2010
Volume 45

Modelling of a Drainage System Collecting Contaminated Groundwater

Aivars Spalvins, *Riga Technical University*, Janis Slangens, *Riga Technical University*, Inta Lace, *Riga Technical University*, Kaspars Krauklis *Riga Technical University*

***Abstract* – In Latvia, the Ventspils sea port oil terminal area is heavily contaminated by various petroleum products. The groundwater table of the area must be lowered by using a drainage system. Water that is pumped of from the system must be cleaned before it is returned to an environment. For a rather long time (since 2001), the system has not been used regularly, due to a high cost of the water treatment. The groundwater table has mounted up to inadmissible levels. The hydrogeological model has been created.**

It has been found out that it is possible to use considerably lower water withdrawal rates of the steady regime. If no special regimes of restarting are taken, it will take a rather long time for an idle system to reach its steady state.

***Keywords* - hydrogeological models, transient and steady models, contaminated groundwater, drainage system.**

I. INTRODUCTION

The Ventspils sea port oil terminal area (Fig. 1) is contaminated by petroleum products. The area is ameliorated to lower its groundwater table. Groundwater pumped out from the drainage system must be cleaned. The water treatment is costly and for this reason, since 2002, the system has not been used regularly. Groundwater table has mounted up to unacceptable levels. Recently, the local water treatment plant has been established and unsuccessful attempts have been taken to restart the drainage system.

The hydrogeological model (HM) has been created to obtain knowledge how to restart the drainage system and how to keep low its water withdrawal rates when the steady regime of the system is reached.

The groundwater table of the area depends mostly on seasonal precipitation that alters considerably. For this reason, observed seasonal withdrawal rates of the system, in 2001, changed from 500 m^3/day to 2100 m^3/day [1]. The mean withdrawal rate is about 1300 m^3/day. This rate exceeds the current capacity 1000 m^3/day of the water treatment plant.

Fig.1. Location of the Ventspils town where the hydrogeological model is used

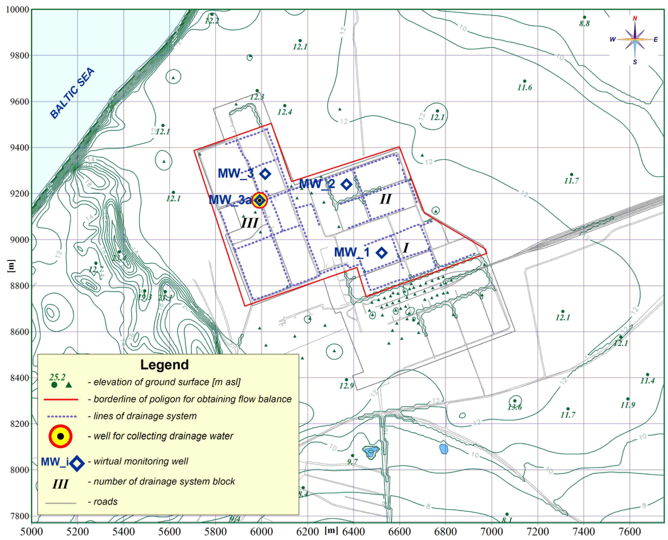

Fig.2. The model area with the drainage system and virtual monitoring wells shown

To make simulation simpler, HM accounts only for the mean seasonal conditions. HM is based on the Groundwater Vistas (GV) modelling system [2]. The steady and transient HM regimes were used to investigate possibility of lowering the withdrawal rate and system restarting regimes, accordingly. In Fig. 2, the HM area 2750 m × 2200 m is shown. The drainage system consists of the three blocks I, II, III. The block III presents the deepest part of the system and there the well for collecting drainage water is situated. To obtain hydrographs of the groundwater table for these blocks and for the discharge well, four virtual observation wells MW1, MW2, MW3, MW3a are introduced. The groundwater flow balance of the drainage system is obtained within the polygon, which borderline encloses the system.

The HM plane approximation step h = 10 m. The 3D finite difference approximation scheme is used and HM contains 7 layers: rel, aer, Q1a,Q1b, Q1c, gQ, Q2 where rel-the ground surface elevation map that is used as the boundary condition of the HM top; aer-the aeration zone treated as a formal aquitard; Q1a, Q1b, Q1c-the subaquifers of the unconfined quarternary Q1 aquifer (Q1a includes the drainage system, Q1b and Q1c have equal thicknesses and these subaquifers are introduced to simulate more accurately the spatial groundwater flow); gQ-the moraine; Q2-the quarternary confined aquifer. Below it, the thick Devonian nr aquitard is located. For this reason, the HM bottom surface is set impermeable. The HM vertical schematization is demonstrated in Fig.3 where the vertical cross section along the HM borderline is shown.

