2010 ITP report

Research at Department of Water Resources Engineering, Lund University, Sweden

DANG THUONG HUYEN
PhD Student of Department of Urban and Environmental Engineering
Graduate School of Engineering
Kyushu University
Host Institute: Department of Water Resources Engineering, Lund University
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Based on International Training Program supported by JSPS (Japan Society for the Promotion of Science), I had visited Lund during 2 months for research exchange (12th January – 16th March, 2010). Life experiences and results of research will be explained following:

1. Life experiences

Lund University is located in Lund City, southern part of Sweden. **Figure 1** show the main building of Lund University. By train, it takes about 10 minutes from Lund center to Malmo, the third city in Sweden, and about 50 minutes to Copenhagen airport, Denmark. There are several buses from the department to downtown costing 17 SEK one way. In case having bicycle, it takes about 10 minute to the center.

Lund is an old city with two big cathedrals. There are many supermarkets, bars and restaurants (Nordic, French, Italian, Vietnamese, Japanese, Middle-East, Chinese, etc) in the downtown. In Sunday morning, there is a traditional market where sells very fresh vegetable with cheap price. They are also many student nations such as Östgotä nation, Västgöta nation, Lunds nation, where held parties and activities for the memberships. If you join a nation, you will have good experiences with English practice and also Swedish student life. Each semester, there is an introduction day for the nations, so new comers can decide to join which nation they prefer. With about 95% Swedish people speak English, students easily communicate when they have any problem or they want to make friend.

Fig.1 Main building of Lund University, Sweden

Every weekday, there are two coffee-breaks at 9.30am and 2.30 pm in the Department of Water Resources Engineering (in V-building). Students and professors often share ideas about life and researches. The drinks are always available, for example, coffee, milk, chocolate milk, etc. There is a small gym room inside the building where students can do whenever they want. They play inner bandy game on every Thursday. They are almost PhD students including foreigner students and Swedish students.

Nearby the V-building, there is a super market and canteen so that you can buy food during lunch time.

The important thing when living in Lund is the apartment room. It is difficult to find available room there because many students are coming to study in Lund University. It is better to find the room in Lund city at least before two months or you can live in Malmo and take the bus come to the university.

2. Research

Title of research: "effectiveness of a super well point to prevent leachate transferring from a municipal landfill to the neighboring environment". This paper is submitting to Journal of Hydrology

