

# Contents

<i>Foreword</i>	page xiii
<i>Preface</i>	xv
<b>1 A View of River Basins</b>	<b>1</b>
1.1 Introduction	1
1.2 River Basin Geomorphology: A Brief Review	4
1.2.1 Ordering of the Channel Network	4
1.2.2 Drainage Density and the Hillslope Scale	7
1.2.3 Relation of Area to Length	9
1.2.4 Relation of Area to Discharge	11
1.2.5 Relation between Magnitude and Area	12
1.2.6 Stream Channel Geometry	12
1.2.7 The Width Function	15
1.2.8 The Three-Dimensional Structure of River Basins	18
1.2.9 River Basins from Digital Elevation Models	19
1.2.10 Slope-Area Scaling	26
1.2.11 Empirical Evidence	31
1.2.12 Where Do Channels Begin?	34
1.2.13 Experimental Fluvial Geomorphology	44
1.3 Statistical Models of Network Evolution	47
1.3.1 Introduction	47
1.3.2 Random-Walk Drainage Basin Models	49
1.3.3 The Random Topology Model	55
1.3.4 Limitations of Statistical Models	63
1.4 Deterministic Models of Drainage Network Development	63
1.4.1 Introduction	63
1.4.2 Models Based on Junction Angle Adjustments	64
1.4.3 Models of Erosion and the Evolution of River Networks	67
1.4.4 A Process-Response Model of Catchment and Network Development	77

1.4.5	Detachment-Limited Basin Evolution	83
1.4.6	Limitations of Deterministic Models	93
1.5	Lattice Models	95
<b>2</b>	<b>Fractal Characteristics of River Basins</b>	<b>99</b>
2.1	Introduction	99
2.1.1	Fractals and Fractal Dimensions	99
2.1.2	The Box-Counting Dimension	105
2.1.3	The Cluster Dimension or Mass Dimension	106
2.1.4	The Correlation Dimension	108
2.1.5	Self-Similarity and Power Laws	109
2.2	Self-Similarity in River Basins	110
2.3	Horton's Laws and the Fractal Structure of Drainage Networks	120
2.4	Peano's River Basin	123
2.5	Power Law Scaling in River Basins	128
2.5.1	Scaling of Slopes	129
2.5.2	Scaling of Contributing Areas, Discharge, and Energy	133
2.6	Self-Similarity of Topographic Contours	145
2.7	Self-Affinity in River Basins	145
2.7.1	Brownian Motion and Fractional Brownian Motion	146
2.7.2	Power Spectrum and Correlation Structure of Fractional Brownian Motion	149
2.7.3	Characterization of Self-Affine Records	152
2.7.4	Self-Affine Characteristics of Topographic Transects	157
2.7.5	Self-Affine Characteristics of Width Functions	160
2.7.6	Other Self-Affine Characterizations	161
2.7.7	Self-Affine Scaling of Watercourses	165
2.7.8	Self-Affine Scaling of Basin Boundaries	168
2.8	Transects, Contours, Watercourses, and Mountain Ridges as Parts of the Basin Landscape	171
2.9	Hack's Law, the Self-Affinity of Basin Boundaries, and the Power Law of Contributing Areas	174
2.9.1	Does Hack's Law Imply Elongation?	174
2.9.2	Power Law of Contributing Areas, Hack's Relationship, and the Self-Affinity of Basin Boundaries	179
2.9.3	Hack's Law and the Probability Distribution of Stream Lengths to the Divide	182
2.10	Generalized Scaling Laws for River Networks	185
2.10.1	Scaling of Areas	186
2.10.2	Scaling of Lengths	190

