GW FLOW AND CONTAMINANT TRANSPORT MODELING

Hydrogeological Engineering MSc mesterszak

2018/19 II. félév

TANTÁRGYI KOMMUNIKÁCIÓS DOSSZIÉ

Miskolci Egyetem
Műszaki Földtudományi Kar
Környezetgazdálkodási Intézet

Tartalomjegyzék

1. Tantárgyleírás, tárgyjegyző, óraszám, kreditérték

Course Title: Groundwater flow and contaminant transport modeling **Instructor:** Dr. Balázs Kovács, honorary associate professor	**Code:** MFKHT720028 **Responsible department/institute:** Institute of Environmental Management Type of course: Compulsory
Position in curriculum (which semester): 2	**Pre-requisites (if any):** MFKHT710017
No. of contact hours per week (lecture + seminar): 2+2	**Type of Assessment (examination/ practical mark / other):** exam
Credits: 5	**Course:** full time
Course Description: The students will be familiar with the theoretical and practical aspects of the numerical methods widely used in the modern hydrogeology. The students will be able to use a worldwide known numerical environment. Using this environment the students will possess an ability to solve simple problems in the field of hydrodynamics and contaminant transport, and will learn that basic knowledge based on which getting more experiences they will be later able to solve also more complex simulation problems. The short curriculum of the subject: Tasks and aims of GW flow and contaminant transport modeling. Theory of GW flow modeling: the flow equation and its numerical solutions. The phenomena of contaminant transport in porous medium, the different forms of the transport equation. Analytic and numerical solutions. Particle tracking algorithms. Data-system of GW flow and contaminant transport models. The reliability of data, the aspects of data evaluation and control, type of dataset errors. Calibration of models. GW flow and contaminant transport modeling using the Processing MODFLOW environment. Solution of demo problems and investigation of case studies. Practical work: self-made models of simple real problems.	
Compatencies to evolve: Knowledge: T1 – It includes knowledge of hydrogeology, water resource management, water quality protection, water treatment, production and waterworks operat T2 – Extensive knowledge of hydrogeological assessment and monitoring techniques related to watershed approach and considers ecological water demands. T4 – Have a working knowledge of computer-aided design and analysis T5 – Knows and understands hydrogeological modelling techniques. T7 – Have knowledge of a wide range of problem-solving techniques for research or academic work. Ability: K1 – Ability to understand the laws and relationships related to the location, movement and quality of groundwater, to apply and put into practice the knowledge acquired, and to use problem-solving techniques. K2 – Ability to process information from the knowledge frontiers of professional experience of the discipline, ability of problemsolving, and interpreting hydrogeological issues. K3 – Ability to independently plan and execute tasks related to groundwater exploration, exploitation and well hydraulics at a high professional level. K4 – Ability to effectively apply water production techniques and knowledge of modern well construction technologies. K5 – Ability to apply design, knowledge and technologies related to water supply and water treatment at a high level. K6 – Prepared to tackle complex water resource management, water conservation and aquifer protection challenges. K7 – Prepared to identify and solve geotechnical problems.	

K8 – Able to solve mining and pit dewatering problems at a high level
K13 – The ability to independently participate in and manage research, development and expertise in the field of hydrogeology
K15 – Ability to solve complex problems in a flexible way through creative problem solving, to work in a team, to think and cooperate effectively with representatives of other disciplines (e.g. environment, quality, consumer protection, human health, construction, etc.)
Attitude:
A8 – Characterised by intuition, consistency and a willingness to learn.
Autonomy and responsibility:
F1 – Act independently and proactively to solve professional problems.
F5 – Committed to sustainable natural resource management practices.
F6 – He/she is responsible claims in expert oppinions, professional judgements and for the work carried out under his/her supervision.

Assessment and grading: Students will be assessed with using the following elements.

Attendance:	15 %
Short quizzes	10 %
Midterm exam	40 %
Final exam	35 %
Total	100%

Grading scale:

% value	Grade
90 -100%	5 (excellent)
80 – 89%	4 (good)
70 - 79%	3 (satisfactory)
60 - 69%	2 (pass)
0 - 59%	1 (failed)

Compulsory or recommended literature resources:

- Chiang, W-H. – Kinzelbach, W.(2001): 3D-Groundwater Modeling with PMWIN, A Simulation System for Modeling Groundwater Flow and Pollution, Springer-Verlag Berlin, Heidelberg, New York, ISBN 3-540-67744-5, SPIN 10774334
- Kinzelbach, W. (1986): Groundwater Modelling (An Introduction with Sample Programs in BASIC), Elsevier, p.331.
- Kovács B.: Hidrodinamikai és transzportmodellezés Processing MODFLOW környezetben I., 2004, Miskolci Egyetem – Szegedi Tudományegyetem – GÁMA-GEO, p. 160., ISBN 963 661 637 X
- Kovács – Szanyi: Hidrodinamikai és transzportmodellezés II., 2005, Miskolci Egyetem – Szegedi Tudományegyetem – GÁMA-GEO, p. 213., ISBN 963 661 638 8
- Neven Kresic (1997): Quantitative Solutions in Hydrogeology and Groundwater Modeling. Lewis Publishers
- Andersen P. F., 1993. A manual of instructional problems for the U.S.G.S. MODFLOW model. Center for Subsurface Modeling Support. EPA/600/R-93/010.
- Anderson, M. P. and W. W. Woessner, 1991. Applied groundwater modeling: simulation of flow and advective transport. 381 pp. Academic Press, San Diego, CA
- Bear, J., 1972. Dynamics of fluids in porous media. American Elsevier Pub. Co., New York
- Bear, J., 1979. Hydraulics of Groundwater, McGraw-Hill, N.Y., 569 p
- Bear, J. and A, Verruijt, 1987. Modeling groundwater flow and pollution, D. Reidel Publishing, Dordrecht, Holland
- Fetter, C.W. 1994. Applied Hydrogeology, 3rd Edition. Macmillan College, New York, 691 p
- Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

