

**AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CIVIL ENGINEERING - IRRIGATION AND HYDRAULICS**

Ph.D. THESIS

GROUND WATER QUALITY MODEL WITH DECAYING POLLUTANTS

BY

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M. Sc. C.E.**

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of **Philosophy Doctor in Civil Engineering**.

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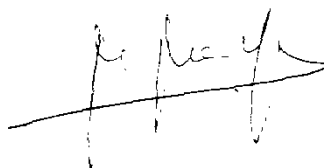
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Abstract:

Groundwater constitutes an important component of many water resource system, supplying for domestic use, for industry, and for agriculture. Therefore, groundwater must be managed carefully to be the most beneficial use. Good management requires the ability to forecast the aquifer's response to planned operations, such as pumping and recharging. The response may take the form of changes in water levels, changes in water quality, or land subsidence. Any planning measures to consider mitigation, clean-up operations, once contamination has been detected in the saturated or unsaturated zones, requires the prediction of the path and the fate of the contaminants in response to the planned activities. For most practical problems, because of the heterogeneity of the considered domain, the irregular shape of its boundaries, and the nonanalytic form of various source functions, only a numerical model can provide the required forecasts. In this work, a numerical model has been developed to simulate the groundwater flow and conservative and nonconservative pollutant transport through the saturated porous media. The Finite Element Method has been used to solve the partial differential equations that govern the groundwater flow and solute transport. Problems with available analytical or numerical solutions have been used in order to verify the capability of the model in simulating the different field situations in one- or two- or three-dimensions. The model has been applied to a selected region in the East Nile Delta in Egypt in order to calibrate the aquifer properties. Also the model has been applied to hypothetical three-dimensional problems which may be occurred in the real world. It is concluded that the model can be used efficiently and successfully in simulating and predicting the fate of conservative and nonconservative pollutants in aquifers under a variety of conditions with the minimum of simplifying assumptions.

NOTATION

a	Compressibility of water	$[LT^2M^{-1}]$
A_{ij}	Conductance matrix	$[L^2T^{-1}]$
A_e	Elemental area	$[L^2]$
a_T	Transversal dispersivity	$[L]$
a_L	Longitudinal dispersivity	$[L]$
a_v	Vertical dispersivity	$[L]$
B_{ij}	Storage matrix	$[L^2]$
b	Compressibility of the aquifer	$[LT^2M^{-1}]$
b'	Thickness of the layer that represents the stream bottom.	$[L]$
C	Concentration of the solute	$[ML^{-3}]$
C_n	Courant number	
C''	Ratio between the mass held on the solid surface and the mass of the solids in solution	
C_{in}	Concentration of the inflowing water in the case of infiltration or the average concentration in the aquifer in the case of abstraction of water	$[ML^{-3}]$
d'	Effective grain diameter	$[L]$
d_i	Thickness of the aquitard	$[L]$
D'_{ij}	Hydrodynamic dispersion-diffusion coefficient	$[L^2T^{-1}]$
D_{md}	Molecular diffusion coefficient	$[L^2T^{-1}]$
D_0	Diffusion coefficient in a free water system	$[L^2T^{-1}]$
Δt	Time step size	$[T]$
Δ	Elemental cross-sectional area of cubic element perpendicular to the pore-water velocity	$[L^2]$

e	Element number	
erfc(x)	Complementary error function= 1- erf(x);	
G_{ij}	Capacitance matrix	$[L^2]$
g	Gravity acceleration	$[LT^{-2}]$
h	Hydraulic head	$[L]$
k	Permeability	$[L^2]$
K_{ij}	Hydraulic conductivity tensor	$[LT^{-1}]$
K_{vi}	Vertical hydraulic conductivity of the aquitard	$[LT^{-1}]$
K_d	Distribution coefficient	$[L^3M^{-1}]$
k'	Hydraulic conductivity of the layer that represents the stream bottom	$[LT^{-1}]$
J_{disp}	Dispersive flux	$[MT^{-1}]$
l_i	Aquitard resistance i	$[T^{-1}]$
λ	Decay constant	$[T^{-1}]$
m	Aquifer thickness	$[L]$
N_e	Total number of elements.	
μ	Viscosity	$[ML^{-1}T^{-1}]$
n_e	Effective Porosity	
NP	Total number of the nodal points	
$N_i(x, y)$	Shape function.	
ν	Kinematic viscosity	$[L^2T^{-1}]$
$\partial h / \partial x_j$	Hydraulic gradient in the j-direction;	
$\partial C / \partial x_i$	Concentration gradient in the direction i	$[ML^{-4}]$
P_n	Peclet number	
P_{ij}	Solut tran. conductance matrix	$[L^2T^{-1}]$
$\pm Q_i$	Sink or source flow rate at the node i	$[L^3T^{-1}]$
QC'	Concentration of the solute of a source or sink of a strength which is assumed to be known	$[ML^{-3}T^{-1}]$

