Experimental and numerical analysis of the influence of the positioning of the inlet and outlet channels on flow patterns and sediment deposition in shallow reservoirs

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Period
2014-2019

Funding
FCT scholarship (PD/BD/135219/2017)

Summary

Shallow flows correspond to turbulent flows with water depth limited by a bottom surface and by a free surface, whose dimension is significantly smaller compared to the horizontal ones. They are of great importance for Hydraulic Engineering, since they are related to frequently adopted applications, such as detention basins, stabilization ponds for effluent treatment, as well as aquaculture tanks. Usually, shallow flows are treated as two-dimensional or "quasi-two-dimensional" flows, because of the water velocity, depth-averaged, and because of their turbulent fluctuations. Their three-dimensional features are provided by additional turbulent diffusive and dispersive effects. Shallow reservoirs, for which the aforementioned premises are applied, are often affected by a continuous sedimentation process, since they are associated with low flow velocities. For this reason, it is important to increase the knowledge about their hydrodynamic behavior as a function of their geometric configuration and the hydraulic conditions. Once the main involved phenomena were understood, it would be possible to establish an adequate maintenance plan for these reservoirs and to estimate their useful life in a more robust and assertive way. The present research had as objective to analyze, from an experimental and numerical approach, the influence of the variable positioning of the inlet and outlet channels on the flow pattern and on the sediment deposition in two shallow rectangular reservoirs, for different flow rates and water depths. For that, two experimental programs were performed in reservoirs with different dimensions, linked by the 1: 2 scale ratio, one at the Hydraulic Research Center of the Federal University of Minas Gerais (CPH-UFMG, Brazil) and the other at the Laboratory of Hydraulics of the Instituto Superior Técnico of Lisbon (LH-IST, Portugal). In both cases, three possibilities of coupling the inlet and outlet channels were considered in the corresponding reservoir wall: left (L), central (C) and right (R). For five different geometric channel combinations (CC, LC, LL, LR and CR), clear water tests were carried out in both reservoirs, in order to characterize the flow pattern in each case. In addition, for the Portuguese reservoir, experiments were carried out involving the continuous introduction of granular bakelite, in order to characterize the sedimentation trends for the different geometric channels combinations, to assess the sediment volumes retained in the reservoir in each case and to allow the analysis of flow pattern after the establishment of the solid balance condition of the reservoir. At the same time, numerical simulations were generated for all the clear water scenarios of this research, aided by two computational programs, WOLF 2D and Autodesk® CFD. It was verified in the clear water tests and in the corresponding numerical simulations that the flow pattern was comparable for all geometric configurations whose inlet channel was positioned to the left of the longitudinal axis of the reservoir (LL, LC and LR configurations). For the CC and CR configurations, however, it was observed in some situations that there was no convergence between experimental and numerical results, probably due to some slight geometric disturbance not identified during the tests. With respect to the sediment tests, it was verified that the jet path was significantly affected from the beginning of the solid feed until the end of the test by the alteration of the bottom morphology, in turn, due to the sedimentation process. All solid volume introduced into the reservoir was retained until about half the duration of each test. On the other hand, in the final half of each experiment, the retention rate decreased progressively until it reached the solid balance between the inlet and the outlet of the reservoir. The LR configuration was the one in which there was greater sediment retention inside the reservoir, while the LL configuration would have been the one with the lowest solid retention.

Keywords

Shallow flow, sedimentation, hydrodynamic behavior, experimental evaluation, numerical evaluation.

Physical models at UFMG, Brazil (left) and at IST, Portugal (right).