2. TANTÁRGYTEMATIKA

GW Flow and Contaminant Transport Modeling
Tantárgytematika (ÜTEMTERV)
Aktuális tanév tavaszi félév
Hydrogeological Engineering mesterszak MSc, 2. félév, törzsanyagos tárgy

Hét	Date	Előadás
1.	02.11.	Introduction. Models, Goals of modeling. Numerical methods' basic. First model.
2.	02.18.	Steady state modeling in general
3.	02.25.	Some intensively used MODFLOW packages (Recharge, Horizontal flow barrier, Well, River, Drain, General Head Boundary)
4.	03.04.	Boundary conditions. Zones and continuous parameter fields. Interpolations.
5.	03.11.	Steady state modeling summary
6.	03.18.	2D vertical profile modeling: Tothian Unit basin model, Seepage under dams
7.	03.25.	Transient modeling Some special packages: Timevariant specified head
8.	04.01.	Transient modeling summary
9.	04.08.	An introduction to contaminant transport modeling
10.	04.15.	Contaminant transport model of a site remediation
11.	04.22.	Holiday (Easter)
12.	04.29.	Contaminant transport modelling summayr
13.	05.06.	Consultation
14.	05.13.	Individual model building: a test

3) Házifeladatok

GW Flow and Contaminant Transport Modeling

Homework #1: Determination of breakthrough time of a well doublet of injection and production wells vs. well distance

Hydrogeological conditions:

There is a shallow sandy gravel, gravelly sand aquifer suitable to establish fully penetrating wells. The shallow aquifer is phreatic (unconfined) with negligible horizontal groundwater flow. The hydraulic parameters of the aquifer can be freely chosen but the different parameters (horizontal and vertical hydraulic conductivity, effective porosity) should be coherent to each other. The thickness of the aquifer is also up to the student but at least 2/3 of the aquifer must be saturated, so the groundwater level is to be determined to keep this condition.

Hydraulic problem:

There are two wells installed to support an open water to water heat-pump system. To make the proper operation of the system possible a given break-through time is to be assured, therefore it is to be calculated. Please determine the function describes the trend of breakthrough time vs. injection to production wells distance. Install wells into different distances and determine the breakthrough time. Based on the data calculated at 5-6 different well distances the function is to be plotted.

Materials to be presented:

In printed form a short report of the problem with

- the details of the chosen data
- graphic presentation of potential fields, pathlines
- breakthrough-time vs. well distance function
- the description and evaluation of results

Digitally (only at the end of semester)

- report in document form
- full dataset of the model
- plots in graphical form

GW Flow and Contaminant Transport Modeling

Homework #2: Transient simulation of pumping test of two wells on the modeled well field

Hydrogeological conditions

There are four distinguished reservoirs (aquifers) on the study area signed by A, B, C & D. The leaky layers between the aquifers are referred as AB, BC & CD, meanwhile the over- and underlying ones called 0A and D0. Please find the aquifer properties in the table below.

Sign	Formation type	Elevation Top [m asl]	Elevation Bottom [m asl]	Thickness [m]	Horizontal Hydraulic Conductivity [m/s]	Vertical Hydraulic Conductivity [m/s]	Effective Porosity [%]	Specific Storage [-]	Spec Yield [%]
0A	Overlying layer	-754	-864	110	5,00E-08	5,00E-08	7,5	0,0001	6
A	Aquifer/reservoir	-864	-937	73	5,00E-05	1,00E-05	12	0,00001	9,6
AB	Leaky layer	-937	-964	27	5,00E-08	2,50E-08	6	0,0001	4,8
B	Aquifer/reservoir	-964	-1056	92	3,00E-05	1,00E-05	10	0,00001	8
BC	Leaky layer	-1056	-1069	13	3,00E-08	1,50E-08	5	0,0001	4
C	Aquifer/reservoir	-1069	-1094	25	1,00E-05	5,00E-06	9	0,00001	7,2
CD	Leaky layer	-1094	-1110	16	1,00E-08	5,00E-09	4,5	0,0001	3,6
D	Aquifer/reservoir	-1110	-1162	52	7,00E-06	4,00E-06	8	0,00001	6,4
D0	Underlying layer	-1162	-1252	90	5,00E-09	4,00E-09	4	0,0001	3,2

There is a regional groundwater flow characterized by a given horizontal and vertical hydraulic gradient and the depth of GW level from the surface on the middle of the modeling area. The flow regime characteristics can be freely chosen by the student in the following interval and range: horizontal hydraulic gradient: 0.5 - 2.5 m/km, vertical hydraulic gradient: 2 mm/m – 5 mm/m, horizontal direction: any)

There are several wells operating screened to the layers A, B and D.

The problem to be investigated:

There are two wells W15 and W6 tested after each other, having 3 weeks of recovery period between the tests. The test of each well takes as follows: 1/3·Q (for 3 weeks), 2/3·Q (for 3 weeks) and Q (for 3 weeks), 3 weeks recovery, and cyclic testing Q, recovery, Q recovery, Q (for 1 weeks each scenario), where Q is the normal production rate of the well (see table below). Your task is to determine the GW level fluctuation due to testing in the existing wells.

