

Principles of River Engineering

The non-tidal alluvial river

Editorial Board

P Ph Jansen,
NEDECO, Netherlands Engineering Consultants (Chief Editor)

L van Bendegom,
Delft University of Technology

J van den Berg,
NEDECO

M de Vries,
Delft Hydraulics Laboratory

A Zanen,
Rijkswaterstaat



Pitman

LONDON · SAN FRANCISCO · MELBOURNE

Contents

Contributors	v
Preface	xi
List of symbols	xiii
Part 1 Introductory matters	
1 Introduction	3
2 River characteristics	8
2.1 The channel	8
2.2 The catchment area	10
2.3 Rainfall—runoff	12
2.4 Sediment yield	14
3 Use of rivers	20
3.1 Introduction	20
3.2 Navigation	21
3.3 Hydropower	24
3.4 Water supply	26
3.5 Irrigation	29
3.6 Planning, legislation	31
Part 2 River Hydraulics	
1 Introduction	37
2 Water-movement	38
2.1 General	38
2.1.1 Introduction	38
2.1.2 Basic equations	39
2.1.3 Integration over a cross-section	41
2.2 Steady flow	44
2.2.1 Turbulence and velocity profiles	44
2.2.2 Resistance coefficients	46
2.2.3 Practical considerations	50
2.2.4 Non-uniform flow	52
2.2.5 Classification of backwater curves	54
2.2.6 Transitions	55
2.2.7 Rating curve	56
2.2.8 River bends	59
2.2.9 Secondary flow	63
2.3 Non-steady flow	64
2.3.1 Propagation of surface waves	64
2.3.2 Characteristics	66
2.3.3 Regions of influence and dependence	67
2.3.4 Distortion of waves	68
2.3.5 Flood waves: kinematic approach	69
2.3.6 Flood waves: diffusion analogy	70
2.3.7 Velocity of propagation of flood waves	71
2.3.8 Classification and comparison	71
2.3.9 Flood wave maxima	73
2.3.10 Rating curve	75
2.3.11 Linear approximations	77
2.3.12 Flow in flood plains	79
2.4 Dispersion of heat or dissolved matter	79
2.4.1 Transport mechanisms	79
2.4.2 Longitudinal and transverse mixing in rivers	79
2.4.3 Time required for vertical or lateral mixing	82
3 Sediment transport	83
3.1 General	83
3.1.1 Introduction	83
3.1.2 Sediment characteristics	83
3.1.3 Initiation of motion	87
3.1.4 Transport of sediment	90
3.2 Bedform and alluvial roughness	91
3.2.1 Introduction	91
3.2.2 Propagation of disturbances	93
3.2.3 Theoretical bedforms	96
3.2.4 Bedform characteristics	100
3.2.5 Alluvial roughness	103
3.3 Transport formulae	109
3.3.1 Introduction	109
3.3.2 Transport mechanism	109
3.3.3 Transport formulae	114
3.3.4 Application of transport formulae	118
3.4 Non-steady aspects	121
3.4.1 Introduction	121
3.4.2 Analytical approaches	122
3.4.3 Morphological time-scale	123
3.4.4 Approach for predominant suspended load	125
3.4.5 Dominant discharge	128
4 River morphology	130
4.1 Introduction	130

