Bulletin of the *Transilvania* University of Brasov • Vol. 11 (60) Special Issue No. 1 - 2018
Series I: Engineering Sciences

DESIGN OF DEWATERING SYSTEM FOR WASTE WATER TREATMENT PLANT

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Abstract: *This paper presents the results of design of groundwater lowering system for building the waste water treatment plant in Kruševac, Serbia. Entire complex consists of around 40 objects on area of about 2ha, while there are 4 objects critical in terms of groundwater lowering. The soil parameters are estimated according to soil geotechnical site. laboratory examination results and borehole pumping tests. The groundwater lowering is calculated numerically by finite difference method for the unsteady flow regime. Lowering of the groundwater and pit excavation was successfully carried out according to the design documentation.*

Key words: *groundwater lowering, pit excavation, numerical model*

1. Introduction

The location of the Wastewater treatment plant is on k.p. 3453, Bivolje, in the city of Kruševac, located in central Serbia (Figure 1). The town of Kruševac is predominantly built on the alluvial level and the terraces of the watercourses of western Morava and Rasina. The terrain in a wider sense consists of the remains of the lake plateau that form three terraces around the perimeter of the Kruševac basin. After the lake was draw back, the river was reined in and the terraces formed. Of all morphological elements, the alluvial plane of the Western Morava, whose width in the zone of the subject location is about 5 km [1], has the dominant significance.

Fig. 1. *Wider view of location*

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According to the data of the Republic Hydrometeorological Institute of Serbia (http://www.hidmet.gov.rs), for the water station Jasika, which is about 2.8km upstream, the maximal level of the Western Morava is 138.8 MASL and the minimal is 137.8 MASL.

Viewed in the profile, the aluvion of this flatland river in a literal view represents a two-layered environment. In the upper part of the profile there are predominantly silty clays below which are sandy gravel, gravel and sand. Within the lower package of sands and gravel, a free level aquifer was formed. At the location of the wastewater treatment plant, the thickness of the first gravel-sand part of the alluvion is about 6.0m in average.

Wastewater treatment plant in Kruševac consists of about forty objects, of which the most critical are, from the aspect of groundwater lowering, the basins with active sludge (facilities 5.1 and 5.2), and final sedimentation tanks (facilities 6.1 and 6.2) (Figure 2).

2. Objectives

In order to allow the construction of these structures in dry pit, the groundwater reduction system should allow the groundwater level to be lowered by about 0.5 m below the bottom of the pit.

Objects 5.1 and 5.2 have an excavation level of 136.6 MASL and for them it is necessary to maintain groundwater level at 136.0 MASL. For the object 6.1 groundwater level is necessary to keep at the level of 137.0 MASL, while for the object 6.2 groundwater level should be maintained at 134.0 MASL. Average terrain level is about 141.5 MASL.

