SIXTH EDITION

Hydrology and Floodplain Analysis

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Dedication

To Cindy, Eric, and Courtney,
to my parents for their guidance, and
to my teachers, and to all my students
over the past 35 years.

P.B.B.

To My Family

W.C.H.

To my wife, Jean, and to our children
William, Ellen, Laura, Anne, and Kimberly,
and to my parents

B.E.V.

Contents

PREFACE

The field of hydrology is of fundamental importance to civil and environmental engineers, hydraulic engineers, hydrogeologists, and other earth scientists because of the overall significance of water in modern society. Topics include water supply, major floods, droughts and their management, urban drainage and stormwater issues, floodplain management, climate change, and water quality impacts. In recent years, hurricanes and storm surge have caused significant coastal disasters, especially in coastal areas where urban development has expanded rapidly. This book was written to address the computational emphasis of modern hydrology both at an undergraduate and graduate level, and to provide a balanced approach in terms of theory and important applications in hydrologic engineering and science. A particular emphasis in the sixth edition is the incorporation of new examples, homework, and computer modeling applications.

THE EVOLUTION OF HYDROLOGY

Increasing use and sophistication of computer software and the accessibility of large-scale data have revolutionized the daily practice of hydrology. The impact of transferring online data from governmental and scientific sources to the practicing hydrologist or student has been phenomenal. Hydrologic rainfall data, digital terrain models, and mapping software linked with hydrologic modeling now allow complex problems to be solved efficiently. Geographical information systems (GIS) and radar rainfall have greatly improved our ability to predict hydrologic response. A number of major improvements have been made to existing hydrologic models, such as HEC-HMS, HEC-RAS, and EPA SWMM. These advances are highlighted with examples in the sixth edition. Important websites and links currently used routinely in hydrology are listed in Appendix E and can also be found at the textbook website: **hydrology.rice.edu**. While the entire textbook was updated with many new examples and new homework problems, the following lists the most important updates incorporated for the sixth edition.

- Chapter 6: New SWMM5 example embedded in a real case study of the application of decentralized stormwater controls
- Chapter 7: New HEC-RAS discussion with a new detailed example
- Chapter 8: New examples in groundwater modeling
- Chapter 10: New chapter on GIS in Hydrology with a new example
- Chapter 11: Completely updated and includes new V*flo*® example

- Chapter 12: New chapter highlighting flood policy evolution in the United States.
- Chapter 13: New chapter on water resources case studies across America.

ORGANIZATION OF THE SIXTH EDITION

The sixth edition of the text is still divided into three main sections. **The first section**, consisting of the first four chapters, covers traditional topics in hydrology related to the water balance such as: (1) hydrologic principles, hydrologic cycle, and measurement techniques, (2) hydrologic analysis using hydrographs for rainfall-runoff, (3) statistical and flood frequency analysis, and (4) hydrologic and hydraulic flood routing methods. These chapters provide a lot of the basis for more applied modeling applications in later chapters of the text. Many new figures, examples, and homework problems have been included throughout.

The second major section, Chapters 5 through 9, is designed to apply hydrologic theory and available hydrologic modeling techniques to several areas of engineering hydrology and design: watershed analysis, floodplain delineation, urban stormwater, ground water, and drainage design. The latest methods and computer models are described in enough detail for practical use. Updated examples and new case studies are also provided. Chapter 5, Hydrologic Simulation Models, has been updated to include the latest versions of the HEC-HMS model. Chapter 6, Urban Hydrology, presents methods and reviews of available computer models for pipe and open channel storm drainage systems. The Storm Water Management Model (SWMM5) is highlighted with a new watershed planning example. Chapter 7, Floodplain Hydraulics, first covers open channel flow concepts, including uniform flow and critical flow. These concepts form the basis for various hydraulic analyses such as water surface profile computations in a hydraulic model, HEC-RAS, described in detail with a new case study demonstrating the power of the model in steady and unsteady mode to evaluate natural floodplains. Chapter 8 presents ground water hydrology as a stand-alone chapter, including flow in porous media, aquifer properties, well mechanics, and computer applications. Governing equations of flow are derived and applied to a number of ground water problems, and a new example has been added. Chapter 9 is a comprehensive chapter on design applications in hydrology. It addresses design rainfall, small watershed design, hydraulic design, detention pond design, detailed culvert design, and floodplain mitigation design issues.

The final major section includes four chapters (10, 11, 12, and 13) that have been completely redone to cover a variety of interesting and relevant topics such as GIS data analysis and hydrologic computation, radar rainfall and watershed evaluation, severe storm impacts and flood management, and water resource case studies from across the United

States. No other hydrology textbook presents this type of material all in one place. Chapter 10 presents current geographic information systems (GISs) and digital elevation models (DEMs) as important tools for watershed and land use analysis, hydrologic modeling, and advanced floodplain delineation. Many useful hydrologic datasets and software are now widely available in high-resolution digital form on the web (see Appendix E). Chapter 11 depicts some of the latest technology on the use of NEXRAD radar data to estimate rainfall intensities over watershed areas. Radar rainfall has greatly improved our ability to predict rainfall patterns over a watershed and offers real advantages for hydrologic flood alert systems.

