SOLUTIONS MANUAL FOR

Groundwater Hydrology: Engineering, Planning, and Management

by

Mohammad Karamouz
Azadeh Ahmadi
Masih Akhbari

CRC Press
Taylor & Francis Group

SOLUTIONS MANUAL FOR

Groundwater Hydrology: Engineering, Planning, and Management

by

Mohammad Karamouz
Azadeh Ahmadi
Masih Akhbari

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an informa business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-1-4398-5605-5 (Paperback)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

Preface

Demand for fresh water is increasing as the world's population continues to grow and we are looking for higher standards of living. Water conservation, better operation, end use and water allocation efficiency has not been able to offset the growing demand. So many societies are struggling for bring supply and demand to a sustainable level. Although water is abundant on earth, fresh water accounts for only about 2.5% of global water reserves. Out of this amount, approximately 30% is stored as groundwater and the same amount is on the surface as rivers and lakes, while the remaining reserves are held in glaciers, ice caps, soil moisture, and atmospheric water vapor. Groundwater is source of vital natural flow. In arid and semiarid areas groundwater may represent 80% or more of the total water resources. Public has a perception for groundwater as a reliable, clean, and virtually unlimited source of water supply. Even though there could be exception, it is a dependable source almost every where in the world.

The term groundwater is usually used for subsurface water that is located bellow the water table in saturated soils and geologic formations. Groundwater is an important element of the environment, it is a part of hydrologic cycle, and an understanding of its role in this cycle is necessary if integrated analyses ought to be promoted. Aquifers and watersheds resources are two inseparable media for regional assessment of water and contamination movement and soil-water interaction.

Water enters the formation of the earth from ground surface by natural or artificial recharge. Within the ground, water moves slowly downward through unsaturated zone under gravity force and in the saturated zone in the direction determined by the hydraulic gradient. It is discharged naturally to the streams and lakes or as a spring or by transpiration from plants. It can also be discharged by pumping from wells. Storage of groundwater could be significantly beneficial compared to surface storage that may require massive infrastructure. This book presents a completion of the state of the art subjects and techniques in groundwater education and practice. The materials are presented in a system and integrated fashion useful for undergraduate and graduate students and practitioners.

In **Chapter 1**, an introduction to different aspects of groundwater science, engineering, planning, and management is presented. The concepts of integration, sustainability and public perception are discussed with emphasis on laws and regulations governing groundwater operation and management.

Chapter 2 presents an overview of general concepts on the occurrence of groundwater as a part of the hydrologic cycle. The basic definitions of subsurface water and aquifers are discussed in this chapter. Moreover, the occurrence of groundwater in karst areas and karst aquifers are explained.

Chapter 3 discusses groundwater hydrology and the basic laws of groundwater movement. Some characteristics of aquifers and soil formation that govern the movement of groundwater, such as hydraulic conductivity, transmissivity, homogeneity and isotropy of soil layers are described in this chapter. Then, flownets as simply procedures to solve a flow equation are discussed. Statistics and probabilistic methods in hydrogeologic studies are explained. The analysis of time series and the methods of generating synthetic time series and forecasting data are introduced.

Chapter 4 presents the technical aspects in developing and solving governing groundwater flow equations. The mathematical description of groundwater flow based on the continuity equation and the equation of motion are explained. The groundwater utilization by pumping from wells leads to decline in the water level. The theoretical analyses of the aquifer system's response based on the physics of flow toward a well are presented in confined and unconfined aquifers for steady and unsteady states in details. Also pumping test to estimate the aquifers' parameters as well as the methods of well design and well construction are described.

Chapter 5 describes the environmental water quality issues related to groundwater systems. Factors that can affect groundwater solubility as well as the evaluation of non-equilibrium status of groundwater are followed by a short discussion of different types of contaminants in groundwater. Pollution of groundwater are caused by many activities, including leaching from municipal and chemical landfills and abandoned dump sites, accidental spills of chemicals or waste materials, improper underground injection of liquid wastes, and placement of septic tanks. Finally, the principals of reactive and non-reactive contaminants' transport are briefly expressed in both saturated and unsaturated zones.