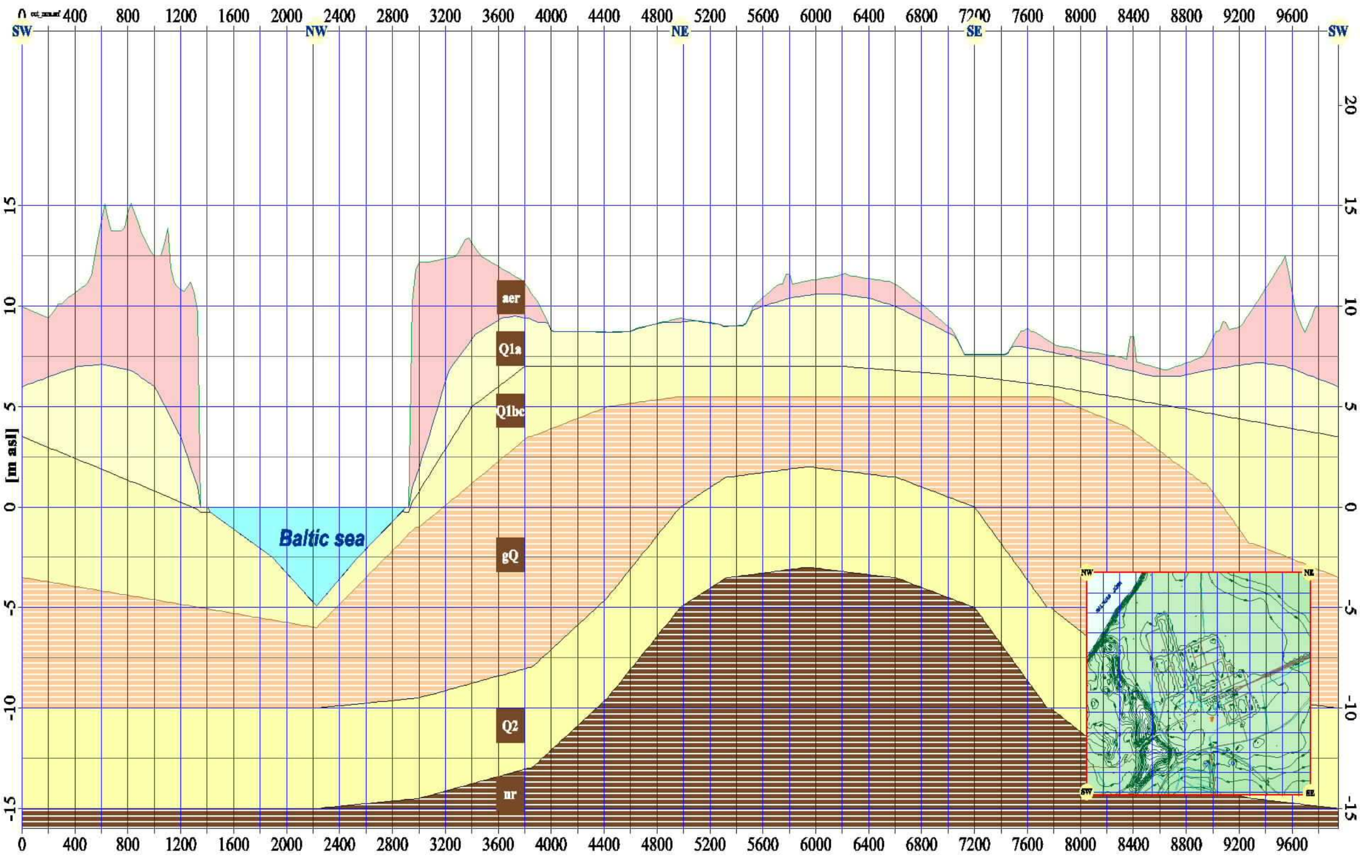

Fig.3. Vertical cross section along the model perimetre

II. Basic Mathematics of Steady Hydrogeological Model

To create HM for the Ventspils oil terminal area, some innovations have been applied. To explain them, the basic mathematics of steady state HM is presented. Transformation of steady state HM into the transient one is performed formally, within the GV environment. For this reason, mathematics of the transient regime is not presented. The HM of steady state solves the following algebraic equation system:

$$A\varphi = \beta - G\psi, \qquad A = A_{xy} + A_z, \tag{1}$$

where φ is the solution vector (heads) at nodes of HM grid; A - the symmetric sparse matrix of the geological environment presented by the xy-layer system containing horizontal (A_{xy} - transmissivity) and vertical (A_z – vertical hydraulic conductivity) elements of the grid; ψ - the boundary head vector: ψ_{top}, ψ_{bot} and ψ_{bound} - subvectors on the HM top, bottom and borderlines, accordingly; G – the diagonal matrix (part of A) assembled by elements, linking the nodes where φ must be found with the ones where ψ is given; β - the boundary flow vector.

By using the 3D finite difference approximation, the xyz grid of HM is built using ($h\times h\times m$) - sized blocks (h is the block plane size; m is the variable thickness of a layer).

The elements a_{xy}, a_z of A_{xy} A_z (or g_{xy}, g_z of G) are computed by using the following formulas:

$$a_{xy} = k\times m,\ a_z = \frac{h^2\times k}{m}, \qquad m_i = z_{i-1} - z_i > 0,\ i = 1,2,..s \tag{2}$$

where z_{i-1}, z_i are the elevations of the top and bottom surfaces of the i-th geological layer; z_0 represents the ground surface elevation map $\psi_{top} = \psi_{rel}$ with the hydrographical network included; m, k are, accordingly, elements of the digital m, k -maps of the computed layer thickness and permeability; s – the number of layers.

The set of z-maps describes full geometry of HM. It is built incrementally: $z_0 \rightarrow z_1 \rightarrow \ldots \rightarrow z_5$ by keeping the thickness of the i-th layer $m_i > 0$. If in some areas $m_i = 0$ then the i-th layer is discontinuous. To prevent "division by zero" in the a_z calculation of (2), m_i=0 must be replaced by $\varepsilon > 0$ (for example, $\varepsilon = 0.02$ metres). In GV, only the z-maps serve as the geometrical ones (no m-maps accepted).

Two tasks of the HM creating are the most burdensome ones: obtaining the right distribution for the infiltration flow β_{inf} on the HM top; building the set of z-maps.

For reported HM, the first task was considerably eased. By using the ψ_{rel} –map, a feasible infiltration flow was obtained, as a part of the solved system (1). When ψ_{rel} is used, the flow $\beta_{aer} = \beta_{inf}$ passes through the aeration zone:

$$\beta_{aer} = G_{aer}(\psi_{rel} - \varphi_{Q1}) \tag{3}$$

where φ_{Q1} is the computed head (subvector of φ) for the first Q_{1a} aquifer; G_{aer} (diagonal submatrix of G) contains the vertical ties g_{aer} of the aeration zone connecting ψ_{rel} with φ_{Q1a}. The expression (3) reflects the usual result of HM, when the ψ-condition is applied. As a rule, even the first run of HM provides good results for β_{aer} that can be easy calibrated.

