

Solute pollutants transport modeling in the city Giarmata, Timis County – Romania

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Abstract: The Paper present confined groundwater flow and solute transport modeling in the city Giarmata, using the PMWIN applications. Modeling purpose is to constitute extending pollution zone of aquifers in space and time generated of waste water pumping stations. Knowledge of extending of pollution zone is necessary to settle technical measures to closing nonconformity landfill. The companion software Processing Modflow for Windows (PMWIN) offer a totally integrated simulation system for modeling groundwater flow and transport processes with MODFLOW-88, MODFLOW-96, PMPATH, MT3D, MT3DMS, MOC3D, PEST and UCODE.

Keywords: Hydraulic modeling, pollutants transport

1. INTRODUCTION

The works of extension and rehabilitation of the water supply system have as location the streets of the town of Făget, Timiș County. Giarmata is a temperate continental region with a slight Mediterranean influence, with generally mild winters, hot summers and sudden crossings from winter to summer, with short springs.

The town of Făget is situated in the contact area between the Lipovei hills and the Timiș Plain, being a hilly region with terraces and meadows formed by the streams that cross it. Up to 50 m deep, the deposits are predominantly fluvial (in the eastern compartment) and fluvial-lacustrine (in the western compartment), the frequencies of granulometric variations (from boulder to sand) reflect the significant variations of the slopes determined by the vertical movements of the different compartments.

The deep aquifer structure consists of a variable number of layers, between 7-12, with thicknesses of 3-16 m. The granulometric composition is predominantly fine, fine sandy sands, clayey parts and gravel elements. Piezometric levels are 7-14 m deep in the terrace area and 3.0 m deep in the meadow. In the Chizatau-Belint sector, aquifers often have artesian character, rising to +0.8 ... +1.2 m above the ground. The aquifer potential is average $q = 1.0 - 1.2 \text{ l/s/m}$. Chemically the water falls

within the permissible limits of drinking.

The proposed works are structured in:

- extension of the domestic sewerage network with $l = 3800 \text{ m}$
 - realization of 116 chambers
 - construction of 3 waste water pumping stations
- Modernization of water supply system, $L = 9,007 \text{ km}$;

2. MATERIAL AND METHODS

The applications of MODFLOW, a modular three-dimensional finite-difference groundwater model of the U. S. Geological Survey, to the description and prediction of the behavior of groundwater systems have increased significantly over the last few years. Models or programs can be stand-alone codes or can be integrated with MODFLOW. A standalone model or program communicates with MODFLOW through data files. The advective transport model PMPATH (Chiang and Kinzelbach, 1994, 1998), the solute transport model MT3D (Zheng, 1990), MT3DMS (Zheng and Wang, 1998) and the parameter estimation programs PEST (Doherty et al., 1994) and UCODE (Poeter and Hill, 1998) use this approach. The solute transport model MOC3D (Konikow et al., 1996) and the inverse model MODFLOWP (Hill, 1992) are integrated with MODFLOW. The companion software Processing Modflow for Windows (PMWIN) offer a totally integrated simulation system for modeling groundwater flow and transport processes with MODFLOW-88, MODFLOW-96, PMPATH, MT3D, MT3DMS, MOC3D, PEST and UCODE.

PMWIN comes with a professional graphical user-interface, the supported models and programs and several other useful modeling tools. The graphical user-interface allows you to create and simulate models with ease and fun. It can import DXF- and raster graphics and handle models with up to 1,000 stress periods, 80 layers and 250,000 cells in each model layer. The modeling tools include a Presentation tool, a Result Extractor, a Field Interpolator, a Field Generator, a Water Budget Calculator and a Graph Viewer. The Result Extractor allows the user to extract simulation results from any period to a spread sheet.

