別紙様式８

研　究　主　論　文　抄　録

論文題目

熊本地域における地下水の時間的－空間的水理挙動の特徴抽出に関する地球情報学的研究

Geoinformatics study on characterizing spatio-temporal hydraulic behaviors of groundwater in Kumamoto Area

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主論文要旨

《本文》

Preservation of the amount and quality of groundwater resources is an important issue around the world. Changes in groundwater levels need to be monitored in efforts to preserve groundwater. This study investigates suitable methods to characterize changes in the groundwater level and determine the factors involved. The area of Kumamoto, a city in central Kyushu, southwest Japan, was selected to demonstrate the usefulness of the methods because this area is one of the richest in Japan in terms of groundwater resources and takes all its water from groundwater.

Data of the groundwater level recorded at 69 wells from 1979 to 2007 were used in geostatistical and correlogram analyses. First, strong correlation between the topography and groundwater level was identified. Incorporating this correlation into spatial modeling of the groundwater level, co-kriging was demonstrated to be more accurate than ordinary kriging. The co-kriging results clarified the hydraulic characteristics of the Kumamoto area; the patterns of shallow and deep groundwater levels were agreeable generally, and the general trends of their annual average levels were similar regardless of precipitation. Another important feature was that the correlograms for the precipitation amount and groundwater level had a constant shape and changed smoothly with a change in lag time regardless of the precipitation only in the area of Togawa lava. These characteristics are probably due to the connections

between shallow and deep aquifers and the high permeability of Togawa lava.

The second study was aimed at clarifying spatial distribution of coseismic change of groundwater levels in detail over an unconsolidated sedimentary basin being rich in groundwater resource. One new motivation of this study is to compare the level changes between shallow and deep groundwater. Being a part of the Circum-Pacific seismic belt, Japan is one of the most seismically active regions in the world. Therefore, groundwater levels of the wells in Japan are anticipated to change frequently in response to earthquakes. In particular, Kumamoto is one of the most suitable site to research on the above spatial distribution, because systematic measurement of groundwater levels has been implemented at many wells.

Groundwater level change is influenced by earthquake and a great attention has been paid to earthquake because the correlation between groundwater level fluctuations and earthquakes can contribute to establishing a pre-warning system for earthquake disasters. Groundwater levels trend to be changed abruptly during earthquakes, particularly in the seismically active area. During the study period (2000 to 2009), four large earthquakes known as Kumamoto Earthquake (KME), Geiyo Earthquake (GYE), Fukuoka West Offshore Earthquake (FOE), and Sichuan Earthquake (SCE) in China occurred in 2000, 2001 2005 and 2008 in the ascending temporal order, which had remarkable effects on the groundwater levels at the 54 wells in the Kumamoto City area, were detected with hour based data. At most multiple-well stations, the direction and magnitude of coseismic groundwater-level changes were found to be variable in wells at different depths. Although the Kumamoto Earthquake (KME in short) was the smallest in energy (M_w 4.8) among the four earthquakes, a strong influence was observed on the groundwater level change from -0.2 m (0.2 m coseismic drop of the level) to 0.67 m (0.67 m coseismic rise of the level) among the 54 wells. The maximum amplitude of the oscillation in ground water pressure was 8.6 kPa, equivalent to the groundwater level of 0.67 m. This is attributable to the nearest distance from the hypocenter.

Large coseismic responses were found during KME in the south-east part of the study area. Because the porous Togawa lava is distributed in this part, the magnitude of coseismic change may be caused by the existence of Togawa lava rather than by the depth of aquifer. The effect of GYE was small because of the long distance, while the FOE had the second strongest effect on the level with the second shortest distance. It should be noted that small effect of the SCE known as a recent destructive earthquake was detected in spite of the long distance over 2500 km. Spatial modeling of groundwater level fluctuations and groundwater pressure changes associated with the earthquakes in Kumamoto was studied with geometrical method, spline. The distribution of groundwater level fluctuations induced by the earthquakes may provide significant information concerning hydrogeological properties. From the modeling results, it was revealed that the groundwater levels show systematic small changes. The systematic change suggests the common response of the hydraulic pressure in the aquifers against the earthquakes.

An effort was also given to determine the hydraulic conductivities of groundwater flows in Kumamoto Area. The vertical conductivity is mainly related to precipitation. The vertical hydraulic conductivity was estimated by spline method and was found to be from 1.9×10^{-2} to 3×10^{-2} cm/sec. These data reveal that the study area is semi-pervious. These values increase toward the southwest part covered with Togawa lava because of their porous characteristics.

In conclusion spatial modeling of groundwater levels was accomplished correctly by co-kriging than ordinary kriging in consideration of the strong correlation between the topography and levels. The groundwater levels in the Kumamoto City area is relatively stable regardless of the precipitation change. The correlograms between the monthly precipitation and the monthly average of groundwater levels were constant in shape and smooth in change with lag time regardless of the precipitation in the distribution area of the Togawa lava. Spatial modeling of groundwater pressure change associated with the earthquakes in Kumamoto reveals that the characteristics of groundwater pressure changes were varied with different layer of groundwater. Moreover, from this study it can be assumed that the spatial distribution of groundwater pressure changes due to earthquakes is largely affected by local geological structure of Kumamoto City.