PRINCIPLES OF SEDIMENT TRANSPORT

IN

RIVERS, ESTUARIES AND COASTAL SEAS

PART I: Edition 1993

by

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WL | delft hydraulics

Other publications:

Principles of Fluid Flow and Surface Waves in Rivers, Estuaries, Seas and Oceans by Leo C. van Rijn, 1990

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 of Sediment Transport Measurements (update 2006) by Leo C. van Rijn, 2006

Aqua Publications
The Netherlands
(WWW.AQUAPUBLICATIONS.NL)

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AQUA PUBLICATIONS

Published in The Netherlands
Bound Edition 1993
Paperback Edition 2002
Loose leaf Edition 2005
CD-ROM 2006

Aqua Publications
The Netherlands
(WWW.AQUAPUBLICATIONS.NL)

CIP-DATA KONINKLIJKE BIBLIOTHEEK, DEN HAAG, THE NETHERLANDS

Rijn, Leo C. van

Principles of sediment transport in rivers, estuaries and coastal seas / Leo C. van Rijn - Amsterdam: Aqua Publications - I11.
with ref.
ISBN 90-800356-2-9 bound
NUGI 816/831

Subject headings: Sediment transport and fluid mechanics

For those who like sediments

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PREFACE

This book reflects the results of basic research and practical experience in sediment transport and morphology in rivers, estuaries and coastal seas all over the world during a period of about 15 years.
The purpose of this book is to give a unified view of sediment (sand and mud) transport over a wide range of conditions; from quasi-steady river flow to the violent wave-breaking processes in the surf zone of coastal seas. It was not the intention of the author to give a complete overview of the overwhelming amount of literature available. On the contrary, the emphasis is laid on the description and the application of those theories and formulae which have proven to give realistic results based on the authors experience.
The application of refined theories consisting of many complicated equations is often not justified, given the uncertainties of the input data like current velocity, wave height, bed material composition, bed forms and roughness. An elegant way to overcome this problem is to represent the refined model by a much more simple parameter model or computer data base model.

Chapter 2 presents an overview of the near-bed fluid velocities and shear stresses, both being the driving agents of the sediment particle motions. The current boundary layer as well as the wave boundary layer are discussed. Basic wave properties are presented. Mass transport by non-breaking and breaking waves is summarized.

Chapter 3 covers the fluid and sediment properties like density, porosity, shape, size and settling characteristics of the sediment particles.

Chapter 4 presents the processes of initiation of motion and suspension in terms of the critical velocities and bed-shear stresses. Special attention is given to the design of stable channels which is an important aspect of irrigation projects.

Chapter 5 covers the characteristics of bed forms generated by currents alone, by waves and by combined currents and waves. Bed form classification diagrams are given and the shape and dimensions of the bed forms are discussed.

Chapter 6 presents information of the effective (grain and form) roughness of a sediment bed. Methods based on bed-form parameters as well as methods based on integral parameters (velocity, depth, sediment size) are discussed.

Chapter 7 deals with bed load and suspended load transport in steady flow. Both deterministic and stochastic approaches are discussed. The classical diffusion theory is used to describe the distribution of the sediment concentrations over the depth. Special attention is given to stratification effects of high-concentration suspensions.

The Chapters 8 and 9 cover the field of sediment transport by waves and by combined currents and waves. The various transport processes related to breaking and non-breaking waves are identified; high-frequency and low-frequency phenomena are discussed. Emphasis is put on data analyis of concentrations and transport rates measured in flumes, tunnels and in nature.

Chapter 10 is related to the transport of sediments in non-steady and non-uniform conditions. The basic principles of erosion and deposition of sediment particles are presented.

Chapter 11 presents detailed information of the transport of cohesive sediment materials (mud). Basic phenomena like cohesion, flocculation, settling, deposition, consolidation and erosion which take place in a continuous cycle, are discussed.

Chapter 12 deals with the mathematical modelling of sediment transport and morphology. Three-, two- and one-dimensional models of flow, waves, sediment transport and morphology are presented.

