DOI: 10.14264/uql.2020.513

Hydraulic Structures: Challenges, Diversity, Ecology, Energy Dissipation, Hydrodynamics of the 21st Century

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ABSTRACT

The Proceedings of the 8th IAHR International Symposium on Hydraulic Structures (ISHS2020) focus on many aspects of hydraulic structures and their design, especially in terms of diversity, ecology, energy dissipation, and hydrodynamics relevant to the 21st century. The event organisation aimed to facilitate the sharing of information among water engineers coming from different regions, universities, industries and background, including developed and developing countries, and hydraulic engineering students, young and senior professionals. After reviewing the challenges associated with hydraulic structures in terms of diversity, ecology, energy dissipation, hydrodynamics, socio-economics into the 21st century, the proceedings peer-review process is detailed. The proceedings contents are listed, as well as the ISHS2020 organisation. At the end, the reviewers are acknowledged.

Keywords: *Hydraulic structures; Challenges; Diversity; Peer-review process; Proceedings.*

1. INTRODUCTION

The Proceedings of the 8th IAHR International Symposium on Hydraulic Structures (ISHS2020) focus on many aspects of hydraulic structures and their design, especially in terms of diversity, ecology, energy dissipation, and hydrodynamics relevant to the 21st century. The event organisation aimed to facilitate the sharing of information among water engineers coming from different regions, universities, industries and background, including developed and developing countries, and hydraulic engineering students, young and senior professionals. Let us ask a basic question: what are the challenges associated with hydraulic structures in terms of diversity, ecology, energy dissipation, hydrodynamics, socio-economics into the 21st century?

Hydraulic structures are man-made waterworks interacting with the rainfall runoff to store and convey water, or mitigate the impact of runoff, built across, along or beside a water body, in fluvial, estuarine and coastal environments, that interacts with the rainfall runoff, to store and distribute water (Fig. 1). Figure 1 illustrates a few examples. The three main purposes of hydraulic structures are water storage, water conveyance and mitigation of water impacts, e.g. a culvert beneath a road embankment, a stilling basin at a spillway toe (Schuyler 1909, Wegmann 1922, Novak et al. 2001). The construction of hydraulic structures is one of the most important civil engineering outputs, because life is absolutely dependent upon drinking water supply (Smith 1971, Levi 1995). A number of world-famous historical systems the Roman aqueducts in Rome and around the Mediterranean Sea, the qanats in South East Arabia and Persia, the Mochica and Chimu water canals in coastal Peru. Key requirements for any development of civilisations have been the storage and transportation of water, e.g. for irrigation water supply arising from the development of intensive agriculture, drinking water demands, public health, industrial use, sanitary requirements and flood protection of large urban systems; as a source of energy and for transportation of goods and people.

Basic hydraulic engineering calculations rely upon fundamental hydrodynamics and theoretical studies with a range of trusted and proven solutions. Although hydraulic engineers were at the forefront of science for centuries, current hydraulic structures are too often designed and optimised for simplistic situations, in light of the knowledge available at the time, leading to conservative designs which might not be conservative according to current findings, while they differ barely from ancient designs (Chanson 2007, 2008). Modern hydraulic structures are typically designed based upon steady monophase Newtonian fluid flow concepts for a single design discharge, e.g. to optimise the cross-sectional shape of a canal, the discharge capacity of a spillway crest, the energy dissipation performance of a stilling basin, the size of a culvert barrel. A number of underlying assumptions might become invalid, e.g. in catchments affected by flash flooding, in sediment-laden river floods with suspended sediment concentrations in excess of 100 kg/m^3. The design optimisation of hydraulic structures for a single discharge might need to be reviewed in the light of a number of recent failures during operation for less-than-design flow conditions, e.g. Paradise dam stilling basin, Oroville dam (primary and emergency) spillways.

