Abstract: A hydraulic structure is an artificial system which interacts with the flow of water. A number of engineering challenges are closely linked to the hydrodynamics and fluid flow motion. Two key issues during the design and operation of hydraulic structures are conveyance and energy dissipation. The energy dissipation at a hydraulic structure can be enormous and its estimate is far from trivial. The re-evaluation of spillway discharge capacity, including the spillway re-design, is a further challenge, especially in the regions with extreme hydrology and limited records. Our community needs to broaden the knowledge base in hydraulic structures, through the development of independent learning skills, further education in hydraulic engineering and innovative research and development (R&D). It is believed that the proceedings of the 5th IAHR International Symposium on Hydraulic Structures (ISHS2014) provide the engineering profession with real-world state-of-the-art expertise in hydraulic structure design.

Keywords: Hydraulic structures, Engineering challenges, Extremes, Perspectives

1. PRESENTATION

The 5th IAHR International Symposium on Hydraulic Structures (ISHS2014) together with the 11th National Conference on Hydraulics in Civil Engineering addressed conventional and innovative aspects of hydraulic structure design, operation, rehabilitation, and their interactions with the environment relevant to the 21st century. The main themes of the symposium, Hydraulic Structures and Society – Engineering Challenges and Extremes, embraced the hydraulics of dams and hydropower schemes, river structures, hydraulic structures in urban drainage and sewer systems, as well as coastal protection systems. But let us consider the basic questions: what constitutes a hydraulic structure? what are the engineering challenges associated with hydraulic structures?

A hydraulic structure is an artificial system which interacts with the flow of water. It may be introduced in a natural system to divert, control, store and manage the water flow: e.g., a dam and its reservoir (Fig. 1 to 3). Hydraulic structures may be used to pro-actively control the water flow motion: e.g., a coastal breakwater built to protect a harbour or stabilise a coastline. The construction of dams and hydraulic structures is one of the oldest civil engineering activities, because our species (*homo sapiens*) is totally dependent upon water. Like human beings, the beaver is the only animal building hydraulic structures and the result is the beaver dam. Beavers are sometimes called "the engineers of Nature" (Dubois and Provencher 2012). While the date and location of the oldest hydraulic structure are lost to time, the world's most famous heritage structures encompass the water supply system of Babylon's Hanging Gardens, the Grand Canal linking Guangzhou, Shanghai and Beijing (China), the Marib dam in Sheba (Yemen), the Roman aqueducts including the 132 km long Carthage aqueduct (Tunisia), and the Taj Mahal water supply system (India). Hydraulic structures were utilised in historical conflicts. Droughts were artificially introduced, as during the siege of the ancient city of Khara Khoto when the Chinese army diverted the Ezen river supplying the water to the city in AD 1372. Artificial flooding created by dam and dyke destruction were used, including during the war between the cities of Lagash and Umma (Assyria) around BC 2,500 for the control of water supply and irrigation systems, and with the breaching of the Huang He River dykes by the Chinese Nationalist army during World War II. During World War II, the Royal Air Force bombed the Ruhr dams. The Möhne dam was badly damaged by the "dam busters" on 16/17th May 1943, and almost 1,300 people died in the floods,
mostly inmates of a prisoner of war (POW) camp located just below the dam.

A number of engineering challenges are closely linked to the hydrodynamics and fluid flow motion. Theoretical and numerical studies of turbulent flows at hydraulic structures are complicated by (a) the large number of relevant equations: i.e., three basic equations (continuity, momentum, energy) with a number of turbulence closure relationships, plus some mass transfer equations, and (b) the complexity of the boundary conditions. Many studies rely upon some physical experiments. Laboratory model studies are performed under controlled flow conditions with geometrically similar models (Henderson 1966). In the study of hydraulic structures with free-surface flow operation, a Froude similitude is commonly used because the gravity effects are dominant (Novak and Cabelka 1981, Chanson 2004). The model and prototype Froude numbers must be equal. However the turbulent dissipation processes are dominated by viscous forces (Liggett 1994). Dynamic similarity becomes impossible using the same fluids because of too many relevant parameters. Although most hydraulic structure model studies are designed based upon a Froude similitude, the dynamic similarity implies drastically smaller Reynolds numbers than in the corresponding prototype flows. There are hence a number of critical issues with the validity of model result extrapolation to prototype flow conditions, the validation of numerical results calibrated against small-size physical model data and the use of un-tested model data. Relevant discussions include Novak and Cabelka (1981), Liggett (1994) and Chanson (2009). A recent study demonstrated that true dynamic similarity might not be achieved unless at full scale in some situations and called for prototype testing (Chanson 2013).