BACKGROUND

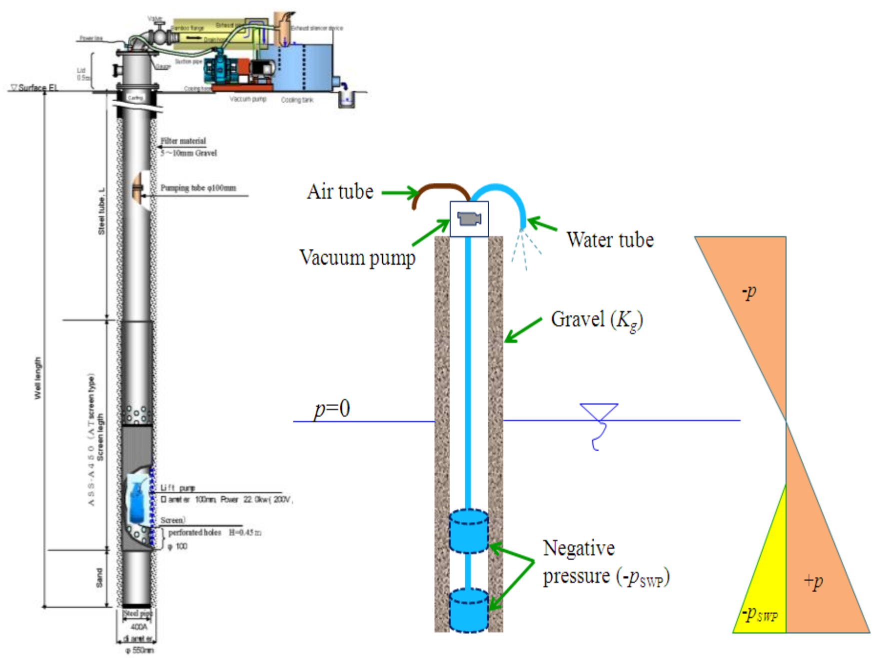

Fig.2 Illustration of SWP

Figure 2a shows the real structure of the SWP. The super well point method is a new dewatering method. This method will supersede the conventional dewatering methods, such as well point method (by forced dewatering), deep well method (by gravity dewatering), and vacuum deep well. Super Well Point Method is the vacuum dewatering method that does not suck air, but sucks groundwater only. By utilizing a special strainer section make of doubles tubes (a separation screen); forced dewatering while maintaining a vacuum in the well is achieved.

Owing to the special separation screen, which presents the air from entering to the well, forced dewatering at great depth. The separation screen is a double tube structure, which is made of an internal pipe and a wrapped screen (mesh) strainer. Groundwater passing through the wrapped screen strainer well is separated in to water and air. The water without air passes the bottom inlets and flow into the well. The vacuum pump creates the suction force inside the inner pipe and enables the continuous vacuum dewatering (Asahi Techno 2005). Super well point can lower groundwater table with wider area (Asahi Techno 2005 and Iwai et al. 2007) and also used as a vacuum consolidation (Miyazaki et al. 2005).

Figure 2b is a conceptual illustration of the SWP. *p* in **Fig.2** indicates the pressure head at the unconfined aquifer. The screens of the SWP include several perforated holes, allowing groundwater to flow in. At the screen locations, the groundwater is set up to have negative pressure head ($-p_{SWP}$) and be in the saturated zone. In other words, the water content close to the perforated holes of the SWP is the saturation value. This is in contrast to natural media. Normally, in the natural environment of the unsaturated zone, water content is less than the saturation value where pressure head (*p*) is negative (van Genuchten 1980). In the saturated zone, water content is equal to the saturation values where pressure head (*p*) is positive or zero.

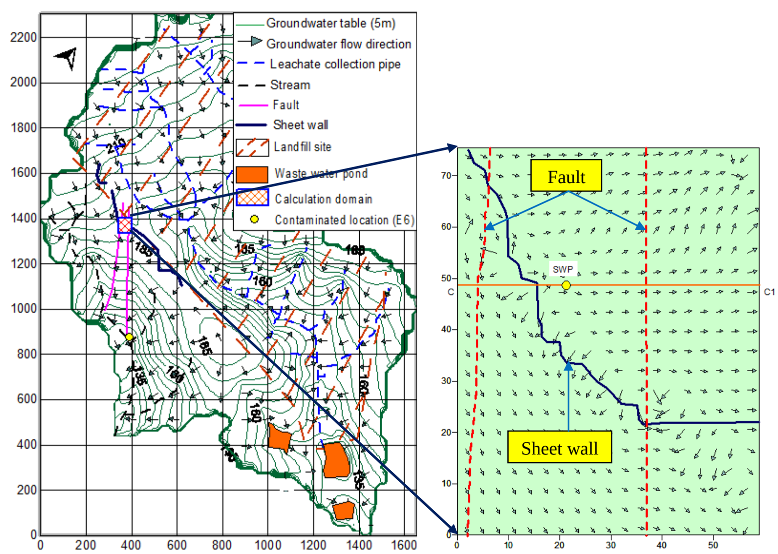

Fig.3 Study location

This study aims to simulate the effectiveness of the SWP for groundwater extraction.

The study site was selected closed to the sheet wall and the faults in **Fig.3**. The SWP was constructed inside the landfill site, from which the leakage of leachate into the surroundings has been already observed. The land outside the landfill is owned privately, rather than by local government. The area of the study site is 76 x 59.5 m. The highest point at the site is 239 m above the sea level.