q_i	Average discharge in the direction i	$[L^3T^{-1}L^{-2}]$
T_{liquid}	Water filled area perpendicular to the direction of	
	Darcy's velocity	$[L^2]$
Re	Reynold's number	
ρ	Density of water	$[ML^{-3}]$
R	Retardation factor.	
r	Distance from the pumped well	$[L]$
ρ_b	Bulk density of the porous media	$[ML^{-3}]$
ρ_{dry}	Dry matrix material	$[ML^{-3}]$
S	Storativity of the aquifer	
S_0	Specific storativity)	$[L^{-1}]$
T	Transmissivity of the aquifer	$[L^2T^{-1}]$
t	Time	$[T]$
$t_{.5}$	Half-life of the isotop	$[T]$
V	Velocity resultant	$[LT^{-1}]$
V_b	Elemental bulk volume	$[L^3]$
V_e	is the volume of the element	$[L^3]$
$W(u,r/B)$	Hantush well function	
∇	vectorial-delta $(\partial/\partial x + \partial/\partial y + \partial/\partial z)$	$[L^{-1}]$
$!$	the factorial	
τ	Time factor	

CONTENTS

<u>TITLE</u>	<u>PAGE</u>
Acknowledgment.....	i
Abstract.....	ii
Notation.....	iii
Contents.....	vi
List of Figures.....	x
List of Tables.....	xvi
<u>Chapter I</u>	
Introduction.....	1
Research Objectives.....	4
<u>Chapter II</u>	
Literature review.....	5
II.1. Groundwater Flow Modeling.....	5
II.2. Solute Transport Modeling.....	11
II.2.1. Analytical Solutions.....	12
II.2.2. Numerical Solutions.....	16
<u>Chapter III</u>	
The Mathematical Approach.....	30
III.1. Groundwater Flow in Porous Media.....	30
III.1.1. The Continuity Equation.....	32
III.1.2. Darcy's Law.....	35
III.1.2.1. Confined Aquifer.....	37
III.1.2.2. Leaky Aquifer.....	38
III.1.2.3. Phreatic Aquifer.....	38
III.1.3. Initial and Boundary Conditions.....	40
III.1.3.1. Initial Conditions.....	40
III.1.3.2. Boundary Conditions.....	41

III.1.3.2.1. First-type Boundary of Prescribed Head.....	41
III.1.3.2.2. Second-type Boundary of Prescribed Flux.....	41
III.1.3.2.3. third-type Semi-pervious Boundary.....	42
III.2. Contaminant Transport in Porous Medium.....	44
III.2.1. The Conservative mechanisms of Solute Transport.....	45
III.2.1.1. Convection	45
III.2.1.2. Molecular Diffusion.....	45
III.2.1.3. Hydrodynamic Dispersion.....	48
III.2.2. The Non-conservative Mechanisms of solute Transport.....	49
III.2.2.1. Decay.....	49
III.2.2.2. Adsorption.....	50
III.2.2.3. Absorption.....	51
III.2.2.4. Precipitation, Co-precipitation, and Dissolution	51
III.2.3. General equation for a Nonconservative Solute Transport System.....	52
III.2.4. Initial and Boundary Conditions.....	53
III.2.4.1. Initial Conditions.....	54
III.2.4.2. Boundary Conditions.....	54
<u>Chapter IV</u>	
The Finite Element Formulation.....	56
IV.1. Two-Dimensional Model for Subsurface water Flow....	56
IV.1.1. Numerical Integration.....	64
IV.1.1.1. The First Integral.....	64
IV.1.1.2. The Second Integral.....	65
IV.1.1.3. The Third Integral.....	66
IV.1.2. Elemental Velocity.....	68
IV.1.3. Special Cases.....	68

IV.1.3.1. Leaky Aquifer.....	68
IV.1.3.2. Phreatic Aquifer.....	69
IV.2. Three-dimensional Model for Subsurface Water Flow..	70
IV.3. Integration over Time.....	74
IV.4. The Two-dimensional submodel for Mass Transport....	75
IV.5. The Three-dimensional Model for Mass Transport.....	78
IV.6. Integration over Time.....	80
IV.7. Stability, Consistency and Convergence.....	80

Chapter V

Model Description.....	82
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Chapter VI

Model Verification.....	87
VI.1. Verification of the Groundwater Flow Submodel.....	88
VI.1.1. Two-dimensional Groundwater Flow Problem.....	89
VI.1.1.1. Transient Unconfined Groundwater Flow.....	89
VI.1.2. Three-dimensional Groundwater Flow Problems.....	95
VI.1.2.1. Transient Confined Groundwater Flow.....	95
VI.2. The Mass Transport Submodel.....	96
VI.2.1. One-dimensional Solute Transport Problems.....	100
VI.2.2. Two-dimensional Solute Transport Problems.....	117
VI.2.3. Three-dimensional Solute Transport Problems.....	138
VI.2.3.1. Saltwater intrusion in three-dimensional aquifer	145

Chapter VII

Model Application.....	158
VII.1. Groundwater Flow Model in East Delta.....	158
VII.1.1. General description of Study Area.....	158
VII.1.1.1. Geographic Setting.....	160

