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Groundwater Level Analysis Using GIS

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Abstract

The aim of this study is to analyse the groundwater condition of Tuul River Basin at the regional and local levels using a GIS. For this aim, the data acquired from two different seasons are analysed for the same wells.

Introduction

The water sources for domestic, municipal and industrial use in the Ulaanbaatar area consist mainly of groundwater along the Tuul River. There are 133 pumping wells and depending upon their locations they fall under the four major sources called the Upper, Central, Industrial and Meat Complex [18]. The increasing consumptions of water due to population growth, industrial and agricultural activities have resulted in lowering down of water table and drying up some springs and small streams.

The aim of this study is to analyse the groundwater condition of Tuul River Basin at the regional and local levels using a GIS. Previously, JICA conducted research on water supply condition of Ulaanbaatar City completely in detail and investigated available water source area near the city. In this study, we converted all existing spatial and non-spatial data sets, provided by JICA and some other research institutes, including texts, tabular information and paper maps related to groundwater level change of Tuul River Basin to digital form and analyzed them using GIS different techniques.

Hydrology of Tuul River Basin

The Tuul River originates in the Hentii Mountains and flows generally from northeast to southwest in a variably meandering channel. The total length of the Tuul River is 819 km, and the total catchment area is 50.4 km^2. The catchment area near Ulaanbaatar is about 6300 km^2. Flow gradually begins in the spring than in March the discharge gradually increases to peak in the rainy seasons from July to August. River water levels during flooding are typically 1.8-2.0 m higher than in drought periods. Water levels at Ulaanbaatar increase 1-2 days after rain in the catchment area.

Groundwater Condition of Ulaanbaatar City

Owing to active exploitation of the groundwater and the construction of water processing and supply systems by the Municipality of Ulaanbaatar, almost a half of the population of the city are supplied with clean water by pipelines. The remaining half of the residents relies on water wagons or is self-supported by their own wells. Daily consumption of water in Ulaanbaatar city is 160,000 m^3 and average consumption per person is 200-250 liters, while average consumption per person in suburban areas of Ulaanbaatar is 8-10 liters. Because of the increase in population and economic activities, and despite the efforts made by the Municipality, the present water supply capacity is insufficient to meet the rapidly increasing demand.

Groundwater Level Study Using GIS

In this study, groundwater level was analyzed at 2 levels:

- Regional level – Central Water Source Area of Ulaanbaatar City, Mongolia.
- Local level – Pumping well No.10, Central Water Source Area.

Groundwater Level Change Study at Regional Level

At regional level, the Central Water Source Area of Ulaanbaatar City was chosen as a test site. The Central Water Source Area as for its location occupies an area 1.5-3.2 km wide stretching for 16.5 km from the western outskirts of Gachuurt village to Ikh Tenger. The wells in Central Water Source have comparatively shallow depth, and it is 29.6 m in average. The average ground level is +1286.2m above the sea level. The height difference between the highest well and the lowest is about 30m. The monitoring measurement of groundwater level in Central Water Source Area has been conducted by Russian and Mongolian experiments at several times. Also JICA conducted the groundwater level observation at the 36 test wells on September 1993, April and September 1994.

In this study we used the existing groundwater level data to estimate seasonal water level fluctuation in regional level. All existing data was in analog (paper map) form therefore it needed to be converted into digital form. Topographic information has been collected from topographical map of Ulaanbaatar area of year 1984 at scale 1:50000. Mapping the groundwater level elevation is a useful tool for understanding and connecting the movements and changes within groundwater aquifers, and relationships with land use and development. Using well data of JICA, we created groundwater level map. For 2 seasons by digitizing the groundwater level elevation contour Triangulated Irregular Networks (TIN) were created at 1m intervals. By creating TIN surfaces in GIS a difference map can be generated to show the change between the two seasons.

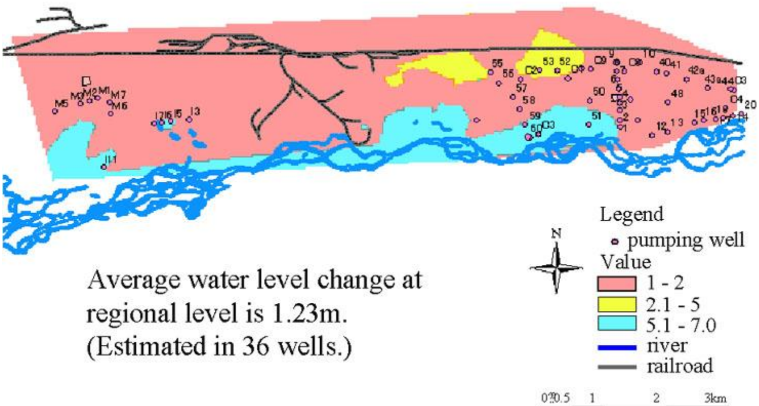

Figure 1. Analyzed groundwater level change of
Central Water Source Area using GIS.