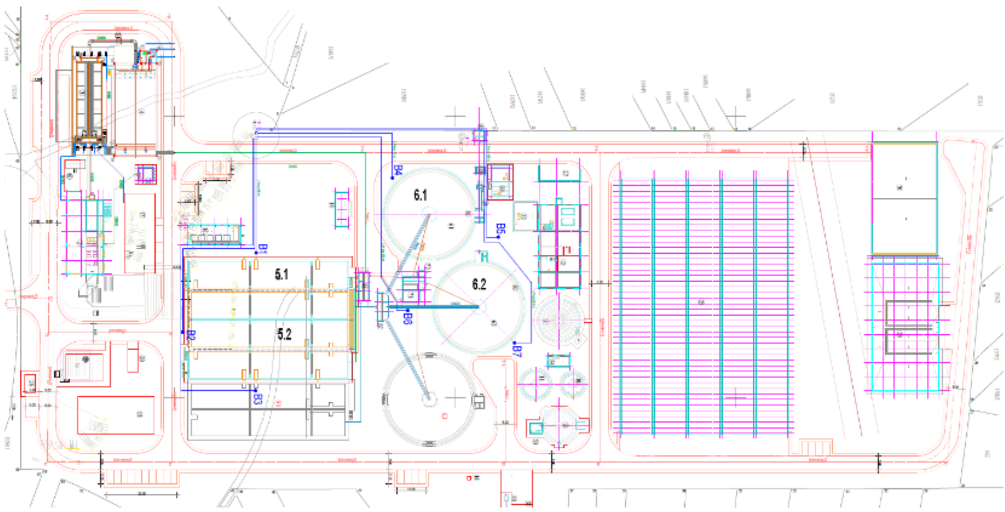

Fig. 2. *Disposition of waste water treatment plant*

The hydro-geological properties of groundwater in the West Morava alluvion are completed by the data obtained by making exploratory drills, piezometers and exploratory-exploitation wells. Within the hydrogeological investigation works, one exploration-drainage well DB-1 and two accompanying piezometers (P1 and P2) were constructed. After that, hydrodynamic tests were performed, i.e., testing wells for determining field permeability.

Piezometers P1 and P2 are made in line with the DB-1 well, perpendicular to the Western Morava direction, i.e. to the direction of the largest inflow of underground waters towards the well. Piezometers are from well 5.0 m (P1) and 15.0 m (P2) in the direction of the West Morava.

The hydraulic calculation is performed using numerical simulation with method of finite difference method, MODFLOW.

3. Materials and Methods

Groundwater flow through 3 dimensional inhomogeneous, anisotropic, saturated or unsaturated porous media, is described using partial differential equations. Instead of analytical solution, because of their complexity, these equations are solved using numerical methods like finite element method or finite difference method. In particular case, finite difference method was used, using commercial software MODFLOW. Differential equation of groundwater flow is given as:

$$k_x \frac{\partial^2 h}{\partial x^2} + k_y \frac{\partial^2 h}{\partial y^2} + k_z \frac{\partial^2 h}{\partial z^2} + W = S_s \frac{\partial h}{\partial t} \qquad h = z + \frac{u}{\gamma_w} \tag{1}$$

where: *kx, ky, kz* – hydraulic conductivity in x, y and z direction,*h* – is the potentiometric head,*t* – time,*W* – is a volumetric flux per unit volume representing sources and/or sinks of water,*Ss* – is the specific storage of the porous material [2]:

For the successful application of the model, its calibration is necessary, primarily in terms of determining the porous media hydraulic conductivity. For the need of pumping test, during the geotechnical investigations [1], one depression well (DB-1) and two piezometers were made on the plot, at 5.0 and 15.0 m distance from the well. Flow rate during pumping test was 8.0 l/s.

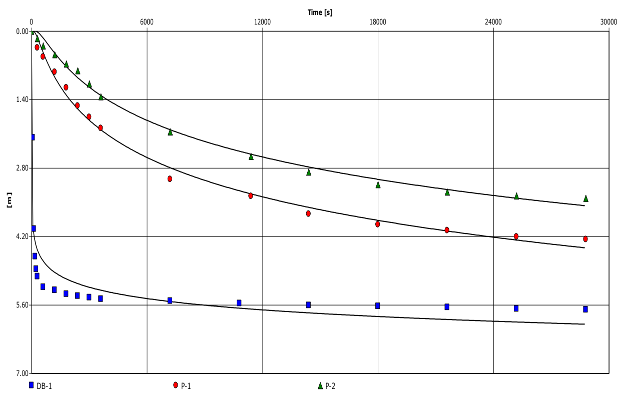

Fig. 3. *Graphical representation of a pumping test result*

In a geotechnical elaborate, analysis of pumping test result from well only (not the piezometers) gave an average hydraulic conductivity of porous media of $K=1.48x10^{-3}$ m/s [1].

In this project hydraulic conductivity is calculated again using the method of C.V.Theis (1935) for confined aquifer and well drilled throughout whole aquifer thickness. Results of the hydraulic conductivity calculations are shown on Figure 4.