Because (3) includes the vector φ_{Q1} (groundwater table), the infiltration flow (alters if the distribution φ_Q changes under influence of the drainage system discharge flow in steady and in transient regimes of HM.

In GV, an ordinary drain is simulated, as a special case of the ψ-type condition [2]. For HM considered, the regime of a flooded drain is necessary. Such a case is not available in the GV system. To overcome this drawback, along a flooded drain line, a high hydraulic conductivity of the Q1a aquifer is used. This method is not an exact one, but it enables to simulate a flooded drain of HM.

III. Results for the steady regime of HM

The steady regime of HM was used for investigating possibility to apply lower drainage withdrawal rates.

In Fig. 4, the groundwater table φ_{Q1} of the Q1 aquifer is shown when no drainage system exists. In the right side of the block I, the maximum of the groundwater table is situated. It is caused by the infiltration flow. Boundary conditions of the ψ-type are fixed for the Q1 and Q2 aquifers, on the HM borderline. The groundwater flow is more intense, in the Baltic sea direction and towards the Venta river (southern side of HM). No flow enters the HM area through its borderline.

In Fig. 5, the groundwater table φ_{Q1} is shown if the drainage system is in the idle state (no water is pumped out from the system). There all drains of the system are flooded. However, the flooded drains alter considerably the φ_{Q1}–distribution (compare φ_{Q1} of Fig. 4 and Fig.5), because they act like shortcuts with respect to the body of the Q1a layer. The φ_{Q1} distribution of Fig. 5 is rather similar to the one that exists in the real drainage system [3]. The distribution of Fig.5 is applied, as the initial condition, for the transient model when the problem of restarting the drainage system is considered.

In Fig. 6, the φ_{Q1} distribution is shown when the drainage system is in the steady state and no flooded drains are present. The modelled discharge rate q=1336m^3/day is close to the mean observed one 1300m^3/day. The depression cone of the system is caused mainly by the block III. Part of the drains of the blocks II and III are switched out, because the groundwater table is below them. It means that the discharge rate may be lower than 1336m^3/day.

In Fig. 7, the φ_{Q1} distribution is presented when q=700m^3/day. The drains of block III are flooded and drain of the blocks I and II are not switched out.

In Table 1, withdrawal rates for various regimes of the drainage system are given [3]. Three steady state regimes are considered: the whole system, the block III only, without the block III.

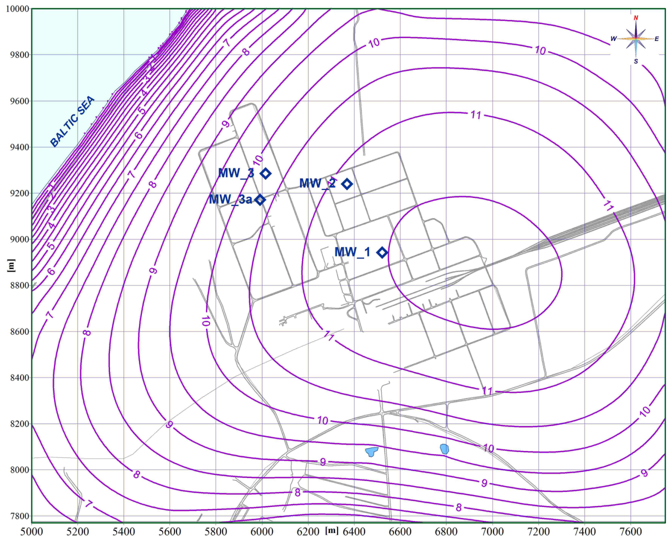

Fig.4. Groundwater table [m asl] of the Q1 aquifer if no drainage system exists

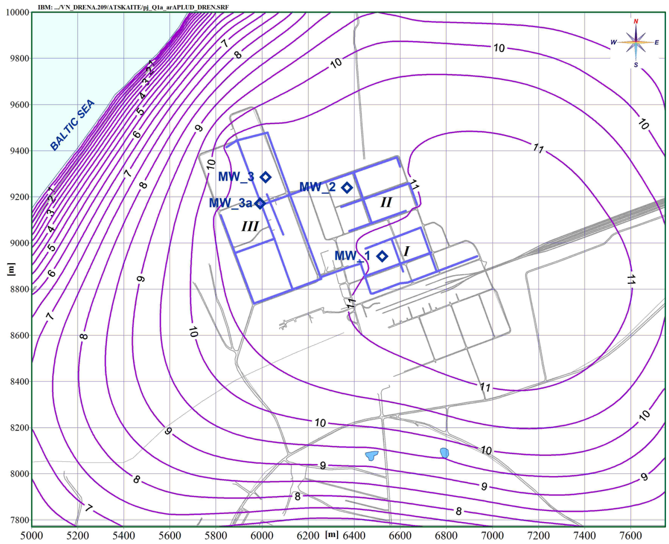

Fig.5. Groundwater table [m asl] of the Q1 aquifer if the drainage system is idle

If all blocks are used (Fig. 6) then most drains of the block II are not acting (q_{II} = 68 m^3/day). If the block III is switched out (flooded) then the rates q_I and q_{II} of the blocks I and II become higher and the total discharge rate q = 700 m^3/day (Fig. 7). It means that such a value may be used when the steady state regime will be applied after restarting of the system.

IV. Results of the transient regime of HM

The regime of restarting the drainage system is the transient one. In Fig. 8, the modelled recharges rates are given that are needed to restart the system. During the first days, the rates must exceed 50000m^3/day. It is not possible to keep them because the maximal possible discharge rate of the system q_{max}=7200m^3/day and the current capacity of the treatment plant q_{tr}=1000m^3/day. In Fig. 8, the graph q=1336m^3/day of the steady state regime is also shown.

