USING NUMERICAL MODELING FOR BORJOMI- BAKURIANI DRINKING WATER RESERVOIR

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The applied modelling considers mainly the interaction between surface water and groundwater of the Bakuriani-Borjomi lava flow and the possibility of their pollution with hydrocarbons in case of oil spilling. In order to define the possible pollution propagation, we apply slag-testing technology and numerical modelling methods.

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Keywords: Surface and ground water, oil spilling.

Introduction

The Tbilisi-Baku-Ceykhan pipeline is of course very beneficial for the country of Georgia. At the same time even after its opening there are intensive discussions on the possibility of ecological catastrophe in the case of its damage (spilling) at some areas. One of such most complicated and extremely responsible sections lies within the geomorphologically dangerous Borjomi area, where the problem is connected with possible pollution of drinking groundwater source from lava layer at Bakuriani-Tsikhisjvari area by oil-products.

Conceptual model

Study area is located in the central part of Adjara -Trialety folded system on the plateau between the valleys of rivers Gudjaretis-Tskali and Borjomula, altitude 950-1450 m. The middle mountain erosive relief, created by river net, is complicated by various local micro-relief forms (erosion creeps). Volcanic activity in cretaceous provided the structuring of Daba-dzveli, Bakuriani and Gudjareti volcanic formation (Skhirtladze, 1958, Gabechava et al., 2000). And the latter two created long, narrow lava flows. The first one follows to the river bed reaching Borjomi, and the another one Tsagveri.

Model was built in MOFLOW package (Beradze et al., 1985). It was decided to divide the model into 5 layers (Chkhaidze et al., 1988). First upper layer is very thin and represents soil. Second layer simulates volcanogenic andesitic deposits (green layer in Fig. 1). Lava is added into the model as middle layer (light blue layer in Fig. 1). The lava takes place 180 m below the surface, within the early Quaternary alluvial sediments of the paleo-channel of the river Borjomula.

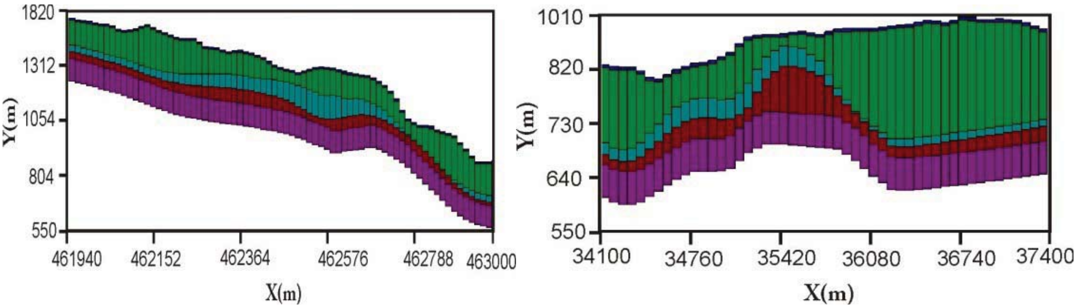


Fig. 1 Vertical and horizontal Borjomi model cross section

Tuff-breccia which forms Basin of Borjomula river and other waterways (river Gujaretistskhali) is represented by 4-rd layer in the model (red colour in Fig. 2).

Those zones in 4th layer which relates to the old riverbed are very high hydraulic conductible. The lower layer is an impermeable layer which represents flysh.

Layers change their form and thickness from North to South under consideration of available electromagnetic profiles.
In general hydrodynamic parameters of layers were found from available literature (Anderson et al., 1999, Meskhia et al., 2002, Chikhelidze et al., 1954). Hydraulic conductivities were estimated from the aquifer tests. See Table 1.

Table 1 Value of hydraulic parameters of layers

Layers	**Specific Storage 1/m**	**Specific Yield** unitless	**Effective Porosity** unitless	**Total Porosity** unitless	**Hydraulic Conductivity m/s**
1	7.1E-3	5E-1	2.53E-1	3E-1	2.1E-3
2	3.8E-3	1E-2	2.9E-1	3.5E-1	3.5E-4
3	3.8E-6	3.2E-4	4E-2	5E-2	1.5E-6
4	2.5E-3	1.4E-1	1.7E-1	2.5E-1	9.5E-4
5	8.5E-4	3.2E-3	8.5E-3	1E-2	2E-8

Precipitation occurs mostly on the plateau Bakuriani-Tsikhijvari and serves as the main source of model recharge. Participation in the recharge of lava plateau (the area between Sadgeri and Tsemi) occupies approximately 3-4 km^2.

