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Editorial

Techniques and Applications in Water Science and Engineering

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Abstract: This Special Issue of *Water* on “Techniques and Applications in Water Science and Engineering” publishes selected high-quality research papers presented at the Inaugural International Symposium on Water Modelling (iSymWater2019). The symposium was hosted by Beijing Normal University and Manchester Metropolitan University, and took place during 8–10 July 2019 in Beijing, China. A wide range of research topics were considered, including hydraulic modelling, hydro-environment modelling, hydro-ecology modelling, water management simulation, physical experiments, and software. The Issue reports eight papers by researchers from many institutions around the world, and focuses on solving sustainable water challenges through theoretical and physical modelling approaches.

Keywords: hydraulic engineering; environmental hydraulics; physical modelling; numerical modelling

1. Introduction

1.1. Scientific Questions

Water is the key to future prosperity and wellbeing. However, the world is faced with serious water-related problems, which pose a major challenge to water resources engineers and scientists. In hydraulic systems, transient flow often occurs in pipelines and may interact with pipe structures [1,2]; aquatic vegetation widely occurs in surface water, affecting the flow field [3], and then further interfering with the water environment and aquatic biodiversity; and, due to climate change and rapid urbanization, extreme floods are becoming more frequent and intense, threatening human lives and causing significant damage to property [4]. An understanding of the water borne transport of emerging contaminants, such as plastic debris and antibiotics, is relevant to the remediation of rivers, lakes, and oceans [5,6]. Driven by natural and anthropogenic stressors, hydrological change is causing substantial impacts on hydro-ecology, affecting the morphological evolution of deltas [7] and decreasing the availability of ecological lake water in arid areas [8]. Technological tools to characterize hydrological and hydraulic conditions and potential future changes are prerequisites for tacking the aforementioned water-related problems.

1.2. Technical Problems

Advanced modelling techniques are essential in order for water resources engineers to ensure water security and quality, in keeping with the UN Sustainable Development Goals, particularly Goal 6 relating to clean water and sanitation. Water is often transported by pipes and open channels. For flows in pipes, hydraulic transients may arise from rapid changes in flow speed that pressurize pipelines, and are characterized by strong positive and negative pressures. Such transients may be of a sufficient magnitude to cause device failure, system fatigue, etc. Turning to open channels, the critical depth plays a significant role in the analysis, design, operation, and maintenance of such conduits, but the mathematical equations that govern the critical depth for arbitrary flow sections are complicated, implicit, and transcendental, and so have to be solved numerically. Almost all natural channels contain vegetation that help dissipate energy, and can be very useful in river restoration and flood prevention schemes. Obviously, studies of flow–vegetation interactions can lead to a better understanding of fluvial processes and promote the hydro-environmental benefits of vegetated surface water. At the global scale, associated with socio-economic development, the massive discharges of new and emerging pollutants, such as plastic debris and antibiotics, have led to serious damage to aquatic biota and habitats. High performance modelling tools are therefore required for simulating the transport and fate of emerging contaminants in natural waterbodies. A further globally important technical challenge relates to hydro-ecology, which is closely related to hydraulic and environmental conditions, and is sensitive to human activities that disturb the aquatic environment, such as dam construction, river dredging, and lake restoration. A comprehensive analysis of the hydro-ecological impacts of human and climate changes on the water environment requires sophisticated modelling techniques and their integrated application, and is the subject of this Special Issue.

1.3. Classification of the Papers

Addressing different water resources problems through hydraulic modelling [1–4], hydro-environmental modelling [5,6], and hydro-ecological modelling [7,8], the papers in this Special Issue report on hydraulic mechanisms [1–3], modelling techniques [4–6], and natural effects [7,8]. Analytical and numerical tools are used to improve simulation calibration and validation [1–6] as well as future ecological modeling performance [7,8].

2. Summary of Papers (Revised Based on the Abstract of the Papers)

2.1. CFD Investigations of Transient Cavitation Flows in Pipeline Based on Weakly-Compressible Model, by Tang et al. (2020)

In this study, a computational fluid dynamics (CFD) method based on Fluent software was used to investigate cavitation flow in a pipeline. The software was based on a weakly compressible fluid Reynolds Averaged Navier–Stokes (RANS) scheme, and the results were validated against experimental data. By incorporating a user-defined density–pressure model in the continuity equation, the variable wave speed of the transient cavitation flow was correctly reproduced. The resulting model successfully captured the formation, development, and collapse of the cavity, and showed the slow movement and uneven distribution of the vapor cavity in the pipe. It was found that the propagation of a rarefaction wave into regions where the pressure decreases or increases can lead to different types of cavitation flow.

2.2. Explicit Solution for Critical Depth in Closed Conduits Flowing Partly Full, by Shang et al. (2019)

Critical depth is an essential parameter that requires evaluation by water resources engineers involved in the design, operation, and maintenance of conduits. Circular, arched, and egg-shaped cross sections are often used in non-pressure conduits for irrigation and sewerage works in hydraulic and civil engineering. However, the equations governing the critical depth in various cross sections are complicated, implicit, and transcendental. In this paper, a function model was established for the geometric features of multiple sections using the mathematical transform method while considering non-dimensional parameters. Then, the correct solution for the critical depth was determined using improved PSO algorithm implemented in MATLAB. Error analysis showed that the approach has broad applicability.