Sediment transport cannot be studied without proper knowledge of measuring instruments. The accuracy of the data is strongly related to the type of instrument applied. Chapter 13 presents a detailed overview of the available measuring principles, statistics, methods and instruments. Simple mechanical and sophisticated optical, acoustical and nuclear instruments are discussed.

The book ends with four appendices. Appendix A presents the TRANSPOR-program (available on CD-ROM) which is the sediment transport model of the author. Appendix B deals with sand transport in closed conduits (pipelines). Appendix C presents a method to eliminate side wall roughness which is necessary for narrow flumes and channels. Appendix D is related to pollution aspects of sediments.

Many calculation examples of available methods and formulae are presented throughout the book, which may help the reader to find a way through the many available equations. A CD-ROM (TRANSPOR1993-program) for computing sediment concentrations, transport rates and bed-form dimensions in a current alone and in combined currents and waves is available to help the reader to solve practical problems.

The present book has been written with a view to morphology of sediment beds. This latter field of work will be described in a forthcoming book: "Principles of Morphology in Rivers, Estuaries and Coastal Seas".

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

Leo C. van Rijn
Oldemarkt
January 1993

ACKNOWLEDGEMENTS

The author wishes to acknowledge Delft Hydraulics and the Department of Physical Geography of the University of Utrecht for the typing and the editing of the manuscript.
I am grateful to the discussions and comments of all my national and international colleagues, without whom this book could never have been written.
I am also grateful to the following copyright holders for permission to reproduce figures: Delft Hydraulics, American Society of Civil Engineers, North-Holland Publishing Company, U.S. Geological Survey, Nedeco, D and A Instruments USA.

ERRATA 1

Page	Line	Subject
2.5	**Line 19**	The current-related bed-shear stress can also be expressed as: $\tau'_{b,c}=(1/8)\rho f'_c(u_{mean})^2=0.5\ \rho\ (0.25f'_c)(u_{mean})^2$ using: $u_a=[\ln(30a/k_c)/(-1+\ln(30h/k_c))]u_{mean}$ with u_a=velocity at reference level (a) above the bed, it follows that: $\tau'_{b,c}=0.5\ \rho\ (0.25f'_c)\ [(-1+\ln(30h/k_c))/\ln(30a/k_c)]^2(u_a)^2$ $f'_{c,effective}=0.25\ f'_c\ [(-1+\ln(30h/k_c))/\ln(30a/k_c)]^2$ The bed-shear stress can also be determined from: $u_a=(u_*/\kappa)\ln(30a/k_c)$ or $\tau_{b,c}=0.5\ \rho\ (2\kappa^2)[\ln(30a/k_c)]^{-2}\ (u_a)^2$ and $\tau'_{b,c}=\mu\tau_{b,c}=0.5\ (f'_c/f_c)\ \rho\ (2\kappa^2)[\ln(30a/k_c)]^{-2}\ (u_a)^2$ This latter equation can also be expressed as: $\tau'_{b,c}=0.5\ \rho\ (0.25f'_c)\ [(-0.92+\ln(30h/k_c))/\ln(30a/k_c)]^2(u_a)^2$; which is almost equal to: $\tau'_{b,c}=0.5\ \rho\ (0.25f'_c)\ [(-1+\ln(30h/k_c))/\ln(30a/k_c)]^2(u_a)^2$