Two key issues in hydraulic structure design are conveyance and energy dissipation. Conveyance means the (safe) transport of a large amount of water, for example into the intake and barrel of a culvert. The conveyance of the system is closely linked to the intake structure (e.g. spillway crest) and channel design (Fig. 1). It relies upon fundamental hydrodynamics and theoretical studies with a range of trusted and proven solutions. Figure 1 illustrates a labyrinth spillway crest designed to maximise the discharge capacity in a relatively confined environment. The energy dissipation takes place down the chute and at the downstream end of the structure. The amount of kinetic energy to be dissipated can be gigantic, and it must be dissipated safely before the floodwaters rejoin the natural river system. The design of the energy dissipators relies upon some sound physical modelling combined with solid prototype experiences.

A massive challenge is the magnitude of the rate of energy dissipation in some hydraulic structures at design flow conditions. As an illustration, a small weir discharging 25 m$^3$/s with a 2.5 m high drop would dissipate turbulent kinetic energy flux per unit time at a rate of 600,000 W. As another example, the Paradise Dam spillway system (Fig. 2) experienced several major floods between 2010 and 2013. The 37 m high dam experienced a peak discharge of 17,000 m$^3$/s during that period, although well below the design flow. At the peak flood flow, the spillway system dissipated energy at a rate of

![Figure 1 – Jindabyne dam labyrinth spillway (Australia) on 17 December 2011](image)
7,500,000,000 W, comparable to and larger than the energy production rate of eight 900 MW nuclear reactors. For comparison, the combined power output of the two Three Miles Island nuclear reactors was 1,750,000,000 W, while the power output of Fukushima nuclear power plant was 4,700,000,000 W, and the Chernobyl nuclear power station produced 4,000,000,000 W, prior to their respective accidents.

The energy dissipation at a hydraulic structure can be enormous and its design is far from trivial. Many engineers have never been exposed to the complexity of energy dissipator designs, to the physical processes taking place and to the structural challenges. Several energy dissipators, spillways and storm waterways failed because of poor engineering design (Novak and Cabelka 1981, Novak et al. 2001). It is believed that a major issue was the lack of understanding of the basic turbulent dissipation processes and the intrinsic limitations of physical and numerical models. Physical studies are conducted traditionally using a Froude similitude which implies drastically smaller laboratory Reynolds numbers than in the corresponding prototype flows. Despite advances, there are some basic concerns about the extrapolation of laboratory results to large size prototype structures, as well as the implications in terms of numerical model validation and numerical data quality.

In dam engineering, the re-evaluation of spillway discharge capacity, including the spillway re-design, is a further challenge, especially in the regions with extreme hydrology and limited records, like Australia, Africa, and Asia. For the last few decades, a number of dams sustained a flood significantly larger than their original design flow, before their spillway capacity was re-evaluated (Lemperiere et al. 2012). A further number of structures experienced discharges larger than the design capacity and failed. Worldwide there is a lack of broad guidelines to estimate the maximum spillway capacity: "consensus is far from being reached on the issue of spillways design" capacity (Lemperiere et al. 2012). Figure 3 illustrates a modern dam spillway recently enlarged to increase the spillway capacity and reservoir storage.