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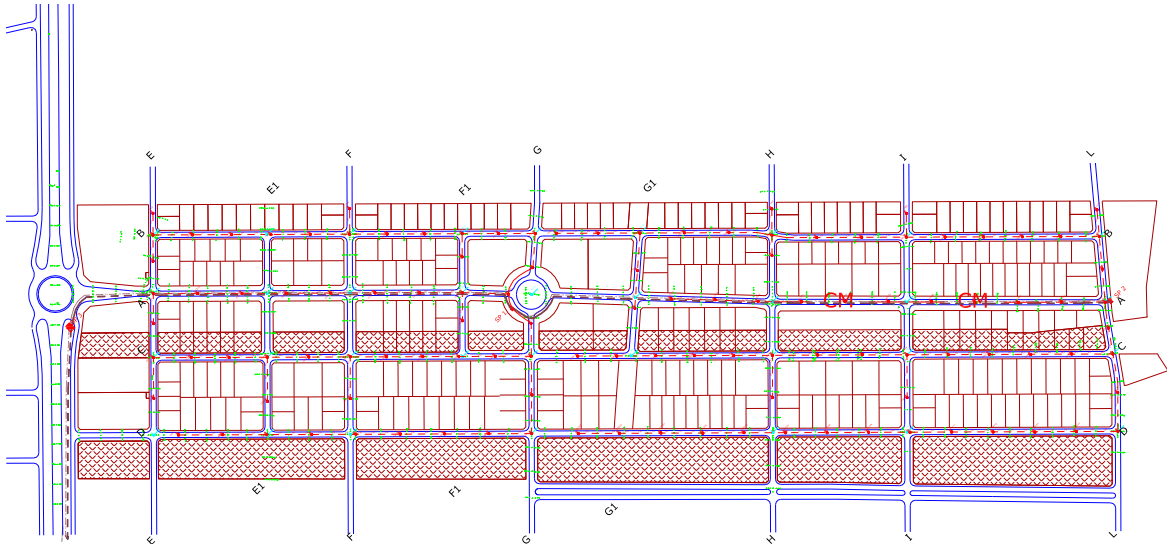


Figure 1. Plan view Giarmata

You can then view the results or save them in ASCII or SURFER-compatible data files. Simulation results include hydraulic heads, draw downs, cell-by-cell flow terms, compaction, subsidence, Darcy velocities, concentrations and mass terms. The Field Interpolator takes measurement data and interpolates the data to each model cell. The model grid can be irregularly spaced.

The Water Budget Calculator not only calculates the budget of user-specified zones but also the exchange of flows between such zones. This facility is very useful in many practical cases. It allows the user to determine the flow through a particular boundary.

The Field Generator generates fields with heterogeneously distributed transmissivity or hydraulic conductivity values. It allows the user to statistically simulate effects and influences of unknown small-scale heterogeneities.

The Field Generator is based on Mejía's (1974) algorithm. The Graph Viewer displays temporal development curves of simulation results including hydraulic heads, draw downs, subsidence, compaction and concentrations.

Using the Presentation tool, you can create labeled contour maps of input data and simulation results. You can fill colors to model cells containing different values and report-quality graphics may be saved to a wide variety of file formats, including SURFER, DXF, HPGL and BMP (Windows Bitmap). The Presentation tool can even create and display two dimensional animation sequences using the simulation results (calculated heads, drawdowns or concentration).

At present, PMWIN supports seven additional packages, which are integrated with the "original" MODFLOW. They are Time-Variant Specified-Head (CHD1), Direct Solution (DE45), Density (DEN1), Horizontal-Flow Barrier (HFB1), Interbed-Storage (IBS1), Reservoir (RES1) and Stream flow-Routing (STR1).

The Time-Variant Specified-Head package

(Leake et al., 1991) was developed to allow constant-head cells to take on different values for each time step. The Direct Solution package (Harbaugh, 1995) provides a direct solver using Gaussian elimination with an alternating diagonal equation numbering scheme.

The Density package (Schaars and van Gerven, 1997) was designed to simulate the effect of density differences on the groundwater flow system. The Horizontal-Flow Barrier package (Hsieh and Freckleton, 1992) simulates thin, vertical low-permeability geologic features (such as cut-off walls) that impede the horizontal flow of ground water. The Interbed-Storage package (Leake and Prudic, 1991) simulates storage changes from both elastic and inelastic compaction in compressible fine-grained beds due to removal of groundwater.

