Groundwater modelling : Project

The practical works of the course « Groundwater Modelling » are dedicated to solving a hydrogeological problem using a numerical model. The methodology, the results and the conclusions of the study will be described in a report expected for November 27 (5 weeks after the last practical session).

The numerical model can be built by groups of two students. However, each student must write an individual report.

Problem statement and objectives

For the construction of an underground parking lot of a shopping center (indicated as ☒ on the basemap) a pit needs to be excavated.

The excavated pit needs to be dry for a period of at least 4 months. The excavation pith has a depth of +/- 6 m (1/3 of the thickness of the alluvial aquifer), and a width and length of 50 m. The general objective of this study is to:

1) calculate the flowrate that is required to deplete the pit of water
2) calculate the time it takes to make the pit dry at that flowrate
3) roughly estimate if a continuous contaminant leakage present at the surface +/- 300m east of the pit (indicated as ⚠ on the basemap) will enter the pit during the construction works. The contaminant has a leakage rate of 1m^3/h and a concentration of 20 ppb.

More specifically, it is asked to:

1. Develop a **conceptual model** of the problem (definition of the boundaries of the area, number of layers, boundary conditions, use of available data, choice between steady- state and transient conditions etc.). This conceptual model must be described in detail in the final report with a specific emphasis on the choice of the boundary conditions.

2. Model the studied area with a numerical model using MODFLOW GWF and **calibrate the model in natural and pumping conditions (flow calibration)**. At the end of the calibration, a value of hydraulic conductivity, specific yield and specific storage will be available at each location of the model. The calibration will ensure that the misfit between observed andcalculated hydraulic heads is minimum.

3. Model with MODFLOW GWT the tracing experiment carried out on the study site to estimate the value of **transport parameters (transport calibration)**. Check the breakthrough curve, do the concentrations make sense (according to what was injected).

4. Assess the effect of dispersion on the first arrival of pollutant using the calibrated transport model. What would the breakthrough curve of an unresolved (ie continuous) leakage look like?

5. Perform, for the parameters, a local **sensitivity analysis** to estimate the relative importance of a specific parameter on the results.

6. Use the calibrated steady state flow model to **estimate the minimum flowrate** to deplete the pit of water.

7. Is there a way to further decrease the required flowrate? Is there a way to decrease the impact of the pumping on the environment?

8. Use the calibrated transient flow model to **estimate the time** it takes to pump the pit dry at that flowrate.

9. Estimate with MODPATH (= advection only) if the **contaminant leakage** will enter the pit during the construction works of 4 months. Start from the calibrated flow (for SULAMA)/transport model (and divide the upper aquifer into three layers of equal thickness). Where would the leakage end up in natural conditions? What do you think that the difference would be if you did a full transport simulation? What is the influence of the porosity?

10. Discuss the model and the results thoroughly in a report.

The students following the master in Sustainable Land Management do not have to model the tracer experiments (point 3) nor assess the effect of the dispersion on the first arrival (point 4).

Description of the available data

The study area is located in the alluvial plain of a river flowing in the east of the area from south to north (Figure 1). The alluvial plain is composed of gravels, sands and clays. Under alluvial formations, limestone and sandstone formations are found (Figure 1).