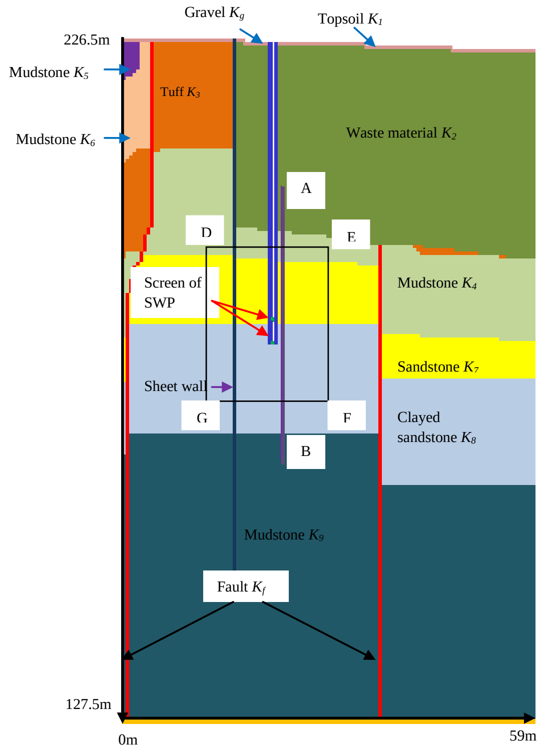

Fig.4 Geological condition at C-C1

Table 1 Permeability values

Permeability	Value (cm/s)	Note
K1	10^{-3}	Topsoil
K2	$5x10^{-3}$	Waste material
K3	$3.6x10^{-4}$	Tuff
K 4	$4x10^{-4}$	Mudstone
K 5	$3x10^{-4}$	Mudstone
K 6	$5.2x10^{-4}$	Mudstone
K 7	$8x10^{-4}$	Sandstone
K8	$6x10^{-4}$	Clayed sandstone
K 9	$3.5x10^{-4}$	Mudstone
Kw	10^{-7}	Sheet walls
$\mathbf{K_f}$	10^{-2}	Scenario 3 (Faults)
$\mathbf{K_g}$	10^{-2}	Gravel

Figure 4 shows the geological conditions of the calculated area along cross section C-C1. The bottom domain elevation is 127.5 m. The depth of the cross section C-C1 is 99m. There are nine layers with different permeabilities. K1 to K9 in **Fig.4** denote the permeabilities of the nine layers, the values of which are shown in **Table 1**.

The permeabilities were determined from the measured data of Luzion test. Most layers are mudstone. The depth of the sheet wall is 80 m from the ground surface. In the area of interest, permeability of the faults is unknown and thus assumed to be 10^{-2} cm/s (Dang [a)] et al 2009). The permeability surrounding the SWP is equal to 10^{-2}cm/s (K_g). The vertical cross-section A-B is discussed later in term of the pressure head distribution.

NUMERICAL SOLUTION

The transient groundwater flow equation (1) is solved employing an implicit finite difference method (IFDM) and iterative successive over-relaxation (SOR) technique. Grid size was divided into uniform grid system (0.5 x 0.5 x 0.5 m).

Figure 5 is a flow chart of the pressure head calculation. The most expression is to calculate a zone of the pressure head distribution near the SWP. As mentioned above, this zone has negative pressure but saturation water content. The groundwater table is calculated for each time step and the obtained pressure head is applied in calculating water content for each grid point. If the elevation of a grid point is higher than the groundwater table, the grid point is in the unsaturated zone and the water content is calculated from the pressure head. In contrast, where a grid point is located inside the saturated zone; water content is the saturation water content. After calculating the water content, pressure head distribution will be calculated by IFDM and SOR technique. The numerical results are stored at each appropriate time step. The program stops when the time step is greater than the time required for simulation or when the water table is below the screen of the SWP. If the water in the aquifer becomes less, the SWP suck only air. The numerical solution of the pump rate is compared with observed data to demonstrate the accuracy of the model.