The Reservoir package (Fenske et al., 1996) simulates leakage between a reservoir and an underlying ground-water system as the reservoir area expands and contracts in response to changes in reservoir stage. The Stream flow-Routing package (Prudic, 1988) was designed to account for the amount of flow in streams and to simulate the interaction between surface streams and groundwater.

In the block-centered finite difference method, an aquifer system is replaced by a discretized domain consisting of an array of nodes and associated finite difference blocks (cells).

The nodal grid forms the framework of the numerical model. Hydro stratigraphic units can be represented by one or more model layers. The thicknesses of each model cell and the width of each column and row can be specified. The locations of cells are described in terms of columns, rows, and layers.

MODFLOW requires initial hydraulic heads at the beginning of a flow simulation. Initial hydraulic heads at fixed-head cells will be kept constant during the flow simulation. An IBOUND array is required by the flow model MODFLOW. The IBOUND array contains a code for each model cell. A positive value

in the IBOUND array defines an active cell (the hydraulic head is computed), a negative value defines a fixed-head cell (the hydraulic head is kept fixed at a given value) and the value 0 defines an inactive cell (no flow takes place within the cell).

3. RESULTS AND DISCUSSIONS

The tasks are:

- to calculate and show head contours,
- model calibration,
- to calculate and show time variant concentration of solute pollutants transport

The aquifer extends several square kilometers (1,34 x 1,02 km), situated in space of irrigation channel.

In map presented in Figure 2 is marked model limits.

The top and bottom elevations of the aquifer are variably 93 m and 13 m, respectively.

The average horizontal hydraulic conductivity is 0.0001 m/s; the effective porosity is 0.20.

The water stage between 2 irrigation channel is 89,5 m to 91,50 m above the bottom elevation, which is the reference level for the simulation. The aquifer is simulated using a grid of one layer, 100 columns and 100 rows. A grid spacing is irregular (13,40 m is used for column and 10,2 m is used for row) (Figure 2).

The layer type is confined. The irrigation channels are modeled as fixed head in the channel. Two boundary is fixed hydraulic head boundaries.