At the 4th IAHR International Symposium on Hydraulic Structures (Porto, 9-11 February 2012), a panel of leading practitioners highlighted: "our design procedures for major hydraulic structures is often all too optimistic"; "on many occasions, the expression of one's experience on the extremes of hydraulics behaviour is often countered with skepticism "; "there is nothing virtual about hydraulic engineering and hydraulic structures". The 5th IAHR International Symposium on Hydraulic Structures (Brisbane, 25-27 June 2014) is a timely reminder that our society needs innovative design in hydraulic engineering and structures. A key challenge is the diversity of hydraulic structure designs, the complexity of each type of design, and the challenges associated with the magnitude of the rate of energy dissipation during major flood events. Our community needs to broaden the knowledge base in hydraulic structures, through the development of independent learning skills, further education in hydraulic engineering and innovative research and development (R&D). It is believed that the present
symposium proceedings do provide the engineering profession with real-world state-of-the-art expertise in hydraulic structure design.

(A, Left) Stage 2 on 4 September 2002 - Note the turning veins in the foreground  
(B, Right) Stage 3 in operation on 29 January 2013, Q ≈ 200 m³/s, d/h ≈ 2.5  
Figure 3 – Hinze dam spillway (Australia)

1.1. References

Henderson, F.M. (1966), Open Channel Flow, MacMillan Company, New York, USA
Lempérière, F., Vigny, J.P., and Deroo, L. (2012), New methods and criteria for designing spillways could reduce risks and costs significantly, Hydropower and dam construction, No. 3, pp. 120-128
2. SYMPOSIUM PROCEEDINGS

2.1. Peer review process

All papers published in the Proceedings and presented at the 5th IAHR International Symposium on Hydraulic Structures have been peer-reviewed for technical content through a formal and rigorous process, as outlined below. The Proceedings are an University of Queensland publication. Each paper was allocated a direct object identifier (DOI), is accessible open access at the University of Queensland institutional open access repository UQeSpace (http://espace.library.uq.edu.au/) and is indexed by Scopus and Compendex. Each work is available to users through UQeSpace pursuant to a Creative Commons Attribution-NonCommercial CC BY 4.0 License (1).

In response to the Call for Papers which was sent out in 2013, the Scientific Committee received over 50 full papers for presentation at the conference, either orally or as a poster. The Panel of Reviewers was drawn from the IAHR and Engineers Australia communities and other international and national experts in fields relevant to the symposium themes. The Panel reviewed all papers submitted for publication in the ISHS2014 Proceedings. All papers submitted for presentation were peer-reviewed by at least two independent reviewers according to a set of criteria established by the Scientific Committee. Authors were then requested to revise their manuscript in accordance to the reviewers' comments and editorial recommendation, and to submit for final review before inclusion in the Proceedings. The final number of papers accepted for publication in the Proceedings was 37. The publication of the symposium papers marked a significant contribution of this event. Altogether the proceedings contain 40 papers involving 84 authors from 17 countries and 6 continents, including 2 invited keynote papers and an editorial paper. The symposium proceedings were edited by the Chairs of the Scientific Committee, Hubert Chanson and Luke Toombes.

2.2. Proceedings referencing

The Proceedings papers are accessible open access at UQeSpace (http://espace.library.uq.edu.au/). UQeSpace is the institutional digital repository for the University of Queensland (UQ). It encourages the deposit of open access material and supports the Open Archives Initiative (OAI), thus allowing eSpace content to be harvested by Internet search engines and cross-archive search tools such as OAIster.

The full bibliographic reference of the ISHS2014 symposium proceedings is:


Each paper of the proceedings must be referenced as, for example:


In this case, the article is directly accessible on the Internet at {http://dx.doi.org/10.14264/uql.2014.9}.

1 {http://creativecommons.org/licenses/by/4.0/}
2.3. Statistical summary

40 peer-reviewed papers including 2 keynote papers, 84 authors from 17 countries and 6 continents.