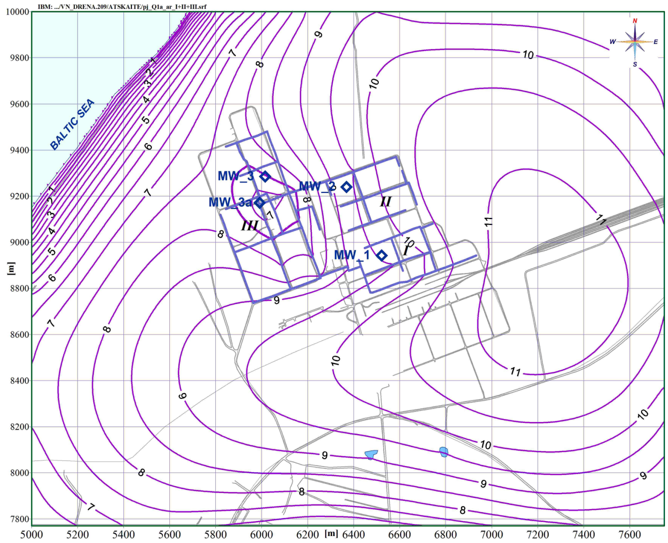

Fig.6. Groundwater table [m asl] of the Q1 aquifer if the drainage system is in steady state regime, q=1336 m3/day

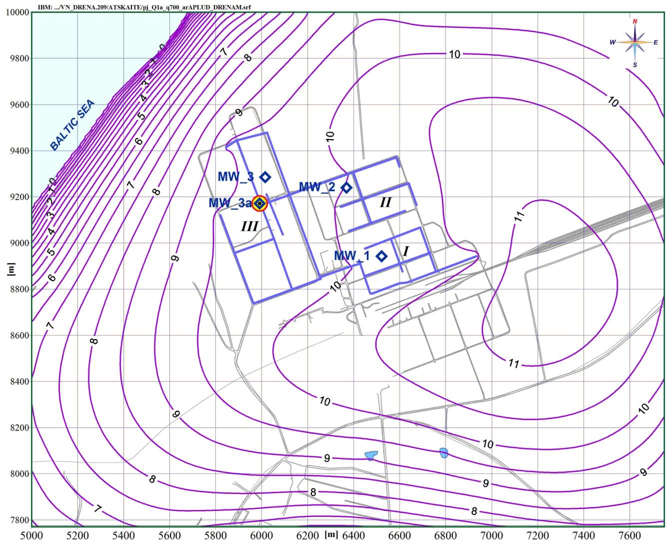

Fig.7. Groundwater table [m asl] of the Q1 aquifer if the drainage system is in steady state regime q=700 m3/day

TABLE 1
WITHDRAWAL RATES FOR VARIOUS REGIMES OF DRAINAGE SYSTEM

No.	Regime	Total rate [m^3/day]	Block I [m^3/day]	Block II [m^3/day]	Block III [m^3/day]
1.	whole system	1336	354	68	914
2.	block III only	1099	0	0	1099
3.	without block III	700	434	266	0
4.	whole system in transient regime after 100 days	2638	724	364	1550

Regimes 1, 2, 3 for steady regime.

In Fig. 9, graphs of the cumulative volume of discharged water are shown for the transient and steady regimes. During 100 days, 740 thous.m^3 and 133.6 thous.m^3 must be pumped out for the transient and steady regimes, correspondingly. These results explain why attempts to restart the drainage system have not been successful. No notable results can be obtained, in a short time, if a small discharge rate is used to restart the system.

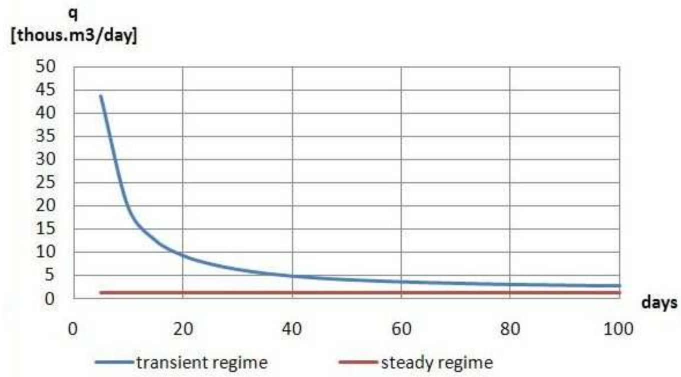

Fig. 8. Water withdrawal q [m^3/day] when the drainage system operates in transient and steady regimes

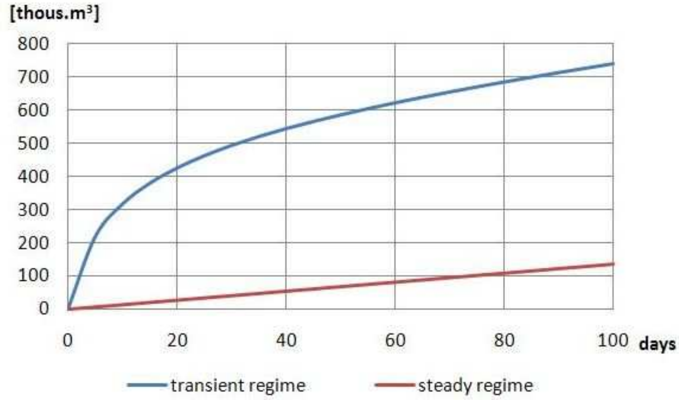

Fig. 9. Total volume of water [thous.m^3]pumped out when the drainage system operates in transient and steady regimes

In Fig. 10., hydrographs of the virtual monitoring wells are presented, for the classic transient regime (theoretical transient discharge rates used). It takes (200 - 300) days for the groundwater table, to approach its steady state (q = 1336 m^3/day).