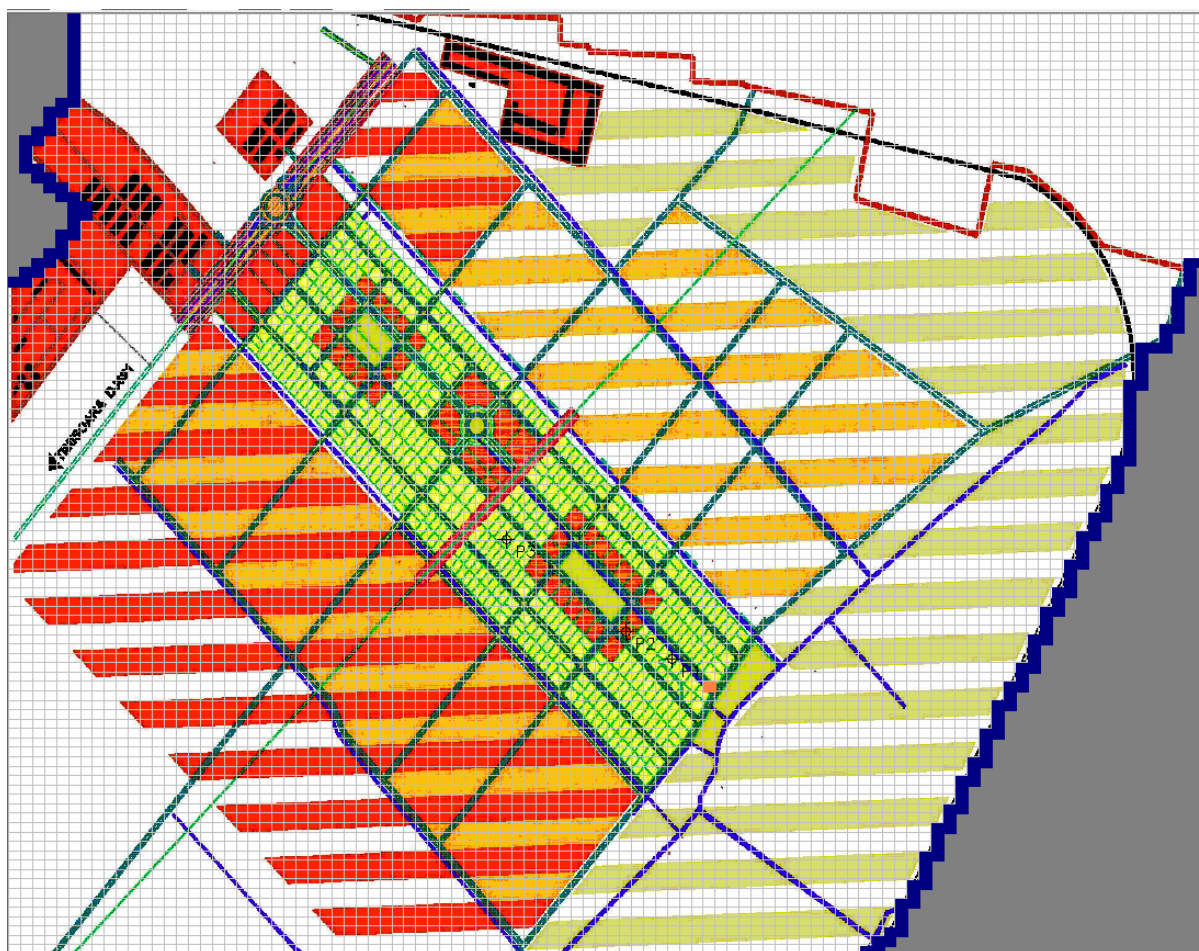


Figure 2. Model and Discretization

Figure 3 shows the head contours.

To modeling polluted transport the pollution source is the landfill considered as a permanent pollution.

As boundary conditions there are accepted:

- concentration $C=100\%$ on the treatment plant as a permanent pollution source
- concentration $C=0$ in the field outside of landfill area.

The dispersivity has the following characteristics: $\alpha L=50$; $\alpha T/\alpha L=0.1$.

Permanent source assumption is based to fact treatment plant is in function of more decades and

determinant pollution infiltration process in conjugate precipitation effects persist in many years.

Results are presented in figures under polluted extending areas with different concentrations (isoconcentrations) for 20 years (Figure 4).

The results of simulation permit exactly quantify evolution of concentrations in time, for all points of polluted zones. This think is important to find a technical method for limitation, reduce or eliminate in time pollution.

A special remark that is not necessary to specify pollutant nature, because the modeling was making in

general for all kind of pollutants. The concentration values are expressed in percentage from the total quantity of pollutant.

Concentration is a general parameter and maybe serve base for calculation an absolute concentration (for example mg/l) for all dissolved pollutants in

water. From the concentrations diagrams the Local Authorities has possibility to know the directions and

evolution in time of the pollution from waste water pumping stations (Figure 5).

