PRINCIPLES OF FLUID FLOW

AND

SURFACE WAVES

IN

RIVERS, ESTUARIES, SEAS AND OCEANS

(Edition 2011)

Leo C. van Rijn

Universiteit Utrecht

Physical Geography

Deltares

Enabling Delta Life

Other publications:

Principles of Sediment Transport in Rivers, Estuaries and Coastal Seas by Leo C. van Rijn, 1993 and 2006 (update)

Principles of Coastal Morphology, by Leo C. van Rijn, 1998

Principles of Sedimentation and Erosion Engineering in Rivers, Estuaries and Coastal Seas by Leo C. van Rijn, 2005

Manual Sediment Transport Measurements in Rivers, Estuaries and Coastal Seas by Leo C. van Rijn, 2007 (update)

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Yangtze river, China
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Ocean wave, Hawaii

FOR THOSE WHO LIKE WATER

PRINCIPLES OF FLUID FLOW AND SURFACE WAVES IN RIVERS, ESTUARIES, SEAS AND OCEANS

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PREFACE 1

This book reflects a one-year lecture course of fluid flow and surface waves for physical geographers of the University of Utrecht in The Netherlands. The book deals essentially with the basic principles of fluid mechanics in rivers, estuaries, seas and oceans.

The early Chapters 2, 3 and 4 cover the field of fluid properties, hydrostatics and kinematics. Chapter 5 on fluid dynamics describes the momentum equations of Euler, Bernoulli, Navier-Stokes and finally Reynolds, who introduced a time-averaging method to deal with turbulent flow. Chapter 6 deals with steady uniform flow in rivers. Phenomena like subcritical and supercritical flow, smooth and rough flow, boundary layer flow and flow resistance are explained. Work and power related to fluid dynamics are also explained.
Chapter 7 presents steady non-uniform flow in rivers giving information of potential flow, gradually varied and rapidly varied flow, curved flow and flow-induced forces (drag and lift).
The last two Chapters 8 and 9 deal with non-steady flow related to long and short surface waves.
Long wave phenomena like progressive waves, standing waves, translation waves, river flood waves, tidal waves, density-induced-waves and storm surge waves are described in detail.
Basic short wave properties are presented in Chapter 9. Phenomena like shoaling, refraction, diffraction and breaking are explained. Phenomena of the wave boundary layer and its effect on a current are also presented. The generation of longshore currents inside the surf zone is described. Finally, random waves are explained. The book ends with Appendices on basic formulae, mathematics, turbulence, methods to solve the flow equations and model scaling laws.

Basic knowledge of mathematics (especially differential equations) is required to understand the derivation of the equations of continuity and motion which appear throughout the text. To fresh up the readers memory, the most essential information of mathematics with respect to fluid mechanics is presented in Appendix B.

The book has been written with a view to sediment transport and morphology. Both fields of work are described extensively in: "Principles of Sediment Transport in Rivers, Estuaries and Coastal Seas" and "Principles of Coastal Morphology".

The author hopes that the present book will serve as a useful tool for scientists, engineers and students in civil engineering, earth sciences, physical geography and oceanography.

Professor Leo C. van Rijn, 1993, 2011

PREFACE 2

In his long career as a researcher, Professor Leo van Rijn has given a major boost to sediment transport research. The transport formulae he derived are used all over de world and many researchers and professionals are familiar with his books on coastal sediment transport and morphology. Moreover, he has led a number of landmark research programs, national as well as international, with sediment transport as a common denominator.

On top of this, he has tested his knowledge and trained a large number of young colleagues in a wide range of practical application projects, all with a sediment transport component. He has done this first under the umbrella of WL|Delft Hydraulics, and after the merger of WL into Deltares in 2008 under the umbrella of Deltares. Many clients have profited from his sometimes unconventional views and insights.

But this is not his only career. He also serves since many years as a professor at Utrecht University, training generations of students in Physical Geography with his courses and exercises in hydrodynamics and sediment transport. Without exaggerating, one may claim that he has brought these courses and exercises to a substantially higher level.

Now that he is about to retire, Leo has found the time for an extensive write-up of his course material on coastal hydrodynamics, enriched with many insights he has gathered over the years. The result is this impressive book, which in my opinion is a must for every researcher in coastal dynamics. It gives an almost complete overview of the aspects of hydrodynamics that are necessary to understand coastal dynamics.

Thorough knowledge of the water motion due to waves and currents on a coast, including their complex interactions, is indispensable to understand how a coast behaves. This knowledge ranges from classical textbook material through to state-of-the-art research results.

Maybe the greatest value of this book lies in the fact that it covers this entire range. This makes it a goldmine to people entering this fascinating field, be it students or young professionals, and an invaluable reference to the more experienced. I congratulate Leo with this laudable initiative. Deltares is proud to have had him among its staff and happy to have been able to support the production of this book.

Professor Huib de Vriend

Director Science Deltares, Delft, The Netherlands, 2011

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Ocean tides are periodic rises and falls in the level of the sea, and are formed by the gravitational attraction of the Moon and Sun on the water in the ocean. Although the Moon is much smaller than the Sun, it has a greater gravitational attraction for the Earth because the Moon is much closer to Earth.Â Lunar Tides. Water responds to the Moon's gravitational force by flowing toward it, making a bulge on the surface of the ocean. On the side of Earth facing the Moon, gravitational force is applied to water particles toward the Moon.Â This type of constructive interference can also occur as tides flow into an estuary against an outflowing current. Standing waves, termed tidal bores, will form and progress upstream at heights of several feet. Principles of Fluid Flow and Surface Waves in Rivers, Estuaries, Seas and Oceans consists of 881 pages and figures and contains all details of fluid mechanics in rivers, estuaries, seas and oceans. Principles of Fluid Flow and Surface Waves in Rivers, Estuaries, Seas and Oceans can be used as a basic text book for students and as a practical reference book for graduates in civil engineering, earth sciences, physical geography and oceanography.Â 1. introduction 2. fluid properties 3. fluid statics 4. fluid kinematics 5. fluid dynamics 6. steady uniform flow 7. steady non-uniform flow 8. non-steady flow: long free surface waves 9. non-steady flow: short free surface waves. Principles of fluid flow and surface waves in rivers, estuaries, seas and oceans. List of contents. 1. introduction.Â The book deals essentially with the basic principles of fluid mechanics in rivers, estuaries, seas and oceans. The early Chapters 2, 3 and 4 cover the field of fluid properties, hydrostatics and kinematics. Chapter 5 on fluid dynamics describes the momentum equations of Euler, Bernoulli, Navier-Stokes and finally Reynolds, who introduced a time-averaging method to deal with turbulent flow. Chapter 6 deals with steady uniform flow in rivers. Phenomena like subcritical and supercritical flow, smooth and rough flow, boundary layer flow and flow resistance are explained. Work and power related to fluid Subjects. Fluid mechanics, Hydrodynamics, Rivers. There's no description for this book yet. Can you add one? Edition Notes. Includes bibliographical references. Waves. Ocean Literacy Principles: OLP 1: The earth has one big ocean with many features. OLP 1.C.Â Water waves are generally caused by winds, and they can transfer energy over long distances across ocean basins. Activities: Activity: Watching Waves.Â Further Investigations: Circulation in Marginal Seas and Estuaries. Atmospheric Effects. Introduction to Atmospheric Effects.