In Table 1, the transient rates are given after 100 days. The total transient discharge q = 2638 m^3/day is about two times larger than the steady state one (1336 m^3/day).

To evaluate various versions of restarting, of the system by using the two stage regime is used: 1) 400 thous.m^3 by a forced discharge rate; 2) a reduced rate that supports the groundwater table practically unchanged during 400 days. The start value 400 thous.m^3 was taken by considering the transient water volume of Fig. 9 where about 740 thous.m^3 of water must be pumped out to get over the most intensive transient drainage discharge period (100 days). The reduced rate value (stage 2) was found experimentally. In Fig. 11, hydrographs for three regimes are presented: (1000/700); (2000/1100); (4000/1800) – (forced rate m^3/day / reduced rate m^3/day). It follows from these results then by using forced discharge rates, the restart time of the system can be considerably reduced. If the realistic regime (1000/700) is used then about 400 days are needed to approach the quasi steady state.

The real pump-out system can keep rather large discharge rates. This fact causes the idea of using a periodical discharge regime, if it is possible to accumulate about 10 thous.m3 of contaminated water in tanks. For example, during one day 10 thous.m3 is pumped out and accumulated. During the following four days no water is pumped out and accumulated

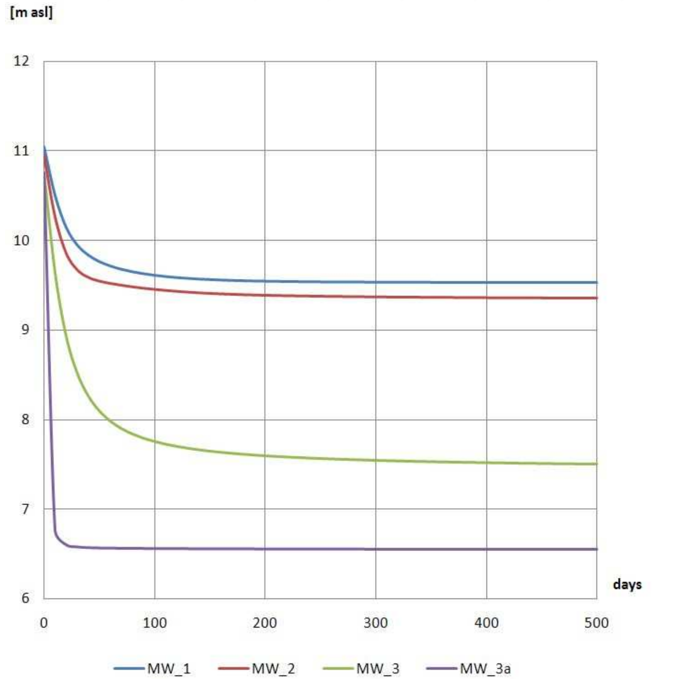

Fig.10. Hydrographs [m asl] of virtual monitoring wells for the drainage system in transient regime

water is cleaned. The mean discharge rate during 5 days is 2000 m3/day.

In Fig.12, results of the regime (2000/1100) are presented for the continuous and for the periodical drainage discharge versions. It follows from the graphs of Fig. 12 that no notable difference exists between the continuous and periodical regime. For the monitoring well MW3a (discharge well), pulsations of the hydrograph exist. However, their mean integral value equals with the one for the continuous discharge.

V. FLOW BALANCE OF THE DRAINAGE SYSTEM

For various regimes of the drainage system, by using instruments of the GV program, the flow balance of the Q1 aquifer has been obtained. The balance was computed for the area of the polygon which borderline encloses the drainage system (Fig. 2). Results for light regimes of the system are presented by Table 2.

If the idle drainage system is flooded (the case 1), the infiltration flow 330.83 m^3/day (Q_{1a} top) is spent by the outward lateral flow – 310.5383 m^3/day (total perimeter flow) an by the flow – 20.3083 m^3/day towards the gQ aquitard (Q_{1c} bottom). Within the Q_1 aquifer, the flows of subaquifers Q_{1a}, Q_{1b} , Q_{1c} demonstrate their spatial nature. Due to the outward flows, the idle system presents a source of contamination (see Fig.5).

For the steady system (the case 2.), the withdrawal rate q_w = 1336.00 m^3/day is cowered by the infiltration flow 711.95 m^3/day, by the incoming lateral flow 627.61 m^3/day and by the small outward flow – 3.56 m^3/day towards the gQ aquitard. The acting drainage system prevents lateral spreading of contaminated groundwater (see Fig. 6).

The case 4 presents the recommended steady regime where the withdrawal rate is reduced from 1336 m^3/day to 700 m^3/day.

