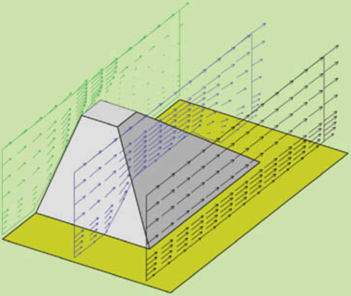
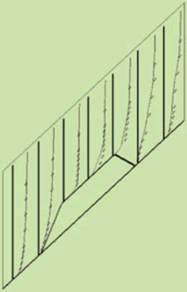
VERIFICATION AND VALIDATION OF
3D Free-Surface Flow Models





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VERIFICATION AND VALIDATION OF 3D FREE-SURFACE FLOW MODELS

SPONSORED BY
Task Committee on 3D Free-Surface Flow Model Verification and Validation

Environmental and Water Resources Institute (EWRI)
of the American Society of Civil Engineers

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Preface

In recent years, more and more computational models for free surface flow simulations are needed in engineering analysis, design, and in making policy, planning and management decisions. Many computational models have been quickly developed and released to the clients without adequate verification and validation. As projects being planned and designed today have to include the considerations of multi-disciplinary interactions; their local, regional and even global effects; and short-/long-term impacts, the capability, quality and reliability of these computational models used as research, planning and design tools, are of great importance. Responding to these concerns model developers have applied various ways to verify the mathematical correctness and physical validity of the models which they have developed. Due to the lack of an established rigorous and systematic verification and validation process, some of the verification and validation tests found in the open literatures are from the Test of Symmetry and Mass/Volume Conservation to Tests of Translation/rotation of a Gussian Cone and Vortex Shedding, Tests of Analytic Verification and Grid Convergence, and the Validation by field data alone, just to list a few.

A method used most often has been the comparison of model results directly to the field measurements. Once agreement is obtained, either the model developer or the user would claim that the model is validated. Since it is so easy to do, this method has been widely adopted. Recently, more and more professionals have found out that the method was often irresponsibly abused and thus raised doubts about its adequacy and dependability. After careful examination, it was found that in many cases the agreement obtained was by "fine tuning" the model parameters exclusively. The fine-tuning is acceptable only during the model parameter calibration process, provided that it is conducted properly. After the calibration is completed, the values of the model parameters should not be changed to perform a validation test. The field data used during this validation test should not be the ones, which have been used already to do the calibration. Some modelers and users justified the use of the same set of field data for both calibration and validation by saying that because of the amount of field data measured is insufficient, so they have to accept the calibration as also validation. This is not acceptable. Furthermore, instances have also been found that the fine-tuning was used for the sole purpose of matching the modeled value to the field measurements. For example, some skillful fine-tuning expert have changed the flowfield, say stream or pathlines, by adjusting the Manning's n-values or bed friction factors of the depth-averaged flow models, just for the sake of obtaining a flowfield of his/her liking. This is wrong.

The ASCE/EWRI Task Committee is actually a defacto international committee with members representing academic, governmental and private research institution from six countries. After having spent nearly 10 years, a comprehensive, rigorous and systematic three dimensional free surface flow model verification and validation procedure has been developed, which is presented in this report. It consists of three steps, namely the Mathematical (Code) Verification, Physical Process Validation, and Application site Validation. In the Mathematical Verification Step, the numerical model results are compared with a known analytic or prescribed or manufactured solution of the same boundary value problem. Since all physical, mathematical and geometric parameters are identical, neither calibration nor fine-tuning is needed. During the verification, if the discrepancies are found, they must be due to the calculation errors and/or model (code) mistakes. In addition, the order of convergence and error can be determined quantitatively. Therefore, this step is very important. In the Physical Process Validation, the model's capability of representing all the essential and basic physical processes of the problem is determined. The validation is confirmed, if the simulated results are in good agreement of the physical process with the measurements of the same process in laboratories. After the model is proven to be able to simulate all the essential and basic physical processes, it is then ready to go through the Application Site Validation. This last step requires two sub-steps: The first sub-step is the model parameter calibration, which is to insure that the unique and site-specific characteristics of a natural system are taken into account in the model. Without this calibration, the governing equations can not be assured to be realistic when applied to specific site applications. Then, the calibrated model is to be tested by comparing the simulated results with the rest of the collected data, which have not been used in performing calibration. A reasonable agreement is needed to confirm the success of the Application Site Validation.

It is important to call reader's attention to the two key points affecting the success of this validation step: (1) the field data collected must be sufficient in the amount and high quality in accuracy to meet the rigorous calibration and validation needs, and (2) the calibration and validation are required on a case to case basis at each particular site and from time to time, especially when the lapse of time from one case to the next is of significance and/or during which major hydrologic event(s) has happened. During each step of the tests, the tester is recommended to perform Calculation Verification to estimate the error accumulated during the process of calculations.

It is the Committee's belief, that the Verification and Validation Procedure for 3D Free Surface Flow Model developed by this committee has been proven to be the most comprehensive in the open literature. Therefore, the Committee recommends its adoption by professionals in the field to carry out a free surface flow model verification and validation before applying the model to the investigation of real life problems.

The Committee fully realizes, however, that the comprehensive and systematic verification and validation procedure as presented in this report is far from being perfected. Therefore, the researchers in the field are strongly encouraged to further advance the state of the art. Some of the areas need further advancements include (but not limited to): the method for analytic verification of non-linear models, such as the methods using prescribed solution forcing, manufactured solutions, and other new approaches; the systematic method for conducting calculation verification; additional test cases for physical process validation; more complete sets of sufficient quantity and high quality field data for application site validation, etc. Most of these advancements can be quite involved and require considerable effort and time to accomplish. Therefore, it is hoped that the publication of this report is just a step forward at the beginning of a long term task, and a stimulant to the fellow researchers to devote their wisdom, knowledge, expertise and energy to continue the march to a better system for more rigorous and comprehensive verification and validation of the three-dimensional free surface flow models in particular, and all computational models in general.

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