Chapter 12 is a new chapter on flood control and risk management in the United States and includes a number of new examples from across the country, including discussion of Mississippi River flood control strategies and the surge mitigation response in New Orleans from Katrina. Chapter 13 is also a new chapter for the sixth edition, and details major water resources projects around the United States with detailed case studies from the Colorado River, the Columbia River, major flooding issues in Texas, and a water rights issue between Florida and Georgia.

AUDIENCE AND AVAILABLE RESOURCES

The sixth edition of the text should provide the civil or hydraulic engineering or science student with all the necessary theory to understand principles of hydrology, hydrologic modeling, floodplain hydraulics and analysis, data analysis, and water resources management in the modern digital world. The student or practicing engineer should find the book a useful reference for hydrologic methods, current models, design examples, and extensively documented case studies. In addition, simple calculations and spreadsheet examples are utilized and highlighted in numerous places in the sixth edition, which contains over 80 worked examples, over 220 homework problems, and 13 major case studies.

The Internet offers many sources for access to regional data with minimal cost and effort. Among those, U.S. Geological Survey, National Weather Service, National Resources Conservation Service, U.S. Army Corps of Engineers, and other state and local agencies should be emphasized for students as likely sources of regional hydrologic data. The textbook website (**hydrology.rice.edu)** contains a complete set of PPT slides for classroom instruction, along with datasets, spreadsheets, modeling hints, tutorials, and other resources. Dr. Bedient maintains the website that is available to any instructor and student in the course at no charge. These resources are designed to improve the teaching of a hydrology course at either the undergraduate or graduate level. In addition, an updated **Solutions Manual** is available for instructors. For more details on available resources, see the textbook web site—**hydrology.rice.edu**.

ACKNOWLEDGMENTS

The current edition of the textbook was developed over a period of 35 years, beginning in 1982, from original course notes in a class in Hydrology and Watershed Analysis at Rice University. During the many years of interaction with colleagues and students, the book evolved into its present form with emphasis on simple examples, clear explanations, and modern computational methods. The sixth edition includes updated text, homework, and examples in all chapters, and new chapters written by a number of amazing colleagues. I am of course indebted to my co-authors, Dr. Wayne Huber and Dr. Baxter Vieux for their invaluable contributions over the years and the new updates in Chapters 3, 6, and 11. I am also indebted to Dr. Wesley Highfield and Dr. Antonia Sebastian for a newly revised Chapter 10, Dr. Antonia Sebastian and Avi Gori for a newly revised Chapter 12, and Dr. Nick Fang, Dr. Andrew Juan, and Catherine Nikiel for a newly revised Chapter 13. Significant example updates are included in Chapter 7 (Dr. Jacob Torres) and Chapter 8 (Dr. Phil DeBlanc). We also thank Dr. Jeri Stedinger of Cornell University for his highly informed help in updating the Bulletin 17B flood frequency analysis procedures described in Chapter 3.

The City of Austin Watershed Protection Department led and funded the project that was used as the SWMM5 Case Study in Chapter 6, Section 8. Geosyntec Consultants was the prime contractor and lead modeler, with assistance from Chan and Partners Engineering, Heather Venhaus, Linda Pechacek, ACR LLC, and Dr. Michael Barrett. Key staff at the City of Austin included Mike Kelly, Leila Gosselink, and Roger Glick.

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A successful textbook always represents a team effort, and the support team at Rice University has been excellent in their organization and great attention to detail. Special thanks are due to Megan Goings and Rik Hovinga at Rice University for their technical skills in organizing and reviewing text and figures, permissions, and for providing valuable input to examples and homework problems. We would also like to thank Rice University students Matt Garcia, Alison Archibal, Bob Zhang, and Toby Li who assisted greatly in developing new problems, solving examples, and developing and checking new homework solutions for the sixth edition.

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ABOUT THE AUTHORS

Philip B. Bedient is the Herman Brown Professor of Engineering with the Department of Civil and Environmental Engineering, Rice University, Houston, TX. He received the PhD degree in environmental engineering sciences from the University of Florida in 1975. He is a registered professional engineer and teaches and performs research in surface hydrology, modeling, and flood prediction systems, and ground water hydrology. He has directed over 60 research projects over the past 41 years, and has written over 200 journal articles and conference proceedings over that time. He has also written four textbooks in the area of surface water and groundwater hydrology. He received the Shell Distinguished Chair in environmental science (1988–92), the C.V. Theis Award in 2007, and he was elected Fellow of ASCE in 2006.