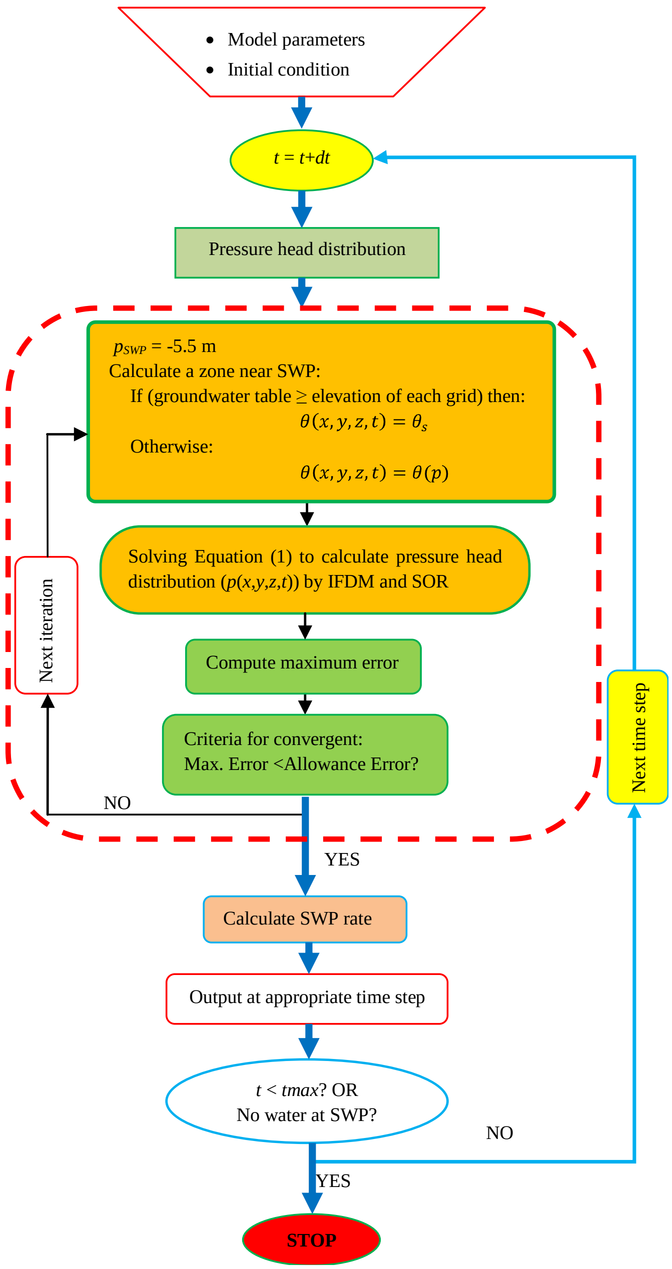

Fig.5 Flow chart model

RESULTS AND DISCUSSION

Observed and calculated pumping rates

Figure 6 shows the observed and calculated values of SWP rate (l/min). The calculated SWP rate was shown for seven days. Observed data was recorded every 10 minutes. The calculation results show that the SWP rate reduced rapidly within first day of the SWP operation. In the remaining calculation time, the SWP rate decreases slowly and stabilizes. The observed data show that the decrease in SWP rate is slower than that calculated on the first day. Afterward, there is good agreement between the calculation and observation data. This figure also shows high pumping rate of observation and calculation.

