Gravitational drainage systems in urban areas case study - Galați town, Romania

Florian Zamfirescu, Iulian Popa, Alexandru Danchiv

Bucharest University, Faculty of Geology and Geophysics, Dept. of Geological Engineering, 6 Traian Vuia str., 70139 Bucharest, Romania;
E-mail: zamfl@gg.unibuc.ro, danchiv@gg.unibuc.ro, julip@gg.unibuc.ro

Abstract: The water leakage in the urban areas causes a continuous water table rise, with injurious effects. An experimental drainage system, based on horizontal well technology was designed and implemented in an inhabited area. Groundwater flow modelling was used to assess the drain conductance parameter as hydrodynamic efficiency indicator.

Key words: urban area, gravitational drainage system, horizontal wells, drain conductance, hydrodynamic efficiency

Introduction

One of the critical environmental problems, which the urban communities have to resolve, is the continuous rise of the water table level due to the uncontrolled losses of industrial and municipal water. These phenomena are common for the most of Romanian towns. The induced effects are generally severe, especially where the loessoid deposits are present: hydrodynamic erosion, high differential settlement, and landslides.
Design of the classical drainage systems for the large urban areas, in the presence of low permeable and high anisotropy loessoid deposits, is difficult and inefficient. Also, the horizontal drainage method, with a long tradition in Romania, has a slight efficiency because of the reduced length of the screens. Nowadays, the technology of horizontal guided well allows employing longer screens, up to 350-400 m.
The present paper describes an experimental gravitational drainage system designed in the urban area of Galati town and evaluates the efficiency of the drainage process through drains conductance estimation.

Specific geologic and hydrogeologic conditions

This experiment was realized on a 14 ha surface residential area of Galati town, located on the first level of Danube River terraces. Because of the leakages from the municipal water system, during the last 20 years, the water table raised with about 4-5 m.
Based on measurements recorded by a 20 wells monitoring system it resulted a piezometric map (Fig. 1) which allow the following observations:

- from hydrogeological point of view a phreatic aquifer is developing in this area, located in loess and loessoid clay deposits, with uniform granulometry and 14 - 16 m of thickness;
- the aquifer is recharged mainly from precipitation and the second level of terraces;
- the piezometric map suggests an artificial recharge in the central part.

Scientific paper

Development of the groundwater flow model

In order to select the optimum drainage variant a steady state, 2D groundwater flow model was developed using the Visual ModFlow package. By model calibration it was obtained the aquifer parameters distribution with following characteristics:

- the mean values of parameters are: hydraulic conductivity K = 0.8 m/d and the recharge coefficient $R=4.5x10^{-3}$ m/d;
- there is a central zone, with higher values of parameters: K=2-3 m/d, $R=10^{-3}$ m/d;
- for the discharge area (slope of terrace), the smaller values of hydraulic conductivity, K=0.2-0.3 m/d, cumulates also the effect of the seepage face;
- the recharge from the upper terrace represent only 10 % from the groundwater circulated in this area.

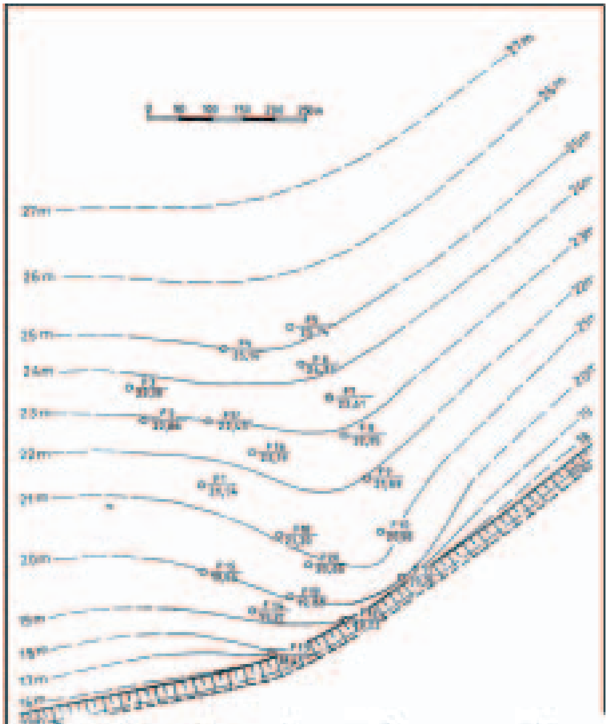

Figure 1. Piezometric map (reference year 1998)

Design and construction of the drainage system

Considering the very difficult local conditions (vertical anisotropy of loessoid deposits, low permeability, inhabited area) the drainage solution could be implemented only through horizontal guided well technology. It has been chosen a system with 3 cvasi-paralel drains, with about 500 m of length. Due to the great length the wells were drilled in two hydraulically joined sectors (Fig. 2).

Figure 2. Cross-section showing the hydraulic connection between the two drilled sectors

The drains were equipped with Schumasoil type screens (VBW3 model). The main screen characteristics are: f=125 mm, 45 % porosity, 36 % surface open area, 200 µm mean pore size, 0.1 cm/s hydraulic conductivity.

