# PREFACE

## WHAT'S NEW IN THE SECOND EDITION

In this second edition, material has been added on long-throated flumes as flow measuring devices, flood control channel design including the Corps of Engineers riprap revetment design procedure, computation of canal delivery curves, reservoir outflow control using gated spillways, HEC-RAS implementation of WSPRO and other bridge backwater computation methods, HEC-RAS unsteady flow module for flood routing, and an introduction to pier and abutment scour countermeasures. Existing material on turbulent flow resistance, grass lining of channels for stability, and hydraulic jump in rough channels has been expanded and updated.

Another important change in the second edition is the addition of Chapter 11 on Computational Fluid Dynamics (CFD) contributed by my colleague at Georgia Tech, Dr. Thorsten Stoesser. Three-dimensional CFD techniques are becoming more and more important in hydraulic engineering and more accessible to the practicing engineer as well. In this chapter, Dr. Stoesser introduces CFD as applied to open channel flow and demonstrates its tremendous potential to add to our knowledge of three-dimensional turbulent flow in open channels and improve our design of stream restoration measures, floodplain management schemes and hydraulic structures. As hydraulic engineers, we now have CFD as a third tool, in addition to experimental and theoretical techniques, to attack the challenging problems of hydraulic engineering in the 21st century. It is hoped that this chapter will encourage practicing engineers to further explore the possibilities of CFD.

Finally, I have increased both the number of illustrative examples and end-of-chapter exercises by 25 percent in this revision of the textbook.

## PURPOSE OF TEXT

The study of open channel hydraulics is a challenging and exciting endeavor because of the influence of gravity on free surface flows. The position of the free surface is not known *a priori,* and counterintuitive phenomena can occur from the viewpoint of the first-time student of open channel flow. This book offers a study of gravity flows starting from a firm foundation in modern fluid mechanics that includes both experimental results and numerical computation techniques. The development of the subject matter proceeds from basic fundamentals to selected applications with numerous worked-out examples. Experimental results and their comparison with theory are used throughout the book to develop an understanding of free-surface flow phenomena. Computational tools range from spreadsheets to computer programs to solve more difficult problems. Some computer programs are provided in Visual BASIC, both as learning tools and as examples to encourage the use of computational methods regardless of the platform available in a very dynamic environment. In addition, several well-known computer packages available in the public domain are demonstrated and discussed to inform users with respect to the methodologies employed and their limitations.

This book has grown out of instructional and research materials developed over several years and used in a graduate course sequence in open channel flow and sediment transport, as well as in a continuing education course that I have taught at the Georgia Institute of Technology. Because of its unique focus on fundamentals as well as applications, and experimental results as well as numerical analysis, this book should fill a niche between exhaustive handbooks and purely academic treatises on the subject of open channel hydraulics.

## ORGANIZATION OF CHAPTERS

The basic equations of continuity, energy, and momentum are derived for open channel flow in the first chapter, from the viewpoint of both a finite control volume and an infinitesimal control volume, although the complete derivation of the general unsteady form of the differential momentum equation is saved for Chapter 7. Dimensional analysis is introduced in some detail in the first chapter because of its use throughout the book. This is followed by Chapters 2 and 3 on the specific energy concept and the momentum function, respectively, and their applications to open channel flow problems. Design of open channels for uniform flow is examined in Chapter 4 with a detailed consideration of the estimation of flow resistance. Applications include the design of channels with vegetative and rock riprap linings, and the design of storm and sanitary sewers. Chapter 5, on gradually varied flow, emphasizes modern numerical solution techniques. The methodology for water-surface profile computation used in current computer programs promulgated by federal agencies is discussed, and example problems are given. The design of hydraulic structures, including spillways, culverts, and bridges, is the subject of Chapter 6. Accepted computer programs used in such design are introduced and their methodologies thoroughly explored. Chapters 7, 8, and 9 develop current techniques for the solution of the one-dimensional Saint-Venant equations of unsteady flow and their simplifications. In Chapter 7, the Saint-Venant equations are derived, and the method of characteristics is introduced for the simple wave problem as a means of understanding the mathematical transformation of the governing equations into characteristic form. The numerical techniques of explicit and implicit finite differences and the numerical method of characteristics are given in Chapter 8, with applications to hydroelectric transients in headraces and tailraces, the dam-break problem, and flood routing in rivers. Chapter 9 covers simplified methods of flow routing including the kinematic wave method, diffusion method, and the Muskingum-Cunge method. The complex subject of alluvial channel flows that have a movable bed as well as an adjustable free surface is explored in Chapter 10. This chapter emphasizes the important links among sediment discharge, bed forms, and flow resistance that are essential to an understanding of open channel flow in rivers. Also covered in Chapter 10 are alluvial channel adjustments in slope, form, and shape; and bed scour in response to the flow blockage caused by bridge foundations. Finally, the book concludes with a chapter introducing the methods of CFD applied to open channel flow that includes a case study.

The book includes an appendix to supplement the text material. It is a general discussion of some selected numerical techniques that can be used throughout the book. The book website contains some example computer programs for the computation of normal and critical depth in prismatic channels, including compound channels, and computation of water surface profiles. These programs are written in Visual BASIC as learning aids for more extensive programming exercises at the end of several chapters. Additional programs for solution of the more advanced exercises on unsteady flow computations can be found on this website.

## TEACHING WITH THIS TEXTBOOK

*Open Channel Hydraulics* is intended for advanced undergraduates and first-year graduate students in the general fields of water resources and environmental engineering. Chapters 1 through 5 and Chapters 7 through 9 provide sufficient material for a semester course in open channel hydraulics covering both steady and unsteady flow. The book also can be used for a first-year graduate course or a senior elective course on hydraulic structures and river hydraulics, utilizing Chapters 4, 5, 6, 9, 10, and 11. This material, which includes several applications and example problems, should be useful to the practitioner charged with the responsibility for such tasks as floodplain management, spillway design for small reservoirs, culvert and sewer design for drainage, investigation of stability and flow resistance of alluvial streams, and estimation of bridge backwater and scour. Because of this applied focus of the book, it should be a useful addition to a consulting engineer's library as well as a practical textbook on the fundamentals of open channel flow.

Each chapter contains worked-out example problems to aid in the understanding of the text material. Where possible, solutions are given in dimensionless form in graphs to provide an intuitive understanding of the physics of the problem and the behavior of its solution over a wide range of variables. At the end of each chapter, exercises are presented that involve application of the material in the chapter as well as student exploration of further ramifications of the text material. In some chapters, actual laboratory results are given for data reduction and presentation by students to experimentally verify text material.

## ONLINE RESOURCES

Visit the text website at www.mhhe.com/sturm <http://www.mhhe.com/sturm> for various resources available to instructors and students.

## ACKNOWLEDGMENTS

I am indebted to more people than I can enumerate here for the completion of this project. My initial motivation for preparing for an academic career in hydraulics dates back to a keynote address that I heard delivered by Hunter Rouse, who was an accomplished orator as well as writer, at a conference held at the University of

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