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Application of Differential Quadrature Method in numerical solution of flow through porous media

A. A. Ameli and M. J. Abedini
Department of Civil and Environmental Engineering, School of Engineering, Shiraz University, Shiraz Iran

ameli_ali2005@yahoo.com

abedini@shirazu.ac.ir

Abstract
Numerical models in groundwater hydrology are considered as an important tool for describing the dynamic of flow through porous media. Available numerical models are quite successful in delineating the capture zone when the flow geometry is quite simple. In light of more complex flow geometry, the available software still can simulate the flow using more computational effort. The current study tries to address head distribution delineation process when the flow geometry and boundary condition is complex, the porous media is non-homogeneous and under constant recharge. For this purpose, a numerical scheme so called Differential Quadrature Method (DQM) is implemented to simulate the dynamic of flow in the study area. At first, a numerical program so called SEEP/W is utilized to calibrate the physical domain taking hydraulic conductivity as the tuning parameter. Then, the identified system is submitted to DQM for further analysis and performance assessment. Results of this numerical modeling exercise show that DQM is quite capable of reproducing the observed piezometric head with fewer nodes and less computational effort. In conclusion, DQM can be considered as a potential and competitive numerical scheme to model flow through porous media.

Keywords: Hydraulic Head, Unconfined aquifer, Differential Quadrature, Numerical solution, SEEP/W

1. INTRODUCTION

In recent decades, due to lack of reliable water resources across the world, groundwater is the primary source of water supply for domestic, municipal, industrial and agricultural uses. Consequently, reliable computation of groundwater head distribution and contaminant migration studies in confined and unconfined aquifers are highly important. Hydraulic head distribution in porous media is considered to be the most important variable for delineating capture zone and pump and treat design. Due to complex geometry and difficult boundary condition, the analytical solutions for characterizing head distribution, are available only for regular domain and simplified boundary conditions. As an example, Daly and Morel–Seytoux [1] developed an analytical solution to calculate the head distribution in a rectangular aquifer. Similarly, Ram and Chauhan [2] derived an analytical solution for groundwater flow in a homogeneous, isotropic, and unconfined aquifer. Bakker [3] presented an analytical solution for steady flow with elliptical boundaries. Chang [4] proposed an analytical solution to describe the hydraulic head distribution in anisotropic, rectangular unconfined aquifer with simplified boundary condition. As can be seen, most analytical solutions suffer from simple geometry, simplified boundary conditions, homogeneous spatial domain, and space invariant forcing function.

Numerous numerical methods such as finite difference method [5] and finite element method [6, 7, 8] are used to numerically solve the governing equation. He et al [9] presented a three-dimensional finite element groundwater model to simulate groundwater flow in steady and unsteady case. A majority of numerical solution