Monitoring of the drainage process

The performance of the drainage system was monitored through periodical measurements of discharges and piezometric levels in the observation wells. The analysis of these data leads to following observations:

- The discharges decrease after the drains execution, with a trend to a constant value; some fluctuations appear because of precipitations and leakage variability (Fig.3);
- The piezometric level has an initial slight decrease, followed by fluctuations caused probably by external recharge sources. The recorded drawdowns were: 0.74 - 0.98 m in the downstream area (wells F11, F12, F13); 0.54 - 0.77 m in the upstream area (wells F3, F4, F5) and up to 1.5 - 2 m in the central area.

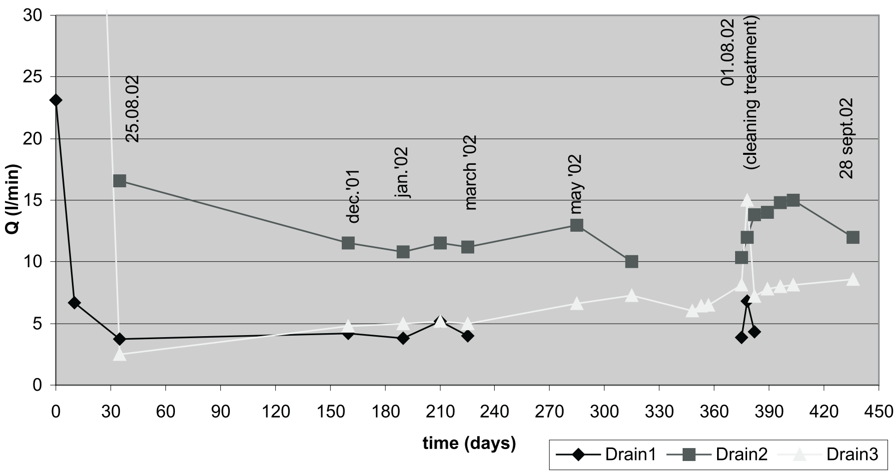

Figure 3. Variation of the discharge (Aug. 2001 – Sept. 2002)

Assessment of the drainage system efficiency

The hydrodynamic efficiency of the drainage could be expressed through drain conductance estimation. It is a global parameter, which describes all of the head losses between the drain and the surrounding area: convergent flow toward the drain; flow through material of different conductivity immediately around the drain; flow through the screen, depending upon the number and size of the openings and the degree of physico-chemical clogging (McDonald and Harbaugh, 1988).

By trial and errors with VisualModflow package it was recalculated the conductance by minimizing the error between measured and calculated parameters. The calibration was performed at for different moments of time, covering one-year period of operation. The drains conductance variation is represented on Fig. 4.

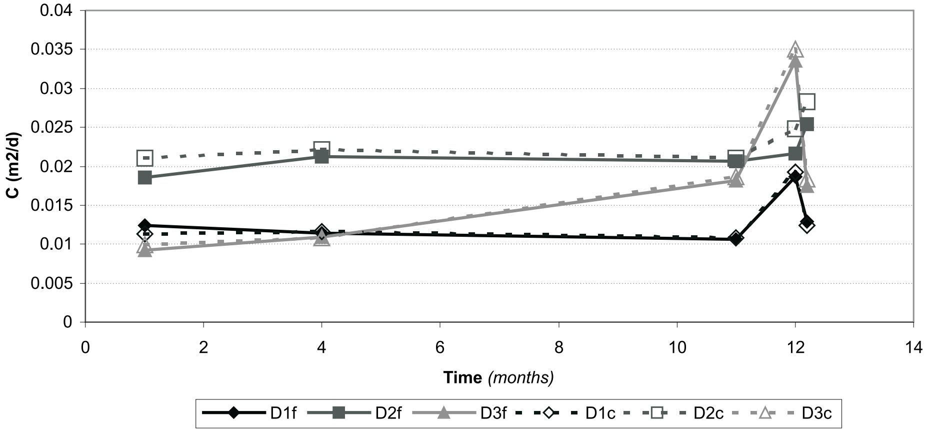

Figure 4. Drains Conductance Variation (Sept. 2001 – Aug. 2002)
(f – values estimated from equation; c – values estimated by calibration)

Conclusions

Despite the local difficulties, generated by presence of loessoid deposits, with low permeability, high anisotropy and heterogeneity, the drainage process has a normal evolution, the discharges remaining almost stable during this period.
The drainage effect is the drop of the piezometric surface with 0.4 – 0.8 m. However, the increase of the piezometric level, still recorded at the upstream limit of the drained area, suggest a local recharge, certainly caused by water pipes leakage. These leakages, still difficult to control and estimate, diminish the effects of the drainage in this area. Thus, the understanding and modelling of the drainage system become more complex.
In time, there is a slight decrease of conductance while the discharges are rather constants. That means the conductance estimation was affected mainly by raise of piezometric levels, probably done by a leakage increase, than by decline of drain hydrodynamic performance. It is obvious that a realistic assessment of the drain conductance require accurate monitoring data. For a successful drainage experiment would be very useful to detect and eliminate the leakage from the water pipes system.
The results obtained from this study allow us to promote this drainage solution, for other affected urban areas and also to recommend this methodology for drain hydrodynamic performance assessment.

References

MCDONALD, M. G., HARBAUGH, A. W. (1988): *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. Chapter A1.* in Techniques of Water-Resources Investigations of the US Geological Survey, Geraghty & Miller, Inc.

POPA, I. (2002): *Hydrodynamic Efficiency of the Hydrogeological Wells. Significant Case-Studies*. PhD Thesis, Bucharest University.