Well data:

Well ID	Local X [m]	Local Y [m]	Prod. Rate [m^3/d]	Layer
W10	102351	53408	852	A
W11	102558	53866	936	A
W14	106033	53248	860	A
W15	103998	52520	1096	A
W17	105446	51627	860	A
W19	103431	53007	1160	A
W8	101805	52971	1308	A
W1	105445	54191	1284	B
W12	104458	52922	1240	B
W20	105985	54438	1316	B
W3	104798	52285	1164	B
W4	102331	53752	808	B
W5	103498	54160	1324	B
W6	103862	52395	1344	B
W13	102131	51693	1260	D
W16	102269	53372	1196	D
W18	101731	53160	1236	D
W2	105752	52865	1332	D
W7	103662	53962	1092	D
W9	104095	52422	1232	D

Subtasks:

Subtask1. Building of a transient model of the existing well field

Subtask2. Establish monitoring wells to determine the effects of well testing

Subtask 3. Determination of the transient potential field in all the aquifers and charting the GW fluctuation in monitoring wells

Subtask 4. Comparison of the potential vs. time curves of different monitoring wells in the aquifers

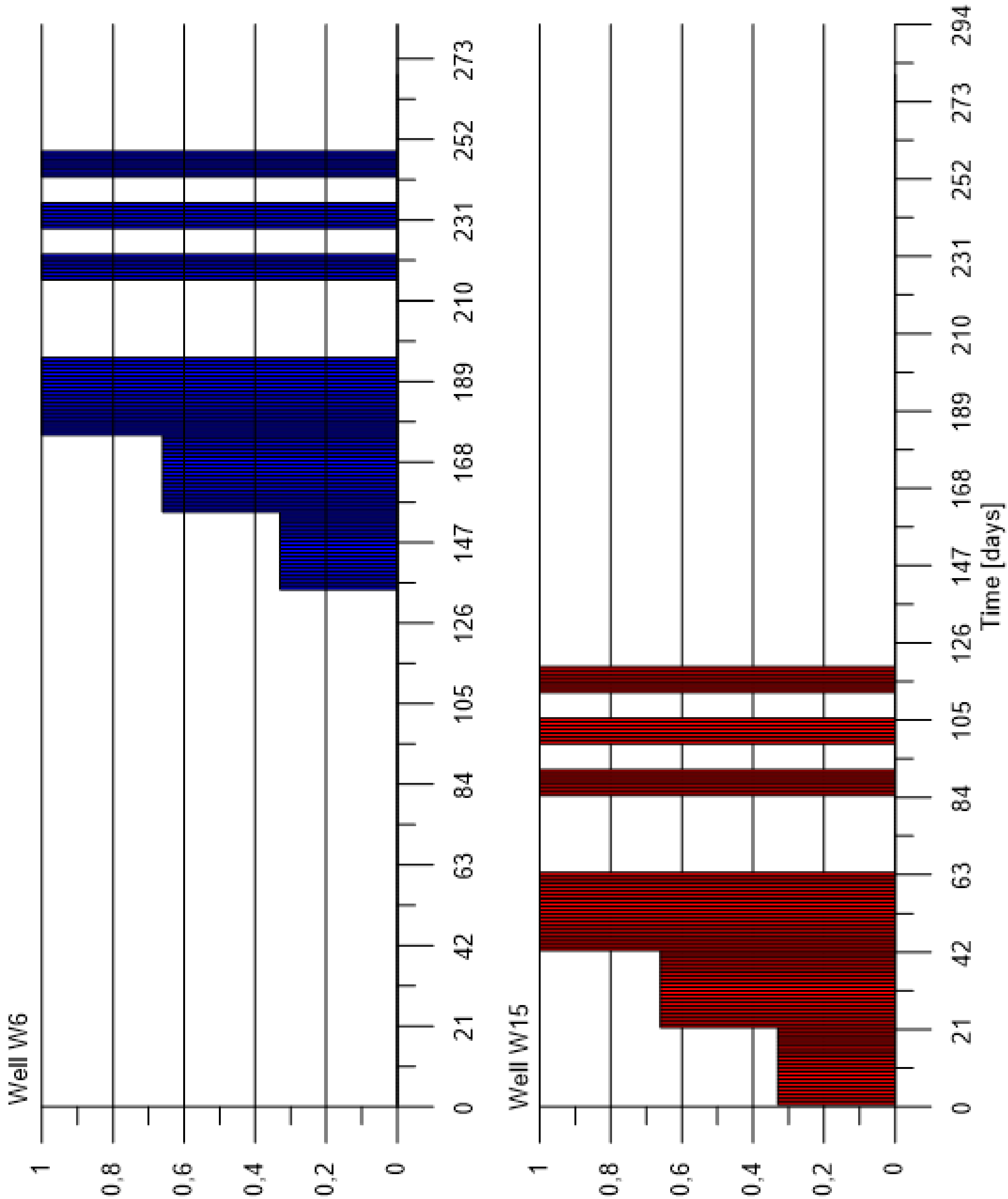
Subtask 5. Comparison of the potential vs. time curves of different monitoring wells in the aquifers with and without assuming unlimited or zero lateral recharge on one of the model boundaries

Deliverables:

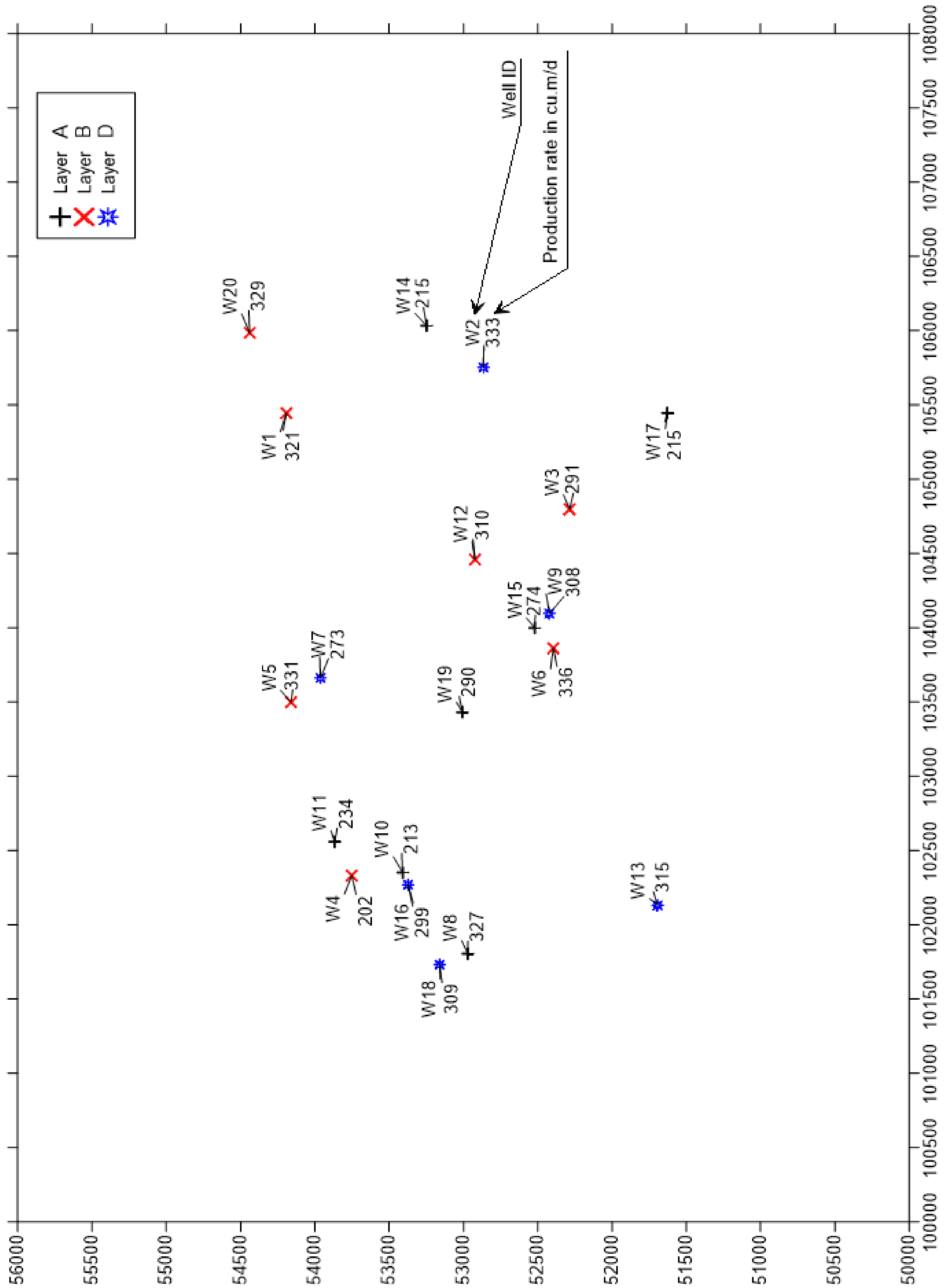
Model's data set in digital form

Report about the task evaluation with short description of the model

Printed potential vs time curves (each monitoring well and each tested well, Comparative graphs of wells screened to the same layer)



Time schedule of pumping [relative pumping rates to the maximal pumping rate]



Well locations

GW Flow and Contaminant Transport Modeling

Homework #3: Simulation of unit basin problems – Steady state simulation of flow in a vertical profile

Hydrogeological problem

The continuity approach of hydrogeological regimes was firstly published by Joe Toth (1963). He assumed a „Unit Basin" defined as a vertical 2D problem: a slope with no flow boundary at the sides and the bottom and a linearly decreasing potential at the top.

First task is to build a Unit Basin model (Case 0). Hydrogeological conditions of the base model: The simulated system consists of a silty, silty sand aquifer (the parameters can be freely chosen). There are no flow boundaries at all sides. The potential distribution on the top surface is linearly decreasing, the horizontal hydraulic gradient is constant (please apply freely chosen a horizontal hydraulic gradient in the range of 1-3 m/km).

Further cases to be investigated:
Case 1a&1b: Modify hydraulic conductivities by 5 and 0.2 times.
Case 2: Apply an anisotropy of 20.
Case 3: Modify the homogeneous flow field to layered system of silty and sandy layers.
Case 4: Modify the top boundary conditions (3-5 total waves: 2 m/km average horizontal hydraulic gradient with amplitude of 0.4 m).