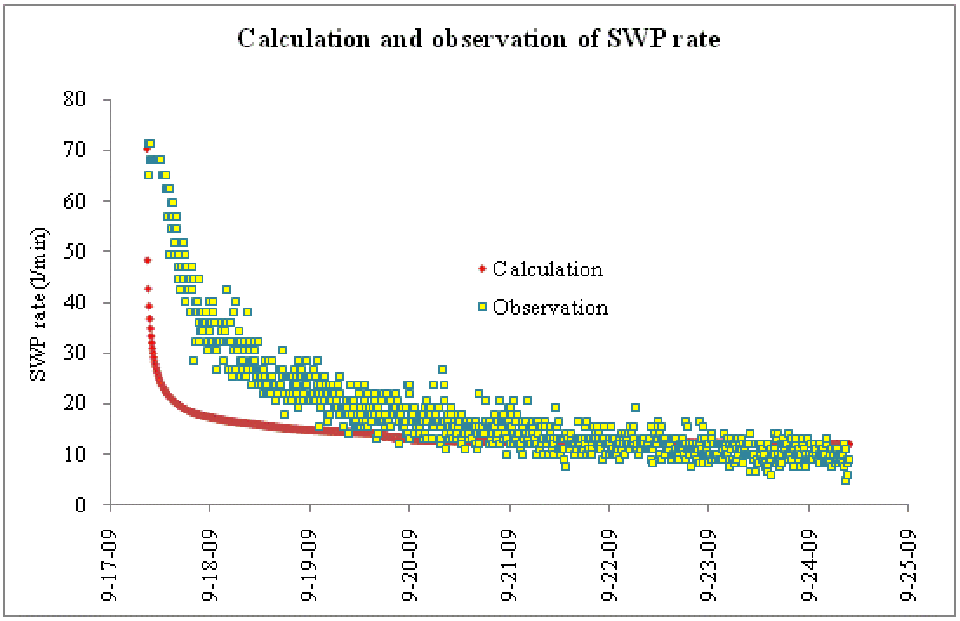

Fig.6 Calculation and observation of SWP rate

Pressure head distribution

Figure 7 presents the pressure head distribution at DEFG (**Fig.4**). At 2 screens (**Fig.2b**), the pressure head is originally -5.5 m. Distance between 2 screens is 6m. After 1 hour, the negative pressure head zone is formed surrounding these screens (**Fig.7a**). Then, the negative pressure head zone expands with time around the SWP (**Fig.7b-d**). **Figure 8** shows water content along A-B crossing the negative pressure head zone. Normally, there is saturation water content when the pressure head is positive. However, the SWP's operation affects the natural process and the pressure head thus becomes negative in the saturated zone.