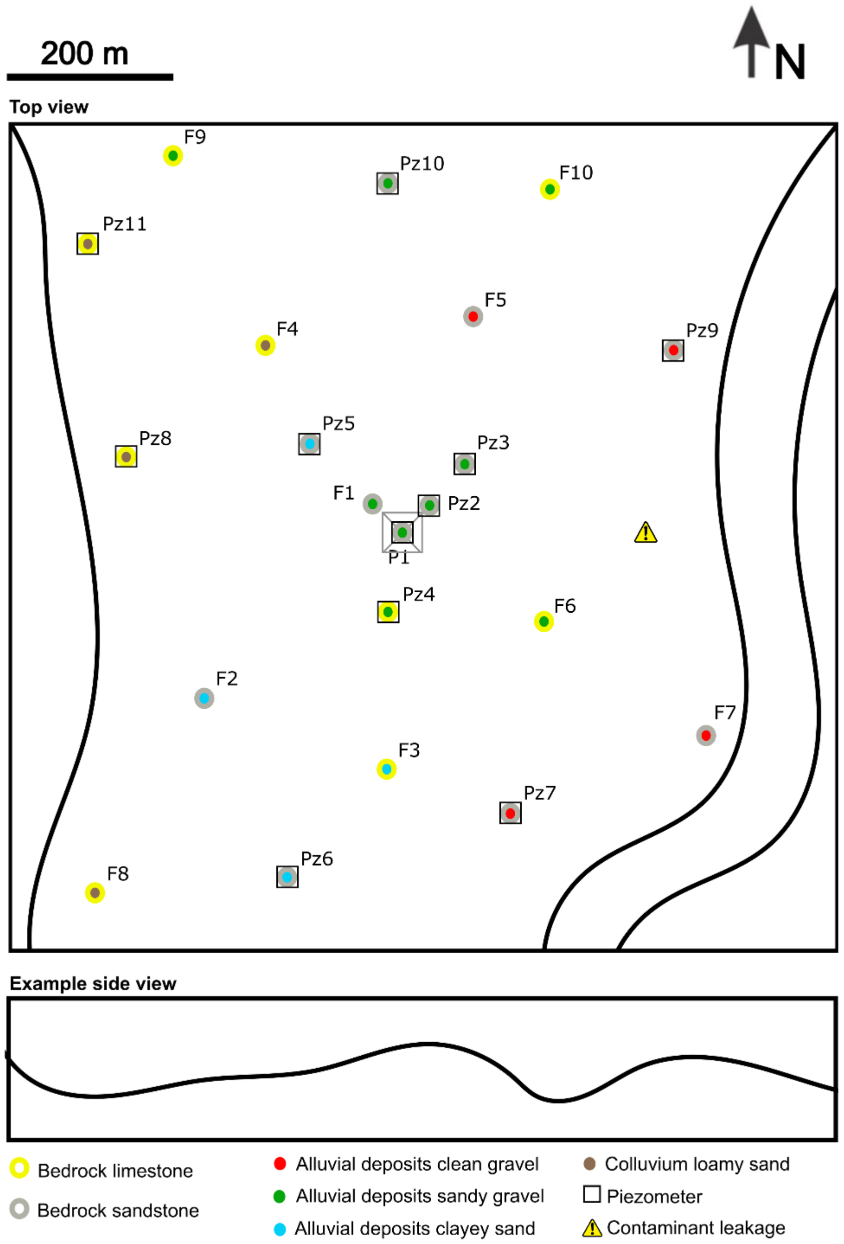

Figure 1: Map of the area with location of drillings and piezometers and geological interpretation

The area is flat, the elevation of the surface is 40 m. The thickness of the alluvial deposits varies (Table 1) between 7 m at the hill in the northwest and 21m in the northeast . For the purposes of this study, the bottom of the bedrock can be limited to an elevation of 10 m. The western limit of the study area corresponds to the bottom part of the hillslope. The catchment area of the slope has an average surface area of 140 ha per km length of the river.

The recharge through rainfall has been estimated to 125 – 210 mm/year. A river measuring station is present at the southern end of the river (X=700, Y=0). The mean water level in the river is 38 m at the river level measuring station. Another measuring station located 3 km to the north indicates a mean water level of 32 m. The river has a depth of 1 meter. Slug tests in the neighborhood estimated that the conductance of the river bottom should be between 8E-5 and 2.5E-4 m^2/s.

A total of 12 well and piezometers (P1 to Pz12) are located in the study area. P1 to Pz11 are screened in the alluvial deposits. Pz12 is at the same location as the pumping well but is screened in the bedrock. Ten additional drillholes (F1 to F10) are available to refine the geological description of the deposits (Table 1) but were not equipped with piezometers. To study the hydrogeological properties of the study area, the water level has been monitored in the 12 piezometers in natural conditions (no pumping) and during a long-term pumping test performed in P1 (extraction rate of 100 m^3/h, elevation of 32 m). Table 2 provides the stabilized hydraulic heads measured in the different piezometers.