Chapter 6 provides details of the specific information about groundwater flow modeling. In the application of numerical methods, partial differential equations of groundwater are transformed into a set of ordinary differential or algebraic equations. State variables at discrete nodal points are determined by solving the equations. Three major classes of numerical methods have been presented for solving groundwater problems including Finite Difference Method (FDM), Finite Element Method (FEM), and Finite Volume Method (FVM).

In **Chapter 7**, conceptual models to simulate the groundwater systems are introduced. The management problem can be viewed and determined in an appropriate type, location and setting for controls of desirable system outputs. In this Chapter a comprehensive description planning tools and important issues related to groundwater management in order to optimize the groundwater resources and allocation schemes. Optimization methods are powerful tools that could maximize water utilization, minimize the costs of groundwater operation, and minimize the adverse impacts of over-exploitation of groundwater. This chapter provides a set of analytical tools to assist the analyst in solving complex management problems. These tools are based on coupling groundwater simulation and optimization models. The applications of topics presented in this chapter are illustrated by examples and some case studies.

Chapter 8 presents basic information about conjunctive use of surface and groundwater. The interaction between groundwater and different types of surface water are explained with emphasis on planning issues. Also, certain advantages of conjunctive use planning especially in semi arid regions are explained and case studies are presented.

In **Chapter 9,** aquifer restoration in the context of different groundwater pollution control issues and utilizing of groundwater treatment are explained. First the processes affecting the amount of contaminant, as well as natural and mechanical means of that reducing the concentration of contaminants, are described. Then the importance of groundwater monitoring and the corresponding processes are explained.

Chapter 10 discusses the different groundwater disasters and aquifers vulnerability to natural hazards and human impacts. Drought, flood, widespread contamination and land subsidence that could devastate a groundwater system are described. In this chapter, risk as an overlay of hazard and system's vulnerability and methods for risk analysis are presented. Also the planning processes for groundwater disaster management including contingency plans are discussed.

Chapter 11 presents the climate change impacts on hydrological cycle. Then, the direct impacts of climate change on groundwater as affected by changes in precipitation, temperature, evaporation, and soil moisture are evaluated. Moreover, to adjust the resolution of data for climate change impact studies, different downscaling models are presented. Indirect impacts as salt water intrusion, sea level rise, changes in land use are assessed to find their impacts on groundwater. Then, methods to cope with climate change are discussed and some adaptation techniques to climate change impacts on groundwater are presented.

This book can serve water communities around the world and add significant value to engineering and application of systems analysis techniques to groundwater engineering, planning, and management. It can be used as a text book by the students in civil engineering, geology, soil science, urban and regional planning, geography, environmental science, and in courses dealing with hydrologic cycle. It also introduces basic tools and techniques for engineers, policy and decision makers who plan for the future groundwater development activities toward regional sustainability.

It is our hope that this book can add significant value to the application of system analysis techniques for groundwater engineering and management around the world.

Mohammad Karamouz
Azadeh Ahmadi
Masih Akhbari

Solution Manual
Table of Content

CHAPTER 1: INTRODUCTION

PROBLEMS

1.1 Make an assessment of groundwater resources around the world and compared them with the U.S. share of total groundwater.

Hint: use UNESCO, Cambridge /Oxford L.C. World Resources, World Bank, EU Switch program, FAO, USGs, sites and publications.

Solution:

Students can select a region/ country and search on the internet. Based on the internet and library findings, they can assess the groundwater resources around the world and compare with the U.S resources.

1.2 In Problem 1, make an assessment of groundwater quality figures around the world.

Solution:

Students can select a region/ country and search on the internet and in the library. Based on the findings, they can make a comparison.

1.3 Identify the federal and national agencies involved in management and protection of groundwater, At least one in each part of the globe.

Solution:

Use internet and other resources determine the U.S., Canada, EU and agencies in major countries in other continents. It will be useful to look at the mission statements for these agencies.

1.4 Compare the driving forces dealing with groundwater science and engineering with those affecting groundwater planning and management.

Solution:

Driving forces of groundwater science include: Climate Change, Natural Recharge, Physical & Chemical Properties, Water & Soil Interaction, Permeability, Storability, Hydraulic gradient.

