INTERACTIONS BETWEEN THE RED RIVER AND GROUNDWATER OF CONFINED AQUIFER IN HANOI, VIETNAM

Tokyo Metropolitan University ○Thuy Thanh NGUYEN
Tokyo Metropolitan University Akira KAWAMURA
Tokyo Metropolitan University Hideo AMAGUCHI
Tokyo Metropolitan University Naoko NAKAGAWA

1. INTRODUCTION

Domestic and industrial water supply in Hanoi is provided mainly with groundwater. Rapid growth of population and urbanization in Hanoi has put more pressures on water supply. As a consequence of insufficiency of infrastructure, surface water, especially river and lake water have been seriously polluted and high level of suspended deposit. Although the present situation in some parts of Hanoi is a warning for Arsenic-affected regions (Lenny at al. 2011), but surface water is higher prone to contamination and preparing drinking water out of surface water can be unreliable and difficult or expensive. Therefore, groundwater has become the most important sources of water supply in Hanoi. During the past two decades, a great deal of groundwater related studies has been carried out. For example, Bui et al. (2011) identified aquifer system not only for Hanoi but also for the entire Red River Delta. Modelling subsidence in Hanoi City area, Vietnam was also conducted by Trinh and Delwyn (2000). However, there are very limited understandings on groundwater and surface water interactions in Hanoi to quantify the gains to or losses from the river, temporal variations of gains and losses due to changes in streamflow and groundwater levels, and the conditions (saturated or unsaturated) beneath losing reaches of the river,. An improved understanding of the surface water/groundwater interaction along the Red river is needed to address the overall significance of the Red river in the water budget, which is critical for effective water management and conjunctive water use planning.

Specific objectives of this study were to: (1) increase the understanding of the dynamics of the surface water/ groundwater interaction along the Red river in Hanoi, Vietnam, (2) quantify the recharge between the Red River and groundwater of confined aquifer in Hanoi, (3) investigate temporal variations of groundwater level in confined aquifer in response to the fluctuating water level of the Red River.

2. STUDY AREA

Hanoi is the capital of Vietnam with a total area of about 3.344 km^2 in the northern part of Vietnam (Fig.1). The population was about 6.5 million in 2009, occupying 7.5% of the Vietnam's population. The Hanoi belongs to the tropical monsoonal region with two distinctive seasons. The rainy season is from May to October and the dry season lasts from November till April. The annual rainfall is about 1,600 mm of which rainfall in the rainy season occupies about 75%. The annual average humidity is about 90% and the average temperature is around 24^{o}C. Evaporation is quite high with an annual average of 900 mm. The river network is quite dense with the density of about 0.7 km/km^2. There are also more than 100 lakes with a total surface area of more than 21.8 km^2. (Bui et al. 2012).

Fig.1 Study area, locations of hydrological stations, observation wells and three typical hydrological cross sections.

3. METHEDOLOGY

The method used in this study is coupling MIKE 11 and MODFLOW. MIKE 11, developed by DHI, is a modeling package for the simulation of surface runoff, flow, sediment transport and water quality in rivers, channels, estuaries, and floodplains. MODFLOW (Harbaugh and Mc Donald, 1996) is a public domain, finite- difference code developed by the United States Geological Survey (USGS) that is capable of simulating groundwater flow in transient, three-dimensional, anisotropic and heterogeneous systems.

4. DATA USED

The data processing in the MIKE 11 involves: networks, cross section and hydrodynamic and boundary parameters. Daily discharges recorded at Son Tay station and watershed outlets were used as the downstream and upstream boundary condition respectively. The output hydrograph from MIKE 11 were compared to the observed hydrograph at Hanoi, Thuong Cat, Hung Yen station. The daily data in 1996 were used for model calibration and the daily data in 2003 were used for its validation. After model calibration and validation, the daily data in 2006 were used for evaluating the interactions between groundwater and the Red River. Output data of Mike 11 are the water levels at the cross sections, which are used as the input data for MODFLOW.

Data used for MODFLOW model setup consist of: available geological information (e.g. boreholes data and cross sections) and topographic maps used to determine the aquifer-system geometry; hydrogeological parameters including hydraulic conductivity, specific storage and specific yield; pumping volume; effective recharge; groundwater evaporation; groundwater heads at observation wells.

5. RESULTS AND DISCUSSION

Model Calibration and Validation

Model calibration was achieved through the classic trial and error procedure, by matching simulated stream stages with observed stream stages and simulated heads with observed heads with the Nash being the criteria. As shown in Table 1, the Nash index ranging 0.77-0.88 for calibration and 0.77-0.86 for validation indicate that parameter were properly calibrated.

Table 1. The results of calibration and validation.