Imposed on upper layer recharge boundary condition is not the same for the whole model. 40% of annual rainfall was assigned to the southern part of model area and 30% to the northern part.

Head –depended flow boundary (Cauchy) conditions were imposed along the Borjomula and Gijaretistskali rivers. No flow conditions were imposed along streamlines on the northern and southern (Bakuriani, Didi-Veli plateau) borders.

Springs were added as flow boundary condition. The elevations of springs as it emerged at the land surface were considered as head values. Impermeable flysh formed the lower boundary of a modeled system.

Numerical model

In the base of numerical model lies the Laplaces equation, which takes into account distribution of heads, hydraulic conductivities, storage properties everywhere in the system and allows treatment of flow in three-dimensional profile (Beradze et al., 1985):

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}-R$$

Where Kx, Ky and K_z are components of the hydraulic conductivity tensor. S_s is the specific storage, R is a general sink/source term that is intrinsically positive and defines the volume of inflow to the system per unit volume of aquifer per unit time. To simulate outflow R=-W. (where W is withdrawal rate).

Next step after conceptual model is model running. After, successful first run model calibration has been carried out.

Aim of model calibration was to minimize difference between the simulated and observed water levels. Model has been calibrated in a steady-state mode by head and deuterium observation data. Head data were collected on the rivers Borjomula and Gujaretistskali, in Daba and Tba boreholes during 2 years. Together with head observation isotope data (deuterium observation) were used. Deuterium data showed different values for Bakuriani and Borjomi regions, what gave possibility of using deuterium for improving calibration process. Deuterium samples from Borjomula river, Tba, Sadgeri, Borjomi park were added into model as concentration observation points. The concentration was added into model by using particles tracking package (Modflow package's part). Each particle represents mass of concentration, which is transported by groundwater flow.

Calibration residuals were calculated by subtracting the head and concentration observed values measured at observation points from the values calculated by the model at those points. The value of the calibration residual represents a quantitative measure of the "goodness-of-fit" between the simulation results and the 'known' or observed conditions of the system. Goodness-of-fit satisfies (discrepancy 1.8%, required <2%) the

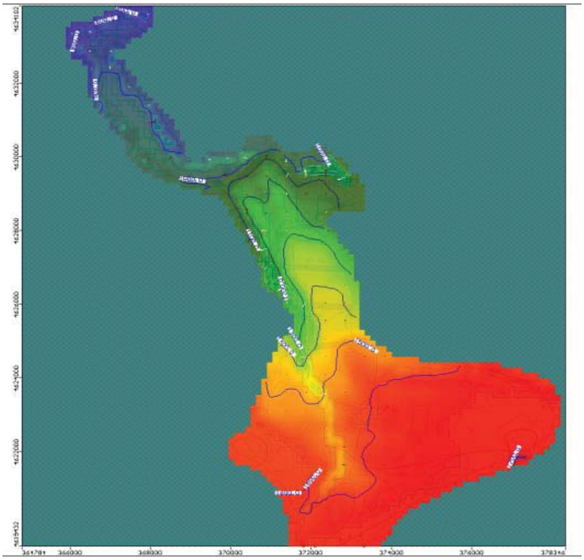


Fig. 2 Model of water table elevation

minimal requirements of calibration, but is not perfect. Additional head observation can decrease calculation error.
Inflow balance in Fig. 2 shows that that river contribution to the groundwater system does not prevail over to recharge from precipitation and the system assumes deeper water circualtion.