Tasks to be performed at each investigated case (from Case 0 to Case 4)

- Determination of the flow field (potential distribution)
- Determination of the potential changes compared to Case 0 (from Case 1 to Case 4)
- Plotting pathlines starting from the surface at constant distance intervals

Materials to be presented:

In printed form a short report of the problem with
- the description of the models
- the details of the chosen data sets
- graphic presentation of the mentioned potential fields or drawdown distributions
- graphic presentation of pathlines at different scenarios
- the evaluation of results

Digitally (only at the end of semester)
- report in document form
- total dataset
- plots in graphical form

GW Flow and Contaminant Transport Modeling

Homework #4: Determination of well-head protection area of a municipal well

Hydrogeological conditions:

A shallow well (total depth of 50 m) is used for municipal water supply. The data sheet of the well is attached. The sheet is in Hungarian but the explanation of the listed data is commented in English. Based on the prescriptions of the authorities the 3D volumes of $t \leq 50$ and 5 years, 6 months and 20 days transit-times to well screens is to be determined. In case the 3D volumes of different transit times the surface area of the influence zones is also to be determined.

The region the well is situated is a typical recharge zone where the vertical hydraulic gradient is 40 cm/100 m, the horizontal hydraulic gradient is 1.5m/km (direction (azimuth) can be freely chosen by the student). The average long term production rate of the well is 450 dm^3/min.

There are no additional wells in the surroundings therefore the well can be considered as a single (stand-alone) well.

Tasks to be solved:

1. Calculate the hydraulic conductivity of the aquifer using Dupuit-Thiem iteration
2. Determine the potential field that fits the horizontal hydraulic condition prescriptions
3. Calculate the potential in each layer using the given vertical hydraulic gradient
4. Make the model of the well end its surroundings. Use the real-world coordinates of the well. The other hydraulic parameters of the aquifer can be freely chosen but the different parameters (horizontal and vertical hydraulic conductivity, effective porosity) should be coherent to each other.
5. Run the model and determine the 20 d, 6 months, 5 and 50 years areas of influence using the long term production rates at 6 months, 5 and 50 years, the daily maximum production rate of 520 dm^3/min at 20 days. Determine the vertex coordinates of the polygon describing the boundary of the influence and also the top and bottom levels (as altitude of horizontal planes) of the zones.
6. Check if the zones of influence reach the surface. If yes, then determine the coordinates of the polygon vertexes.
7. Prepare a short report

Materials to be presented:

In printed form a short report of the problem with
- the description of the model
- the calculation of hydraulic conductivity
- the details of the chosen data
- graphic presentation of potential fields, pathlines
- the description of influence zone boundaries
- the evaluation of results

Digitally (only at the end of semester)
- report in document form
- total dataset
- plots in graphical form

Groundwater Flow and Contaminant Transport Modeling Spring Fall 2017/2018

Homework #5

Simulation of a pump&treat system – parallel transient flow and transport simulation

Problem setting

A chloride and sulphate contamination occurred at a given industrial site. The chloride is originated from a leakage due to recharge caused by dilution of chloride containing salts by precipitation, the sulphate originates from an underground pipe leakage. A pump&treat system is planned to be operated at the site, which consists of several wells and possibly infiltration trenches also. The task is to build the model of both the contamination and the remedial activities.

Hydrogeological conditions of the base model:

The simulated system consists of a sand aquifer (the parameters can be freely chosen) of 13 m thickness. There is a slow regional flow: the horizontal hydraulic gradient is 1 m/km. The chloride contamination occurred at a surface deposit of a 30·40 m area, where a kind of soluble salt was stored.

The solubility of the salt is high, the solution has a chloride content of 300 000 mg/l. The contamination started in 1987. The chloride is hardly adsorbing and not degrading component. The sulphate contamination is originated from a pipeline damage, where the loss of liquid was approx. 15 m^3/d. The concentration of sulphate was 5000 mg/l during the period of 1965-2002, later (after 2002) it was reduced to 3200 mg/l due to change of the industrial technology. The first signs of losses during the pipeline transport were detected in 1992.

The location of the two contamination sources are different. The source of sulphate contamination is in 45 m down-gradient and 100 m side-gradient from the chloride contamination source. Both sources were eliminated in 2017.

Task 1. Build the flow model of the site. Determine the flow field (potential distribution) and pathlines starting from the sources until now and for another 15 years, please.

Task 2. Simulate the transport of the two contaminants during the past and the in the future (for 30 years until 2047). Calculate with no sorption and no decay for chloride and with Ca induced slow immobilization of sulphates. Based on laboratory tests the immobilization of sulphates can be simulated as a superposition of a linear adsorption characterized by 0.7 cm^3/g and a “decay” due to gypsum formulation with a half-life of 45 years (Despite the fact that no real adsorption of decay occurs!).

The longitudinal dispersivity is 8 m the transversal (lateral) dispersivity is 2 m. The effective diffusion coefficient is $5 \cdot 10^{-10}$ m^2/s for both contaminants.

The local contamination limit is 250 mg/l for chloride and 400 mg/l for sulphate.

All not mentioned flow or transport parameters can be freely chosen!

Task 3. A desalinization and desulfurization plant of 100 m^3/d capacity is to be installed at the site. Design a pumping well system and injection wells or infiltration trench(es) that efficiently helps the remedial activities of the plume. The total production rate is limited to the plant’s treatment capacity.

Calculate the concentration distribution after 1, 2.5, 5, 7.5, 10 and 15 years of operation. All treated water is to be infiltrated. Please to take in account that the production and injection efficiency of wells are different! Determine the time needed to reach at least the remediation limit, which is three times larger than the contamination limit for each contaminant.