Figure 1 shows the difference of measured groundwater level between the September and April that were estimated for same wells, using spatial analyst technique of GIS. The fluctuation of groundwater level reached the value of 1-7m, depending on geological structure and its hydrodynamic parameter. From the GIS Analysis high groundwater level change estimated in the pumping well, located along Tuul River, it means groundwater level change depends river recharge and also well location. The level of groundwater decreases when the water supplying wells are in operation and it increase and restores when some of them are being fixed.

Groundwater Level Change Study at Local Level

At local level, the pumping well No.10 of Central Water Source Area was chosen. Field experiments for groundwater monitoring at pumping well No.10 were conducted by ground penetration radar (GPR) experiment. From 1999 in this area we carried out GPR experiment 8 times. To monitor seasonal groundwater level change clearly, field survey was conducted in different seasons and conditions. In field experiment a GPR system (MALA, GeoScience, Sweden) with 100MHz and 25MHz antennas was used. Figure 3.8 shows the GPR experiment in pumping well No.10 area of 2000. During GPR experiment we observed the depth to the water table in the well by using water level. Table 1 shows the observed water table in the well from 2000 during GPR experiment.

Table 1 Observed water level of pumping well No.10

No	Period of GPR survey	Depth to the water table in the well (m)
1	3-5 August, 1999	not observed
2	5-7 September, 2000	5.6
3	4-5 October, 2001	5.3
4	2-4 April, 2002	6.85
5	7-8 November. 2002	4.85
6	23 February, 2003	6.5
7	11-13 June, 2003	4.0
8	4-6 November, 2003	4.52

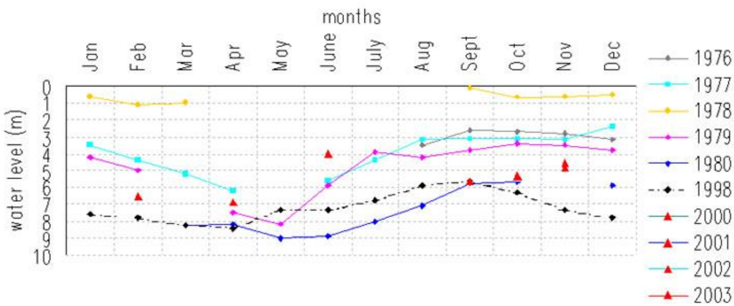

Figure 2. Seasonal water level fluctuation of pumping well No.10

Linkage Between Regional and Local Level

By comparing water level data in well No.10 of year 1976-1980, monthly average data of year 1998, also seasonal data of year 2000-2003 were measured by our experiments, we can see seasonal groundwater level fluctuation as shown in Figure 2.

From the figure the in pumping well No.10 groundwater level amplitude lowering down by gradually increasing by year.

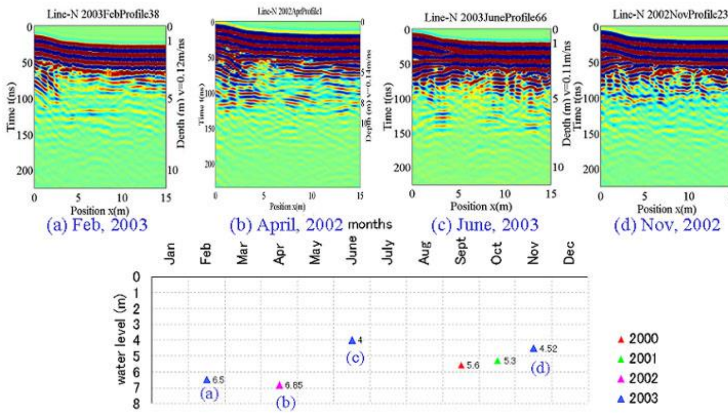

Figure 3. Seasonal fluctuation of GPR profile corresponding to observed groundwater level during GPR experiment from 1999 to 2003. The reference level of the water level is 1.15m below the level of the survey line at x=0m [21] as each observed water table +1.15m

As shown in Figure 3 it can be seen, during GPR experiment in pumping well No.10 low water level observed as 6.85m +(1.15m offset), high water level was 4m +(1.15m offset) and average water level was 5.34m +(1.15m offset). An average groundwater level change were estimated in Central Water Source Area as 1-2m, meanwhile in pumping well area it was estimated 1.25m. This means that there is a relationship between local and regional levels and surely for more accurate estimation of the groundwater level at the regional level one should conduct very precise analysis at the local level.

Conclusions

The aim of this study was to analyse the groundwater level change at the Tuul River Basin, Mongolia at regional and local levels using a GIS. For this aim, the data acquired from two different seasons were estimated for the same wells. As seen from the analysis, the fluctuation of groundwater level reached the value of 1-7m, depending on geological structure and its hydrodynamic parameter. As it could be seen from the GIS analysis, high groundwater level change estimated in the pumping wells located along Tuul River. Furthermore, it is seen that an average groundwater level change in Central Water Source Area was 1-2m, whereas in pumping well area it was estimated 1.25m. This indicates that there is a relationship between the local and regional levels and most probably for more accurate estimation of the groundwater level at the regional level should conduct very precise analysis at the local level.