Table 1	*Coordinates*		*Borehole logs*
	x(m)	*y(m)*	***Thickness** alluvial deposits (m)*
P1 = pumping well	475	504	18
Pz2	507	538	18
Pz3	545	585	18
Pz4	455	411	18
Pz5	359	614	17
Pz6	338	90	14
Pz7	599	168	14
Pz8	143	596	11
Pz9	801	721	21
Pz10	458	924	15
Pz11	94	850	7
Pz12	475	504	18
F1	444	537	18
F2	235	302	12
F3	456	217	13
F4	312	734	9
F5	562	766	18
F6	647	393	17
F7	843	257	19
F8	99	70	10
F9	196	962	10
F10	656	922	12

Table 1: Borehole log description

Table 2	*Flow condition*	
	h natural (m)	*h pumping(m)*
P1	37.21	35.05
Pz2	37.21	36.32
Pz3	37.19	36.56
Pz4	37.23	36.49
Pz5	37.31	36.7
Pz6	37.5	37.01
Pz7	37.21	36.84
Pz8	37.55	37.07
Pz9	37.15	36.8
Pz10	37.24	36.83
Pz11	37.46	37.01
Pz12	37.22	36.21

Table 2 : Hydraulic heads measured in natural and pumping conditions

From previous studies in the area, the range of value of hydraulic conductivity has been estimated:

- alluvial deposits : 10^{-5} to 10^{-1} m/s ;
- limestone : 10^{-4} to 10^{-3} m/s ;
- sandstone : 10^{-5} to 10^{-4} m/s.

The pumping test performed in well P1 with a rate of 100 m³/h has been monitored through time. The drawdowns in the well P1 and piezometer Pz12 have been measured for 432000 seconds (Figure 2, Tables 3 and 4).

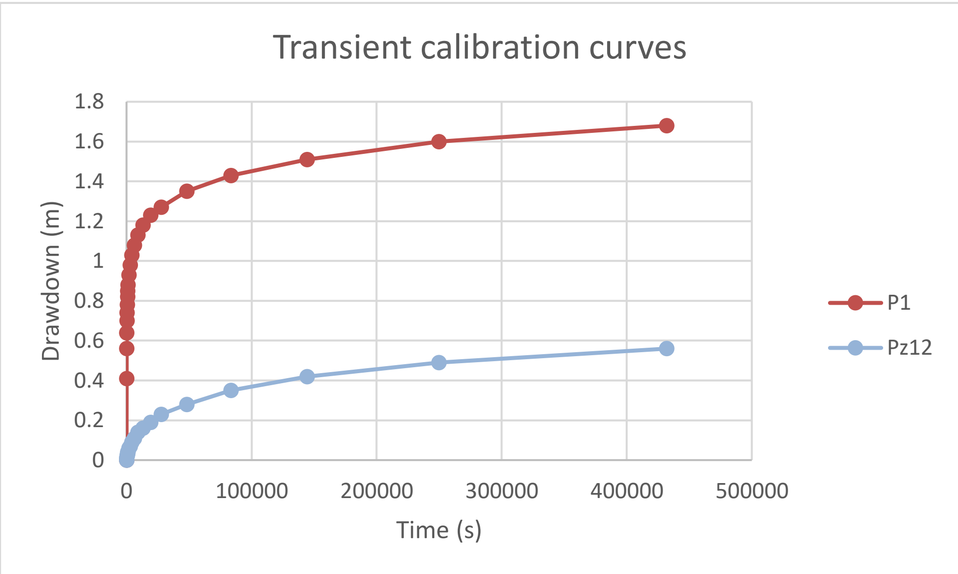

Figure 2 : Temporal variation of the drawdown in well P1 (upper curve - alluvial deposits), and Pz12(bottom curve - bedrock).