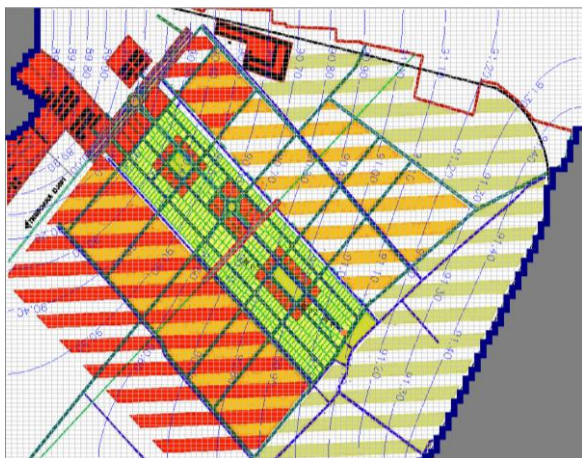


Figure 3. Head contours

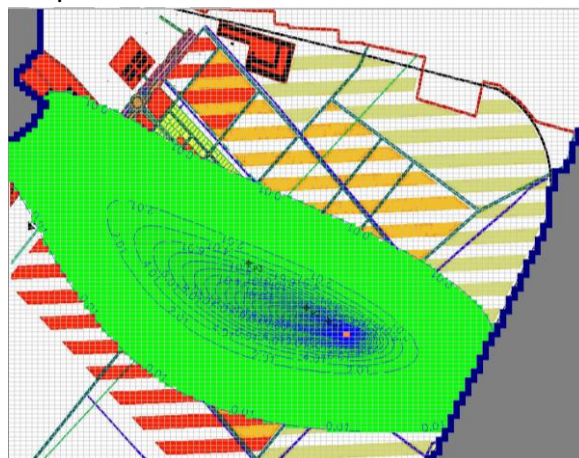


Figure 4. Distribution of the pollutant

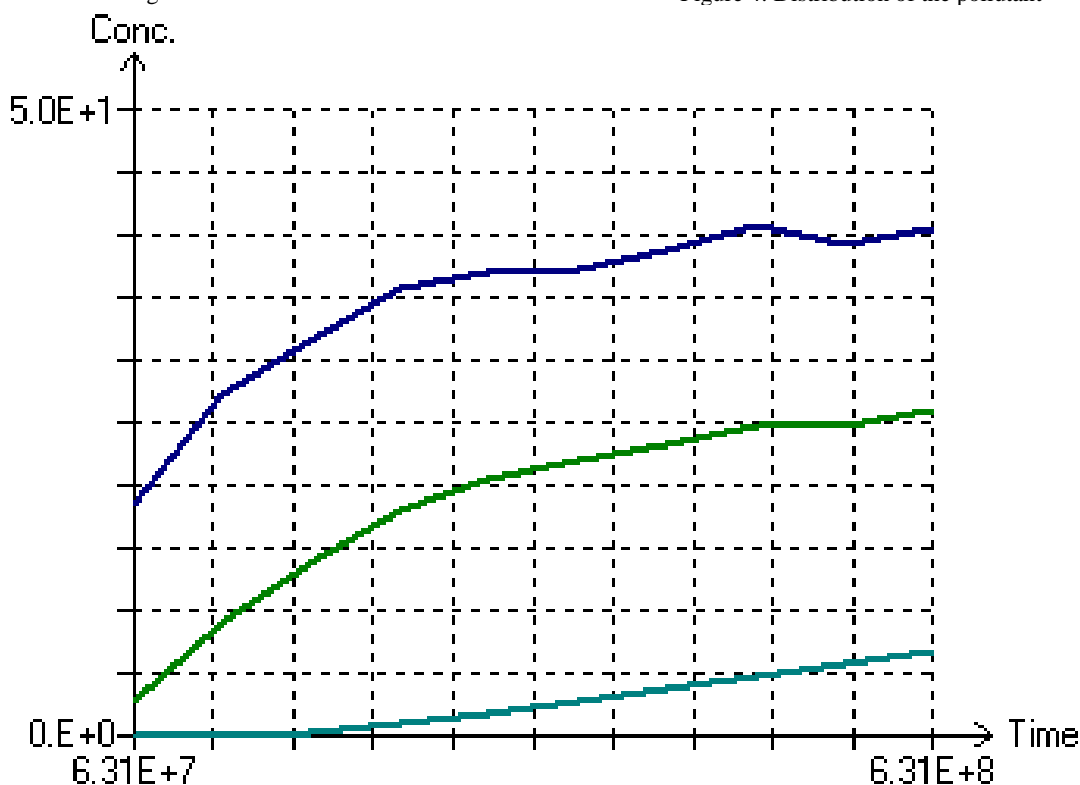


Figure 5. Concentrations time curve

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