VII.1.1.2. Climatology.....	160
VII.1.1.3. Geology.....	160
VII.1.1.4. Surface Water.....	164
VII.1.1.5. Land Use.....	164
VII.1.1.6. Aquifer Properties.....	166
VII.1.2. Model Construction.....	166
VII.1.3. Model Calibration.....	174
VII.1.4. Unsteady State Calibration.....	175
VII.2. Solute Transport Model in East Delta.....	178
VII.2.1. Model Construction.....	185
VII.2.2. Model Calibration.....	187
VII.3. Three-dimensional Model Application.....	189
<u>Chapter VIII</u>	
Conclusions and Recommendation.....	208
Appendix I (References)	
Appendix II List of program	

LIST OF FIGURES

<u>FIGURE NO.</u>	<u>PAGE</u>
III.1	A SCHEMATIC DISTRIBUTION OF SUBSURFACE WATER.....31
III.2	A CONTROL VOLUME FOR GROUNDWATER FLOW.....33
III.3	THE LEAKY AQUIFER.....39
III.4	A RIVER BED SERVING AS SEMIPERVIOUS BOUNDARY.....43
III.5	A CONTROL VOLUME FOR SOLUTE TRANSPORT.....46
IV.1	DOMAIN DIVIDED INTO TRIANGULAR ELEMENTS.....58
IV.2	A TYPICAL SHAPE FUNCTION.....59
IV.3	LINEAR INTERPOLATION OF HEAD WITHIN ELEMENT.....61
IV.4	SUBDIVISION OF CUBIC ELEMENTS INTO TETRAHEDRONS....71
V.1	GENERALIZED FLOW CHART FOR AQUIFER SIMULATION MODEL85
VI.1	NETWORK OF ELEMENTS FOR PROBLEM NO. 1.....92
VI.2	COMPARISON BETWEEN ANALYTICAL AND NUMERICAL SOLUTIONS.....93
VI.3	COMPARISON OF RESULTS AT NODE 23 FOR PROBLEM NO.1 IN 2-D WITH VARYING TIME SCHEME.....94
VI.4	SKETCH FOR PROBLEM NO.2.....97
VI.5	FINITE ELEMENT MESH FOR PROBLEM NO.2.....98
VI.6	COMPARISON OF SOLUTIONS FOR PROBLEM NO.2.....99
VI.7	SKETCH FOR PROBLEM NO.3.....101
VI.8	NETWORK OF ELEMENTS FOR PROBLEM NO.3 (COARSE MESH)104
VI.9	COMPARISON OF SOLUTIONS USING THREE TIME SCHEME WITHOUT DECAY CONSTANT (AT X= 30 m.).....105
VI.10	COMPARISON OF SOLUTIONS AT THREE DIFFERENT TIMES WITHOUT DECAY CONSTANT..106

<u>FIGURE NO.</u>	<u>PAGE</u>
VI.11	FINE NETWORK OF ELEMENT.....108
VI.12	COMPARISON OF SOLUTIONS FOR PROBLEM NO.4 WITHOUT DECAY CONSTANT USING FINE MESH AND COARSE MESH....111
VI.13	COMPARISON OF SOLUTIONS AT THREE TIME SCHEMES FOR PROBLEM NO.3 WITH DECAY CONSTANT (0.0003 DAY ⁻¹)AT TWO DIFFERENT LOCATIONS.....113
VI.14	COMPARISON OF SOLUTIONS AFTER DIFFERENT TIMES FOR PROBLEM NO.3 WITH DECAY CONSTANT.....114
VI.14a	COMPARISON BETWEEN THE NUMERICAL SOLUTION WITH AND WITHOUT DECAY CONSTANT.....116
VI.14b	THE REDUCTION PERCENT OF CONCENTRATION FOR THE DIFFERENT VALUES OF DECAY CONSTANT.....116
VI.15	SKETCH DEFINITION FOR PROBLEM NO. 4.....120
VI.16a	NETWORK OF ELEMENTS FOR PROBLEM NO.4(COARSE MESH)122
VI.16b	NETWORK OF ELEMENTS FOR PROBLEM NO.4(FINE MESH)..123
VI.17	COMPARISON OF SOLUTIONS FOR PROBLEM NO. 4 WITHOUT DECAY CONSTANT (AT Y= 30 m.).....125
VI.18	CONCENTRATION DISTRIBUTION IN mg/l WITHOUT DECAY CONSTANT FOR PROBLEM NO.4.....128
VI.19	COMPARISON OF SOLUTIONS FOR PROBLEM NO. 4 WITHOUT DECAY CONSTANT (AT X = 110 m.) AT TWO DIFFERENT TIMES.....129
VI.20	COMPARISON OF SOLUTIONS FOR PROBLEM NO. 4 WITHOUT DECAY (AT X = 80 AND 170 m. AFTER 150 DAYS).....131
VI.21	COMPARISON OF SOLUTIONS FOR PROBLEM NO. 4 WITH DECAY CONSTANT (0.003 DAY ⁻¹) (AT Y= 30 m.).....133