UNSYMMETRICAL DEPRESSION CONES OF DOLOMITE EXCAVATION QUARRIES THAT ARE SITUATED CLOSE TO LARGE SURFACE WATER BODIES IN LATVIA

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ABSTRACT

The case is considered when at the Koknese district in Latvia the hydrogeological situation for dolomite excavation quarries is heterogeneous. The place geological build is complex and the quarries are situated close to large surface water bodies represented by the Daugava river and by the Urgu reservoir. The depression cones of the quarries were obtained by using the local hydrogeological model (HM). The primary data for creating the local HM were provided by the regional HM of Latvia LAMO4. The Groundwater Vistas 7 (GV) system was applied to run HM.

The original method for obtaining the depression cone was used. It did not applied any data on the undisturbed and disturbed (active quarries) groundwater heads To obtain the depression cone, the quarry drawdown was applied as the boundary condition. The quarry depression cones are unsymmetrical, especially explicitly, for the quarries that are situated beside the Urgu reservoir.

Interdependence of the quarries was estimated. The impact of groundwater sources in supporting the quarry drainage flow was found. The flow was supported mainly by the Daugava river (~50%) and the Urgu reservoir (~80%). The drainage flow for the related uniform situation was considerably smaller and it was supported by the flow through the HM border.

The results considered in the paper may be useful for specialists dealing with obtaining of depression cones when conditions of a place are heterogeneous.

Keywords: draining of mineral excavation quarries, obtaining of depression cone, hydrogeological model

INTRODUCTION

To excavate dolomite, its quarry must be drained. It causes the depression cone that may harm the place environment.

If the place hydrogeological situation is uniform, analytical methods provide good results. The cone depression isoline contours have the circle form.

In the paper, the case is reported for the place heterogeneous situation at the Koknese district in Latvia (see. Fig. 1). The depression cones were obtained for three dolomite excavation quarries. They are named, as follows: A1–Koknese, A2–Grotani and A3-Jaunsmilktinas (Fig. 2). The place geological build is complex and the quarries are situated close to the Daugava river and to the Urgu reservoir.

Fig. 1. The study area location

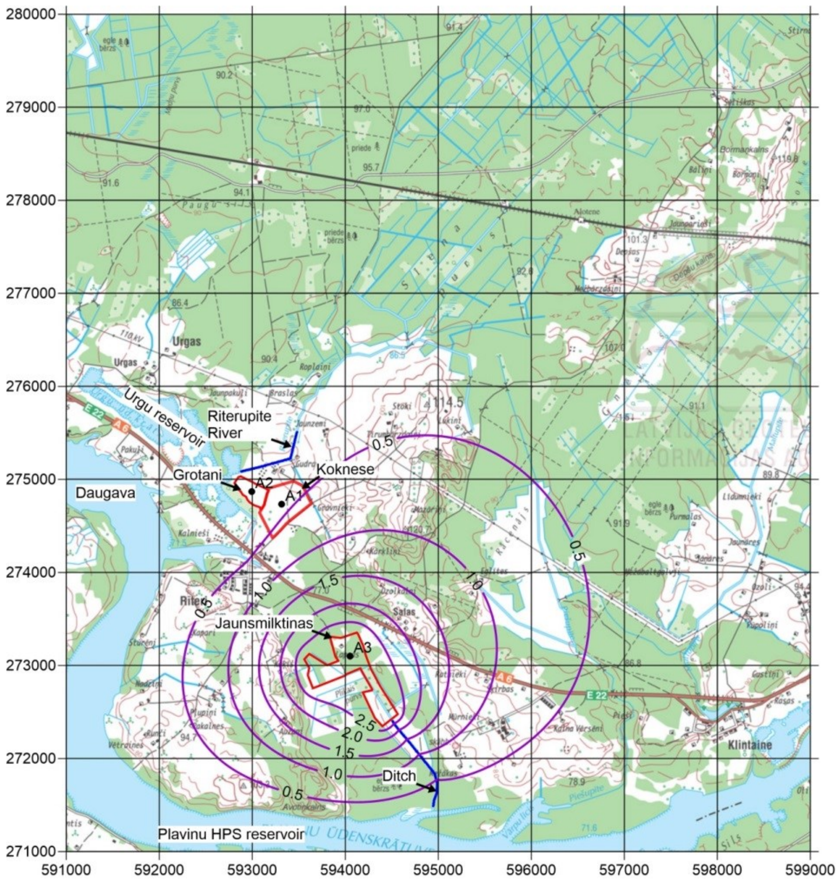

Fig. 2. Locations of quarries and surface water objects within the HM area. The depression cone isolines [m] for the quarry "Jaunsmilktinas" are shown, S_{A3}=3.0m