4.2	Planform	132	3.3.2	Automatic data recording	177
4.2.1	General	132	3.3.3	Data recording systems	177
4.2.2	Meandering rivers	133	3.4	Data processing	178
4.3	Longitudinal profile	140	3.5	Accuracy	181
4.4	River bends	141	4	Bed levels	183
4.4.1	General	141	4.1	General	183
4.4.2	Deterministic approach	141	4.2	Set-up of measurements	183
4.4.3	Stochastic approach	143	4.2.1	Sounding systems	183
4.5	Channel characteristics	144	4.2.2	Determination of the location of sounded points	184
4.6	Bifurcations and confluences	145	4.2.3	Determination of water level	186
4.6.1	General	145	4.2.4	Sounding	186
4.6.2	Examples of bifurcations	146	4.3	Instruments	186
4.6.3	Example of confluence	147	4.3.1	Optical and electronic instruments for determination of location	186
5	Quality of river water	151	4.3.2	Sounding instruments	190
5.1	Introduction	151	4.4	Data processing	192
5.2	Biology of stream life	151	4.5	Accuracy	193
5.2.1	General	151	5	Discharges	198
5.2.2	Stream flora and stream fauna	151	5.1	General	198
5.2.3	Aquatic food cycle	152	5.2	Instruments	199
5.2.4	Oligotrophy and eutrophy	154	5.2.1	Floats	199
5.3	Sources of pollution	155	5.2.2	Pendulum current meter	200
5.3.1	General	155	5.2.3	Cup- and propeller-type current meters	201
5.3.2	Domestic sewage	155	5.3	Methods of determination of discharge	203
5.3.3	Urban runoff	156	5.3.1	Velocity-area method	203
5.3.4	Bacteria and viruses	157	5.3.2	Moving-boat method	206
5.3.5	Industrial wastewaters	157	5.3.3	Slope-area method	208
5.3.6	Agricultural runoff	158	5.3.4	Dilution methods	209
5.3.7	Oil	158	5.4	Statistical evaluation of data on discharges	210
5.4	Oxygen balance	159	6	Stage-discharge relationship	215
5.4.1	General	159	6.1	General	215
5.4.2	Dissolved oxygen	159	6.2	Determination of the rating curve	215
5.4.3	Absorption of atmospheric oxygen	160	6.3	Accuracy	216
5.4.4	Photosynthesis	161	6.4	Correction of rating curves at confluences and bifurcations	218
5.4.5	Carbonaceous oxygen uptake	161	7	Sediments	219
5.4.6	Nitrification	161	7.1	General	219
5.4.7	Benthic oxygen demand	162	7.2	Bed material sampling	220
5.4.8	Plant respiration	163	7.2.1	General	220
			7.2.2	Set-up of measurements	220
			7.2.3	Instruments	221
			7.2.4	Data processing	225
			7.2.5	Accuracy	225
			7.3	Bed load measurement	225
			7.3.1	General	225
			7.3.2	Set-up of measurements	225
			7.3.3	Instruments	226
			7.3.4	Calibration and accuracy	229
			7.4	Suspended load measurement	231
			7.4.1	General	231
			7.4.2	Instruments	232
			7.4.3	Data processing	234
			7.4.4	Accuracy	234
			7.5	Tracer methods	234
			7.5.1	Principle of tracer methods	234
Part 3 River Survey					
1	Introduction: aims and framework of river surveys	167			
2	Mapping	169			
2.1	General	169			
2.2	Principles of aerial photography	169			
2.3	Maps	170			
2.3.1	Types of maps	170			
2.3.2	Scale of maps and accuracy	173			
2.4	Interpretation of aerial photographs	173			
3	Water levels	174			
3.1	General	174			
3.2	Set-up of measurements	174			
3.2.1	Selection of gauge sites and site requirements	174			
3.2.2	Selection of gauge type	175			
3.3	Instruments	175			
3.3.1	Types of gauges	175			

7.5.2	Types of tracers	235	2.4.6	Boundary conditions	292
7.5.3	Technical requirements for tracer methods	235	2.4.7	Example	294
7.5.4	Fluorescent tracers	236	2.5	Water quality	295
7.5.5	Radioactive tracers	237	2.5.1	General	295
7.5.6	Interpretation	238	2.5.2	Two-dimensional spreading	296
8	Water quality	243	2.5.3	One-dimensional spreading: analytical approach	297
8.1	General	243	2.5.4	One-dimensional spreading: numerical aspects	299
8.2	Sampling	243	2.5.5	Multiconstituent systems in one dimension	300
8.3	Monitoring	244	2.5.6	Example of an ecological model	302
8.4	Biological observations	244			
Part 4 River Models					
1	Introduction	249	3	Scale models	305
2	Mathematical models	250	3.1	Introduction	305
2.1	General considerations	250	3.2	Fixed bed models	307
2.1.1	The concept of a mathematical model	250	3.3	Mobile bed models	310
2.1.2	Choice of model	250	3.3.1	General	310
2.1.3	Classification	251	3.3.2	Principles of scaling	310
2.1.4	Model operation	252	3.3.3	Tilted models	311
2.2	Steady flow over a quasi-steady river bed	253	3.4	Models of hydraulic structures	312
2.2.1	Backwater curve: analytical method	253	3.4.1	General	312
2.2.2	Backwater curve: graphical method	254	3.4.2	Elastic similarity	313
2.2.3	Backwater curve: numerical method	254	3.5	Examples of scale models	314
2.2.4	Discussion and practical aspects	255	3.5.1	General	314
2.2.5	Numerical aspects of backwater computations	257	3.5.2	Mobile bed models	315
2.2.6	Networks and two-dimensional flow	259	3.5.3	Fixed bed models	318
2.3	Non-steady flow over a quasi-steady river bed	262	3.5.4	Hydraulic structures	319
2.3.1	Kinematic waves	262			
2.3.2	Numerical solution: consistency, stability and convergence	263	Part 5 River engineering		
2.3.3	Examples: explicit and implicit methods	265	1	Introduction	325
2.3.4	Diffusion analogy	267	2	Bed regulation	327
2.3.5	Diffusion equation: numerical aspects	269	2.1	River improvements with temporary effect	327
2.3.6	Dynamic equations	270	2.1.1	General	327
2.3.7	Dynamic equations: numerical aspects	272	2.1.2	Dredging in river crossings	329
2.3.8	Accuracy of wave propagation	274	2.1.3	Temporary regulation structures	332
2.3.9	Comparison of diffusion analogy with dynamic equations	276	2.2	Bed level modifications in the low-water bed	335
2.3.10	Practical aspects	278	2.2.1	Fixation of the bed	335
2.3.11	Flow in two dimensions	280	2.2.2	Elimination of obstacles from the low-water bed	338
2.3.12	Translatory waves	284	2.3	Channel regulation	339
2.4	Flow over a mobile river bed	287	2.3.1	Channel rectification and fixation	339
2.4.1	Steady flow	287	2.3.2	Channel constriction	349
2.4.2	Non-steady flow: formulation	289	2.4	Permanent regulation structures	353
2.4.3	Solution by the method of characteristics	290	2.4.1	Introduction	353
2.4.4	Solution by the finite-difference method	291	2.4.2	Types and shapes	353
2.4.5	Numerical aspects	292	2.4.3	Dimensions and levels	357
			2.4.4	Construction	359
			2.5	Engineering in the flood plain	363
			2.5.1	General	363
			2.5.2	Aims and means	364
			2.5.3	Aspects related to the use of the flood plain	369
			3	Discharge control	370
			3.1	Principles	370
			3.2	Reservoir operation	371
			3.3	Morphological consequences	375