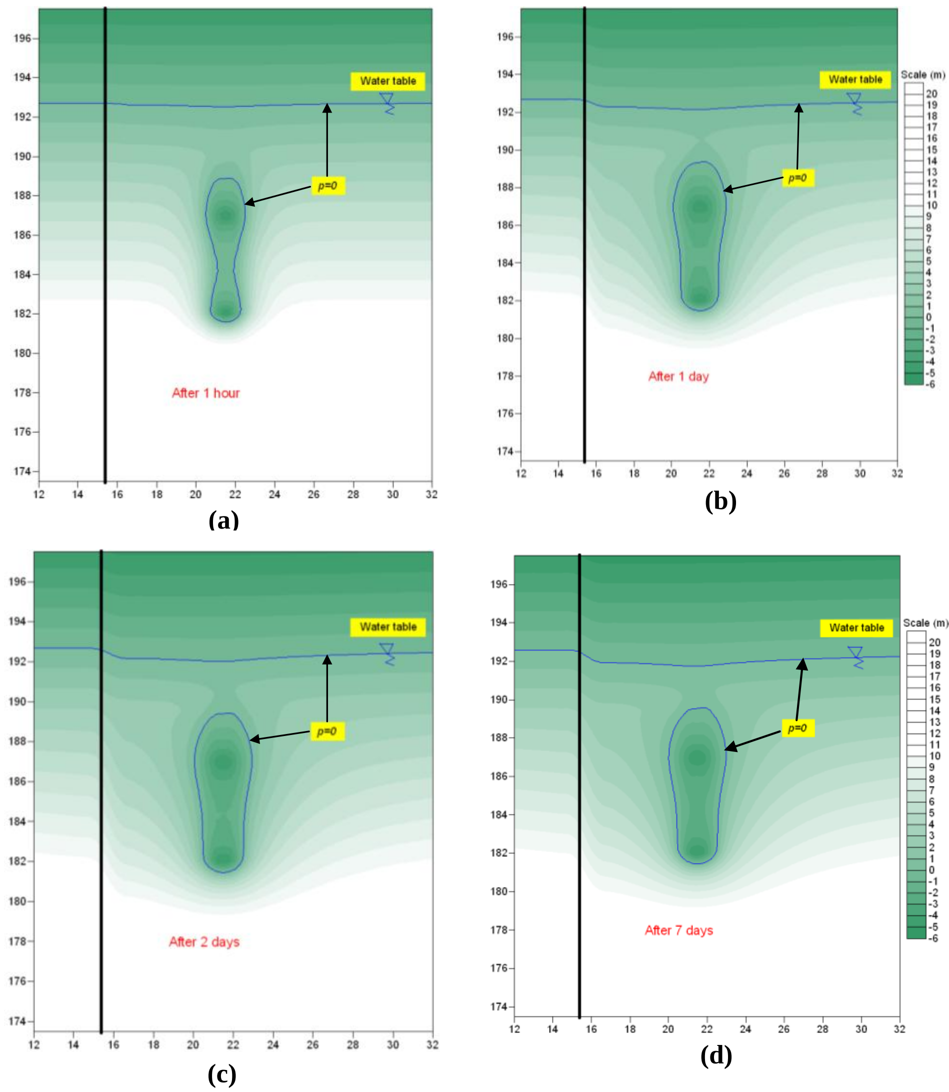

Fig.7 Pressure head distribution at DEFG

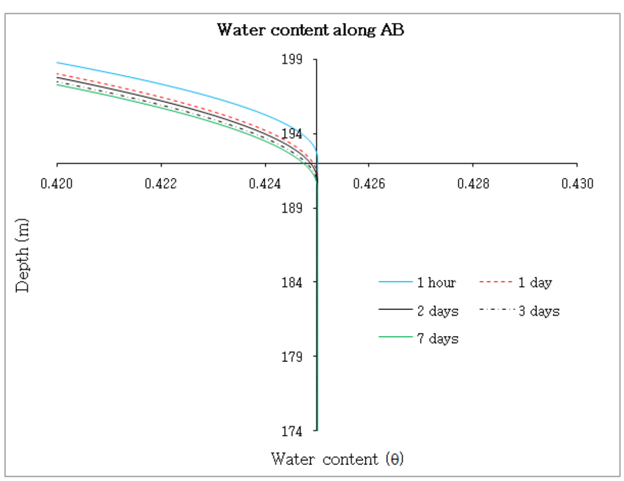

Fig.8 Water content along AB

Groundwater table

Figure 9 shows the water table along C-C1. The water table is influenced more within the landfill site than outside the sheet wall. In addition, the radius of influence of the SWP is larger within the landfill than outside the landfill (**Figs.9** and **10**). Obviously, the function of the sheet wall is to reduce much water entering the SWP. These figures show that high pumping rate of the SWP induces the groundwater direction flow to the SWP. Hence, no chance for groundwater flows along the faults even high permeability at the faults was assigned.

Figure 10 (a)-(d) shows the horizontal view of the change in the water table. The water flows into the SWP quickly after 1 hour (**Fig.10a**). The water table pattern changes with time. All water at the calculation area moves toward the SWP. Therefore, the SWP can recover polluted groundwater that has leaked outside the landfill.