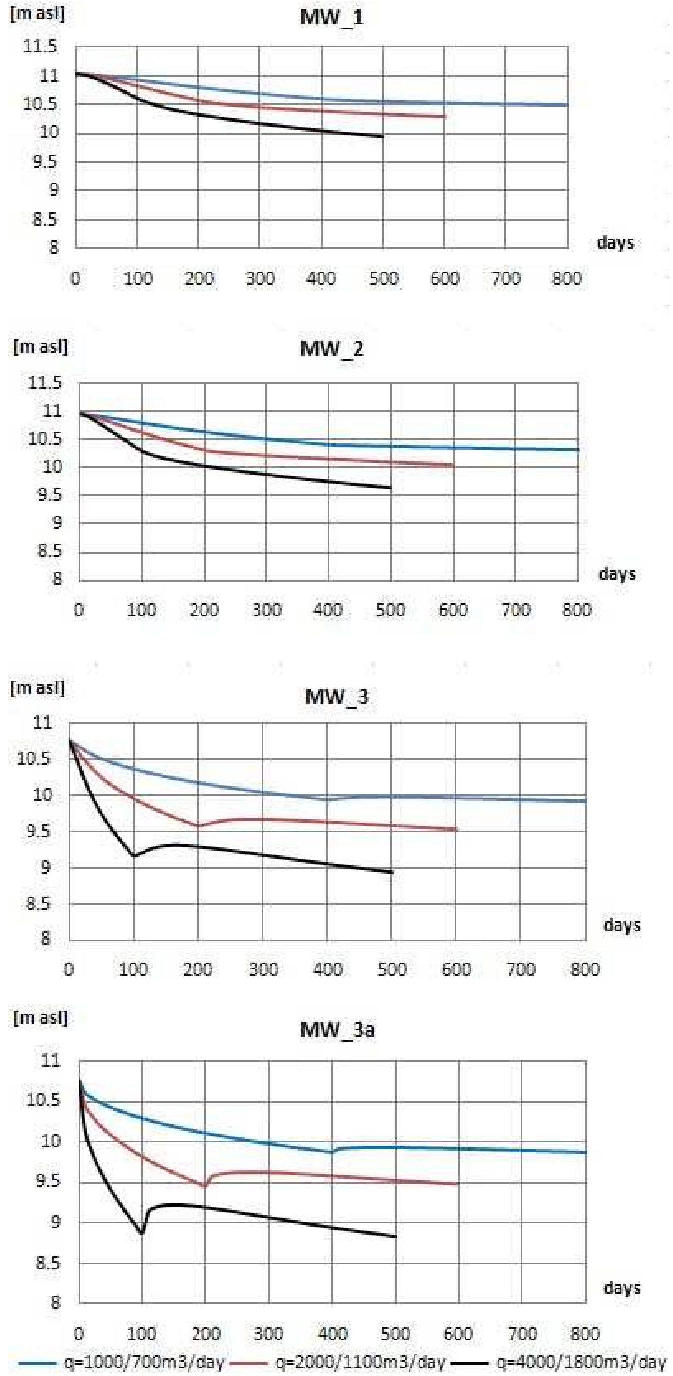

Fig. 11. Hydrographs [m asl] of virtual monitoring wells for flooded drainage system in transient regime if 400 thous.m^3 of water is pumped out during the first forced stage for three two stage regimes (forced withdrawal rate/reduced rate)

For the theoretically possible transient regime (the transient discharge rate of Fig. 8 used), the flow balance is given for the 100th day (the case 3). The withdrawal rate q_w=2638.00 m^3/day is balanced by the infiltration flow 664.47 m^3/day, by the incoming lateral flow 1410.66 m^3/day by the small outward flow – 2.58 m^3/day towards the gQ aquifer and by the transient release flow 565.45 m^3/day. If the time $t\rightarrow\infty$, the system will reach the regime of the case 2.

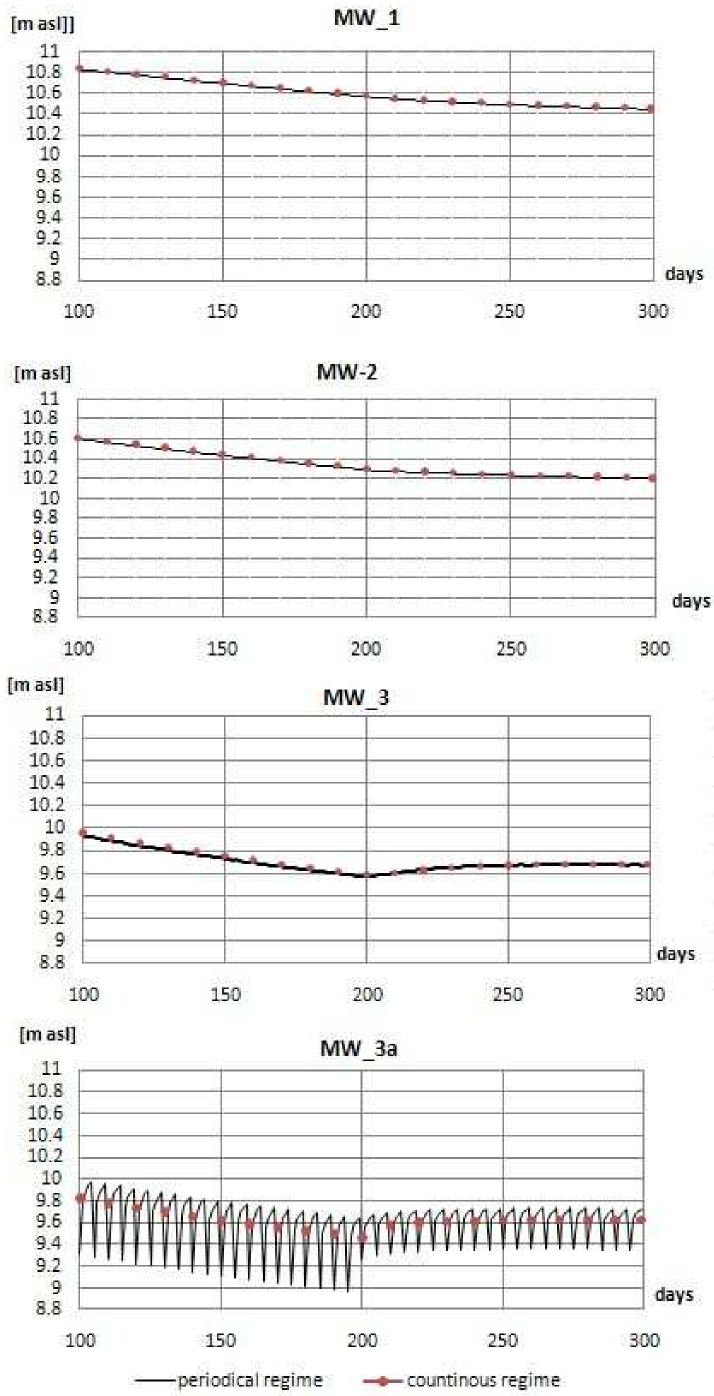

Fig. 12. Hydrographs [m asl] of virtual monitoring wells for flooded drainage system in transient regime (2000/1100) of Fig. 11. if water discharge is periodical and continuous