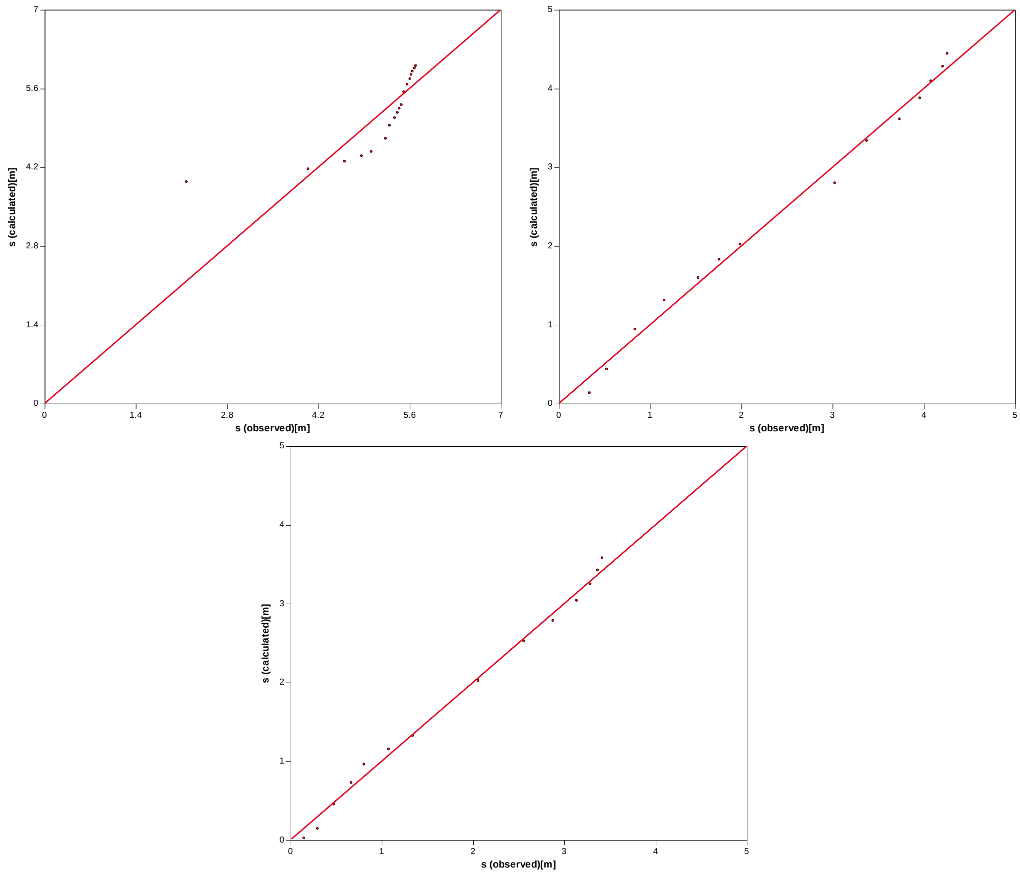

Fig. 4. *Observed vs. calculated drawdown in well and two piezometers*

It is obvious that there is a good correlation, for adopted hydraulic conductivity, between calculated and observed drawdown values for both piezometers (P-1, P-2). Hydraulic conductivity of $K=0.92\ x10^{-4}$ m/s is adopted.

Water level of 138.8 MASL is used as boundary condition which is bounded by river Western Morava (0.5km north), with river Rasina (1.2 km east), on the west with Carski potok river while the railway on the northern part of the Kruševac is used as southern border. In accordance with the geotechnical study, the terrain is presented as a two-layer environment below which is a hydrogeological isolator - clay. The upper layer is 4 m thick (from the level 141.5 MASL to 137.5 MASL) with a hydraulic conductivity of the order of $1x10^{-8}$ m/s, while the lower layer is 6.0 m thick (from the level 137.5 MASL to 131.5 MASL).