In 2020, hydraulic engineers must embrace new challenges, as water plays a key role in human perception and it is indispensable to all forms of life. In dam engineering, the continuous re-evaluation of spillway discharge capacity leads to much needed novel spillway (re-)designs, in particular in geographical regions of extreme hydrology and limited rainfall and runoff data: e.g. the Yaté dam spillway in New Caledonia was built to pass 4,500 m^3/s in 1959 and modified to pass 12,000 m^3/s following a catastrophic flood in 1992. Major advances in two-phase flows in mechanical and nuclear engineering have brought up new forms of multiphase gas-liquid and liquid-solid models, that could be embedded in hydraulic structure designs (Jhia and Bombardelli 2009, Chanson 2013, Bung and Valero 2016). The interactions between hydraulic structures and aquatic flora and fauna constitute further a series of complicated challenges, linked to the targeted fauna and flora species, and rarely well understood (Kemp 2012, Nepf 2012, Maddock et al. 2013). And this is not all. Physical modelling exempted from scale effects is nearly impossible unless working at full-scale (Henderson 1966, Liggett 1994, Chanson 2009). Some aquatic life might adapt their swimming pattern in man-made hydraulic structures to maximise their efficiency (Wang and Chanson 2018a). Reservoir siltation has been a recurrent issue worldwide for more than 2,000 years, exacerbated by the reduction of freshwater resources and suitable dam sites in recent decades (Chanson 2008).

Hydraulics structures have been built for millenia and floods have been recorded for as long, e.g. more than 8,000 years on the Nile River. Open channel hydraulics is a mature science, and many academics and engineers could argue that current open channel hydraulics textbooks are derived from the seminal lecture notes of Professors Bélanger and Bresse, at the Ecole des Ponts et Chaussées (France) (Bélanger 1841, Bresse 1868). Yet the development of cost-effective, fauna- and flora-friendly hydraulic structures, adapted to multiphase flows, is a truly new challenge for the 21st century design engineers. Hydraulic designers are facing massive tests linked to the many technical challenges, ranging from a re-evaluation of discharge capacity, sedimentation and siltation, environmental impacts, interactions between flow, fauna and flora, to multi-phase coupling. In practice, a number of technical solutions are not satisfactory, e.g. in terms of aquatic fauna and flora, fluid-structures interactions and operational restrictions (Chanson, Leng and Wang 2019). Our knowledge of self-aerated air-water flows in hydraulic structures lacks insights into the physical interfacial phenomena at the millimetric and sub-millimetric scales, including the modulation of the turbulence, although the implications in terms of design have been well-known for decades, e.g. flow bulking, drag reduction, re-oxygenation. Similarly, the characteristics of transient turbulence during surge propagation in conveyance structures remain mostly ignored and the practical applications largely untapped, despite the millions of kilometres of water channels worldwide. The adverse impact of low-head hydraulic structures on aquatic life is an emerging concern. Biological science studies have been largely based upon pseudo-quantitative observations, although very recent engineering and bioengineering research has been undertaken, hinged on advanced physics-based theory supported by high-quality experimental data (Wang and Chanson 2018b).

Hydraulic structures have been traditionally designed based upon simplistic optimisation developed for one-dimensional steady monophase Newtonian fluid flow performances at a single design discharge. The approach may be valid to simple hydraulic structures with a proven operational record. But the 21st century has seen a shift towards modern designs based upon advanced methods, encompassing hybrid modelling combining analytical, physical, CFD and field methods, accounting for coupling between turbulence and particles (e.g. air, sediments, aquatic life and plants), and optimised for a broad range of operational flow conditions. A number of recent peer-reviewed scientific publications include several relevant applications, e.g. Chanson, Bombardelli and Castro-Orgaz (2020), as well the present Proceedings (Janssen and Chanson 2020).

The second half of the 20th century marked a change in the perception of the structures by our society, but these man-made waterworks shall continue to play a major role in human life and activities because water is an indispensable element. The technical demands on hydraulic structure designers are formidable. Into the 21st century, the future will require strong links between engineering innovation, excellence in hydraulic research and quality education in universities. Innovative designs rely upon technically sound methods, some good common sense, as well as thinking "outside of the square". Professional engineering must be assisted by excellent research and development, often relying upon theoretical, physical and numerical modelling. Hydraulic engineers can benefit from recent advancement in fluid dynamics, including CFD, albeit validation remains a challenging issue (Bombardelli 2012, Lubin and Glockner 2015, Leng, Simon, Khezri, Lubin and Chanson 2018). The needs for multi-disciplinary expertise of high-level require research teams interacting across a broad range of disciplines, that is anything but trivial. The implications in terms of higher education are far reaching. On one hand, the universities have experienced a massive reduction in funding per full-time student, particularly in western countries (Cunge 2014, Ancey 2020). Fewer university academics have prior professional experiences, often dismissed by university selection panels. On another hand, hydraulic engineering continues to experience a progressive evolution in skill requirements, e.g. CFD modelling, eco-hydraulics and interactions with aquatic life, multiphase flow coupling, sediment processes, water monitoring. Such a shift is not unlike the one discussed by Hunter Rouse in the 1930s (Rouse 1938). University graduates need to be exposed to practical experiences in hydraulic engineering, and there are strong arguments for more laboratory experiences, field trips and field work in the undergraduate curricula (Chanson 2004, Crookston, Smith, Welker and Campbell 2020). All these interactions must be complemented by indispensable exchanges between professionals, researchers and educators in engineering and other fields, e.g. water chemistry, geopolitics, geomorphology, ecology, biology.