If the realistic restart withdrawal rate q =-1000 m^3/day is used (the case 6), then after 400 days the lateral incoming and transient release flows are 323.04 m^3/day and 245.28 m^3/day, accordingly. If the time $t \to \infty$, the system will reach the regime follows: 323.04m^3/day $\to$ 434.14 m^3/day and 245.28 m^3/day $\to$ 0.0 m^3/day, respectively. The infiltration flow of the steady system (case 5) will increase from 446.57 m^3/day to 576.15 m^3/day. The small flow passing through the Q_{1c} bottom will change its direction: 14.67 m^3/day$\to$ -10.29 m^3/day.

TABLE 2
FLOW BALANCE [M^3/DAY] OF Q_1 AQUIFER FOR VARIOUS REGIMES OF DRAINAGE SYSTEM

Sub-aquifer	Top	Bottom	Peri-metre	With-drawal rate	Tran-sient release
1. idle regime of flooded system					
Q_{1a}	330.83	-113.26	-217.57	0.0	0.0
Q_{1b}	113.26	-44.54	-68.72	0.0	0.0
Q_{1c}	44.54	-20.30	-24.24	0.0	0.0
2. steady system (I+II+III)					
Q_{1a}	711.95	153.08	470.97	-1336.00	0.0
Q_{1b}	-153.08	36.95	116.13	0.0	0.0
Q_{1c}	-36.95	-3.56	40.51	0.0	0.0
3. transient system after 100 days					
Q_{1a}	664.47	635.71	1055.73	-2638.00	282.09
Q_{1b}	-635.71	228.73	265.37	0.0	141.61
Q_{1c}	-228.73	-2.58	89.56	0.0	141.75
4. steady system q=700m3/day					
Q_{1a}	502.55	15.31	182.14	-700.00	0.0
Q_{1b}	-15.31	-5.72	21.03	0.0	0.0
Q_{1c}	5.72	-13.29	7.57	0.0	0.0
5. steady system q=1000m3/day					
Q_{1a}	576.15	74.79	349.06	-1000.00	0.0
Q_{1b}	-74.79	11.03	63.76	0.0	0.0
Q_{1c}	-11.03	-10.29	21.32	0.0	0.0
6. transient system q=1000m3/day after 400 days					
Q_{1a}	446.57	164.92	265.88	-1000.00	122.63
Q_{1b}	-164.92	61.11	42.49	0.0	61.32
Q_{1c}	-61.11	14.67	14.67	0.0	61.33
7. transient system q=2000m3/day after 200 days					
Q_{1a}	477.36	512.99	618.66	-2000.00	381.99
Q_{1b}	-521.99	220.71	110.23	0.0	191.05
Q_{1c}	-220.71	-12.40	42.05	0.0	191.06
8. transient system q=4000m3/day after 100 days					
Q_{1a}	502.31	1331.70	1127.45	-4000.00	1038.54
Q_{1b}	-1331.70	593.73	218.52	0.0	519.45
Q_{1c}	-593.73	-9.64	83.85	0.0	519.52

The cases 7 and 8 present the restart variants which apply forced withdrawal rates 2000 m^3/day and 4000 m^3/day, if the cumulative volume of discharged groundwater is 400 thous.m^3. For the both cases, the transient release flows are comparatively large if compared with the case 6. It means that during the following 400 day period of keeping constant reduced withdrawal flows rather complex transient processes must take place.

VI. CONCLUSIONS

The hydrogeological model for the oil terminal area has been created and used. The following results have been obtained:

1. To lower the water treatment cost, it is possible to reduce the withdrawal rate of the drainage system from 1300m^3/day to 700m^3/day.
2. If the withdrawal rate 1000 m^3/day (the current capacity of the water treatment plant) is used for restarting the drainage system, it will take at last (400 - 500) days to approach the quasi steady state regime.
3. The restart time may be reduced if forced withdrawal rates are used during the initial restart period.

4. No real difference exists between periodical and continuous regime of the drainage system if the mean withdrawal rates of the both regimes are equal.
5. An idle flooded drainage system presents an active source of contaminated groundwater.

REFERENCES

[1] Report on Agreement between the Riga Technical university and VentEko, Inc. Hydrogeological model for optimization the drainage system of the "Ventspils nafta" oil terminal. 2001, Riga (in Latvian)
[2] Groundwater Vistas. Version 5. Guide to using, 2007, Environmental simulations
[3] Summary on contaminated drainage and sewage systems of the "Ventspils nafta" oil terminal. VentEko, Inc. 2009, Riga (in Latvian)

Aivars Spalvins was born 1940, Latvia. In 1963, he graduated Riga Polytechnical institute (since 1990, the Riga Technical university) as computer science engineer. In 1967, A. Spalvins received degree of science candidate confirmed by thesis entitled "*Hybrid computers for solving boundary field problems* ". In 1994, this degree was transferred to the one of the doctor of engineering sciences. Aivars Spalvins has been with the university science 1958 (as a student) until now. His present scientific interests are computer modeling of groundwater flows and migration of contaminants. He is author of about 300 scientific papers. His present position is Director of Environment Modelling centre of Riga Technical university. He is member of International Association of Hydrogeologists, since 1995.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
Phone: +371 67089511
E-mail: emc@cs.rtu.lv