Table 3	
P1 alluvial deposits	
Time (s)	Drawdown (s)
1	0.00
60	0.41
130	0.56
215	0.64
317	0.70
439	0.74
585	0.78
761	0.82
972	0.85
1224	0.88
1892	0.93
2854	0.98
4238	1.03
6232	1.08
9104	1.13
13238	1.18
19192	1.23
27765	1.27
48192	1.35
83488	1.43
144481	1.51
249877	1.60
432001	1.68

Table 4	
Pz12 bed-rock	
Time (s)	Drawdown (m)
1	0.00
60	0.00
130	0.01
215	0.01
317	0.02
439	0.02
585	0.03
761	0.03
972	0.04
1224	0.04
1892	0.06
2854	0.07
4238	0.09
6232	0.11
9104	0.14
13238	0.16
19192	0.19
27765	0.23
48192	0.28
83488	0.35
144481	0.42
249877	0.49
432001	0.56

Tables 3 and 4 : Drawdowns measured in P1 and Pz11 during the pumping test

To estimate transport properties in the aquifer, a tracing experiment has been carried out between Pz2 and P1. The continuous extraction rate in P1 was 50 m^3/h. The extraction happened at a depth of 32 m (in the middle part of the upper aquifer). 200 g of eosin were injected in Pz2 at the same depth during 1 hour at the rate of 1 m^3/h. Samples were collected in the pumping well to measure the evolution of the concentration of eosin (Table 5). Tip: divide the alluvial aquifer into 3 layers to increase the accuracy of the results.

Tracing experiment from Pz2 to P1 (200 g of eosin)	
Time (s)	Conc. (µg/l)
1	0.000
51	0.000
93855	0.000
111959	0.000
133684	0.000
159754	0.000
191037	0.000
228577	0.000
273625	0.000
327683	0.000
392553	0.002
470396	0.020
563808	0.102
675902	0.368
810415	0.996

971831	2.116
1165530	3.638
1397969	5.175
1676895	6.189
2011607	6.301
2413261	5.502
2895246	4.144
3473628	2.701
4167687	1.534
5000557	0.760
6000001	0.332

Table 5 :Concentration of eosin (in ppb or µg/l or mg/m³) measured in the pumping well during the tracingexperiment

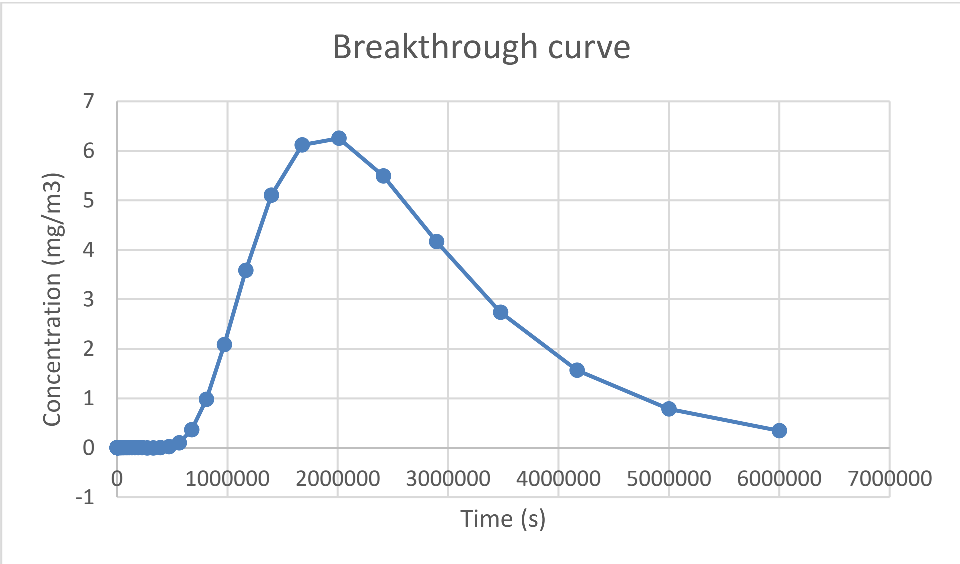

Figure 3 : Concentration observation in the pumping well during the tracing experiments.