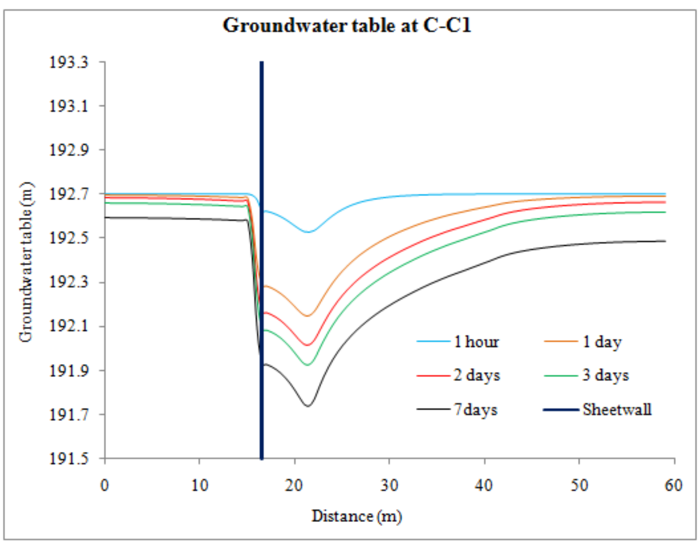

Fig.9 Groundwater table along C-C1

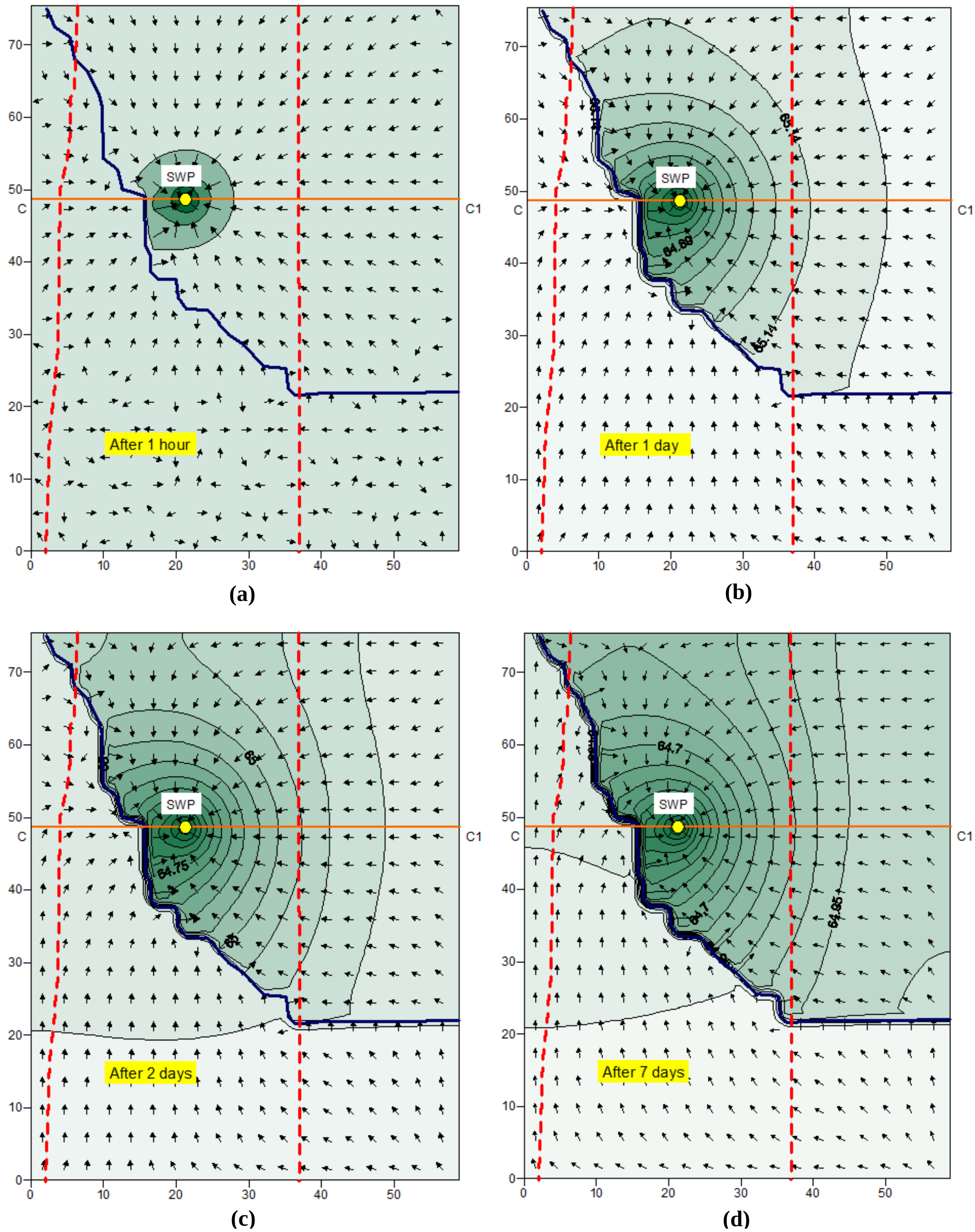

Fig.10 Water table and flow direction at the study site

CONCLUSION

The results of numerical simulation were in good agreement with observation data. Therefore, the simulation can be used to evaluate the effectiveness of the SWP. The results show that the SWP is new technology that has the ability to recover polluted groundwater that leaked from the landfill A. The simulation results also show that all polluted groundwater flows easily to the SWP for extraction and safe disposal. Within the landfill, groundwater flows easier than it does outside because of the sheet wall. However, the polluted groundwater surrounding the landfill can be transported under the sheet wall.