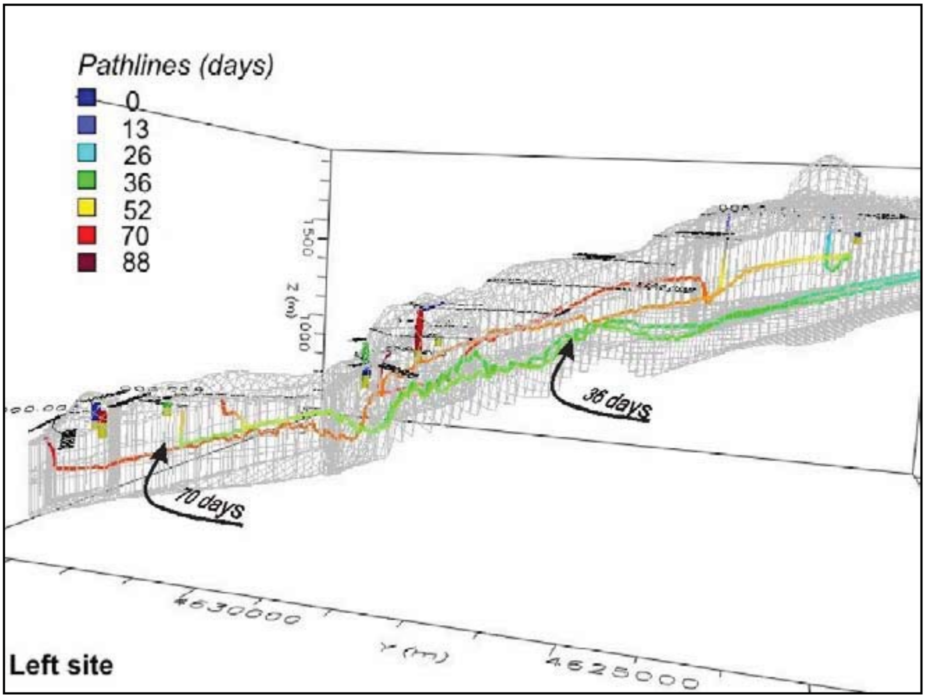
Conclusions

Three flow path ways inside and under lava were determined by the model.

After infiltration in lava sheet “spring water” flows along ancient river valley in Quaternary alluvial and are discharging as Sadgeri and Daba springs.

Water flows along breccia rocks and that is why their pathway to surface is longer than the route of waters flowing to rivers. By numerical modelling: it reveals the difference between durations of water flow for above two pathways, equal from 70 to 30 days;

1st stream flowing coincides with old river bed in breccia's rocks. This stream has direction on the western site of lava stream and passes area near Tba borehole and runs up to Sadgeri springs. For reaching from recharge area to the Tba borehole approximately 30 days are supposed, 80 days are necessary to reach Sadgeri springs. 2nd stream found path on the right eastern site of lava and takes more days (about 70) to run up to the central part of Lava body near Tba village (red-brown segment of path line).



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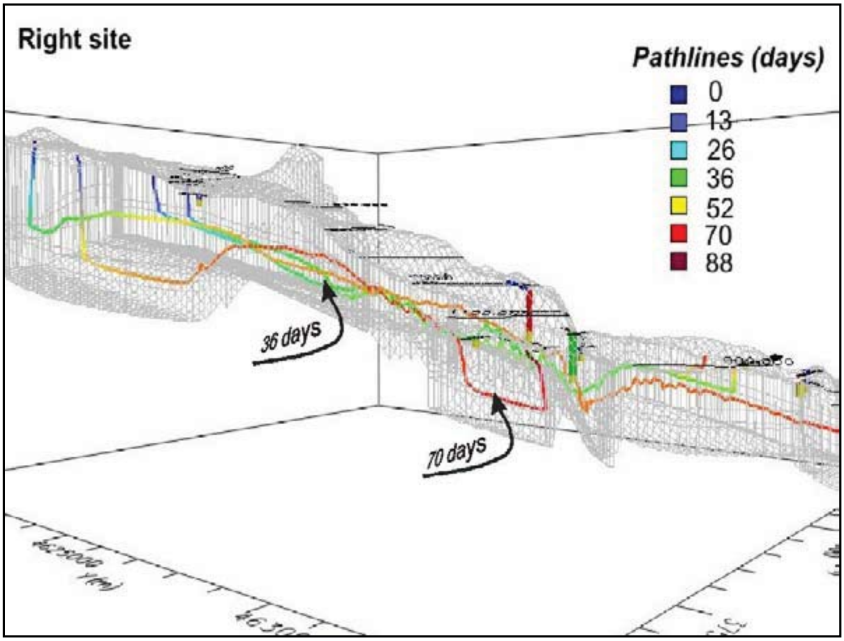

b

Fig. 5 Vertical view of movement (a) Vertical direction of particles' movement from the left site of model is shown; (b) Vertical direction of particles' movement from the right site of model is shown

Flowing from recharge area to the central part of area not along old riverbed takes more time (about 50 days). 26 days of flowing is marked by blue colour of line. It means that contaminant could reach central area where Tba and other boreholes are located at least in 26 days.

Thus, the possibility that oil contaminant in the case of pipeline accident can reach mineral water sources is realistic.

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