVOLUTION OF HYDROINFORMATICS IN MURRUMBIDGEE RIVER COMPUTER

BY STEFAN SZYLKARSKI & TERRY VAN KALKEN

Stefan Szylkarski **is a Group Director with DHI and a civil engineer with over twenty years of experience in hydraulics and environmental engineering in water environments. He has worked extensively with DHI in the application of hydrodynamic models, decision support and integrated hydroinformatic software systems for planning and real time management of regulated rivers systems.**

Terry van Kalken **is a Technical Director at DHI. He has 25 years' experience in the development and application of hydrodynamic models for water resources and flood risk. Following an MSc in Computational Hydraulics at IHE Delft in 1988, he worked initially at DHI in Denmark in the MIKE 11 development team, and subsequently on projects in Asia, Latin America, Africa, UK, Europe and New Zealand. He is currently CARM project manager, based in Brisbane, Australia.**

Hydroinfromatics

The Hydroinformatics industry is a growing branch of informatics which integrates digital information and communication technologies, numerical modelling in a decision support framework to solve problems in water environments, including hydrologic, hydraulic and environmental systems. Hydroinformatics grew out of the earlier discipline of computational hydraulics and was foreseen more than 20 years ago (Abbot et al, 1991) as a natural progression of the 4th generation hydraulic modelling systems that were emerging at the time, and which are in common engineering practice today.

The management of waters in large river systems is a key area where hydroinformatics is being applied today and in recent times has experienced significant evolution.

Hydroinformatics in river management provides support for decision-making in planning and operations of river systems to address increasingly serious problems in the equitable and efficient use of water. River management has traditionally utilised conceptual hydrology approaches as the basis for decision making tools. However, computational hydraulics remains as the core technology of hydroinformatics. As river management continues to evolve into hydroinformatics, the tools applied in river management are shifting towards computational hydraulics at the core and augmented with the traditional and complementary technologies including meteorology, hydrology, optimisation and eco-hydraulics.

Decision Support Processes in River System Management.

Within the area of river management there are two very distinct requirements for a decision support system (DSS) in the management of waters within a river basin; the basin *planning* process and the river operations process.

The river basin planning process requires data, models and analytical tools to support decision-making in terms of allocating water to competing users over long periods of time into the future. The DSS supports the making of value judgments and the trade-offs between social, environmental and economic uses of the water in a river basin. The DSS will therefore incorporate tools and methods suited for analysing high level system behaviour; it utilises conceptual model of complex processes and incorporates tools that focus on uncertainty and trade-offs between overall allocation of water to different users. The system is, in general, data driven with simplified conceptual and empirical models for forecasting future behaviour using historical or long term forecast data for time spans in the order of decades. The DSS used in this process is therefore an offline and stand-alone system similar in nature to the traditional modelling and planning approach.

The river basin operational process requires support for real time decision making in terms of settings for water infrastructure such as valves, gates, weirs and pumps. The DSS supports the operator in making very specific and exact settings for infrastructure in the river basin spanning the coming hours and days. The objective of the DSS is to provide an optimised system setting for all dam and regulated water releases so as to meet the near future demands as efficiently as possible. The operational DSS will therefore require large amounts of real time data and physics based models that precisely predict water flows and process in the system.

The models required for an operational DSS are by nature highly parameterised, a necessary requirement if oversimplification of the complex river processes is to be avoided and to ensure precise decisions can be made on a sound physical basis. The operational DSS combines vast amounts of real time hydrological and hydraulic data, and continuously updates operational forecasts based on the most current river state. This requires a high level of automation and sophistication in operational Information Technology.

The concept of different systems supporting the planning and operation of river basins is analogous to the flying of a modern airliner. The route planning process uses a specific software tool that produces a flight plan which balances value judgments and trade-offs between risks, resources schedule and economy. Once the plane is airborne the pilot acts as the flight

RIVER MANAGEMENT
AIDED RIVER MANAGEMENT (CARM)

Figure 1 - Schematic of the Murrumbidgee River System

operator and flies the plane as close to the flight plan as possible, supported by the plane's flight control system, which is effectively a DSS. This system receives hundreds of pieces of information from sensors all over the aircraft which are interpreted in real time and applied through the pilot's actions to trim the plane continuously so as to optimise fuel efficiency while at the same time ensuring stability and safety. By analogy, a river basin planning DSS can be said to produce the "flight plan", while an operational DSS is a support tool for the "pilot".

