

Contents

Part I Characterization of Karst Aquifer

1	Historical Overview on Karst Research	3
	James W. LaMoreaux and Zoran Stevanović	
	References	17
2	Karst Environment and Phenomena	19
	Zoran Stevanović	
2.1	Past Karst as a Human Shelter and Mythic Understanding of Karst	19
2.2	Present—Man and Karst	21
2.3	Water and Karstic Rocks	24
2.4	Karst Classifications and Distribution	29
2.4.1	Classifications	29
2.4.2	General Distribution	33
2.4.3	Regional Distribution	34
	References	44
3	Characterization of Karst Aquifer	47
	Zoran Stevanović	
3.1	Aquifer Geometry and Elements	51
3.2	Permeability and Storativity	60
3.3	Flow Types and Pattern	74
3.4	Aquifer Recharge	82
3.4.1	Non-geological Factors of Natural Recharge	85
3.4.2	The Geological Factors Influencing Recharge	86
3.5	Aquifer Discharge	89
3.6	Quality of Karst Groundwater	111
	References	122

4	Overview of Methods Applied in Karst Hydrogeology	127
	Nico Goldscheider	
4.1	The Duality of Karst Aquifers and Investigation Methods	127
4.2	The Karst Hydrogeology Toolbox	129
4.3	Geologic and Geophysical Methods	130
4.4	Speleological Methods	134
4.5	Hydrologic and Hydraulic Methods.	135
4.6	Hydrochemical and Isotopic Methods	137
4.7	Artificial Tracer Methods	139
	References.	143
Part II Engineering Aspects of Control and Protection of Karst Aquifer		
5	Surface Waters and Groundwater in Karst	149
	Ognjen Bonacci	
5.1	Introduction	149
5.2	Catchments in Karst.	150
5.3	Karst Aquifers	153
5.4	Karst Springs	160
5.5	Karst Ponders	161
5.6	Karst Open Streamflows.	163
5.7	Piezometers as a Crucial Source of Information in Karst	166
	References.	167
6	Budget and General Assessment of Karst Groundwater Resources . . .	171
	Zoran Stevanović	
6.1	Budget Equation and Parameters	171
6.2	Classification of Groundwater Reserves	183
6.3	Assessment of Groundwater Reserves	186
6.4	Application of Groundwater Budget on Reserves Estimate.	187
6.5	Case Studies and Exercises	191
	References.	201
7	Evaluating Discharge Regimes of Karst Aquifer	205
	Peter Malík	
7.1	Discharge Regime: Definition, Typical Karstic Manifestations. . .	205
7.2	Spring Discharge Variability	208
7.3	Flow Duration Curve	213
7.4	Discharge Regime: Sub-regimes Versus Flow Components	215
7.5	Mathematical Description of Recession and Flow Components . . .	216
7.6	Identification of Flow Components in Recession Curves	220
7.7	Calculations of Flow Component Volumes	224
7.8	Hydrograph Separation into Flow Components.	227
	References.	247

8	Vulnerability to Contamination of Karst Aquifers	251
	Ana I. Marín and Bartolomé Andreo	
8.1	Introduction	252
8.2	Vulnerability Mapping	253
8.3	EPIK Method	254
8.4	PI Method.	256
8.5	COP Method.	258
8.6	Validation	261
	References.	264
9	Physical Modeling of Karst Environment	267
	Saša Milanović	
9.1	Introduction	267
9.2	Background	268
9.3	Overview and Methodology.	269
	References.	281
10	Mathematical Modeling of Karst Aquifers	283
	Alex Mikszewski and Neven Kresic	
10.1	Introduction	283
10.2	Summary of Numerical Modeling Techniques	285
	10.2.1 Equivalent Porous Media Formulation.	285
	10.2.2 Modeling for Karst, the Conduit Flow Process (CFP).	287
10.3	Case Study in Karst Modeling	290
	10.3.1 Conceptual Site Model.	290
	10.3.2 EPM Model Formulation	292
10.4	EPM Model Results	294
10.5	Integrating the Conduit Flow Process	296
	References.	298
11	Tapping of Karst Groundwater	299
	Zoran Stevanović	
11.1	Tapping Karstic Groundwater Flow at Discharge Points—Springs	300
11.2	Tapping Karstic Groundwater Flow Within the Aquifer Catchment—Drilled Wells	308
	11.2.1 Drilling Technology	310
	11.2.2 Well Equipment (Casing, Screening, Gravel Packing, Protecting Well Cap)	313
	11.2.3 Well Development	317
	11.2.4 Well Testing (Pumping)	318
	11.2.5 Optimizing Yield, Install Pump, and Protect Well	320
	References.	334