Task 4. You are authorized to accelerate the remedial activities by the installation of a slurry wall shorter than 200 m. Please to simulate the effect of a slurry wall to the contaminant transport and determine the time needed to reach at least the remediation limit, which is three times larger than the contamination limit.

Materials to be presented:
In printed form a short report of the problem with
- the description of the models
- the details of the chosen data sets
- graphic presentation of the mentioned potential fields, drawdown and concentration distributions
- graphic presentation of pathlines at different scenarios
- the evaluation of results
Digitally (only at the end of semester)
- report in document form
- total dataset of all model variants
- plots in graphical form

4)Házifeladatok megoldása

4) ÖNÁLLÓ FELDATOK

Groundwater flow and contaminant transport modeling test #02

Name and Neptun code : ……………………………………………………………………………………

A geothermal system of six wells (3 production and 3 injection wells) with a total production (and injection) rate of 750 m^3/d is planned to be operated. The site is located in an approx. 400 m wide valley with alluvial sediments. The thickness of the sediments is 15 m, the upper half is fine sand the lower part is gravelly sand. The horizontal hydraulic gradient parallel the midline of the valley in the alluvial formations is 1.5 m/km. To avoid hydraulic shortcut the distance of production and injection wells should be at least 150 m. The injection wells are in upgradient, the production wells are in downgradient direction. All not mentioned parameters are to be freely chosen.

You may solve the task on different levels:

☐ ***Basic level:*** Build up the steady state GW flow model of the system and plot the 1 and 3 months transit time pathlines around the wells.

☐ ***Elevated basic level***: Simulate the effect of a slurry wall positioned between the production and injection wells and plot the alteration of pathlines due to the hydraulic effect of the slurry wall.

☐ ***Advanced level****:* The system operates in wintertime for 6 months at 150 % production level. Prepare the transient model of a 3 years long operation. Plot the drawdown distribution in some characteristic phases of operation.

☐ ***Master level****:* Install some observation wells into the system in relevant positions of the model. Plot the head-time curves of GW level fluctuation.

Groundwater flow and contaminant transport modeling test #02

Name and Neptun code : ……………………………………………………………………………………

A geothermal system of six wells (3 production and 3 injection wells) with a total production (and injection) rate of 750 m^3/d is planned to be operated. The site is located in an approx. 400 m wide valley with alluvial sediments. The thickness of the sediments is 15 m, the upper half is fine sand the lower part is gravelly sand. The horizontal hydraulic gradient parallel the midline of the valley in the alluvial formations is 1.5 m/km. To avoid hydraulic shortcut the distance of production and injection wells should be at least 150 m. The injection wells are in upgradient, the production wells are in downgradient direction. All not mentioned parameters are to be freely chosen.

You may solve the task on different levels:

☐ ***Basic level:*** Build up the steady state GW flow model of the system and plot the 1 and 3 months transit time pathlines around the wells.

☐ ***Elevated basic level***: Simulate the effect of a slurry wall positioned between the production and injection wells and plot the alteration of pathlines due to the hydraulic effect of the slurry wall.

☐ ***Advanced level****:* The system operates in wintertime for 6 months at 150 % production level. Prepare the transient model of a 3 years long operation. Plot the drawdown distribution in some characteristic phases of operation.

☐ ***Master level****:* Install some observation wells into the system in relevant positions of the model. Plot the head-time curves of GW level fluctuation.

Groundwater flow and contaminant transport modeling test #03

Name and Neptun code : …………………………………………………………………………………………

A geothermal system of six wells (3 production and 3 injection wells) with a total production (and injection) rate of 2100 m^3/d (700 m^3/d/well) is planned to be operated. The site is located in a large basin with an approx. 1800 m thick sequences of porous layers (aquifers and aquitards). The thickness of the two productive layers are 45 m/layer, the screened intervals are between 1290-1335 and 1350-1395 m below ground. There are large clayey formations above and below the screened layers (1150-1290 and 1395-1527m intervals). The horizontal hydraulic gradient in the layers is 1.5 m/km from north to south. To avoid hydraulic shortcut the distance of production and injection wells should be at least 500 m. The injection wells are in upgradient, the production wells are in downgradient direction. All not mentioned parameters are to be freely chosen.

You may solve the task on different levels:

☐ ***Basic level:*** Build up the steady state GW flow model of the system and plot the 1 and 3 months transit time pathlines around the wells.

☐ ***Elevated basic level***: Simulate the effect of a clayey lens in the aquifer positioned between the production and injection wells and plot the alteration of pathlines due to the hydraulic effect of the lens.

☐ ***Advanced level****:* The system operates in wintertime for 6 months at 150 % production level. Prepare the transient model of a 3 years long operation. Plot the drawdown distribution in some characteristic phases of operation.

☐ ***Master level****:* Install some observation wells into the system in relevant positions of the model. Plot the head-time curves of GW level fluctuation.

Groundwater flow and contaminant transport modeling test #03

Name and Neptun code : …………………………………………………………………………………………

A geothermal system of six wells (3 production and 3 injection wells) with a total production (and injection) rate of 2100 m^3/d (700 m^3/d/well) is planned to be operated. The site is located in a large basin with an approx. 1800 m thick sequences of porous layers (aquifers and aquitards). The thickness of the two productive layers are 45 m/layer, the screened intervals are between 1290-1335 and 1350-1395 m below ground. There are large clayey formations above and below the screened layers (1150-1290 and 1395-1527m intervals). The horizontal hydraulic gradient in the layers is 1.5 m/km from north to south. To avoid hydraulic shortcut the distance of production and injection wells should be at least 500 m. The injection wells are in upgradient, the production wells are in downgradient direction. All not mentioned parameters are to be freely chosen.