Because no analytical method provides the right depression cone when the place situation is not uniform, the local HM was applied. The modelling GV program [1] was used for running HM. The model operated in the MODFLOW [2] environment which is the GV module.

The primary data for creating of the local HM were provided by the regional HM of Latvia LAMO4 [3]. To supply HM by the local data, the material [4] was used.

The HM area (see Fig. 2) includes the three quarries A1, A2 and A3 and the four surface water objects: the part of the Daugava river (U1) which represents the reservoir of the Plavinu Hydro-power station (HPS); the Urgu reservoir (U2); the Riterupite river (U3) which discharges into the Urgu reservoir and the ditch (U4) that runs water from the Jaunsmilktinas quarry A3 into the Daugava river.

The program SURFER [5] was applied for preparing the HM initial data and for visualization of depression cone isolines on the topographical map [6].

The depression cones were obtained by using the original method. It did not applied data on the undisturbed and the disturbed (active quarries) groundwater heads which difference was the depression cone when the ordinary method was applied.

Interdependence in % of the quarries was estimated. The effect of sources in % that support the quarry drainage flow was found. The results of modelling for the heterogeneous and uniform place conditions were compared.

THE HYDROGEOLOGICAL MODEL

Ordinary, the steady state local HM can be applied for computing the groundwater head φ and the flow q distributions in nodes of the HM spatial grid. In the reported case, the model was used for the straight computations of the depression cone s.

The HM area has the size 8000m×9000m (Fig. 2). The plane approximation step 10m enables to simulate the quarries accurately, especially, at the Urgu reservoir vicinity.

The HM vertical schematization is presented in Table 1. The model contains the following seven layers: 1.- the layer for the boundary condition on the HM top; 2.- the aeration zone aer as the aquitard that controls the infiltration flow; 3.- the Quaternary aquifer Q2; 4.- the Quaternary moraine gQ2z; 5.- the Daugava D3dg# dolomite aquifer where the quarries are located, the aquifer is connected with the surface water objects U1, U2 and U3, U4 that are boundary conditions; accordingly, for the lakes and rivers; 6.- the Salaspils aquitard D3slp#z; 7.- the layer for the boundary condition on the HM bottom.

The first and the seventh layers of HM serve as the locations for fixing the boundary conditions ψ_{rel} and ψ_{D3pl}, accordingly. In order not to distort the HM geometry, their thickness δ=0.02m. As the primary data source for the local HM, the HM of Latvia LAMO4 was used [3].

Table 1

The vertical schematization of the hydrogeological model

No	Name of layer	Layer code	Layer thickness [m]	Permeability [m/day]	Notes
1.	Relief	rel	0.02	10.0	ψ_{rel}- boundary condition
2.	Aeration zone	aer	0-17.7	10^{-7}-4×10^{-4}	
3.	Quaternary aquifer	Q2	0-6.6	10.0	
4.	Quaternary moraine	gQ2z	0-23.0	10^{-3}	
5.	Daugava aquifer	D3dg#	11.0	150.0	quarries, water objects U1-U4 connected,
6.	Salaspils aquitard	D3slp#z	11.0	3×10^{-5}	
7.	Plavinu aquifer	D3pl	0.02	10.0	Ψ_{D3pl} –boundary condition

The following local information was provided by [4]: locations of the quarries, borderlines of the surface water objects U1 and U2 as lakes, the locations of the objects U3 and U4 as rivers; for the aquifer D3dg#, the transmissivity T=11×150=1650m^2/day was used.

DESCRIPTION OF THE METHOD FOR OBTAINING OF THE DEPRESSION CONE

The depression cone s_A for the quarry A is the difference:

$$s_A = \varphi_N - \varphi_A \tag{1}$$

were φ_N and φ_A are the undisturbed and disturbed (the quarry A operates) heads computed by HM. The quarry draining flow q_A also have to be acquired.

