

## ENVIRONMENTAL HYDRAULICS

# Water Science and Technology Library

---

VOLUME 19

---

## *Editor-in-Chief*

V. P. Singh, *Louisiana State University,  
Baton Rouge, U.S.A.*

## *Editorial Advisory Board*

M. Anderson, *Bristol, U.K.*

L. Bengtsson, *Lund, Sweden*

A. G. Bobba, *Burlington, Ontario, Canada*

S. Chandra, *New Delhi, India*

M. Fiorentino, *Potenza, Italy*

W. H. Hager, *Zürich, Switzerland*

N. Harmancioglu, *Izmir, Turkey*

A. R. Rao, *West Lafayette, Indiana, U.S.A.*

M. M. Sherif, *Giza, Egypt*

Shan Xu Wang, *Wuhan, Hubei, P.R. China*

D. Stephenson, *Johannesburg, South Africa*

*The titles published in this series are listed at the end of this volume.*

# ENVIRONMENTAL HYDRAULICS

edited by

**VIJAY P. SINGH**

*Department of Civil and Environmental Engineering,  
Louisiana State University,  
Baton Rouge, U.S.A.*

and

**WILLI H. HAGER**

*Laboratory of Hydraulics, Hydrology and Glaciology,  
Swiss Federal Institute of Technology,  
Zürich, Switzerland*



Springer-Science+Business Media, B.V.

**Library of Congress Cataloging-in-Publication Data**

Environmental hydraulics / edited by Vijay P. Singh and Willi H. Hager.

p. cm. -- (Water science and technology library : v. 19)

Includes index.

ISBN 0-7923-3983-5 (hb : alk. paper)

1. Environmental hydraulics. I. Singh, V. P. (Vijay P.)

II. Hager, Willi H. III. Series.

TC163.5.E58 1996

628--dc20

96-242

ISBN 978-90-481-4686-4 ISBN 978-94-015-8664-1 (eBook)

DOI 10.1007/978-94-015-8664-1

---

*Printed on acid-free paper*

**All Rights Reserved**

© 1996 Springer Science+Business Media Dordrecht

Originally published by Kluwer Academic Publishers in 1996.

Softcover reprint of the hardcover 1st edition 1996

No part of the material protected by this copyright notice may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage and retrieval system, without written permission from the copyright owner.

To

Our families:

Anita

Vinay

Arti

Susanna

Olivia

Mirjam

Caren

# CONTENTS

PREFACE		ix
CONTRIBUTORS		xi
CHAPTER 1.	What is Environmental Hydraulics? by V.P. Singh and W.H. Hager	1
CHAPTER 2.	Jets and Plumes by W.D. Baines and V.H. Chu	7
CHAPTER 3.	Sea Outfalls by P.J.W. Roberts	63
CHAPTER 4.	Diffusion and Dispersion by E.R. Holley	111
CHAPTER 5.	Interaction between Fluid Mud and Water Waves by A.J. Mehta	153
CHAPTER 6.	Heat Transport by M. Hondzo and H.G. Stefan	189
CHAPTER 7.	Chemical Transport by Q. Cheng, X. Zhang, and A. James	219
CHAPTER 8.	River Water Quality Modeling by C. Gandolfi, A. Kraszewski and R. Soncini-Sessa	245
CHAPTER 9.	Estuarine Hydraulics by P.D. Scarlatos	289
CHAPTER 10.	Ecohydrodynamics by P.D. Scarlatos	347
Subject Index		399
Author Index		409

## PREFACE

Triggered primarily by ill effects of polluted air, soil and water resources on living species, public concern for environmental quality has been growing during the past four decades or so. One manifestation of this concern is found in occurrence of public debates as well as in the demand for full environmental impact assessment before a water-resources project is approved. Engineering soundness and economic feasibility are no longer sufficient criteria for construction of hydraulic works. As a result, environmental considerations have become very much a part of hydraulic analyses. In response to growing environmental concerns, the field of hydraulics has expanded and a new branch, called *Environmental Hydraulics*, has emerged. The focus of this branch is on hydraulic analyses of those environmental issues that are important for protection, restoration, and management of environmental quality. The motivation for this book grew out of the desire to provide a hydraulic discussion of some of the key environmental issues. It is hoped that the book would serve to stimulate others to write more comprehensive texts on this subject of growing importance.

The subject of environmental hydraulics is introduced in Chapter 1, which also tries to delineate its scope and makes a comment on its future direction. Jets and plumes are discussed in Chapter 2, with emphasis on the strength of the sources and the nature of the receiving environments. Chapter 3 covers sea outfalls with emphasis on water quality. Both the design and the methods of predicting the environmental impact of these outfalls are included. Also included are such topics as the design of tunnelled outfalls, the use of hydraulic models, new laboratory techniques for investigation of mixing processes, and the use of three-dimensional coastal hydrodynamic models.

