

Contents

Chapter 1 Introduction	1
Scope	1
Historical Background	2
Utilization of Groundwater	7
Groundwater in the Hydrologic Cycle	13
Literature and Data Sources	17
Chapter 2 Occurrence of Groundwater	23
Origin and Age of Groundwater	23
Rock Properties Affecting Groundwater	25
Vertical Distribution of Groundwater	31
Zone of Aeration	31
Zone of Saturation	36
Geologic Formations as Aquifers	37
Types of Aquifers	42
Storage Coefficient	45
Groundwater Basins	49
Springs	49
Hydrothermal Phenomena	50
Groundwater in Permafrost Regions	54
Groundwater in the United States	55
Chapter 3 Groundwater Movement	64
Darcy's Law	64
Permeability	68
Determination of Hydraulic Conductivity	70
Anisotropic Aquifers	78
Groundwater Flow Rates	81
Groundwater Flow Directions	83
Dispersion	93
Groundwater Tracers	97
General Flow Equations	99
Unsaturated Flow	101
Chapter 4 Groundwater and Well Hydraulics	111
Steady Unidirectional Flow	111
Steady Radial Flow to a Well	115

Well in a Uniform Flow	121
Unsteady Radial Flow in a Confined Aquifer	123
Unsteady Radial Flow in an Unconfined Aquifer	134
Unsteady Radial Flow in a Leaky Aquifer	136
Well Flow Near Aquifer Boundaries	139
Multiple Well Systems	147
Partially Penetrating Wells	149
Well Flow for Special Conditions	152
Characteristic Well Losses	152
Specific Capacity	155
Chapter 5 Water Wells	164
Test Holes and Well Logs	164
Methods for Constructing Shallow Wells	165
Methods for Drilling Deep Wells	174
Well Completion	185
Well Development	194
Testing Wells for Yield	199
Pumping Equipment	200
Protection of Wells	205
Well Rehabilitation	209
Horizontal Wells	211
Chapter 6 Groundwater Levels and Environmental Influences	218
Time Variations of Levels	218
Streamflow and Groundwater Levels	222
Fluctuations Due to Evapotranspiration	230
Fluctuations Due to Meteorological Phenomena	235
Fluctuations Due to Tides	242
Urbanization	247
Earthquakes	250
External Loads	252
Land Subsidence and Groundwater	253
Chapter 7 Quality of Groundwater	267
Sources of Salinity	267
Measures of Water Quality	277
Chemical Analysis	277
Graphic Representations	284
Physical Analysis	290

Biological Analysis	290
Groundwater Samples	290
Water Quality Criteria	291
Changes in Chemical Composition	301
Dissolved Gases	306
Temperature	307
Saline Groundwater	310
Chapter 8 Pollution of Groundwater	316
Pollution in Relation to Water Use	317
Municipal Sources and Causes	317
Industrial Sources and Causes	327
Agricultural Sources and Causes	332
Miscellaneous Sources and Causes	334
Attenuation of Pollution	337
Distribution of Pollution Underground	341
Evaluation of Pollution Potential	344
Monitoring Groundwater Quality	344
Chapter 9 Management of Groundwater	353
Concepts of Basin Management	353
Equation of Hydrologic Equilibrium	354
Groundwater Basin Investigations	358
Data Collection and Fieldwork	361
Alternative Basin Yields	363
Evaluation of Perennial Yield	366
Salt Balance	369
Basin Management by Conjunctive Use	371
Examples of Groundwater Management	376
Chapter 10 Groundwater Modeling Techniques	384
Porous Media Models	384
Analog Models	387
Electric Analog Models	393
Digital Computer Models	399
Chapter 11 Surface Investigations of Groundwater	409
Geologic Methods	409
Remote Sensing	410
Geophysical Exploration	413

Electric Resistivity Method	414
Seismic Refraction Method	420
Gravity and Magnetic Methods	425
Water Witching	425
Chapter 12 Subsurface Investigations of Groundwater	431
Test Drilling	431
Water Level Measurement	434
Geophysical Logging	437
Resistivity Logging	439
Spontaneous Potential Logging	444
Radiation Logging	446
Temperature Logging	449
Caliper Logging	450
Fluid-Conductivity Logging	450
Fluid-Velocity Logging	450
Miscellaneous Logging Techniques	452
Other Subsurface Methods	454
Chapter 13 Artificial Recharge of Groundwater	458
Concept of Artificial Recharge	458
Recharge Methods	459
Research on Water Spreading	472
Wastewater Recharge for Reuse	475
Recharge Mounds	479
Artificial Recharge on Long Island, New York	481
Induced Recharge	485
Artificial Recharge for Energy Purposes	488
Chapter 14 Saline Water Intrusion in Aquifers	494
Occurrence of Saline Water Intrusion	494
Ghyben-Herzberg Relation Between Fresh and Saline Waters	496
Shape of the Fresh-Salt Water Interface	499
Structure of the Fresh-Salt Water Interface	500
Upconing of Saline Water	502
Fresh-Salt Water Relations on Oceanic Islands	505
Seawater Intrusion in Karst Terranes	509
Control of Saline Water Intrusion	510
Examples of Seawater Intrusion	512
Recognition of Seawater in Groundwater	515

CONTENTS

xiii

Appendix Metric Units and English Equivalents	521
Metric Units	521
Common Metric Equivalents	522
Metric Prefixes	523
Metric-English Equivalents	523
Numerical Values for Physical Properties	525
Index	527