To obtain the distribution φ_A that simulates the quarry draining, in the quarry area L_A , the drawdown condition s_A must be applied as follows:

$$S_A = \varphi_{NA} - z_A \tag{2}$$

where φ_{NA} is the mean undisturbed head in the area L_A; z_A is the quarry bottom elevation.
In the reported case when only the depression cones were obtained, the cone s_A can be computed straightly, by using the modified regime of HM, as follows:

1. the HM boundary conditions (ψ_{rel}, ψ_{D3pl}, ψ_{lakes}, ψ_{rivers}, and ψ_{border}) must be replaced by ψ =0;
2. in the quarry area L_A , the boundary condition $\psi_A = S_A$ must to be fixed;
3. the local HM computes the depression cone s_A that is equal with the one which is obtained by the ordinary method of (1).

The quarry draining flow was obtained by using the GV tool "Mass balance"[1].

RESULTS OF MODELLING

The results of modelling were described in the report [7].

The depression cones of the aquifer D3dg# for the quarries A1, A2 and A3 (see Fig. 3, Fig. 4 and Fig. 2) were obtained by using the original method.

The depression cones are unsymmetrical, especially explicitly, for the quarries "Koknese"(A1) and "Grotani" (A2) that are situated beside the Urgu reservoir (see Fig. 3 and Fig. 4), The form of the quarry "Jaunsmilktinas" depression cone borderline (s=0.5m) is far from the circle shape (see Fig. 2) because of the Daugava river and the Urgu reservoir influence.

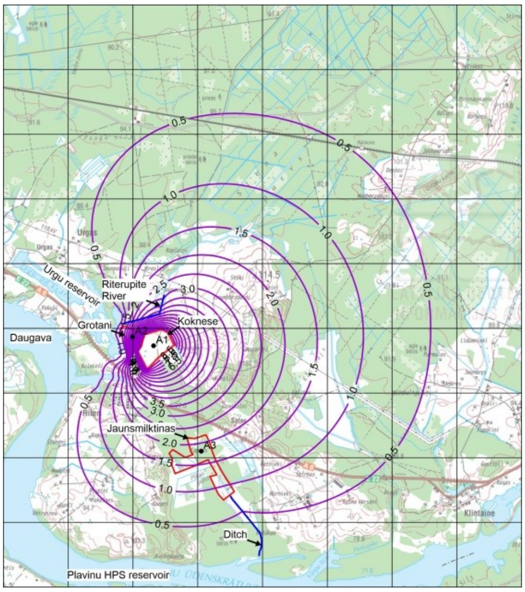

Fig.3. The depression cone isolines [m] for the quarry "Koknese", S_{A1} = 9.0m

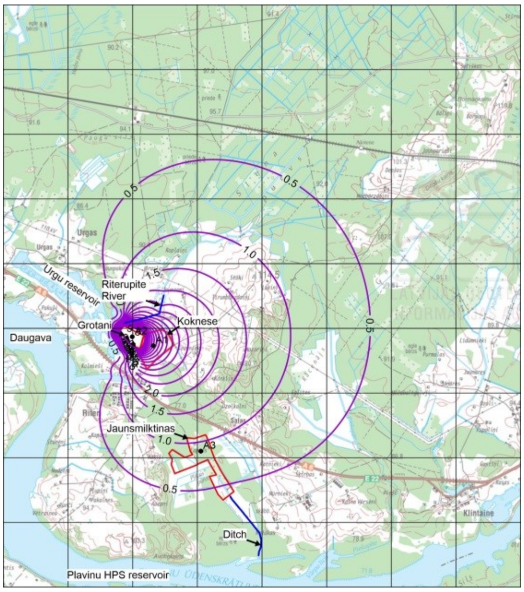

Fig.4. The depression cone isolines [m] for the quarry "Grotani", S_{A2} = 10.5m

The quarry interdependence and numerical data are presented in Table 2. To estimate the quarry interdependence A_{ij} in %, the depression cone data were considered. For example, to estimate the influence of the quarry ”Koknese” on the quarries “Grotani” and “Jaunsmilktinas”, the depression cone of “Koknese” was considered. It provided S_{A1}=9.0m→100%. In the centres A2 and A3 of the quarries “Grotani” and “Jaunsmilktinas”, accordingly, s_{A2}=4.3m→47.8% and s_{A3}=1.8m→20.0%. The quarry “Jaunsmilktinas” is practically independent from the quarries “Koknese” and “Grotani” (13.6% and 4.7%). In Table 2, q and q_v are the drainage flows, when quarries operate singly and together, accordingly, if the quarries operate simultaneously , their drainage flows q_v decrease (q/q_v >1).