Diffusion and dispersion constitute the subject matter of Chapter 4. Described herein are the constituent transport equations, the physical aspects of mixing and the general behaviour of transport problems, with emphasis on rivers with steady flow. Chapter 5 discusses the interaction between mud flow and water waves, including the physical principles underlying the response of the wave - mud system with reference to water - wave attenuation, mud motion, and interfacial erosion. Also included are simple hydrodynamic models that account for rheological constitutive properties of mud and sediment dynamics.

Heat transport is the subject of Chapter 6. It addresses as to how freshwater bodies respond to material and artificial heat inputs. Heat budget of aquatic systems, natural heat transport and temperature regimes, artificial heat pollution, and effects of water temperature on water quality and aquatic biology are included in the chapter. The modelling of chemical transport is covered in Chapter 7. It provides an overview of the models developed for simulating the rate of pollutants in the aquatic environment. The overview is divided into two parts. Beginning with a

discussion of the key processes of advection and dispersion and followed by chemical and microbiological kinetics, the first part surveys the approaches adopted to simulation. The second part deals with the application of modelling techniques to different environments. Chapter 8 encompasses river water quality modeling with emphasis on river water quality models in environmental management and planning, environmental impact assessment, and ecological education. Riverine ecosystem, model structure, simulation and parameter estimation and modeling support system are described in the chapter .

The next two chapters discuss hydraulics of environmental systems. Estuarine hydrodynamics is discussed in Chapter 9. Beginning with classification of estuaries, the chapter goes on to discuss tidal constituents and wave characteristics, hydrodynamic equations, elementary solutions of tidal hydrodynamics and numerical solutions of the St. Venant equations. Hydrodynamics as applied to ecology is the subject of the concluding Chapter 10. With a short introductory background of dissolved and suspended matter, and physicochemical processes, the chapter discusses aquatic systems, mixing processes, and density stratification, and concludes with a treatment of air pollution, and chaos and fractals in ecohydrodynamics.

The editors would like to express their deep gratitude to all the contributors who, despite their busy schedule, were generous and willing to write the chapters. The editors' families offered unwavering support and help without which this book would not have been completed.

V.P. Singh  
Baton Rouge, USA

W.H. Hager  
Zurich, Switzerland



## **CONTRIBUTORS**

Professor W. D. Baines  
Department of Mechanical Engineering  
University of Toronto  
Toronto, Ontario M5S 1A4  
Canada

Mr. Q. Cheng  
Wuxi Chemical Research and  
Design Institute  
109, Pen Ming Xi Road  
Wuxi, Jiangsu  
China

Dr. V. H. Chu  
Department of Civil Engineering  
McGill University  
Montreal, Quebec PQ H3A 2K6  
Canada

C. Gandolfi  
University of Milano  
Istituto di Idraulica Agraria  
Via Celoria 2  
20133 Milano  
Italy

Dr. W. H. Hager  
Laboratory of Hydraulics, Hydrology  
and Glaciology, VAW  
Swiss Federal Institute of Technology  
ETH-Zentrum  
CH 8092 Zurich  
Switzerland

Professor E. Holley  
Department of Civil Engineering  
University of Texas at Austin  
Austin, TX 78712  
USA

Dr. Midhat Hondzo  
Purdue University  
School of Civil Engineering  
West Lafayette, IN 47907-1284  
USA

Dr. A. James  
Department of Civil Engineering  
University of New Castle  
New Castle upon Tyne NE1 7RU  
UK

Andrzej K. Kraszewski  
Institute of Environmental Engineering Systems  
Warsaw University of Technology  
ul. Nowowiejska 20  
00-653 Warsaw  
Poland

Professor A. J. Mehta  
Department of Coastal and Oceanographic Engineering  
University of Florida  
Gainesville, FL 32611  
USA

Professor P. J. W. Roberts  
Department of Civil Engineering  
Georgia Institute of Technology  
Atlanta, GA 30332  
USA

Dr. P. D. Scarlatos  
Department of Ocean Engineering  
Florida Atlantic University  
Boca Raton, FL 33431  
USA

Professor V. P. Singh  
Department of Civil and Environmental Engineering  
Louisiana State University  
Baton Rouge, LA 70803-6405  
USA

Professor R. Soncini-Sessa  
Dipartimento de Elettronica  
Politecnico di Milano  
Piazza Leonardo Da Vinci 32  
I-20 133 Milano  
Italy

Professor H. G. Stefan  
University of Minnesota  
Department of Civil Engineering  
Saint Anthony Falls Hydraulic Laboratory  
Minneapolis, MN 55414-2196  
USA

Mr. X. Zhang  
Farmland Irrigation Research Institute  
Xinxiang, Henan Province  
China