12	Monitoring of Karst Groundwater	335
	Saša Milanović and Ljiljana Vasić	
12.1	Introduction	335
12.2	Location of Monitoring	337
12.3	Type of Monitoring	338
	12.3.1 Quantity	338
	12.3.2 Quality	339
12.4	Equipment Used for Monitoring	339
	12.4.1 Mechanical Devices	339
	12.4.2 Semiautomatic–Automatic	341
	12.4.3 Digital Devices	341
	12.4.4 Equipment for Water Quality Analysis	342
	12.4.5 Equipment for Pumping Tests	342
	12.4.6 Equipment for Groundwater Level Measurement	343
	12.4.7 Intervals of Monitoring	345
12.5	Monitoring Database	345
12.6	Monitoring Network Range	347
	References	358
13	Catalog of Engineering Works in Karst and Their Effects	361
	Petar Milanović	
13.1	Introduction	361
13.2	Building Dams and Reservoirs in Karst	362
13.3	Underground Dams	387
13.4	Tunneling in Karst	389
13.5	Lessons Learned and Recommended Approach	393
13.6	Explanation of Some Specific Terms	395
	References	396
Part III Regulating and Protecting Karst Aquifer—Case Studies		
14	Managing Karst Aquifers—Conceptualizations, Solutions, Impacts . . .	403
	Zoran Stevanović	
14.1	Introduction	403
14.2	Problem Definition and Research Procedure	404
14.3	Kinds of Hydrogeological Surveys	405
14.4	Conceptual Model and Solutions	407
14.5	Environmental Implications of the Engineering Works in Karst . . .	411
14.6	Environmentally Safe Groundwater Extraction and Indicators . . .	415
14.7	Conflicts from Karst Water Utilization	417
	References	418

15	Karst Groundwater Availability and Sustainable Development.	421
	Francesco Fiorillo, Vesna Ristić Vakanjac, Igor Jemcov, Saša Milanović and Zoran Stevanović	
15.1	Hydraulic Behavior of Karst Aquifers	421
15.1.1	Introduction	421
15.1.2	Hydraulic Behavior Under Different Hydrological Conditions	423
15.1.3	Geological and Hydrological Features of Terminio and Cervialto Karst Aquifers	427
15.1.4	Hydraulic Behavior During Droughts and Earthquakes . . .	431
15.2	Forecasting Long-Term Spring Discharge	435
15.2.1	Introduction	435
15.2.2	Autocorrelation and Cross-Correlation Analyses.	436
15.2.3	The Multiple Linear Regression Model	442
15.2.4	Model for Filling the Data Gap and Assess Catchment Size and Dynamic Storage	447
15.3	Model for Assessing Extraction Effects in an Aquifer System . . .	455
15.3.1	Introduction	455
15.3.2	Current Concepts for Assessing Extraction Effects	460
15.3.3	Applied Model for Assessing Extraction Effects in an Aquifer System at Hydrogeological Exploration Early Stages	461
15.4	Speleology and Cave Diving as a Base for Tapping Structure Design.	470
15.4.1	Introduction	470
15.4.2	Overview of Speleology and Cave Diving Explorations	472
15.5	Engineering Regulation of Karstic Springflow to Improve Water Sources in Critical Dry Periods	490
15.5.1	Introduction	490
15.5.2	Solutions to Regulating Karstic Aquifers.	490
15.5.3	Indicators of Prosperous Sites for Engineering Regulation	498
15.5.4	Regulation of Discharge Zone	501
15.5.5	Regulations in Wider Catchment Area	518
15.5.6	Recommended Methods and Programme in Hydrogeology Survey	522
	References	523
16	Prevent Leakage and Mixture of Karst Groundwater	531
	Saša Milanović, Veselin Dragišić, Milan M. Radulović and Zoran Stevanović	
16.1	Choosing Optimal Dam Sites and Preventing Leakage from Reservoirs	531
16.1.1	Introduction	531