In the Proceedings of the 8th IAHR International Symposium on Hydraulic Structures (ISHS2020), the authors have presented a challenging "wake-up call" to our society for the needs of innovative design in hydraulic engineering and structures. A key challenge is the broad range and diversity of hydraulic structure designs, the technical complexity of each type of design, and the quantitative tests associated with the magnitude of flow rates, rates of energy dissipation, hydrodynamics and amount of sediment transport 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 ISHS2020 symposium proceedings do provide the engineering profession with real-world up-to-date state-of-the-art expertise for the hydraulic structures of the 21st century.

(A)

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(C)

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(E)

Figure 1. Photographs of hydraulic structures. (A) River crossing on Le Gouessant River in Lamballe, France on 30 December 2019; (B) Multicell box culvert inlet in Stable Swamp Creek catchment, Salisbury QLD, Australia on 30 November 2019; (C) Urban storm waterway system combined with a leisure park walk in Dongdaemun, Seoul, Korea on 13 January 2020; (D) Burdekin Falls Dam and spillway on 16 November 2019 (Australia); (E) Le Gouet Dam, spillway and bottom outlet, St Brieuc, France on 24 June 2019

1.1. References

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2. INTERNATIONAL SYMPOSIUM ON HYDRAULIC STRUCTURES SERIES

Table 1 shows the listing of the event dates and locations of the ISHS series.

Table 1 - ISHS Event Series

Edition	Year	Location
8th	2020	Santiago, Chile ([1])
7th	2018	Aachen, Germany
6th	2016	Portland OR, USA
5th	2014	Brisbane QLD, Australia
4th	2012	Porto, Portugal
3rd	2008	Nanjing, China
2nd	2006	Ciudad Guayana, Venezuela
1st	2004	Tehran, Iran

Note: ([1]) presentations cancelled because of COVID-19 virus pandemic.

3. ISHS2020 SYMPOSIUM PROCEEDINGS

3.1. Peer review process

All papers published in the Proceedings of the 8th IAHR International Symposium on Hydraulic Structures ISHS2020 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]).

[1] {http://creativecommons.org/licenses/by/4.0/}

In response to the Call for Papers which was sent out in 2019, the Scientific Committee received 70 abstracts, followed by 49 full papers for presentation. The Panel of Reviewers was drawn from the IAHR Hydraulic Structures Technical Committee community and other international and national experts in fields relevant to the symposium themes. The Panel reviewed all papers submitted for publication in the ISHS2020 Proceedings. All submitted papers 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 31. The publication of the symposium papers marked a significant contribution of this event. Altogether the proceedings contain 36 papers involving 85 authors from 20 countries and 5 continents, including 2 invited keynote papers, 2 invited lecture papers and an editorial paper. The symposium proceedings were edited by the Chairs of the Scientific Committee, Robert Janssen and Hubert Chanson.

The scope of the ISHS2020 Proceedings is broad, with one study on fluvial hydraulics, one on coastal hydraulics, eleven on spillway hydraulics, three on culvert hydrodynamics and seventeen on hydraulic structures more broadly. The topics encompasses advanced multidisciplinary subjects such as air-water flows, sediment processes and fish passage. The papers of the Proceedings include contributions on experimental and numerical modelling, as well as combined approaches embedding more than two or more methodologies, e.g., hybrid modelling. Altogether the Proceedings regroups twenty-one physical studies, eleven numerical investigations, including ten computational fluid dynamics (CFD) studies, and two field studies. Furthermore, several contributions embed two or more approaches. Without a doubt, hydraulic structures bring new challenges as well as solutions directly relevant to the broad hydraulic engineering community.

3.2. 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.

The full bibliographic reference of the ISHS2020 symposium proceedings is:

Janssen, R. and Chanson, H. (2020). "International Symposium on Hydraulic Structures (ISHS2020)." *Proceedings of the 8th IAHR International Symposium on Hydraulic Structures ISHS2020*, 12-15 May 2020, Santiago, Chile, R. Janssen and H. Chanson Editors, The University of Queensland, Brisbane, Australia (ISBN 978-1-74272-309-9).

