

# Contents

Foreword	5
<i>Giovanni Seminara, Stefano Lanzoni, Nicoletta Tambroni</i>	
1. Introduction	7
1.1 Early interest in meandering	7
1.2 Meandering as one of the possible fluvial patterns in sedimentary environments	8
1.3 The life cycle of alluvial meanders	10
1.4 Ubiquitousness of meandering patterns in nature	14
1.5 Plan of the Monograph	19
2. Hydrodynamics of sinuous channels	21
2.1 Dimensional formulation	21
2.1.1 Curved channels	21
2.1.2 Governing equations	22
2.1.3 Closure of the governing equations	24
2.1.4 Boundary conditions	25
2.2 Dimensionless formulation	26
2.2.1 Scaling	26
2.2.2 Formulation of the hydrodynamic problem in dimensionless form	29
2.3 Classification of meander bends	33
2.4 Flow in constant curvature wide channels	35
2.4.1 Formulation for the steady state	35
2.4.2 Fully developed steady flow in mildly curved channels: free vortex effect and the role of curvature	38
2.4.3 Fully developed steady flow in mildly curved channels: the role of bed topography	44
2.5 Steady flow in weakly meandering channels	51
2.6 Sharp bends	61
2.6.1 Enhancement and saturation of the centrifugally driven secondary flow	61
2.6.2 Outer bank secondary cells	66
2.6.3 Flow separation	70

CONTENTS

2.6.4	Modeling the hydrodynamics of sharp bends	71
2.7	Modeling the hydrodynamics of natural meanders: rational approximations or empirical modeling?	73
3.	Forced bars in sinuous channels	77
3.1	Formulation of the problem of morphodynamics of sinuous channels	77
3.1.1	The motion of the solid phase in sinuous channels: dimensional formulation	77
3.1.2	The motion of the solid phase in sinuous channels: dimensionless formulation	80
3.2	Forced (point) bars in single bends of cohesionless channels with constant curvature	82
3.2.1	Fully developed point bar in mildly curved bends: linear theory	82
3.2.2	Finite amplitude fully developed point bars in mildly constant curvature bends	86
3.3	Finite amplitude morphodynamics in meandering channels	94
3.3.1	Finite amplitude bars in slowly varying meandering channels with constant width	94
3.3.2	Extension to the case of meandering channels undergoing spatial variations of channel width	100
3.4	Further approaches to the morphodynamics of sinuous channels	101
3.4.1	Laboratory observations: bed topography in movable bed meandering channels with a Kinoshita planform	101
3.4.2	Field observations: three-dimensional flow structure and bed morphology in large elongated meander loops	102
3.4.3	Coupled hydro-morphodynamic simulations at the meander reach scale	103
3.4.4	Field observations through remote sensing	103
4.	The theory of river meanders	107
4.1	Introduction	107
4.2	Depth averaged model of meander morphodynamics	108
4.3	Resonance in meandering channels	112
4.3.1	Linear theory and the resonance mechanism	112
4.3.2	Weakly nonlinear theory of near resonant meanders	116
4.3.3	The nonlinear response far from resonance	120
4.4	Morphodynamic influence	121
4.4.1	What influence?	121
4.4.2	The exact solution of the linear problem of meander morphodynamics	123
4.4.3	Testing linear predictions in the sub-resonant case: downstream influence	128
4.4.4	Testing linear predictions in the super-resonant case: upstream influence	129
4.4.5	Morphodynamic regime in the field	132

4.5	Free bar suppression in meandering channels	134
4.5.1	Experimental and field observations	134
4.5.2	Theoretical interpretation of the suppression mechanism	135
5.	Planform evolution of meandering rivers	143
5.1	Bank erosion and migration rules	143
5.2	The integro-differential equation of planform evolution	146
5.3	Meander formation: an instability process	148
5.3.1	Modern field and laboratory observations	148
5.3.2	Bend instability: linear theory	154
5.4	Nonlinear evolution from incipient meandering to neck cutoff: the origin of fattening and skewing of meander bends	159
5.4.1	Formulation	159
5.4.2	A Landau-Stuart amplitude equation for the fundamental harmonic	161
5.4.3	Can meanders of permanent form exist?	161
5.4.4	General features of the planform development of river meanders in the sub-resonant and super-resonant cases	162
5.4.5	The nature of bend instability in the nonlinear regime	165
5.5	Beyond neck cutoff: Long-term evolution	166
5.5.1	Further effects generating the complexity of meander patterns	167
5.5.2	Numerical simulations	167
5.5.3	Results of numerical simulations: sub- versus super-resonant	170
5.5.4	Effects of floodplain heterogeneity	172
5.5.5	Long-term meander evolution in the light of the modern paradigms of complexity	175
5.6	Planform evolution and meander width	185
5.6.1	The equilibrium approach: Spatial variations of channel width in meandering channels at equilibrium	185
5.6.2	The dynamic approach: Coevolution of meander width and sinuosity	190
5.7	Mechanics of chute-cutoffs	196
6.	Additional features of fluvial meandering	201
6.1	Sorting effects on fluvial meanders	201
6.2	Meanders in mixed bedrock-alluvial channels	205
6.2.1	Morphodynamics of mixed bedrock-alluvial meandering channels	205
6.2.2	How do meanders incise bedrock?	208
7.	Concluding remarks	215
8.	Mathematical Appendix	219
8.1	Forced oscillations and resonance	219

## CONTENTS

8.1.1	Toy model	219
8.1.2	Free oscillations: Temporal normal modes	219
8.1.3	Free oscillations: spatial modes	220
8.1.4	Forced oscillations: linear solution at the steady state and resonance	221
8.1.5	Forced oscillations: weakly nonlinear solution	221
8.2	Interaction between temporal free modes and forced modes	227
9.	Bibliography	233
10.	Notations	247