3. Results and Discussion

Total required flow during the pumping process depends on the construction phase of the object and was obtained by solving the differential equations of flow in the porous medium by the finite difference method.

To reduce the water level to 134.0-136.0 MASL in the area of approx. 2ha, due to the small thickness of the aquifer, the calculated minimum required number of depression wells is 7. The wells are of the perfect type. The diameter of the borehole is ø320 mm, the diameter of the well construction is ø170 mm and the length of the filter part is 6.0 m.

The number of active wells is harmonized with the predicted technology and dynamics of the construction works. For groundwater lowering from the level of 138.8 MASL at the level of 136.0 MASL, for objects 5.1 and 5.2, and at the level of 134.0 MASL for objects 6.1 and 6.2, pumping dynamic is as follows:

- first 15 days wells B1, B2 and B3 are operative with pumping flow of 4.5 l/s,
- at 15th day, pumping flows in wells B1 and B2 are reduced to 2 l/s while well B3 is turned off,
- at 15th day wells B4, B5, B6 and B7 are being activated with flows of 2.5 l/s,
- till 20th day groundwater level on the entire site is on the level which allows works in the dry foundation pit,
- after 20 days it is necessary to control water levels in piezometers and wells and, in case of need, regulate the pumping flow.

For adopted hydraulic conductivity of 0.92×10^{-4} m/s, optimal pumping flow is calculated using Abramov criteria which is:

$$v_{cr} = \frac{\sqrt[3]{K}}{30} \tag{2}$$

where: v_{cr} – is critical flow velocity (m/s),K – hydraulic conductivity (m/s)

For this critical velocity, optimal pumping flow Q, is calculated using given equation [3]:

$$Q = v_{cr} \cdot D_b \cdot \pi \cdot m = 1.5 \cdot 10^{-3} \cdot 0.32 \cdot 3.14 \cdot 6 = 0.009\ m^3/s \tag{3}$$

where: D_b – diameter of borehole (320 mm),m – aquifer thickness (6 m).

Based on the above equations, values for critical velocity and optimal pumping flow are obtained:

- critical velocity, $v_{cr}=1.5 \times 10^{-3}$ m/s,
- optimal pumping flow, Q=0.009 m^3/s which is Q=9 l/s.

It is possible to achieve desired groundwater lowering with coordinated pumping from

7 wells. Well flows for designed conditions, with starting water levels of 138.8 m are given in Table 1.

Pumping dynamics Table 1.

Days	Flow (l/s)						
	B1	B2	B3	B4	B5	B6	B7
1-15	4.5	4.5	4.5	-	-	-	-
15-18	2.0	-	2.0	2.5	2.5	2.5	2.5
18-30	2.0	-	2.0	2.5	2.5	2.5	2.5

Graphical representation of results of numerical simulation is given on Figures 5, 6 and 7.