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

Janssen, R., Chanson, H., and Adriasola, J.M. (2020). "Hydraulic Structures: Challenges, Diversity, Ecology, Energy Dissipation, Hydrodynamics of the 21st Century" in "International Symposium on Hydraulic Structures (ISHS2020)." *Proceedings of the 8th IAHR International Symposium on Hydraulic Structures ISHS2020*, 12-15 May 2020, Santiago, Chile, R. Janssen and H. Chanson Editors, The University of Queensland, Brisbane, Australia, 11 pages (DOI: 10.14264/uql.2020.513) (ISBN 978-1-74272-309-9).

In this case, the above article is directly accessible on the Internet at {http://dx.doi.org/10.14264/uql.2020.513}.

3.3. Statistical summary

36 peer-reviewed papers including 2 keynote papers, 2 invited papers and 1 editorial paper;
85 authors from 20 countries and 5 continents.

3.4. List of Papers

Janssen, R., Chanson, H., and Jose M. Adriasola, J.M. (2020). Hydraulic Structures: Challenges, Diversity, Ecology, Energy Dissipation, Hydrodynamics of the 21st Century. *Proceedings of the 8th IAHR International Symposium on Hydraulic Structures ISHS2020*, 12-15 May 2020, Santiago, Chile, R. Janssen and H. Chanson Editors, The University of Queensland, Brisbane, Australia, 12 pages (DOI: 10.14264/uql.2020.513).

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4. SYMPOSIUM ORGANISATION

4.1. Presentation

The 8th IAHR International Symposium on Hydraulic Structures (ISHS2020) was scheduled to take place on 12-15 May 2020 in Santiago, Chile. Because of exceptional circumstances, i.e. the COVID-19 virus pandemic, the event had to be cancelled in late March 2020. With the agreement of the symposium organisation and contributors, the peer-reviewed technical papers were published in the ISH2020 proceedings, available open access and uniquely identified by a digital identifier called DOI.

4.2. Symposium organisation

4.2.1. Organising committee

José M. Adriasola (Chair)
Alberto de la Fuente (Deputy Chair)
Javiera Córdova
Jorge Gironás
Ricardo González
Héctor Maulén
José Vargas
Scarlett Vásquez

4.2.2. Scientific committee

Robert Janssen (Chair)
Hubert Chanson (Deputy Chair)
Prof. Fabian Bombardelli
Prof. Dr. Ing. Daniel Bung
Prof. Rita Carvalho
Dr. Brian Crookston
Dr. Ir. Sébastien Erpicum
Dr. Cristián Escauriaza
Dr. Stefan Felder
Prof. Óscar Link
Prof. Arturo Marcano
Prof. Mario Oertel
Dr. Michele Palermo
Prof. Blake Tullis
Dr. Hang Wang

5. LIST OF EXPERT-REVIEWERS

5.1.1. Editors

Robert Janssen (Australia)
Hubert Chanson (Australia)

5.1.2. Reviewers

Fabian Bombardelli
Daniel Bung
Iacopo Carnacina
Jose Carrillo
Rita Carvalho
Hubert Chanson
Kamal El-Kadi-Abderrezzak
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Masayuki Takahashi
Carsten Thorenz
Luke Toombes
Blake Tullis
Daniel Valero
Hang Wang
Davide Wuthrich
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6. ACKNOWLEDGEMENTS

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

We also acknowledge the logistics support provided by Sociedad Chilena de Ingeniería Hidráulica (SOCHID). The support of the University of Queensland and UQeSpace for the production and publication of the proceedings is acknowledged.

This type of specialised 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.

7. ORGANISING INSTITUTIONS, SPONSOR AND SUPPORTING ORGANISATIONS

7.1. Organising institutions

Sociedad Chilena de Ingeniería Hidráulica (SOCHID)
IAHR - International Association for Hydro-environment engineering and Research

SOCHID

IAHR AIRH International Association for Hydro-Environment Engineering and Research
Hosted by Spain Water and IWHR, China

7.2. Supporting organisations

IAHR HSTC - IAHR Hydraulic Structures Technical Committee
UQ - University of Queensland
UQeSpace
The University of Queensland, School of Civil Engineering
Colegio de Ingenieros de Chile, A.G.
Dirección de Obras Hidráulicas, MOP Chile
Instituto Nacional de Hidráulica, MOP Chile
Universidad de Santiago de Chile
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