Dr. Bedient has worked on a variety of hydrologic problems nationwide, including river basin analyses, major floodplain studies, flood warning systems, groundwater contamination models, and hydrologic/GIS models in water resources. He has been actively involved in developing radar-based flood prediction and warning, and recently directed the development of a real-time flood alert system (FAS3 and FAS4) for the Texas Medical Center (TMC) in Houston. He has built real-time flood alert systems for several communities across Texas. He currently directs the Severe Storm Prediction Education and Evacuation from Disasters (SSPEED) Center at Rice University, a five-university research organization with private and public entities that predicts and assesses the impacts of severe storms and floods near the Gulf Coast. This center is devoted to developing real-time flood alert and surge alert systems for the coastal areas around Houston such as the Houston Ship Channel, and also evaluates structural and nonstructural methods for mitigation of severe storms. Dr. Bedient has received research funding from the U.S. EPA, the U.S. Department of Defense, NSF, the State of Texas, the U.S. Army Corps of Engineers, the City of Houston, and the Houston Endowment.

Wayne C. Huber is Professor Emeritus of Civil and Construction Engineering at Oregon State University, Corvallis and Senior Consultant with Geosyntec Consultants, Portland, Oregon. His doctoral work at the Massachusetts Institute of Technology dealt with thermal stratification in reservoirs, for which he received the Lorenz G. Straub Award from the University of Minnesota and the Hilgard Hydraulic Prize from the American Society of Civil Engineers (ASCE). Additional awards include the ASCE Environmental and Water Resources Council Julian Hinds Award. He is a member of several technical societies and has served several administrative functions within the ASCE, including service as Associate Editor of the *Journal of Environmental Engineering* since 2007. He is the author of over 120 reports and technical papers, is a registered professional engineer, and has served as a consultant on numerous studies done by public agencies and private engineering firms. He has served on several review committees of the National Academy of Sciences, including serving as chair of the Committee on Independent Scientific Review of Everglades Restoration Progress.

Beginning at the University of Florida and continuing at Oregon State University, Dr. Huber's research has included studies of urban hydrology, stormwater management, nonpoint source runoff, river basin hydrology, lake eutrophication, rainfall statistics, and hydrologic and water quality modeling. He is one of the original authors of the EPA Storm Water Management Model and helped to maintain and improve the model following its 1971 introduction. Dr. Huber is an internationally recognized authority on runoff quantity and quality processes in urban areas.

Baxter E. Vieux is Professor Emeritus in the School of Civil Engineering and Environmental Science, University of Oklahoma, Norman. He taught courses in hydrology, environmental modeling, GIS applications, water resources, and water quality management after joining OU in 1990, until 2013. Prior to his academic career, he spent 10 years with the USDA Natural Resources Conservation Service (formerly SCS) in Kansas and Michigan, with his highest position as Assistant State Engineer and Acting State Engineer. He is a registered professional engineer in several states and is co-principal and founder of Vieux & Associates, Inc., an engineering technology company with clients in radar-based hydrology. Dr. Vieux is the innovator and architect of the first commercially available physics-based distributed hydrologic model, V*flo*®, which was designed from the outset to use high-resolution maps of terrestrial parameters and radar rainfall. He has authored over 110 publications in hydrology including *Distributed Hydrologic Modeling Using GIS,* 3rd ed., Springer Publishers, Norwell, Massachusetts, Water Science Technology Series, vol. 74. Dr. Vieux has developed and deployed radar-rainfall monitoring and runoff modeling technology for operational hydrologic forecasting services in the United States and internationally.

Hydrology for Floodplain Analysis. Presented by Z. John Licsko, PE, CFM. Global Water Cycle â€“ Hydrological Analysis Distribution and movement of water on, above and below earth surface in liquid, vapor, & solid states â€“ Hydrologic Cycle Conservation of Mass: Inflow (I) â€“ Outflow (O) = Â± Change in storage (S). Watershed Scale Hydrologic Processes ï‚§ ï‚§.Â ï‚§ Floating debris. Hydrology â€“ Hydraulics and Floodplain Mapping Process. Hydrology. Hydraulics. Floodplain. Hydrology used in Hydraulic Analysis ï‚§ Recurrence Interval - actual number of years between floods ï‚§ 100-year flood â€“ 1% chance in a year ï‚§ 500-year flood â€“ 0.2% chance in a year ï‚§ 10, 25 and 50 year profiles ï‚§ Purely Statistical Designation. â€¦there can be multiple 100-year floods in a given yearâ€¦ Download Read Hydrology and Floodplain Analysis (5th Edition) | Ebook PDF Free Download Here https://readsebookonlinenew.blogspot.com/?book=0132567962. of 6. Please download to get full document.Â This text offers a clear and up-to-date presentation of fundamental concepts and design methods required to understand hydrology and floodplain analysis. It addresses the computational emphasis of modern hydrology and provides a balanced approach to important applications in watershed analysis, floodplain computation, flood control, urban hydrology, stormwater design, and computer modeling. This text is perfect for engineers and hydrologists. 4. If you want to download this book, click link in the next page.