Simulation of wicked water migration in shallow groundwater

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THE PROBLEM

Wicked problems are generally found in the realm of public policy such as urban renewal, crime, and water resources. Generally speaking, however, water problems in the 18th and 19th centuries were much more benign, but in the 20th and 21st century they have taken on a much more wicked character (Freeman, 2001).

The present study area is located in the vicinity of Universiti Putra Malaysia, which was used as paddy fields, and huge amounts of fertilizer were used for growing the plants during the last few decades. In addition, different agricultural activities that are still in progress next to this field cause migration of contamination (phosphorus) to the study area. Subsequently, experimental tests on different samples show that the swamp, which is located to the east of the study area, is a source of contamination in the study area.

The objective of this study is to perform simulations of the phosphorus migration processes in groundwater and the interaction between surface water and groundwater over 50 years using Visual MODFLOW. The simulation results are essential to understand the hydrocomplexity of the study area, and to make useful suggestions for environmental management and site remediation. Also, they assist in identifying impacts of the phosphorus in future, and the assessment of the amount of contamination in comparison with the Interim National Water Quality Standard for Malaysia (INWQSM), which defines the maximum value of phosphorus in groundwater for Class IIA/IIB and III as 0.1 mg/L and 0.2 mg/L, respectively (DOE, 2004).

METHODOLOGY

Visual MODFLOW, which solves for variable types of groundwater transport and migration of multiple species, was employed to simulate the condition of phosphorus movement in 18 250 days. These long periods were chosen due to the low hydraulic conductivity of Layer no. 1 and also the slow phosphorus movement in soil (Saghravani *et al*., 2009). The simulations are performed using MODFLOW to simulate an aquifer system in which saturated flow conditions exist and Darcy's law applies, and MT3DMS to simulate advection, dispersion, and chemical reactions of contamination in groundwater in three dimensions. The physical setting and groundwater flow conditions at the site were collected between January 2007 and March 2008 by Saghravani (2009).

RESULT AND DISCUSSION

During this process, a root mean square error (RMSE) value of 0.151 mg/L was obtained. The residual mean and standard error of the estimate for the model were 0.045 and 0.065 mg/L, respectively, with a correlation coefficient of 0.69.

Simulation Scenario 1

Groundwater flow could pass through both layers in the same direction. As expected, the rates of groundwater flow in these layers are different due to a difference in transmissibility of the layers. A fast progression of the pollution plume is revealed, which indicates that the contamination plume migrates to another place (Fig. 1).

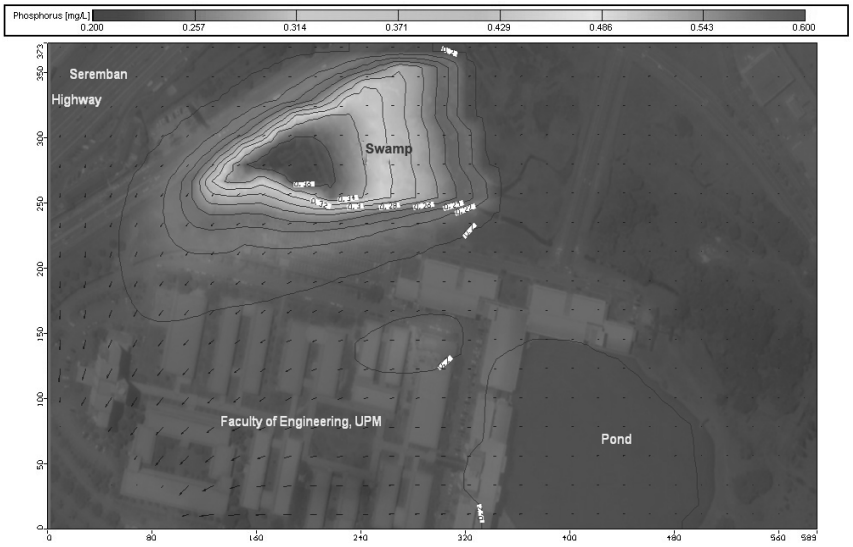

Fig. 1 Groundwater pollution concentration in steady state.

Simulation Scenario 2

A transient regime was considered to simulate the transportation of contamination in the flow for 18 250 days. The flow direction of groundwater was observed to be towards the pond due to the placement of the boundary. In this case the water level dropped 2 m in the pond. This caused a change in groundwater flow direction and water from other parts of the study area, including the swamp area (Fig. 2).

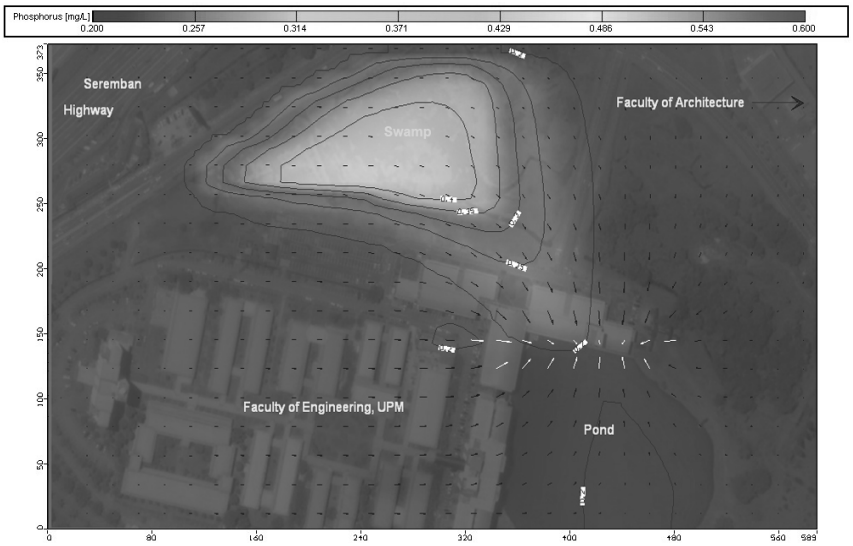

Fig. 2 Groundwater pollution concentration in transient state.

CONCLUSION

Vertical migration may be responsible for the occurrence of phosphorus within the second layer, because the direct horizontal movement of pollutant through the first layer to the pond is limited due to its very low hydraulic conductivity. It was proven that the pollution enters the groundwater (from the major source of pollution in the study area) and is transported to places further away. The distribution of phosphorus level in groundwater in the study area and the demonstration of pollution transport in the aquifer were key points of this research.

It is recommended that the use of fertilizers should be reduced to control the concentration of phosphorus in groundwater. The swamp, the main source of contamination, has increasingly adverse effects on the groundwater. Further studies must be implemented to assess and control the source of wicked water, thereby increasing the water quality of both surface and subsurface water in the future.

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