ERRATA 2

Page	Line	Subject
2.45	Line 5	$k_{a,max}$=10k_a
2.45	Line 19	*insert after* $\tau_{b,cw}$*-values*: according to Equation (2.4.26) and Equation (2.4.27)
2.47	Figure 2.4.13	$\tau_{b,cw}$ refers to flow resistance experienced by the current (Eqs. 2.4.26 and 2.4.27)
3.13	Line 10	Equation (3.2.22) was first proposed by Zanke (1977)
4.5	Figure 4.1.3	$Re_*=u_{*,cr}\ d/\nu$
4.7	Figure 4.1.5	Initiation
4.14	Line 24	Equation (4.1.32) only valid for a flat bed
4.23	Line 8	1.45 should read as 1.42
4.30	Line 4	$1.06\ 10^{-4}(\tau_{b,c})^{0.5}$ should read as $1.06\ 10^{-4}/(\tau_{b,c})^{0.5}$
4.30	Line 13	T should read as T_r
5.28	Line 7	q_b in m^2/s; T_d in seconds
5.28	Line 15	β should read as γ
5.44	Line 5,6,7	$u_{*,c}$ should read as $u'_{*,c}$
5.45	Figure 5.5.1	Vertical axis: current-related in stead of wave-related
5.46	Line 17	wave-induced should read as current-induced
5.47	Table 5.3	Maga should read as Mega
5.51	Line 10	Fig. 5.4.6 should read as Fig. 5.5.1
5.51	Line 13	0.306 m should read as 0.306 m/s
5.51	Line 17	0.00194 should read as 0.0194
5.51	Line 23	2D should read as 3D; Fig. 5.4.6 should read as Fig. 5.5.1
5.51	Line 24	Fig. 5.4.7 should read as Fig. 5.5.2
5.52	Line 3	*insert after velocities:* (parallel to the coast)
5.52	Line 4	*insert after wave height:* (normal to the coast)
5.52	Line 6	*insert:* What type of bed forms are present? What are the bed form dimensions?
6.20	Line 6	$(\rho_s-\rho)$
6.20	Line 14	peak wave -related
6.22	Line 1,2,3,4 from bottom	$k_{s,w}$ should read as $k''_{s,w}$
6.24	Line 10 from bottom	d_{50}=1000 μm should read as d_{90}=1000 μm
6.25	Line 3	Eq.(2.4.29) and Eq.(2.4.30)

ERRATA 3

Page	Line	Subject
7.33	Line 15	$\varepsilon=(1+\alpha\mu)\mu$
7.62	Line 10	$\theta-\theta_{cr}$ should read as $\theta^{/}-\theta_{cr}$
7.67	Equation (7.3.32)	only valid for $\sigma_s<2.5$
7.95	Line 7	$10^{-3.46+2.79(\log D^*)-0.98(\log D^*)2}$; last term of exponent to power 2
7.96	Line 1	80% should read as 75%
7.99	Table 7.12	*Last column:* 0.004 should read as 0.001
7.102	Table 7.14	*Last column:* 12.4 should read as 19.3 1.8 should read as 4.2 0.12 should read as 0.48 0.03 should read as 0.15 0.003 should read as 0.03
8.4	Line 16	C_S should read as C_L; U_L and C_S are also not correlated
8.11	Line 13	Wright et al. (1991) should read as Wright et al. (1992)
8.59	Line 6 from bottom	The sediment transport in the onshore (or offshore) period of the oscillatory flow (q_w) ...
8.60	Line 18	$q_{w,half}$=time-averaged transport rate over a half cycle (onshore or offshore period); $q_{w,net}=(T_{on}\, q_{w,on}+ T_{off}\, q_{w,off})/T$; T_{on} can be computed as: $T_{on}=(U_{off}/(U_{on}+U_{off}))T$
8.60	Line 13 from bottom	$\hat{U}_\delta$= Peak value of near-bed orbital velocity ($\hat{U}_{\delta,on}$ or $\hat{U}_{\delta,off}$)
8.61	Line 11	f_w=fricton factor based on particle diameter or sheet flow layer thickness (about 0.01 m)
8.61	Line 12	$\tan\beta$ is positive for upsloping bottom in x-direction
8.62	Line 2	$q_{w,half}$=time-averaged transport rate over a half cycle (onshore or offshore period); $q_{w,net}=(T_{on}\, q_{w,on}+ T_{off}\, q_{w,off})/T$; T_{on} can be computed as: $T_{on}=(U_{off}/(U_{on}+U_{off}))T$
8.64	Line 2	$q_{w,half}$=time-averaged transport rate over a half cycle (onshore or offshore period); $q_{w,net}=(T_{on}\, q_{w,on}+ T_{off}\, q_{w,off})/T$; T_{on} can be computed as: $T_{on}=(U_{off}/(U_{on}+U_{off}))T$
8.64	Line 24	$T\geq15$ s should read as $T\geq12$ s
8.68	Line 7 from bottom	2.7 should read as 2.
8.69	Line 2 from bottom	T=7 s should read as T=12 s
8.70	Line 7	$f_{w,on}$ should read as $f^{/}_{w,on}$; $f_{w,off}$ should read as $f^{/}_{w,off}$
8.70	Line 11	assuming $T_{on}=T_{off}=0.5$ T
10.18	Line 2, 4 from bottom	T in hours
10.19	Line 4	specific
10.19	Line 10, Equation 10.3.10	$\alpha=1+3r_o$ and r_o=turbulence-related coefficient (0.15 for uniform flow)
11.15	Line 18	**11.5.2 Concentrations larger than 10 kg/m^3 (hindered settling range)**
11.15	Line 6 from bottom	**11.5.3 Concentrations from 0.3 to 10 kg/m^3 (flocculation range)**
11.34	Line 9	SAR=Sodium Absorption Range;CEC=Cation Exchange Range
A-2	Line 1 from below	exponent should read as -0.25
A-4	Line 7	exponent 0.5 (in bed-shear stress current) should be removed