<b>3</b>	<b>Multifractal Characteristics of River Basins</b>	<b>196</b>
3.1	Introduction	196
3.2	Peano's Basin and the Binomial Multiplicative Process	198
3.3	Multifractal Spectra	208
3.4	Multifractal Spectra of Width Functions	220
3.5	Multiscaling and Multifractality	223
3.5.1	Other Multifractal Descriptors	228
3.6	Multifractal Topographies	232
3.6.1	Fractal versus Multifractal Descriptors	232
3.6.2	Generalized Variogram Analysis	238
3.7	Random Cascades	241
3.7.1	Canonical Random Cascades	242
3.7.2	Conservative Random Cascades and Width Functions	247
<b>4</b>	<b>Optimal Channel Networks: Minimum Energy and Fractal Structures</b>	<b>251</b>
4.1	Introduction	251
4.2	The Connectivity Issue	252
4.3	Principles of Energy Expenditure in Drainage Networks	253
4.4	Energy Expenditure and Optimal Network Configurations	254
4.5	Stationary Dendritic Patterns in a Potential Force Field	259
4.6	Scaling Implications of Optimal Energy Expenditure	263
4.7	Optimal Channel Networks	267
4.8	Geomorphologic Properties of OCNs	278
4.9	Fractal Characteristics of OCNs	279
4.10	Multifractal Characteristics of OCNs	285
4.11	Multiscaling in OCNs	287
4.12	Fractals in Nature: Least Energy Dissipation Structures?	289
4.13	On Feasible Optimality	292
4.14	OCNs, Hillslope, and Channel Processes	298
4.15	On the Interaction of Shape and Size	303
4.16	Are River Basins OCNs?	308
4.17	Hack's Relation and OCNs	313
4.18	Renormalization Groups for OCNs	316
4.19	OCNs with Open Boundary Conditions	323
4.20	Disorder-Dominated OCNs	327
4.21	Thermodynamics of OCNs	331
4.22	Space-Time Dynamics of Optimal Networks	339
4.23	Exact Solutions for Global Minima and Feasible Optimality	347

<b>5</b>	<b>Self-Organized Fractal River Networks</b>	<b>356</b>
5.1	Introduction	356
5.2	Self-Organized Criticality	358
5.3	SOC Systems in Geophysics	362
5.4	On Forest Fires, Turbulence, and Life at the Edge	366
5.5	Sandpile Models and Abelian Groups	370
5.6	Fractals and Self-Organized Criticality	377
5.7	Self-Organized Fractal Channel Networks	379
5.8	Optimality of Self-Organized River Networks	389
5.9	River Models and Temporal Fluctuations	393
5.10	Fractal SOC Landscapes	397
5.11	Renormalization Groups for SOC Landscapes	404
5.12	Thermodynamics of Fractal Networks	405
5.13	Self-Organized Networks and Feasible Optimality	410
<b>6</b>	<b>On Landscape Self-Organization</b>	<b>417</b>
6.1	Introduction	417
6.2	Slope Evolution Processes and Hillslope Models	419
6.2.1	The Effects of Nonlinearity	423
6.2.2	The Effects of a Driving Noise	425
6.3	Landscape Self-Organization	429
6.4	On Heterogeneity	436
6.5	Fractal and Multifractal Descriptors of Landscapes	444
6.6	Geomorphologic Signatures of Varying Climate	457
<b>7</b>	<b>Geomorphologic Hydrologic Response</b>	<b>466</b>
7.1	Introduction	466
7.2	Travel Time Formulation of Transport	469
7.3	Geomorphologic Unit Hydrograph	477
7.4	Travel Time Distributions in Channel Links	487
7.5	Geomorphologic Dispersion	493
7.6	Hortonian Networks	498
7.7	Width Function Formulation of the GIUH	504
7.8	Can One Gauge the Shape of a Basin?	508
7.8.1	Estimation of Basin Shape from the Width Function	509
7.8.2	Geomorphologic Hydrologic Response	511
7.9	On the Spatial Organization of Soil Moisture Fields	514
7.9.1	Introduction	514
7.9.2	The Effect of Aggregation on the Statistics of the Soil Moisture Field	518
	<i>References</i>	525
	<i>Index</i>	540