DEVELOPMENTS IN WATER SCIENCE

13

MIGUEL A. MARIÑO AND JAMES N. LUTHIN

SEEPAGE AND GROUNDWATER

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PREFACE

This book covers a broad range of seepage and groundwater problems. It describes the physics of water flow through porous media and soil physical problems associated with that flow. In addition, the book discusses important practical problems of groundwater and illustrates different methods for solving those problems. Among the problems covered are: control of shallow water tables, seepage under dams and other hydraulic structures, flow to wells, evaluation of aquifer tests, construction and maintenance of wells, and exploration for groundwater.

During the past few years, several books have been published in the broad field of groundwater hydrology. These books are concerned to a large extent with water-quality problems associated with groundwater and do not treat the wide variety of problems that we have dealt with in our book. They do not emphasize methods of obtaining solutions to groundwater problems to the same extent that we do, nor do they emphasize the engineering design of groundwater management devices. The writing of a book with such an emphasis was motivated by the authors' teaching of seepage, drainage, and groundwater courses at the University of California at Davis to undergraduate and graduate students that have widely varying backgrounds and interests. Chapters 1 through 6 were written by J. N. Luthin, and Chapters 7 through 12 were written by M. A. Mariño.

This book is designed for use an as undergraduate text in groundwater and seepage courses in civil engineering, agricultural engineering, hydrology, and soil and water science curricula, but it can also be used as a text in introductory seepage-and-drainage and groundwater courses at the graduate level. This book should be useful also to practicing engineers, hydrologists, and agriculturalists in the area of groundwater and seepage problems.

We are indebted to the Department of Civil Engineering at the University of California, Davis, for the assistance provided in the typing of the manuscript. Both the Department of Civil Engineering and the Department of Land, Air and Water Resources at U.C. Davis have assisted us, directly or indirectly, in the preparation of this book. To these and to Irma, Raquel, and Ad we are indebted.

Miguel A. Mariño
James N. Luthin
Davis, California
November, 1980

UNITS AND CONVERSIONS

Length

1 inch (in) = 0.08333 feet (ft) = 0.02540 meters (m)

= 2.540 centimeters (cm) = 254 millimeters (mm)

1 foot (ft) = 12 in = 0.3048 m = 0.3333 yards (yd)

1 mile (mi) = 5280 ft = 1609 m = 1.609 kilometers (km)

Area

1 $inch^2$ = 6.452 cm^2 = 64516 mm^2

1 $foot^2$ = 0.0929 m^2 = 929 cm^2

1 acre = 43560 ft^2 = 4047 m^2 = 0.4047 hectare (ha) = 0.004047 km^2

1 $mile^2$ = 640 acres = 2.590 km^2

Volume

1 $inch^3$ = 16.387 cm^3 = 1.639×10^{-2} liter (l)

= 4.326×10^{-3} U.S. gallons (gal)

1 $foot^3$ = 2.832×10^{-2} m^3 = 7.477 U.S. gal = 28.320 l

= 2.295×10^{-5} acre-feet

1 $mile^3$ = 4.167 km^3 = 4.167×10^9 m^3 = 3.378×10^6 acre-feet

Mass

1 pound (lb) = 453.59 grams (g) = 4.536×10^{-1} kilograms (kg)

Pressure

1 pound/in^2 (lb/in^2 or psi) = 6.895×10^3 newton/m^2 (N/m^2)

= 0.0703 kg(force)/cm^2 (kgf/cm^2) = 0.0680 atmosphere (atm)

1 atm = 1.013 bar = 1.013×10^5 N/m^2 = 1.033 kgf/cm^2 = 14.70 psi

Velocity and hydraulic conductivity

1 foot/second (ft/s) = 0.3048 m/s = 26.3347×10^3 m/day

= 43.1902×10^3 inches/hour (in/hr)

= 645.7627×10^3 U.S. gal/day/ft^2 (gpd/sq ft)

1 U.S. gal/day/ft^2 = 4.078×10^{-2} m/day = 4.720×10^{-7} m/s

Transmissivity

1 ft^2/s = 9.290×10^{-2} m^2/s = 802.656×10^{-1} m^2/day
= 86400 ft^2/day = 6461.3808 U.S. gal/day/ft (gpd/ft)

1 U.S. gal/day/ft = 1.242×10^{-2} m^2/day = 1.438×10^{-7} m^2/s

Discharge

1 ft^3/s (cfs) = 0.02832 m^3/s = 28.32 l/s = 2446.848 m^3/day
= 448.874 U.S. gal/min (gpm) = 6.464×10^5 U.S. gal/day (gpd)

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CHAPTER 1

POROUS MEDIA - SOIL

The porous media that contains groundwater is a three-phase system. It consists of a solid phase (soils), a gaseous phase (air) and a liquid phase (water). The solid phase may consist of consolidated rocks such as limestone, granite, lava and schists. It may be semiconsolidated materials such as sandstones and shales or it may be unconsolidated alluvial deposits and soils formed in place by weathering processes.

1.1 THE SOLID PHASE

The pores in consolidated rocks such as granite are due to fissures and cracks in the rock. In limestone, water often moves through solution channels. In lava, there are gas channels, cracks and unconsolidated sediments that transmit the water. Because of the irregular nature of the pores in these rocks, a successful method of analysis has not been developed. The pores, cracks and interstices occur in a complex fashion and are not always interconnnected. Experience with local conditions forms the best basis for judgement in evaluating seepage through this material.

On the other hand, the pores in sandstones, schists, unconsolidated sediments and soils are more or less interconnected. The physical basis for the flow of water through these materials is well understood. These materials form the bulk of the groundwater areas.

1.1.A Soils and Unconsolidated Sediments

The solid phase of soils and unconsolidated sediments consist of individual particles of various sizes. These particles are classified according to their sizes as cobbles, gravel, sand, silt and clay. Cobbles have an average diameter greater than 76 mm. Gravel sizes range from 4.75 mm to 76 mm. Sands are 0.074 mm to 4.75 mm in diameter. Silt is 5 to 50 microns and clay is less than 5 microns (5×10^{-6} meters).