You may solve the task on different levels:

☐ ***Basic level:*** Build up the steady state GW flow model of the system and plot the 1 and 3 months transit time pathlines around the wells.

☐ ***Elevated basic level***: Simulate the effect of a clayey lens in the aquifer positioned between the production and injection wells and plot the alteration of pathlines due to the hydraulic effect of the lens.

☐ ***Advanced level****:* The system operates in wintertime for 6 months at 150 % production level. Prepare the transient model of a 3 years long operation. Plot the drawdown distribution in some characteristic phases of operation.

☐ ***Master level****:* Install some observation wells into the system in relevant positions of the model. Plot the head-time curves of GW level fluctuation.

Groundwater flow and contaminant transport modeling test#5a

A contamination was detected at a site. The boundary of the contaminated area and the detected concentrations are plotted on the map (the file is to be used as base map for the model, filename: basemap.dxf)

The contamination is detected in the first shallow aquifer located in 3-15 m depth interval below surface. The aquifer is a coarse sand with the following characteristics: horizontal hydraulic conductivity $3\cdot10^{-5}$ m/s, vertical hydraulic conductivity $5\cdot10^{-6}$ m/s, effective porosity 12%, specific yield 10%, specific storage 0.00005. Horizontal hydraulic gradient is 1 m/km, seepage is to the North.

There are 4 production wells P1-P4 are implemented, with the production rates P1: 1 m3/h, P2-P4: 1.5 m3/h. The produced water is injected back to the aquifer at wells I1-I5. The injection rate is 1.4 m3/h in each well.

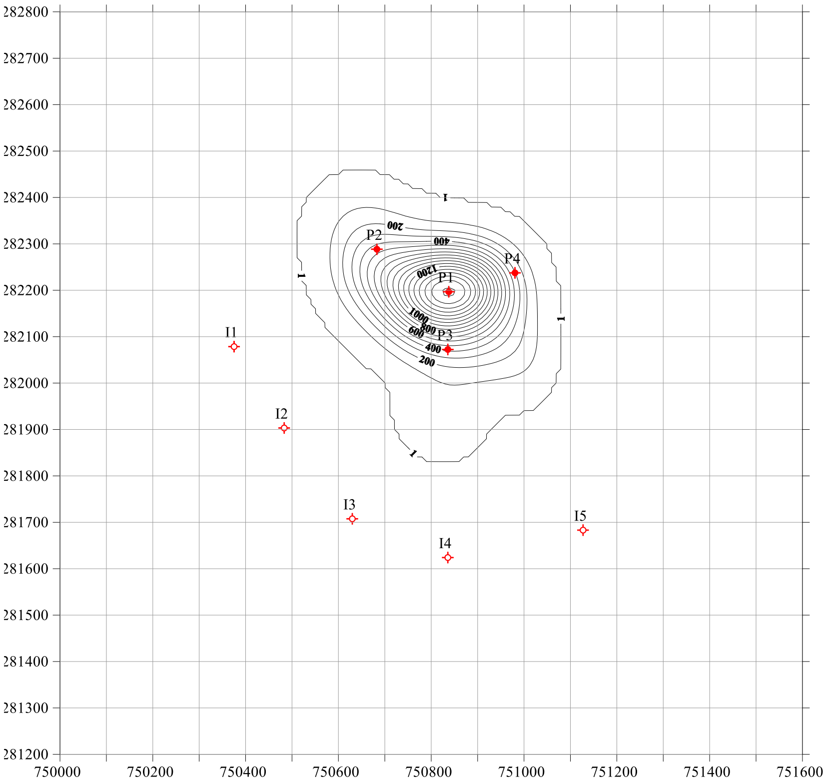
The initial concentration distribution of benzene is shown on the map (even the distribution data is attached in the file: conc.dat. You may implement the concentrations using the data file or by reproduction of concentration distribution using any known modelling methods.

There is an advection, dispersion, adsorption and decay in the system. The longitudinal dispersivity is 5 m, the transversal dipersivities in both direction (laterally and vertically) 1 m. The diffusion coefficient of the contaminant is 5e-10 m^2/s. The contaminant's migration can be simulated using linear adsorption. The K_d distribution coefficient is 2.5 cm^3/g, the half-life of the component is 1000 days (the decay coefficient can be calculated from half-life using the following formula: λ=ln2/T).

All not mentioned parameters are to be freely chosen.

Task: Determine the plume for 3 months, 6 months, 1 and 2 years after starting the remedial activities.

<u>**Groundwater flow and contaminant transport modeling test#5a**</u>



A contamination was detected at a site. The boundary of the contaminated area and the detected concentrations are plotted on the map (the file is to be used as base map for the model, filename: basemap5a.dxf and/or basemap5a.bln). Please remember, that to solve the problem you must use the coordinate system plotted on the figure, otherwise the basemap in not plotted correctly!

The contamination is detected in the first shallow aquifer located in 3-15 m depth interval below surface. The aquifer is a coarse sand with the following characteristics: horizontal hydraulic conductivity $3 \cdot 10^{-5}$ m/s, vertical hydraulic conductivity $5 \cdot 10^{-6}$ m/s, effective porosity 12%, specific yield 10%, specific storage 0.00005. Horizontal hydraulic gradient is 1 m/km, seepage is to the North. The groundwater level at the plume is 4 m below ground.