The SWP induces the change of groundwater flow direction along the faults when the SWP has high pumping rate. Groundwater has no chance to move out. On the other hand, the SWP is able to collect leachate and prevent leachate transferring to the neighboring environment.

3. Seminar presentation

I gave a presentation supporting by Prof. Ronny Berndtsson before he went to India.

Title: effectiveness of a super well point to prevent leachate transferring from a municipal landfill to the neighboring environment.

Date: 24th February, 2010

Place: seminar room in 4th floor in V-building

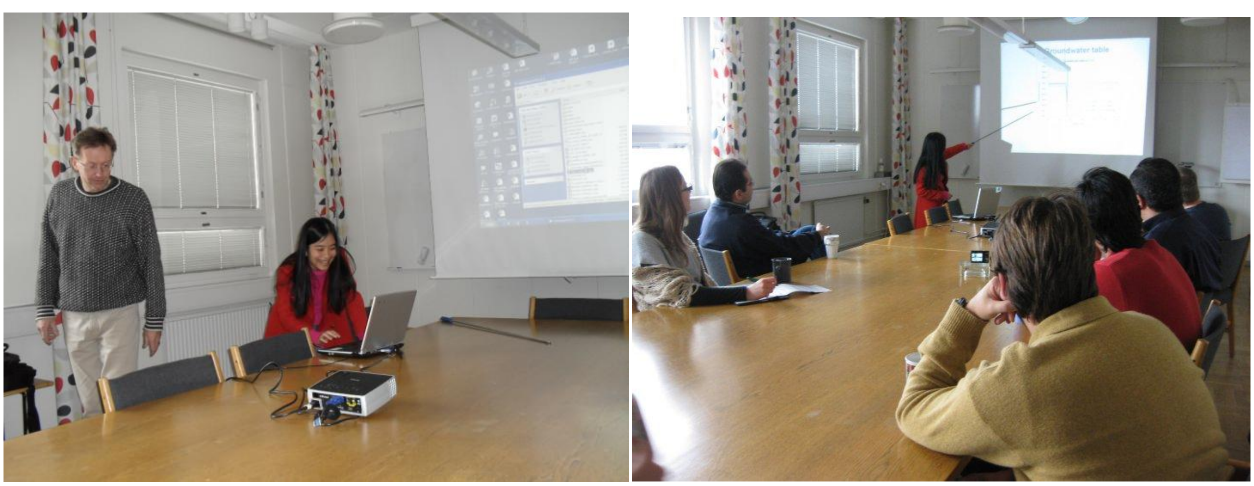

Fig.11 Presentation in Department of Water Resources Engineering

Acknowledgements

I would like to impress my grateful acknowledgement to JSPS program (ITP) for supporting me the scholarship to have a great experience in Lund University.