Table 2

Summary on the quarry interdependence and numerical data

No	Quarry name and HM code		Interdependence [%]			Numerical data			
			A1	A2	A3	S [m]	q [m^3/day]	q_v [m^3/day]	q/q_v
1.	Koknese	A1	100	47.8	20.0	9.0	71011	38810	1.83
2.	Grotāni	A2	61.7	100	8.3	10.5	114310	96220	1.19
3.	Jaunsmilktinas	A3	13.6	4.7	100	3.0	20371	11000	1.85
						Total	205692	146030	1.41

The quarry drainage flows and the impact in % of their sources were obtained. The summary on these data is presented in Table 3. The sources were represented: the object U1, U2, U3, U4, the HM outer border flow q_{border}, the flows q_{aer} and q_{D3pl} through the top and bottom surfaces of the aquifer D3dg#. Due to closeness of the quarries to the Daugava river (U1) and the Urgu reservoir (U2), these sources support, accordingly, up to 50% and 80% of the drainage flow.

Table 3

Impact of groundwater sources [%] on the quarry drainage flow

No	Quarry name	Impact of source [%] on the quarry drainage flow							Flow [m^3/day]
		U1	U2	U3	U4	q_{border}	q_{aer}	q_{D3pl}	q
1.	Koknese	18.8	54.0	11.6	1.6	9.4	4.5	0.1	71011
2.	Grotani	6.1	80.1	8.2	0.4	3.5	1.6	0.1	114310
3.	Jaunsmilktinas	52.5	9.9	2.1	13.2	14.1	7.6	0.6	20371
4.	Quarries together	13.2	67.9	8.1	2.0	5.9	2.8	0.1	146030

In Table 4, the comparison of the drainage flows q_u and q for uniform and heterogeneous conditions is presented. The surface water bodies considerably increase the quarry flow q if compared with the case of the uniform conditions (q/q_v >1.7).

Table 4

Decrease of quarry inflows q_u for the uniform conditions

No	Quarry name	L [km^2]	r_o	S	Q_u	q	q/q_u
1	Koknese	190000	246	9.0	33441	71011	2.12
2	Grotani	65700	144	10.5	37770	114310	3.02
3	Jaunsmilktinas	250000	282	3.0	11721	20371	1.74

The flow q_u was computed by using the following formula:

$$q_u = 2\pi TS/\ln(4000/r_o), \quad r_o = (L/\pi)^{0.5} . \qquad (3)$$

A quarry was located in the 7000m×7000m area centre of the uniform aquifer. The transmissivity T=1650m^2/day and the drawdowns S were the ones of the heterogeneous conditions. For the uniform conditions, the drainage flow q_u is supported by the HM border flow q_{border}.

CONCLUSIONS

The depression cones were obtained for three quarries at the Koknese district in Latvia. The quarries are situated close to large surface water bodies – the Daugava river and the Urgu reservoir. The depression cones were obtained by using the local hydrogeological model, because no analytical method provides the right cones for the reported case. The cones are unsymmetrical and drainage flows of the quarries were considerably larger than the ones for the uniform hydrogeological situation. The original method for simulation of the depression cones was applied. Only the depression in the quarry area was used as the nonzero boundary condition.

The interdependence between the quarries was estimated. The influence of various sources that support the quarry drainage flow was evaluated. The largest part of the flow (up to 80%) is supported the Daugava river and the Urgu reservoir. For the uniform case when no surface water bodies are present, the quarry drainage flow is supported by the border flow of the study area.

The results reported in the paper may be useful for the specialists dealing with obtaining depression cones when the place hydrogeological conditions are not uniform.

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