The Role of Models in River Management

"A complete physically-based synthesis of the hydrologic cycle is a concept that tantalizes most hydrologists" (Freeze and Harlan, 1969)

In the original blueprint for a complete hydrological cycle model by Freeze and Harlan, it was argued that if each of the component processes within the hydrological cycle can be described by an exact mathematical representation then it should be possible to model the different flow processes using their governing partial differential equations. Interestingly, they put forth, a set of questions that must be answered before such a framework would be successful which can be paraphrased as follows; 1. Do we have the science? 2. Do we have the data? 3 Do we have the computational resources? The answer today to all of these questions is most commonly in the affirmative.

River basin planning and management has traditionally relied on simplified and conceptual hydrological approaches to investigate and forecast water movement on large spatial scales and timescales of tens to hundreds of years. In order to be able to simulate such long periods, hydrological models simplify the complex flow behaviour processes and produce average flows at daily or monthly time intervals. The simplifications were traditionally made out of necessity due to a historical combination of lack of science, data and computation resources. However, in today's rapidly evolving digital world these traditional approaches are over simplified and do not make use of all available information, science and resources. The question that must be answered is whether our decision processes are sub optimal if we do not make use of all available data.

Over-simplification of the physical processes in contrast is fraught with difficulties. This has been recognised for some time. D'Alembert, an 18th century contemporary of both Bernoulli and Euler, while working on the new mathematical formulations describing observations in fluid mechanics, was noted to lament: (Rouse and Ince, 1957)

"If it happens that a question we wish to examine is too complicated to permit all its elements to enter into the analytical relation we wish to set up, we separate the more inconvenient elements, we substitute for them other elements less troublesome, but also less real, and then are surprised to arrive, notwithstanding our painful labour, at a result contradicted by nature; as if after having disguised it, cut it short, or mutilated it, a purely mechanical combination would give it back to us."

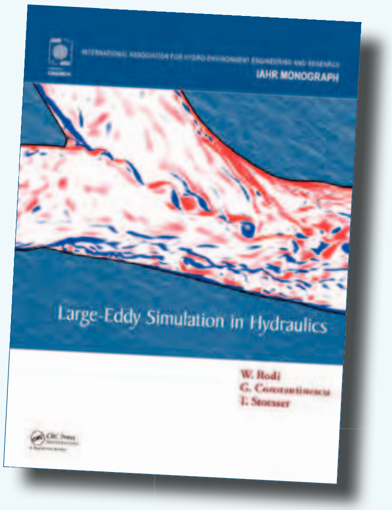
River operators work on forecast horizons much shorter than river planning manager require forecasts looking forward the next few hours, days or weeks. River operations using planning style models based on simplified hydrological approaches ignore important river processes such as channel and floodplain storage, flow dependent travel time and groundwater interactions.

In the modern digital world the three key requirements laid out by Freeze and Harlan can by and large be met. The timescales over which river operators work is relatively short, the advent of remote and low cost sensing and monitoring provides a dazzling array of information and the physics based models have been tuned and optimised to efficiently simulate physcics based water movements. The tantalizing prospect of deterministic modelling in river operations can therefore be achieved with confidence and the industry must move in this direction.

The Murrumbidgee River Computer Aided River Management (CARM) system is one of the significant evolutions of physics based model decision support systems in river operations. It's application will demonstrate this evolution and represents the future direction for river operations dss.

The Murrumbidgee Computer Aided River Management System (CARMs)

The Murrumbidgee River basin covers 84,000 square kilometres forms the largest catchment in the southern connected Murray Darling Basin



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(MDB). The river flows 1000km westward from the catchment headwaters to the Murray River. The average annual rainfall ranges from over 1,700 millimetres in the alpine areas of the Snowy Mountains, to less than 350 millimetres on the semi-arid western plains. Evaporation displays an inverse picture, varying from less than 1,000 millimetres per year in the south-east, to over 1,800 millimetres per year in the west. Major water storages in the headwaters comprise Burrinjuck Dam (1028 GL) and Blowering Dam (1628 GL). River operations are augmented by a series of 6 in-river regulators (weirs) and on off-stream storage reservoir at Tombullen.

