Drinking Water Usage with Riverbed water and Groundwater

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With estmating drinking water demands of Ulsan city, the amount would be increased from 523,000ton/day in 2006 to 635,000 ton/day in 2016. Also, the dependence of Nakdong River on the Ulsan city as a source of drinking water will be very high up to 54.4% of total drinking water demands. Small-scale drinking water dam is no economical because of excessive construction cost and long construction period. However, development of riverbed and ground water of existing rivers is more economical than that of small-scale drinking water dam. In this study, to utilized Dongchun River as a drinking water resource, Modflow model was used to predict the amount of riverbed and ground water of Dongchun River basin. As a result, available amount of riverbed water was assumed in 6,000 ton/day by worst case (when perfect dry stream) and in case of ground water, it was assumed in 17,800 ton/day.

Key words: Riverbed Water, Ground Water, Modflow Model

1. Introduction

Total population of Ulsan city was 1,060,000 people and drinking water supply rate was 90% by 2001. Drinking water supply rate of Ulsan city increased from 290,000㎥/day in 1995 to 386,000㎥/day in 2001. However, lpcd (liter per capita day) of Ulsan city was decreased from 366ℓ in 1998 to 331ℓ in 1999 and 317ℓ in 2001[1)]. Because, it was estimated that drinking water demand in 2006 would be increased to 350ℓ lpcd[2)], plan for drinking water in Ulsan city are supposed to be established. Plans for drinking water supply can be contained with construction of small-scale dam and development of ground water or riverbed water[3)]. Construction of small-scale dam would be economical, because of excessive construction cost and long construction period[4~5)].

However, development of riverbed and ground water of existing rivers is more economical than that of small-scale drinking water dam.

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According to the data announced from the KOWACO (Korea Water Resources Corporation), possible amount of development of ground water in Ulsan city is rich as much as 114,299,724 ㎥/year and useable amount could be reached to 29,992,881㎥/year. Considering development of ground water or riverbed water in Ulsan city, Dongchun River can be one of the alter-natives[4,6)]. Basin area of Dongchun River is 168㎢, and river length is 27.1㎞, average width of basin, 6.20㎞. Dongchun River has much riverbed water and consist of about 85% sands and about 15% gravels. Purpose of this study is estimate the existence amount of riverbed water and possible amount of development of ground water in Dongchun River basin by using Modflow model.

Also, the result of this study can be used as a basic data that is needed to establish a plan for water resources supply in Ulsan city.

2. Experimental Methods

2.1 Numerical analysis of ground water

Modflow model (Modular Three Dimensional Finite Difference Flow Model)[7~10)] was used to estimate the existence amount of riverbed water and possible amount of development in Dongchun river basin. McDonald and Harbough at U.S. Geological Survey[7] developed it. Modflow model can analyse the distribution of ground water by Block-centered finite difference approach[7,11,12]. Also, unconfined ground water as well as confined ground water can be analysed by its three dimensional analysis. Fig. 1 showed the diagram of water system in Dongchun basin.

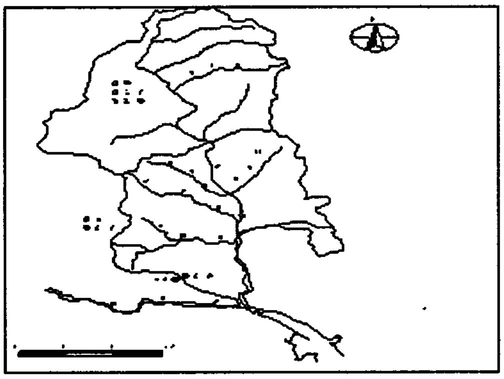

Fig. 1. Diagram of water system in Dongchun basin.

2.2 Grid establishment and boundary condition

For analysis of distribution of ground water in Dongchun basin, Block-Centered Finite Difference Approach was applied. For obtaining hydrological factor, rock distribution of Dongchun basin and geological characteristics was established [13]. Grids (X, Y) in Dongchun basin were formed as 24×45 Ea shown in Fig. 2.

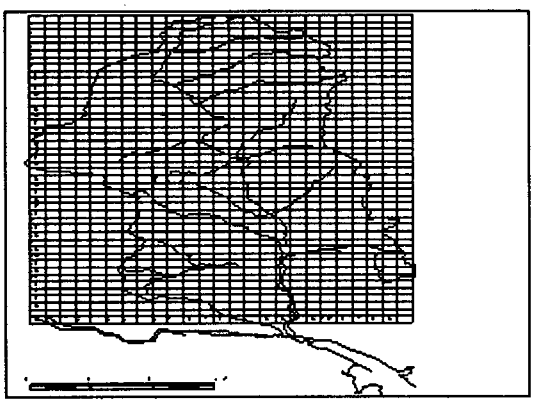

Fig. 2. Grids of Dongchun basin.

Boundary in Dongchun basin were designated by water devide line. Because outside area of Dongchun basin did not affect directly in ground water distribution of investigation area, No Flow Cell was considered as ground watershed, and Active Cell was designated as grids in Dongchun basin.

3. Results and Discussion

3.1 Distribution analysis of Ground water

1) Analysis of steady state flow

SIP (Strongly Implicit Procedure) was applied for calculation of ground water flow system. For appling to the ground water flow, SIP should be examined water balance analysis because of big error, although SIP is numerically stable.

According to the water balance analysis, discrefancy at steady state flow was 0%. Therefore, the amount of inflow was equal to that of outflow.

Analysis result of distribution for underground iso-head under the steady state flow was represented in Fig. 3.