2.3. Effects of Submerged Vegetation Density on Turbulent Flow Characteristics in an Open Channel, by Zhao et al. (2019)

Vegetation density λ affects turbulent flow in rivers containing submerged vegetation. The laboratory study reported in this paper investigated different types of vegetated turbulent flows for a large range of vegetation densities. Vertical distributions of the turbulence statistics, turbulence kinetic generation rate, and turbulence spectra were presented for different λ conditions. It was found that the spectral curves fluctuated intensely within the low-frequency range, and spectra of low-frequency eddies above the submerged vegetation had peak values significantly larger than for the spectra corresponding to eddies passing through the vegetation. Increased vegetation density altered the turbulent flow type, increasing the maximum value of the turbulence kinetic generation rate (GS) and raising the point at which the GS profile has a vertical maximum towards the top of the submerged vegetation.

2.4. Simulation of Hydraulic Structures in 2D High-Resolution Urban Flood Modeling, by Cui et al. (2019)

Urban flooding resulting from inadequate drainage capacity, failure of flood defenses, etc., usually exhibits highly transient hydrodynamics. Reliable, efficient prediction and forecasting of urban flash floods remains a great technical challenge. This paper describes a robust numerical approach that directly simulates the effects of hydraulic gate structures in a 2D high-resolution urban flood model based on a finite volume Godunov-type shock-capturing shallow water scheme. A flux term coupling approach was adopted to enhance the urban flood model, and was successfully validated by reproducing the laboratory experiments of flood routing in a flume with partially open sluice gates, conducted in the hydraulic laboratory at Zhejiang Institute of Hydraulics and Estuary, China. The paper demonstrates that the proposed model was able accurately to simulate the flow through hydraulic structures, with an enhanced predictive capability for urban flood modeling.

2.5. Numerical Prediction of the Short-Term Trajectory of Microplastic Particles in Laizhou Bay, Ding et al. (2019)

Microplastic particles are easily captured by microorganisms and enter the food chain, posing a significant threat to ecological health. Such particles have become abundant in coastal areas through waste discharges, and in local coastal hydrodynamics. Although much research on microplastics has been undertaken, prediction of the transport of microplastic particles in coastal zones remains a challenge. This paper describes the numerical prediction of the trajectories of microplastic particles released from four river mouths around Laizhou Bay. The computational model consists of the lattice Boltzmann method coupled with a Lagrangian particle-tracking method, including inter-particle and particle-wall collisions. Results are presented of the trajectories of the particles released from four river mouths, for a total duration of 30 days.

2.6. Numerical Study of Sulfonamide Occurrence and Transport at the Near-Shore Area of Laizhou Bay, by Xing et al. (2019)

Antibiotics are extensively applied in aquaculture for the treatment of microbial infections and to improve productivity. An understanding of the fate of sulphonamides (SA) in the aquatic environment is a basic prerequisite in solving antibiotic contamination of water ecosystems. This paper introduces a two-dimensional lattice Boltzmann model to investigate the transport and occurrence of SA in Laizhou Bay, a prosperous aquacultural area in China. The model used the Bhatnagaar–Gross–Krook scheme to solve the shallow-water and advection–diffusion equations, and was verified successfully against experimental data. The model provides a potential universal method for the simulation of the fate of antibiotics in the aquatic environment.

2.7. Effects of Dam Regulation on the Hydrological Alteration and Morphological Evolution of the Volta River Delta, by Amenuvor et al. (2020)

The Volta River in West Africa is one of the most dam-regulated rivers in the world, and this has resulted in substantial impacts on the hydrological alteration and morphological evolution of its delta. This paper describes the use of state-of-the-art hydrological methods to analyze inter-annual and intra-annual variations in river discharge and sediment load for pre- and post-Akosombo Dam periods (1936 to 2018). It was found that the inter- and intra-annual variations were much higher in the pre-dam period, suggesting the substantial regulation impact of the Akosombo Dam on the Volta River. Morphological analyses showed that the progradation-erosion of the Volta River Delta constantly fluctuated within a relatively small range after the 1970s. The relationship between the variations of the delta area and sediment load implied that a quasi-equilibrium state may have been established at the Volta River Delta, given the present sediment load. This paper should be useful in informing the future regulation and restoration of the Volta River Delta.

2.8. A Landscape Connectivity Approach for Determining Minimum Ecological Lake Level: Implications for Lake Restoration, by Liu et al. (2019)

This paper proposes a new approach to determine the minimum ecological lake level using landscape connectivity within MIKE 21 and ArcGIS software. Simulations are presented of the water landscape and corresponding connectivity of the Baiyangdian Lake on the North China Plain, and the relationship between the landscape connectivity and lake level is analyzed. The minimum ecological lake level was defined as the breakpoint of the lake level–connectivity curve. The results suggested that the minimum ecological lake level of Baiyangdian Lake is 7.8–8.0 m, below which the lake ecosystem becomes fragmented and potentially fragile. It is suggested that better connectivity at lower lake levels may be achieved by engineered modification of landscape patterns. Such approaches can mitigate wastages in water and economic resources caused by excessive reliance on high water levels to meet minimum connectivity requirements. The paper provides a useful perspective for lake ecosystem restoration in the context of water-resource and landscape management.

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