16.1.2	General Overview of Procedures for Preventing Leakage and Choosing Dam Sites	532
16.2	Karst Aquifers and Mining: Conflicts and Solutions	550
16.2.1	Introduction	550
16.2.2	Hydrogeological Types of Ore Deposits in a Karst Environment	551
16.2.3	Groundwater Inrush into Mining Operations	557
16.2.4	Dewatering of Ore Deposits in a Karst Aquifer Environment	560
16.2.5	Transformation of Karst Groundwater Quality	564
16.3	Remote Techniques for the Delineation of Highly Karstified Zones	567
16.3.1	Introduction	567
16.3.2	The Complexity and Categorization of Karst Terrains	568
16.3.3	The Concept of Mapping of Karstification by Using Remote Sensing and GIS	570
16.3.4	Discussion	578
16.3.5	Conclusion	579
16.4	Combat Mixture of Groundwater and Surface Waters in Karst	580
16.4.1	Introduction	580
16.4.2	Historical Experience	581
16.4.3	Hydraulic Mechanism and Methods to Identify Submerged Flows	582
16.4.4	Sustainable Tapping and Use of Fresh Karstic Waters	587
	References	594
17	Hazards in Karst and Managing Water Resources Quality	601
	Mario Parise, Nataša Ravbar, Vladimir Živanović, Alex Mikszewski, Neven Kresic, Judit Mádl-Szőnyi and Neno Kukurić	
17.1	Hazards in Karst Environment and Mitigation Measures	601
17.1.1	Peculiarity of Karst	601
17.1.2	Sinkholes	604
17.1.3	Mass Movements	608
17.1.4	Floods	609
17.1.5	Loss of Karst Landscape	610
17.1.6	Mitigating Hazards in Karst	610
17.2	Advanced Strategies in Managing and Sustaining Karst Water Quality	614
17.2.1	Karst Groundwater Environmental Issues and Protection	614
17.2.2	The Concept of Vulnerability and Contamination Risk Assessment	615
17.2.3	Commonly Applied Methods in Karst	617

- 17.3 Delineation of Karst Groundwater Protection Zones. 625
 - 17.3.1 Introduction 625
 - 17.3.2 Current Approaches to Sanitary Protection Zoning. 626
 - 17.3.3 Delineation of Sanitary Protection Zones Based on Fixed Radius and Travel Time 628
 - 17.3.4 Delineation of Sanitary Protection Zones with Vulnerability Assessment. 633
 - 17.3.5 Delineation of Sanitary Protection Zones Using a Combined Approach. 633
 - 17.3.6 Delineation of Sanitary Protection Zones Using Groundwater Models. 641
 - 17.3.7 Monitoring in Support of Groundwater Source Protection. 641
- 17.4 Remediation of Groundwater in Karst. 642
 - 17.4.1 Introduction 642
 - 17.4.2 In Situ Treatment Technologies 643
 - 17.4.3 Thermal Technologies 644
 - 17.4.4 In Situ Chemical Oxidation (ISCO). 647
 - 17.4.5 Bioremediation. 649
 - 17.4.6 Groundwater Containment: Pump and Treat 652
- 17.5 Genesis and Utilization of Thermal Flow in Deep Carbonate Systems. 654
 - 17.5.1 Introduction 654
 - 17.5.2 Problem of Scales and Type of Flows in Karst Research. 654
 - 17.5.3 Genesis of Thermal Flow in Deep Carbonates and Consequences for Utilization 655
 - 17.5.4 Drilling in Deep Karstified Formations 664
 - 17.5.5 Summary and Conclusion 666
- 17.6 Transboundary Aquifers in Karst. 667
 - 17.6.1 Introduction 667
 - 17.6.2 Transboundary Aquifers of the World 668
 - 17.6.3 Methodological Approaches to TBA Assessment 670
 - 17.6.4 International Agreements on Transboundary Aquifers. 671
 - 17.6.5 Concluding Remarks 677
- References. 677

- List of Keywords 689**



<http://www.springer.com/978-3-319-12849-8>

Karst Aquifers - Characterization and Engineering

Stevanovic, Z. (Ed.)

2015, XX, 692 p. 437 illus., 291 illus. in color.,

Hardcover

ISBN: 978-3-319-12849-8