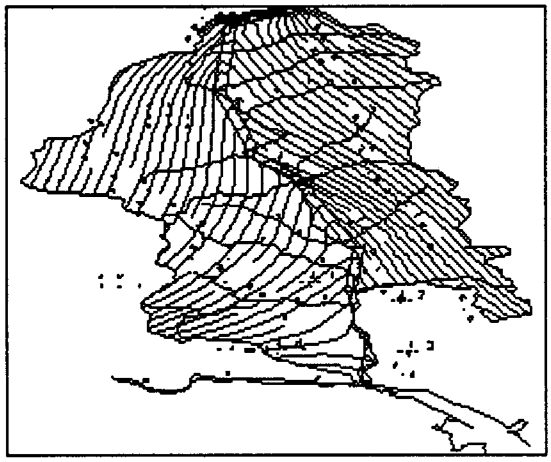

Fig. 3. Distribution of ground water iso-head in Dongchun basin.

Stable water level data in beginning development of water well for analysis of ground water flow is demanded. Therefore, 4 points were chosen as follows. Ulsan Nongso-up sangan-ri(EL. 78.7m : T1), Ulsan Songjeong dong(EL. 62.1m : T2), Ulsan Yaksa dong(EL. 58.3m : T3), Ulsan Jung-gu Jinjang dong(EL. 19.8m : T4).

Table 1. Statistical analysis of observed value and calculated value

(Unit: m)

Dist. Well No.	Observed G.W.L (E.L. (m))	Analyzed G.W.L (E.L. (m))	Statistical Values
T1	6.01	6.07	Residual Mean = -0.0260 Residual Standard Dev. = 0.0620 Residual Sum of Squares = 0.0001 Absolute Residual Mean = 0.0580 Res. Std. Dev. / Range = 0.0120
T2	7.02	6.95	
T3	3.05	2.95	
T4	2.10	2.11	

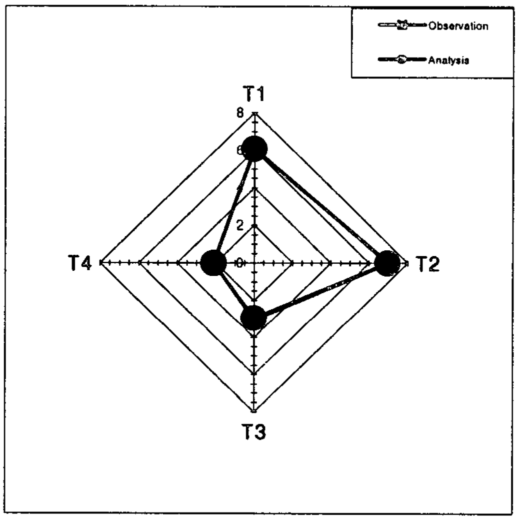

Fig. 4. Diagram of distribution of ground water level

The smallest range of fluctuation by statistical analysis was water well T4 as 0.010m. Otherwise, in T3, the largest range between observed and analyzed value was represented as 0.10m; residual mean of observed and analyzed value was 0.0260. Residual sum of squares was 0.0001, and absolute residual mean was 0.0580. As shown in fig. 4, there were similar results between observed and analyzed value.

2) Analysis of unsteady state flow

To observe the stability of water level, analysis of unsteady state flow was executed by pumping riverbed water of 3 points in Dongchun basin after 50 days and 90 days

In the worst condition, which is perfect dry stream, pumping amount of riverbed water was predicted by Modflow model. 3 points for model application[14] were chosen as follows, Dol is located in 1.3km upper stream of songjeong bridge, Do2 is 0.5km downstream of songjeong bridge, and Do3 is 0.5km downstream of byoungyoung bridge. Pumping point of riverbed water was Dol, Do2, and Do3. Using Trial and Error methods, Ground water level was determined in the range of 5% discrefancy. Analytical results were represented in table 2.

Table 2. Position of pumping well and dimension

Water well	Point		Pumping Amount (t/day)	Remark
	Grid I	Grid J		
Dol	35	16	1,000	-
Do2	37	16	2,000	-
Do3	43	17	3,000	-
Sum.			6,000	

When the pumping was achieved after 50 days and 90 days in the points of Dol, Do2, Do3 simultaneously, water level difference of ground water level in T1 was decreased to 5.47 ~ 5.72m, in T2, 5.31 ~ 5.59m, in T3, 2.88 ~ 2.95m, and in T4, 1.09 ~ 1.14m. Analyzing ground water level distributions by using model, the difference between the smallest ground water level and largest ground water level was 1.09m ~ 5.72m during that period. In this result, ground water level was gradually stabilized after 90 days.

On the other hand, mutual interference was observed between Dol and Do2 by ground water pumping. Because this analysis was carried out only water, mutual interference due to pumping can be solved by stable instream. Therefore, it could be considered that the pumping amount of riverbed water would increase

Table 3. Comparison water level between calculated and observed value (after 50 days and 90 days pumping)

(Unit: EL.m)

Dist. / Water well	Flow analysis			Remark
	Steady state flow	Unsteady state flow (Pumping period)		
		50day	90day	
T1	6.01	0.54	0.29	
T2	7.02	1.71	1.43	
T3	3.05	0.17	0.10	
T4	2.10	1.01	0.96	

4. Conclusions

In this study, to utilize Dongchun River as a drinking water resource, Modflow model was used to presume the amount of riverbed and ground water of Dongchun River basin. As a result, available amount of riverbed water was assumed in 6,000 ton/day at worst case (when perfect dry stream) and in case of underground water, it was assumed in 17,800 ton/day.

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