Driving forces of groundwater engineering: the science of GW, Pollution & Contamination, Fluid Mechanics, Soil Mechanics, Conservation of Mass & Energy, Well Hydraulics Pumping characteristics.

Driving forces of principles of groundwater planning and management framework: Climate

Change Impacts Conflicts, Socio-Economic Issue, Safe Yield, Environmental Issues, Engineering Principles of GW, Laws and Regulations.
1.5 Identify and compare the "response" issues in problem 4, concentrating on improvement of standards and quality of life as well as economic, environmental and legal issues.
Solution: Responses to groundwater Science: Natural Discharge, River Aquifer Interaction, Engineering Principles & Applications. Responses to groundwater engineering: water supply, planning and management of GW, analytical and Physical Modeling Tools. Responses to groundwater Planning and Managements: Conflict Resolution, Operation, Water Allocation, Disaster Management, polices, Rules & Improved Standards, Conjunctive Use, Remediation, Aquifer Restoration.
1.6 Explain IWRM for aquifers in the context of public awareness/ participation and consideration of social impacts.
Solution: In the Integrated Water Resources Management (IWRM) schemes, politics and the traditional fragmented and sectored approach to water is made between resource management and the water service delivery functions. It should be noted that IWRM is a political process, because it deals with reallocating water, the allocation of financial resources, and the implementation of environmental goals. For an effective water governance structure, much more work has to be done. The economic development has imposed considerable pressure on the water resources especially groundwater. Generally people's perception is that groundwater is an unlimited, reliable and safe source of water to drink. The impact of climate change has affected the groundwater recharge and the frequency of drought. That has changed the safe yield of aquifers and has caused considerable drawdown in many aquifers around the world that should be considered in IWRM. Educating the public and considering "stakeholders" various objectives are the crucial path towards sustainable development. Groundwater is a perfect example of many misunderstandings, by both the public and policy makers about the meaning of sustainability.
1.7 What is the estimated water cost for residential customers in east (New York City) and

west (city of Los angles of the U.S.)? Compare it with the price of water in 5 other major cities around the world. Is the price of groundwater in selected areas different from surface water resources?

Solution:

Also search on the internet about water cost. If you know any one getting a water bill, the price is listed there per cubic meter or cubic feet (Gallon).

1.8 Briefly discuss a case of transboundary conflict over shared aquifer.

Hint: Example of Kura aquifer in Caucasus region (Puri, 2001) can be used.

Solution:

There are many conflicts over shared aquifers between politically divided regions. Transboundary aquifers are not well defined and managed by decision makers and authorities on both sides of the borders.

The international association of hydrologists established a commission to investigate the issue of transboundary groundwater in 1999. One of the main objectives of the program is to support cooperation among countries in order to develop technical knowledge and conceptual understanding to alleviate potential conflicts.

Also search on the internet about Kura aquifer in the Caucasus region.

1.9 Identify and briefly explain factors affecting groundwater sustainability.

Solution:

International panel on climate change (IPCC, 2006) shows a broader perspective of sustainable development as showed in Figure 1.8. They have combined the impacts of socioeconomic development paths with technology, population, and governance through adaptation by human and natural systems.

1.10 In demand side management, explain the two periods of demand I and demand II in Figure 1.9.

Solution:

Two periods of demand I and demand II are defined to bring a balance between supply and demand to a level of sustainable limits of water supply.

Developing water saving technologies should be considered in developing water demand management strategies. These methods cover a wide range of solutions, such as dual-flush toilets, flow restrictors on showers and automatic flush controllers for public urinals,

automatic timers on fixed garden sprinklers, masters sensors in public gardens, and improved leakage control in domestic and municipal distribution systems. These options are enter used in demand I period and they are called end use efficiency. Demand II period is concerns about allocation efficiency, reduction of leak, pressure management and bulk metering.
1.11 Identify three local (city or county) agencies in the U.S. or in other countries with the charter of protecting and enforcement issues related to quality and quantity (discharge) of groundwater.
Solution: Federal USGS geological survey, City Department of Environmental protection and state department, Department of Environmental Conservation (DEC)