There are 4 production wells P1-P4 are implemented, with the production rates P1: 1 m3/h, P2-P4: 1.5 m3/h. The produced water is injected back to the aquifer at wells I1-I5. The injection rate is 1.4 m3/h in each well.

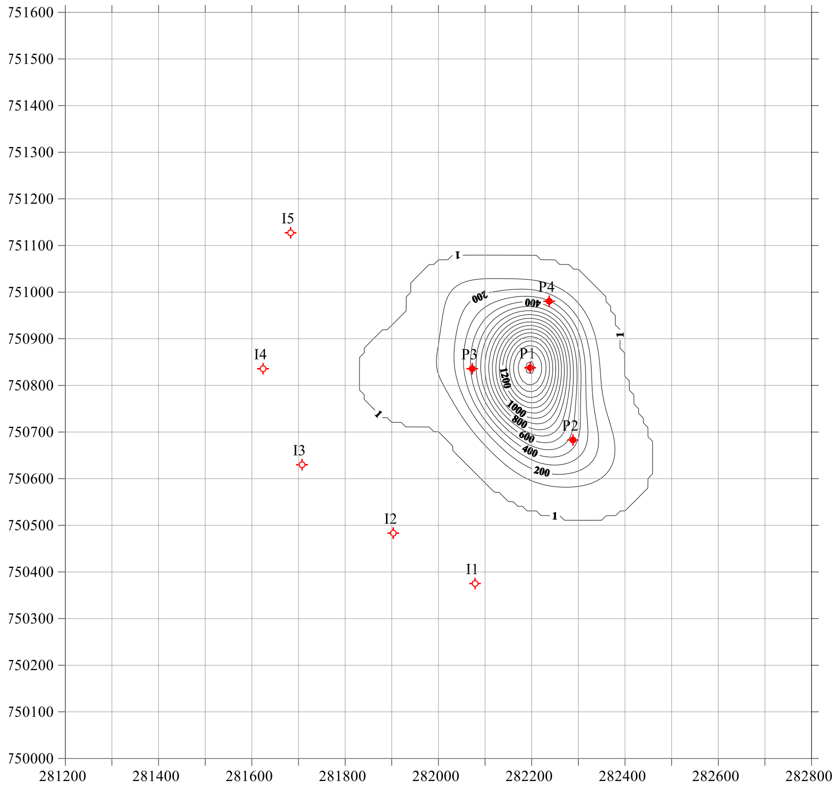
The initial concentration distribution in mikrog/L of benzene is shown on the map (even the distribution data is attached in the file: conc5a.dat. You may implement the concentrations using the data file or by reproduction of concentration distribution using any known modelling methods.

There is an advection, dispersion, adsorption and decay in the system. The longitudinal dispersivity is 5 m, the transversal dipersivities in both direction (laterally and vertically) 1 m. The diffusion coefficient of the contaminant is 5e-10 m^2/s. The contaminant's migration can be simulated using linear adsorption. The K_d distribution coefficient is 1.2 cm^3/g, the half-life of the component is 1000 days (the decay coefficient can be calculated from half-life using the following formula: $\lambda = \ln 2/T$).

All not mentioned parameters are to be freely chosen.

Task: Determine the plume for 6 months, 1, 2, 3 and 5 years after starting the remedial activities.

Groundwater flow and contaminant transport modeling test#5b



A contamination was detected at a site. The boundary of the contaminated area and the detected concentrations are plotted on the map (the file is to be used as base map for the model, filename: basemap5b.dxf and/or basemap5b.bln). Please remember, that to solve the problem you must use the coordinate system plotted on the figure, otherwise the basemap in not plotted correctly!

The contamination is detected in the first shallow aquifer located in 3-15 m depth interval below surface. The aquifer is a coarse sand with the following characteristics: horizontal hydraulic conductivity $3 \cdot 10^{-5}$ m/s, vertical hydraulic conductivity $5 \cdot 10^{-6}$ m/s, effective porosity 12%, specific yield 10%, specific storage 0.00005. Horizontal hydraulic gradient is 1 m/km, seepage is to the East. The groundwater level at the plume is 4 m below ground.

There are 4 production wells P1-P4 are implemented, with the production rates P1: 1 m3/h, P2-P4: 1.5 m3/h. The produced water is injected back to the aquifer at wells I1-I5. The injection rate is 1.4 m3/h in each well.

The initial concentration distribution in mikrog/L of benzene is shown on the map (even the distribution data is attached in the file: conc5b.dat. You may implement the concentrations using the data file or by reproduction of concentration distribution using any known modelling methods.

There is an advection, dispersion, adsorption and decay in the system. The longitudinal dispersivity is 5 m, the transversal dipersivities in both direction (laterally and vertically) 1 m. The diffusion coefficient of the contaminant is 5e-10 m^2/s. The contaminant's migration can be simulated using linear adsorption. The K_d distribution coefficient is 1.2 cm^3/g, the half-life of the component is 1000 days (the decay coefficient can be calculated from half-life using the following formula: $\lambda = \ln 2/T$).

All not mentioned parameters are to be freely chosen.

Task: Determine the plume for 6 months, 1, 2, 3 and 5 years after starting the remedial activities.

5. EGYÉB KÖVETELMÉNYEK

Az önálló munka során a mobiltelefon és internetes hálózat használata tilos!