## CONTENTS

	Preface	ix
1	Introduction The Problem 1 Groundwater Usage and Quality 2 Groundwater and the Hydrologic Cycle 4 Sources of Groundwater Contamination 5 The Extent of Groundwater Contamination 7 Purpose of Groundwater Modeling 8 Modeling Approaches 9	1
2	Groundwater Models Groundwater Models 13 Fluid Flow Model 16 Introduction 16 Zones of Moisture 17 Darcy's Law 18 Groundwater Flow Equations 21 Boundary Conditions 23 Confined Artesian Flow 25 Leaking Artesian Conditions 25 Water Table Conditions (Unconfined Aquifers) 26	13
	Radial Flow 29 Mass Transport Model 30 Introduction 30 Convection, Dispersion and Diffusion 32	

Hydrochemical Aspects 34 Volatility 34 Acids and Bases 35 Precipitation and Solution 35 Surface Phenomena 37 Organics and Heavy Metals 38 Organics 39 Heavy Metals 40 **Biological Activity** 41 Nitrogen 42 Phosphorous 42 Sulphur 43 Pathogens 43 Mass Transport Equations 44 Transport in Homogeneous Materials 46 Transport in Heterogeneous Material 47 Transport of Reactive Constituents 48 Transport in Fractured Media 51 53 3 Groundwater Model Usage Introduction 53 Analytical Models 54 Computer Models 55 Finite-Difference Methods 57 Finite-Element Methods 58 - 125 14 Matrix Methods 59 Specific Groundwater Models 60 Case Histories 62 Limitations and Sources of Error in Groundwater Modeling 63 Difficulties in the Collection of Data 63 Improper Selection of a Model 64 Inappropriate Prediction 64 Inadequate Documentation 65 4 Monitoring 67 Introduction 67 Monitoring 69 Purposes of Monitoring 76 Monitoring Prerequisites 78 Initial Site Inspection 78

	Preliminary Investigations 80 Definition of the Hydrogeologic Setting 81 Objectives 84 Structural Monitoring 91 Biological Monitoring 92	
5	Monitoring Systems Well Installation—Drilling Methods 101 Auger Boring 101 Hydraulic Rotary 102 Air Rotary 104 Percussion Drilling 106	97
	Well Installation 107 Materials of Construction 107 Safety 110 Environmental 112 Sampling and Decontamination 114 Alternatives to Well-Type Monitoring Systems 115 Leachate Seep and Springs 115 Lysimeters 115 Existing Wells 118 Leachate Collection Systems 119 Well Points 119	
6	Sampling Types of Samples 121 Sampling Methodology 122 Sample Withdrawal Methods 122 Records and Chain of Custody 127 Sample Preservation 131	121
	Heterences	

Index