Janis Slangens was born 1940, Latvia. In 1969, he graduated Riga Polytechnical institute (since 1990, the Riga Technical university) as computer science engineer. In 1985, J. Slangens received degree of science candidate confirmed by thesis entitled "*Hybrid computers for solving boundary field problems* ". In 1994, this degree was transferred to the one of the doctor of engineering sciences. Janis Slangens has been with the university science 1965 (as a student) until now. Since 1969 he was assistant, senior lecturer of Department of Computer Engineering of Faculty of Computer Science and Information Technology. Since 1993 he is senior researcher of Environment Modelling Centre.His present scientific interests are computer modeling of groundwater flows and migration of contaminants. He is author of about 200 scientific papers.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
Phone: +371 67089511
E-mail: emc@cs.rtu.lv

Inta Lace was born in Latvia. In 1971, she graduated Riga Polytechnic institute (since 1990, the Riga Technical university) as computer science engineer. In 1995, I. Lace received degree of M.sc. (applied computer science). Inta Lace has been with the university science 1965 (as a student) until now. Since 1971, she is researcher of Environment Modelling Centre, Faculty of Computer Science and Information Technology, Riga Technical University. Since 1991, she took part in projects of Latvian Science Council on informatics for hydrogeology and other projects. Her present scientific interests are computer modeling of groundwater flows and migration of contaminants. She is author and co-author of about 100 scientific papers on software problems of solving boundary field problems.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
Phone: +371 67089511
E-mail: emc@cs.rtu.lv

Kaspars Krauklis holds MSc degree of engineering science in computer systems from Riga Technical University (2007) and the certificate in Teaching of Engineering Sciences from RTU Institute of Humanities (2005). Since 2005 he participated in several projects of ESF, ERDF and Latvian council of science. Since 2007 he is a PhD student in RTU, in the Faculty of Computer Science and Information Technology. Currently he works as the researcher in the Environment Modelling Centre which is the part of the Faculty of Computer Science and Information Technology of the Riga Technical University and as a lecturer in the Division of Applied Systems Software of RTU. His main scientific interests are - groundwater modelling and technologies of e-learning . He is an author or co-author of 17 publications in both above fields.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
Phone: +371 67089511
E-mail: emc@cs.rtu.lv

Aivars Spalviņš, Jānis Šlangens, Inta Lāce, Kaspars Krauklis. Modelis piesārņota pazemes ūdens drenāžas sistēmai
Latvijas jūras ostā Ventspilī pazemes ūdens ir piesārņots ar naftas produktiem. Lai pazeminātu ūdens līmeni, ierīkota drenāžas sistēma. Ūdens, kuru izsūknē no sistēmas, ir jāattīra no naftas produktiem. Jau samērā ilgu laiku (kopš 2001. gada)šī sistēma netiek izmantota regulāri augsto ūdens attīrīšanas izmaksu dēļ. Tāpēc pazemes ūdens līmeņi sasnieguši nepieļaujami augstas vērtības. Nesen pabeigta vietējo attīrīšanas iekārtu izbūve un veikti pirmie nesekmīgie mēģinājumi atkal iedarbināt drenāžas sistēmu. Izrādījās, ka šo sistēmu atkal iedarbināt nav vienkārši. Tika izveidots hidroģeoloģiskais modelis (uz sistēmas Groundwater Vistas bāzes) ar kura palīdzību bija jārod atbildes par drenāžas sistēmas iedarbināšanu un uzturēšanu: atrast optimālu drenāžas sistēmas stacionāro režīmu; saskaņot šo režīmu ar attīrīšanas un atsūknēšanas iekārtu iespējām; kā iedarbināt drenāžas sistēmu (režīmi, laiks u.c.)? Galvenie modelēšanas rezultāti iegūti nestacionāram drenāžas režīmam ar appludinātām drenām. Veikti ūdens plūsmu detalizēti aprēķini drenāžas sistēmai stacionārajā un nestacionārajos režīmos. To analīze dod iespēju novērtēt dažādu drenāžas sistēmas darbības variantus. Konstatēts, ka var izmantot mazākas ūdens atsūknēšanas jaudas stacionāram režīmam. Lai atjaunotu drenāžas sistēmas darbību, ir jārēķinās ar lielu laika patēriņu. Izpētīti dažādi režīmi sistēmas darbības uzsākšanai un daži no tiem ieteikti praktiskai izmantošanai.

Айвар Спалвиньш, Янис Шланген, Инта Лаце, Каспар Крауклис. Модель дренажной системы для загрязненной подземной воды
Подземные воды на территории морского порта Вентспилс (Латвия) загрязнены нефтяными продуктами. Для понижения уровня подземной воды построена дренажная система. Вода, которая откачивается из системы, должна быть очищена от нефтяных продуктов. Продолжительное время (с 2001. года) эта система не используется регулярно по причине больших затрат на очистку воды. Поэтому уровни подземной воды достигли недопустимых значений. Недавно построены местные системы для очистки воды и были приняты безуспешные попытки по возобновлению работы дренажа. Оказалось, что это возобновление не является простой задачей. Была построена гидрогеологическая модель (на базе системы Groundwater Vistas), с помощью которой было необходимо получить ответы по решению следующих задач: найти оптимальный режим дренажной системы в стационарном режиме; согласовать этот режим с возможностями систем очистки и откачки воды; определить как возобновить работу дренажа (режимы, время и др.)? Основные результаты получены для нестационарного режима с затопленными дренами. Выполнены детальные расчеты потоков подземной воды для стационарного и нестационарного режимов дренажной системы. Анализ этих расчетов дает возможность оценить эффективность различных вариантов работы дренажной системы. Выяснено, что можно уменьшить объем воды, который откачивается из дренажа в стационарном режиме. Установлено, что процесс восстановления работы дренажной системы будет продолжительным. Исследованы варианты восстановления работы системы и некоторые из них рекомендованы для практического применения.