State Water Corporation is responsible for bulk water deliveries and river operations in New South Wales (NSW). The daily operation of the river is a complex task that needs to take into account not only the thousands of individual water users but also a range of catchment and river processes that are difficult to quantify. Water once released from the dams takes up to four weeks to travel down the system. Current river operations rely heavily on the experience and judgment of the river operator and are based on simple water balance modelling concepts. The long travel times coupled with dynamic river behaviour and unpredictable future weather conditions leads to significant uncertainty in the volume and timing of dam releases. As a result of the many uncertainties in quantifying the real inflows and extractions to and from the river, the river operator is usually conservative when computing the daily dam releases, with the end result that often more water is released than is needed to satisfy all demands, which affects the future reliability of supply.

As part of a programme to modernise the current operations, State Water have embarked on a US$65m upgrade of the river management and operational system for the Murrumbidgee River that sets a benchmark for efficient river operations in Australia and internationally. The Murrumbidgee River Computer Aided River Management system (CARMs) is an example of an operational DSS in river basin management. The recent recipient of the Australian Water Association's National Award for Innovation in Water Infrastructure, CARMs represents the future direction of contemporary DSS in operational river management.

CARM is true to the vision of the role of hydroinformatics in supporting decision making as envisaged more than two decades ago. The CARM system integrates real time data, hydrological and hydraulic models in a Decision Support framework customised for real time river operations (van Kalken et al, 2012). Real time data feeds include observed and forecast catchment rainfall, river extractions, river flows and levels and dam and regulator gate settings. Real time extraction metering forms a key component of the CARM project and is being realised through the installation of over 700 new flow meters providing real time water extraction information to river operators for the first time (see Fig. 3b). Catchment runoff flows are forecast using rainfall-runoff models, utilising both rainfall observations and Bureau forecasts. These are fed into a hydrodynamic river simulation model that accurately simulates the river behaviour, including flow dependent travel time, channel and weir storage. The hydrodynamic model assimilates the measured river flows and levels to update the river state prior to generating forecasts. Near-river bank and groundwater exchanges, as well as evapotranspiration along the riparian margin, are simulated using an integrated surface groundwater interaction model, fully coupled to the hydrodynamic river model.

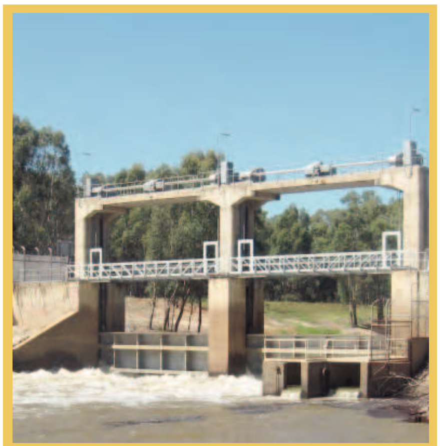
Figure 3a - Yanco Weir, Murrumbidgee River


Figure 3b - Telemetered Water Meter

CARM incorporates an optimisation tool which updates the settings for the dam releases and the downstream re-regulation weirs several times a day. The optimisation recognises system constraints such as channel capacities and desired flow rates of change, and operates with the objective to meet all water demands while at the same time minimising releases from the headwater storages.

The CARM DSS integrates all measured and modelled data will a range of custom tools to allow the operators to check and verify data and results.

Conclusions

The rise of hydroinformatics as the natural progression from computational hydraulics embedded in common hydraulic modelling software was foreseen more than 20 years ago. Advances in information technology, data acquisition and processing and computational power have all contributed to the realisation of the hydroinformatics vision.

The development of DSS in river management is the realisation of the hydroinformatics vision in river management. DSS in river management can be broadly classified into two distinct types supporting river basin planning over long timescales or conversely river operations over shorter timescales. The requirements for the underlying numerical tools are also different, with river basin planning being undertaken over large spatial and temporal timescales, which ultimately leads to the necessary simplification of short term processes. Conversely, river operations requires precise knowledge of the dynamic river and catchment processes on which to base robust decisions, and these cannot be adequately resolved with simplified approaches.

The Murrumbidgee River Computer Aided River Management (CARM) system is one of the significant evolutions of physics based model decision support systems in river operations. Its application will demonstrate this evolution and represents the future direction for river operations.

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