No	Station/ Well	Model	NASH	
			Calibration	Validation
1	Hanoi	MIKE	0.87	0.86
2	Hung Yen		0.82	0.81
3	Thuong Cat		0.85	0.83
4	Q173	MODFLOW	0.77	0.77
5	Q56		0.88	0.85
6	Q57		0.79	0.79
7	Q58		0.84	0.83

Interactions between the Red River stages and groundwater levels in the Pleistocene confined aquifer

Table 2 reveals that the correlation coefficients in the PCA vary from 0.7 to 0.89, with an increasing tendency from far to near the river. Aside from this observation, Table 2 also indicates a decreasing tendency of the correlation coefficients from upstream to downstream along the river.

As shown in Fig. 2, water levels in the nodes in the PCA that are near the river responded more rapidly to changes in the river stage. The rapid response to changes in stage in the near-river nodes is consistent with hydrogeological conditions at those locations. The difference in the magnitude of the response to river stage fluctuations among the wells nearby the river may result from varying hydraulic properties in the near-river aquifer and streambed material, and the resulting amount of leakage from the river.

The close relationship between river water and groundwater found in this study area reveals a clear indication of reduction of water in river during low flow period when water mostly comes from seepage of groundwater into the streambed. Declines of groundwater level can alter intercept of groundwater flow that discharges into river. The ultimate effect is a loss of riparian vegetation and wildlife habitat.

Table 2. The hydraulic interactions between groundwater in the confined aquifer and the river.

Node	Distance from the riverside (m)	Correlation coefficient (2006)
NB1	100	0.89
NB2	1400	0.88
NB3	3000	0.85
NC1	100	0.88
NC2	500	0.89
NC3	4800	0.7

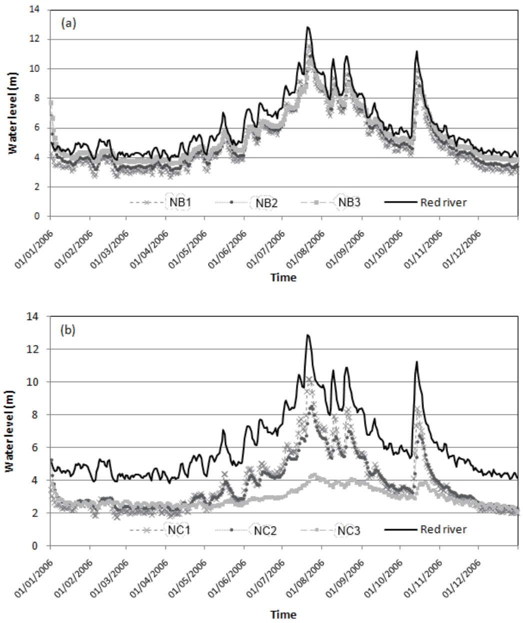

Fig.2 Fluctuation of water level in the Red river and groundwater levels of PCA of nodes: (a) NB1, NB2, NB3; and (b) NC1, NC2, NC3.

6. CONCLUSION

The results show very high correlation ranging 0.7-0.89 between the river water levels and the PCA groundwater levels in six selected nodes. The correlation was highly influenced by not only the hydrogeological conditions of the aquifer and riverbed but also the distance from the river. It was also found that the correlation decreased along the river from upstream to downstream. More specifically, upper parts of the river exhibited seasonal interactions of recharge and discharge between the river and the aquifers, while the lower parts of the river recharged the groundwater almost throughout the year.

7. REFERENCES

Bui, D.D., Kawamura, A., Tong, T.N., Amaguchi, H., Nakagawa, N., Iseri, Y. : Identification of aquifer system in the whole Red River Delta, Vietnam, *Geosciences Journal*, Vol 15, No. 3, 323-338, 2011.

Bui, D.D., Kawamura, A., Tong, T.N., Amaguchi, H., Nakagawa, N.,: Aquifer system characterization for potential groundwater resources in Hanoi, Vietnam, Hydrological Processes, Vol 26, No. 6, 932-946, 2012.

Harbaugh, A.W., McDonald, M.G.,: User's documentation for MODFLOW-96, an update to the US geological survey modular finite-difference groundwater flow model. *USGS Open-File Report* 96-485, 1996.

Lenny, H.E.W, Phan, T.K.T, Pham, H.V, and Michael, B.: Arsenic pollution of groundwater in Vietnam exacerbated by deep exploitation for more than a centery. Proceedings of the National Academy of Sciences of the United States of America, PNAS, Vol 108, No. 4, 124-1252, 2011.

Keyword: groundwater recharge, groundwater flow, Pleistocene confined aquifer, MODFLOW, MIKE 11, the Red River, Hanoi.