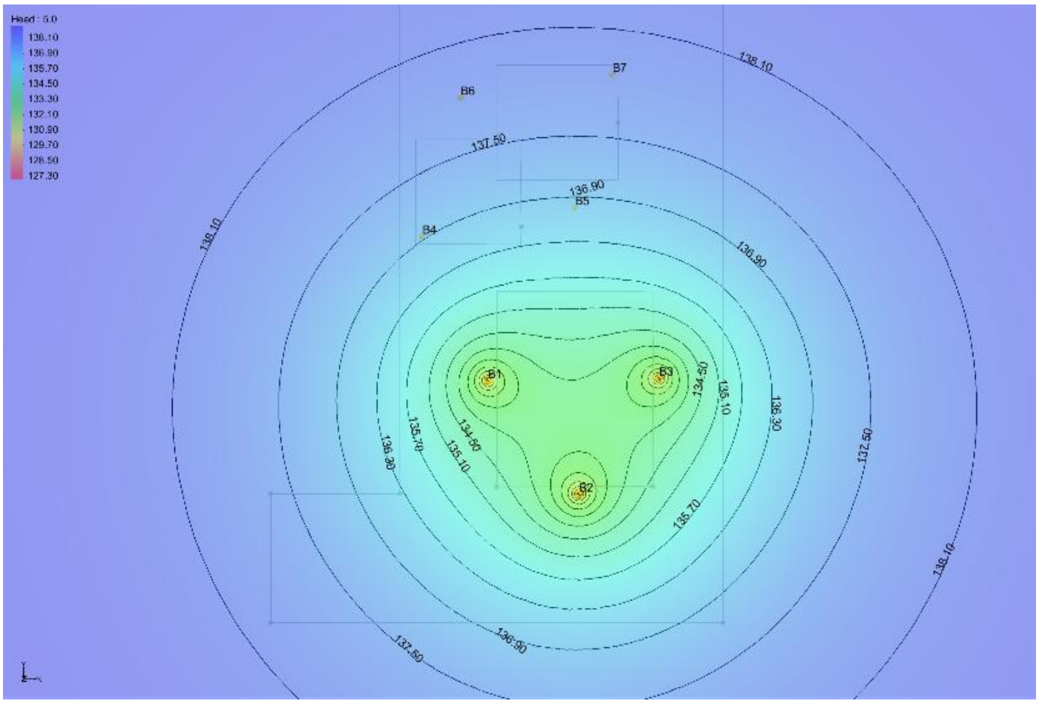

Fig. 5. *Groundwater levels after 4 days (operative wells B1, B2 and B3)*

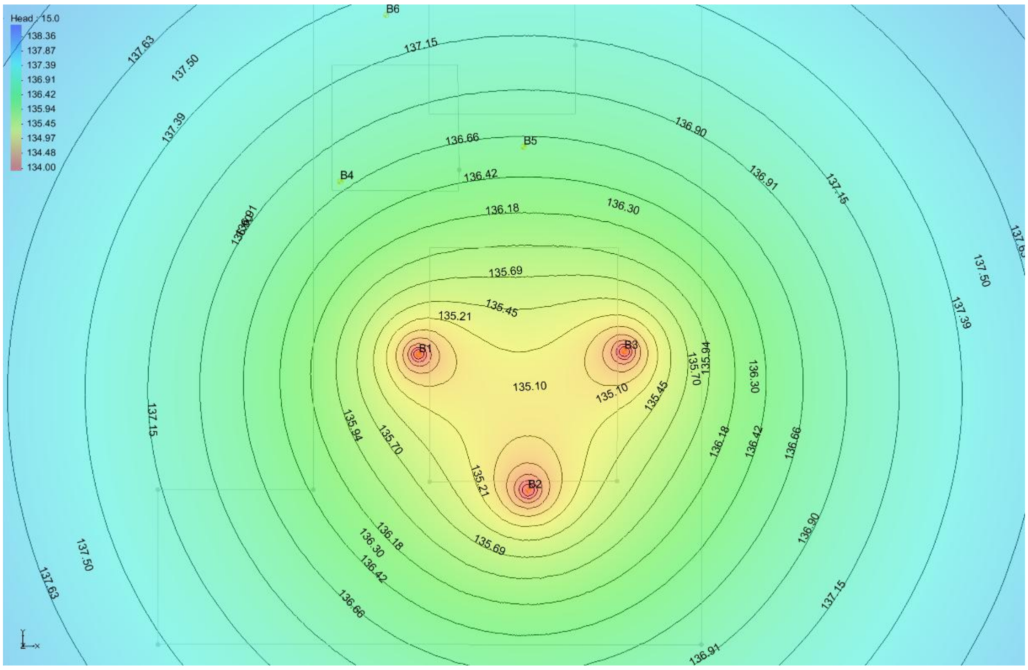

Fig. 6. *Groundwater levels after 15 days (operative wells B1, B2 and B3)*

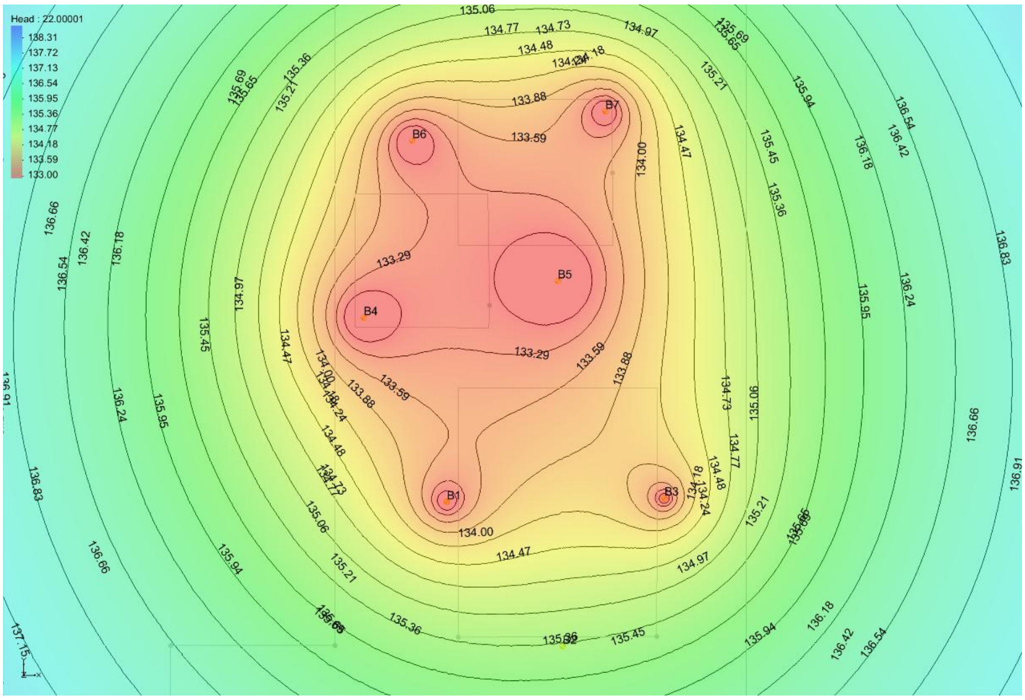

Fig. 7. *Groundwater levels after 22 days (operative wells B1, B3, B4, B5, B6 and B7)*

4. Conclusion

The paper presents the results of calculating of groundwater lowering in a wide excavation pit. This variant was adopted for economic reasons, the construction of an object in a wide excavation pit is considerably cheaper than pit with vertical sides under the protection of RC diaphragm, curtains of RC piles or sheet steel piles, for which additional construction is required.

The groundwater lowering calculation was carried out according to the designed solution, with a total of 7 borehole wells φ360 mm and a depth of ≈12.0 m from the surface of the terrain. The time for which the groundwater level was lowered, generally coincided with the hydraulic calculation.

Acknowledgements

This study was funded by the Serbian Ministry for Science; project TR37010 “Stormwater Drainage Systems as Part of Urban and Traffic Infrastructure”.

References

1. Elaborat o geotehničkim i hidrogeološkim uslovima izgradnje, postrojenje za prečišćavanje otpadnih voda grada Kruševca, LAD GROUP, KR5040 PGD GTE
2. Arlen W. Harbaugh, Edward R. Banta, Mary C. Hill, Michael G. McDonald: *Modflow-2000, The U.S. Geological Survey Modular Ground-Water Model—User Guide to Modularization Concepts and the Ground-Water Flow Process*, U.S. Geological Survey, Open-File Report 00-92, Reston, Virginia 2000
3. Vuković, M; Soro, A: *Hidraulika bunara: teorija i praksa*, Građevinska knjiga Beograd, 1990.