2.4. List of Papers


Rifle Creek Dam DIY Physical Modelling, by F. Jacobsen, http://dx.doi.org/10.14264/uql.2014.23


Analysis of Air Concentration in a Physical Model of the Bottom of a Spillway Chute with Aerators, by J.C. Luna, J. Gracia and V. Ortiz, http://dx.doi.org/10.14264/uql.2014.26

Rapid Operation of a Tainter Gate: the Transient Flow Motion, by S. Sun, X. Leng and H. Chanson, http://dx.doi.org/10.14264/uql.2014.27


Air concentration distribution in deflector-jets, by M. Pfister and S. Schwindt, http://dx.doi.org/10.14264/uql.2014.29


Spillway Rock Scour Experience and Analysis - the Australian Scene over the past Four Decades, by E.F.R. Bollaert and E.J. Lesleighter, http://dx.doi.org/10.14264/uql.2014.35

Spatial Changes of Beach Profiles for a Small Tidal Inlet (Currumbin Creek, Australia), by S. Shaeri,
3. SYMPOSIUM PROGRAM AND ORGANISATION

3.1. Technical program presentation

The ISHS2014 symposium provided an opportunity for academics, researchers, engineers and students to present ideas, findings, and outcomes of their own studies in an inspiring, friendly, cooperative, and collegial environment. The event was attended by over 191 participants including 12 students. A total of 14 countries were represented during the event, namely Australia, Belgium, Brazil, China, India, Japan, Mexico, New Zealand, Norway, Portugal, Singapore, Switzerland, Turkey, and the United States of America. The technical program included 2 invited keynote lecturers, 2 invited speakers, and 37 papers were presented orally over two days, in addition to the technical visit of the Hinze, Moogerah and Wyaralong dams, and a visit of the Hydraulics Laboratory of the University of Queensland.

The symposium technical program was supported by a series of peer-reviewed technical papers published in the ISH2014 proceedings, available open access and uniquely identified by a digital identifier called DOI.

3.2. Statistical summary)

191 participants from 14 countries and 5 continents, including professionals, academics, students and researchers.

40 presentations from 14 countries and 5 continents.
3.3. Symposium organisation

3.3.1. Organising committee

Robert Janssen (Chair)
Anthony Gaffney (Deputy Chair)
Hubert Chanson
John Macintosh
Suzanne Burow
Hang Wang
Megan Gould

3.3.2. Scientific committee

Hubert Chanson (Chair)
Luke Toombes (Deputy Chair)
Bruce Melville
Colin Apelt
Eric Lesleightner

3.4. List of expert-reviewers

3.4.1. Editors

Hubert Chanson (Australia)
Luke Toombes (Australia)

3.4.2. Reviewers

Anthony Gaffney (Australia)
Brian Crookston (USA)
Bruce Melville (New Zealand)
Carlo Gualtieri (Italy)
Carlos Gonzalez (Australia)
Colin Apelt (Australia)
Daniel Bung (Germany)
David Zhu (Canada)
Eric Lesleightner (Australia)
Hang Wang (Australia)
Hubert Chanson (Australia)
John Macintosh (Australia)
Junqiang Xia (China)
Laurent David (France)
Luke Toombes (Australia)
Matthew Gordos (Australia)
Megan Gould (Australia)
Michael Pfister (Switzerland)
Nicolas Riviere (France)
Paul Guard (Australia)
Rita Carvahlo (Portugal)
Robert Janssen (Australia)
Sebastien Erpicum (Belgium)
Stefan Felder (Australia)
Stefano Pagliara (Italy)
4. ACKNOWLEDGEMENTS

The organization of the symposium would not have been possible without the generous and active involvement of the members of the organizing committee since its inception. We would also like to thank all reviewers for their valuable support in reviewing the manuscripts. To all participants and authors, a warm word of appreciation is due for their enthusiasm and dedication.

We also acknowledge the logistics support provided by Engineers Australia (EA), its Queensland Division and the EA Queensland Division Water Panel. The support of the University of Queensland and UQeSpace for the production and publication of the proceedings is acknowledged.

This type of specialized symposium, involving a relatively small participation, is only financially sustainable with some level of support from various institutions. We would like to acknowledge the below supporting organisations.

5. ORGANISING INSTITUTIONS, SPONSOR AND SUPPORTING ORGANISATIONS

5.1. Organising institutions

EA - Engineers Australia
IAHR - International Association for Hydro-environment engineering and Research

5.2. Supporting organisations

IAHR HSTC - IAHR Hydraulic Structures Technical Committee
NCWE - National Committee on Water Engineering
EA Queensland Division Water Panel
UQ - University of Queensland
UQeSpace
The University of Queensland, School of Civil Engineering