Coupling CFD Analysis and 2D Flood Modelling

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Overview

In the course of undertaking 2D flood studies it is often necessary for engineers to estimate nominal head loss factors when representing 1D structures such as bridges, culverts, channels or pits and pipes, which cannot otherwise be resolved by the 2D hydraulic solver schemes. Some guidance around the estimation of such losses is available from both software vendors and industry best practice guidelines for a range typical hydraulic structures. However, circumstances often arise where the arrangement of the hydraulic structures being modelled ends up being more complex than that catered for using standard guides. Additional uncertainty can therefore be introduced into the flood modelling task in relation to specifying the associated loss factors. This can be of particular concern where the complex hydraulic structures in question represent a critical hydraulic control point in the design or analysis of a stormwater system, and the mis-characterisation of the associated losses can result in adverse engineering outcomes.

For situations where empirical formulae and recommended loss values begin to fall short, the typical industry approach has been to seek out similar precedents where available, or in lieu of this, to specify more conservative estimates of head loss to account for the uncertainty. In recent years however, the application of Computational Fluid Dynamics (CFD) practices have enabled the simulation of some of these site specific non-standard hydraulic structures and the derivation of the associated head loss factors directly, which can be fed back into the broader 2D hydraulic models to yield better modelling outcomes.

Several case studies of coupling CFD studies with 2D hydraulic models in the context of deriving clearer estimates of complex head losses are presented in this paper.

Objectives

The primary objective of this paper is to demonstrate how small scale CFD studies can be used in a cost effective manner to supplement broader 2D flood studies. The project examples presented in this paper are focused on the context of the use of CFD models to derive head loss factors for complex or non-standard 1D hydraulic structures.

Method

CFD modelling was conducted to simulate steady state flow conditions through control domains that featured three-dimensional representations of the site specific non-standard hydraulic structures. Boundary conditions for the CFD models were informed by the preliminary 2D flood models.

Total head was calculated in cross sections located a sufficient distance upstream and downstream of the structures, from which the associated ‘K-factor’ loss values were then derived and fed back into the broader 2D

hydraulic models. The revised 2D hydraulic model results were then compared to earlier model results which were generated prior to the use of CFD to estimate the head loss factors, with differences noted where relevant.

Results

In several of the case studies presented, the preliminary loss factor assumptions (considered to be conservative at the time they were made) were found to significantly underestimate the head losses. Findings such as these, if not identified early in the lifetime of a project, have the potential to lead to undesirable outcomes such as engineering assets failing to meet design freeboard clearances, causing adverse afflux conditions on site, or resulting in poor flood mitigation performance despite indications to the contrary from standard flood modelling practices.

Conclusions

The case studies presented in this paper demonstrate that the inclusion of such CFD studies in the broader process of flood modelling can reduce commonly encountered uncertainties relating to complex head losses when representing 1D structures in 2D hydraulic models, and can have significant impacts on an engineering design in cases where the structures in question represent a critical hydraulic control point in the system. This process of coupling CFD studies and 2D flood hydraulics can in turn can help avoid poor engineering outcomes related to the mis-characterisation of complex, site specific hydraulic structures, particularly if the CFD studies are incorporated at concept stage of the design.