4	Water level control	378			
4.1	Aim and applications	378			
4.2	Fixed weirs	378			
4.3	Adjustable weirs	382			
4.4	Details of structural nature	385			
5	Water quality control	388			
5.1	General	388			
5.2	Stream standards	388			
5.2.1	Public water supply	388			
5.2.2	Industrial water supply	390			
5.2.3	Agriculture	390			
5.2.4	Aquatic life	390			
5.2.5	Recreation and aesthetic use	391			
5.3	Land-based quality control	391			
5.3.1	Wastewater	391			
5.3.2	Urban runoff	391			
5.3.3	Agricultural spills	392			
5.4	In-stream quality control	392			
5.4.1	Direct treatment	392			
5.4.2	In-stream aeration	392			
5.4.3	Collection of oil	393			
6	River engineering for various purposes	394			
6.1	Flood control and drainage of the flood plain	394			
6.1.1	Introduction	394			
6.1.2	Flood control by levees	395			
6.1.3	Retarded flood-plain storage	398			
6.1.4	Storage of flood volume in reservoirs	401			
6.1.5	Diversion of flood water	407			
6.1.6	Increase of discharge capacity	410			
6.1.7	Choice and justification of flood control works	412			
6.1.8	Drainage of the flood plain	413			
6.2	Navigation	413			
6.2.1	Introduction	413			
6.2.2	Ships and navigation	414			
6.2.3	Aids to navigation	416			
6.2.4	Waterway improvement	417			
6.2.5	Transport connections	420			
6.3	Hydropower	424			
6.3.1	Introduction	424			
6.3.2	Turbines	425			
6.3.3	Electricity demand	426			
6.3.4	Planning power stations	428			
6.4	Water supply	431			
6.4.1	General	431			
6.4.2	Morphological consequences	432			
6.4.3	Local effects	440			
6.5	Waste discharge	445			
6.6	Crossings by roads, railways, pipelines, cables and canals	447			
6.6.1	Introduction	447			
6.6.2	Ferries	448			
6.6.3	Bridges	449			
6.6.4	Tunnels and pipelines	457			
6.6.5	Canal crossings	459			
6.6.6	Miscellaneous	462			
6.7	Soil conservation and the use of sediments	463			
6.7.1	Soil conservation	463			
6.7.2	The use of sediments	464			
6.8	Nature preservation and recreation	466			
6.9	Multiple-purpose projects	467			
6.9.1	Introduction	467			
6.9.2	Examples	468			
6.9.3	The Kainji reservoir project	469			
6.9.4	The canalization of the Nederrijn	472			
	List of abbreviations	479			
	Bibliography	481			
	Index	505			