In general, sediment particles considered in transport of sediment cycle, consist of non-cohesive and cohesive sediment types (Fig. 1a). (a) Sediments of particle size d50< 4 Âµm, mud or clay, are classified as a cohesive sediments.Â The sediment in the Northern Adriatic Sea is mainly formed by sand with grain size varying from 50 to 2000 Î¼m, and silt with grain size between 2 and 50 Î¼m.Â The Yangtze River or Changjiang River in China, and the indication of the navigation channel used for the trades of Shanghai Port [source: 44]. Coastal sediment transport (a subset of sediment transport) is the interaction of coastal land forms to various complex interactions of physical processes. The primary agent in coastal sediment transport is wave activity (see Wind wave), followed by tides and storm surge (see Tide and Storm surge), and near shore currents (see Sea#Currents) . Wind-generated waves play a key role in the transfer of energy from the open ocean to the coastlines. In addition to the physical processes acting upon the shore 3 PRINCIPLES OF SEDIMENT TRANSPORT IN RIVERS, ESTUARIES AND COASTAL SEAS PART I: Edition 1993 Leo C. van Rijn Professor Fluid Mechanics and Sediment Transport University of Utrecht, The Netherlands Senior Hydraulic Engineer, Delft Hydraulics Delft, The Netherlands AQUA PUBLICATIONS C.3. 4 Published in The Netherlands Bound Edition 1993 Paperback Edition 2002 Loose leaf Edition 2005 CD-ROM 2006 Aqua Publications The Netherlands (CIP-DATA KONINKLIJKE BIBLIOTHEEK, DEN HAAG, THE NETHERLANDS Rijn, Leo C. van Principles of sediment transport in rivers, estuaries and coastal seas / Leo C. van Rijn - This article introduces the Manual Sediment Transport Measurements in Rivers, Estauries and Coastal Seas (Van Rijn, 1986; 2007). The Manual Sediment Transport Measurements in Rivers, Estauries and Coastal Seas is a volume of about 500 pages containing all details of measurement instruments and methods for mud, silt and sand transport in rivers, estuaries and coastal seas. The manual includes: definitions and measuring principles and errors involved, methods to compute sediment transport from measured Start by marking â€œPrinciples Of Sediment Transport In Rivers, Estuaries And Coastal Seasâ€ as Want to Read: Want to Read savingâ€¦ Want to Read. Currently Reading. Read. Principles Of Sediment by Leo C. van Rijn. Other editions. Want to Read savingâ€¦Â Let us know whatâ€™s wrong with this preview of Principles Of Sediment Transport In Rivers, Estuaries And Coastal Seas by Leo C. van Rijn. Problem: Itâ€™s the wrong book Itâ€™s the wrong edition Other.Â To ask other readers questions about Principles Of Sediment Transport In Rivers, Estuaries And Coastal Seas, please sign up. Be the first to ask a question about Principles Of Sediment Transport In Rivers, Estuaries And Coastal Seas. Lists with This Book. This book is not yet featured on Listopia.