Analysis of Groundwater Level Changes at Nuclear Power Plants due to the Gyeongju Earthquake in South Korea.

Sangho Jeong [a*], Eric. Yee [a]
[a]*Kepco International Nuclear Graduate School, 658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014 Republic of Korea*
[*]*Corresponding author: kelvin_81@naver.com*

1. Introduction

Since the publication of "Earthquakes instrumentally recorded in artesian wells" [1], there have been many studies on the correlation between earthquakes and groundwater levels in the world. In the case of South Korea, recently, groundwater level changes by earthquakes have been actively researched.

An **M 5.8** earthquake occurred on September 12, 2016 at 8:32 pm in Gyeongju city, South Korea. It was the largest earthquake recorded on the Korean Peninsula after the earthquake of 1978 **M 5.2** Mt. Songni.

Nuclear power plants (NPPs) should be maintained in safety condition. To review and maintain functional integrity of structures, systems, and components, the groundwater level changes due to the effect of earthquakes should be analyzed. In this paper, we explore the potential groundwater level changes after the Gyeongju earthquake, with the objective of understanding the behavior of groundwater level changes at the Shin-Wolsung NPP.

2. Methods and Results

2.1 Study Area

The epicenter of the Gyeongju earthquake was situated at 35.77°N, 129.18°E, with a depth of approximately 15.0 km. The nearest nuclear power plant was Wolsung NPP located about 27 km away from the epicenter. The Wolsung NPP operates six reactors in total, and the data used in this study are based on the data measured at the site of Shin-Wolsung 1 and 2, which began commercial operations after July 24, 2015

2.2 Stratum Distribution Characteristic

To check the groundwater level fluctuation at the Shin-Wolsung 1 and 2 site during the construction period and to examine the influence of structures by comparing with the designed for groundwater level, Korea Hydro and Nuclear Power (KHNP) and Korea Electric Power Company Engineering and Construction (KEPCO E&C) implemented the recommendations in a geotechnical investigation and installed observation equipment at 10 monitoring wells from September 22, 2009 to March 25, 2010. According to the geotechnical investigation results, the thinly distributed upper landfill and weathered layer are sandy gravel, which are less dense. The groundwater flow is expected to be relatively smooth due to the presence of pore spaces. The bedrock is composed of siliceous claystone and hornblende granite. Permeability of the upper bedrock layer is expected to be relatively larger than that of the general same rock section due to developed joints and shattered zone. The average total core recovery of the 10 monitoring wells was 47.7%, and the average rock quality designation was 8.6%, which is considered quite low [2].

2.3 Groundwater Level Observation

For this study, we analyzed the data collected from 6 monitoring wells (PZ-01, PZ-02, PZ-03, PZ-05, PZ-09, PZ-10) out of 10 monitoring wells. This is because the data from 4 monitoring wells were not measured. The data used for the analyses is from 00:00 on September 1, 2016 to September 30, 2016, and the interval of measurement is one hour. Fig. 1 shows the locations of the monitoring wells at the Shin-Wolsung 1 and 2 site. The instruments used for data measurement are Orpheus Mini and CTD Diver. A summary of the monitoring wells is presented in Table I. However, there are missing intervals in groundwater level data (PZ-01 : 09/22/16 10:00-12:00, PZ-09 : 09/22/16 11:00-12:00, PZ-10 : 09/22/16 10:00-12:00). These missing data are about 10 days after the main shock of the Gyeongju earthquake. For calculations, we assumed that the mean of the measured values is missing values.

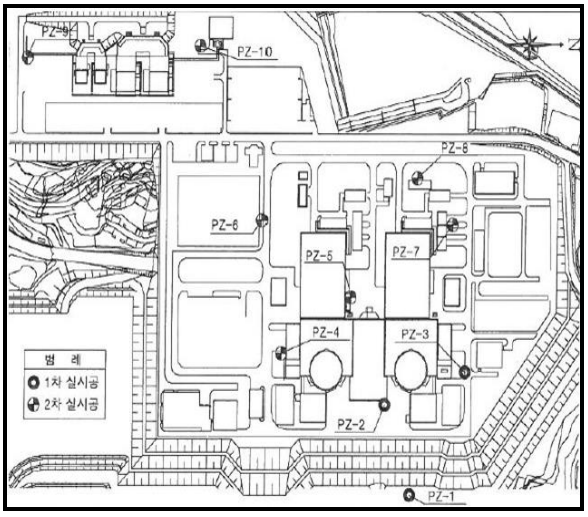

Fig. 1. Locations of monitoring well at the study site [2].

Table I: Information of monitoring wells [2].

Well No.	Ground Elevation (EL. m)	Drilling Depth (GL. -m)	Measuring Equipment
PZ-01	40.4	24.0	Orpheus Mini
PZ-02	12.26	20.0	CTD Diver
PZ-03	10.28	17.4	CTD Diver
PZ-05	10.03	20.0	CTD Diver
PZ-09	10.23	20.0	CTD Diver
PZ-10	10.28	20.0	CTD Diver

2.4 Groundwater Level Analysis

In order to evaluate the potential effect of earthquakes on groundwater level fluctuations, groundwater level fluctuations due to precipitation, atmospheric pressure, and tidal effects should be considered [3]. We did not consider groundwater level changes due to atmospheric pressure and tidal effects. Since earthquakes are phenomena that appear momentarily, it is possible to identify an abnormal groundwater level due to earthquake effects. The groundwater level of two monitoring wells (PZ-02, PZ-03) was closely related with precipitation. The groundwater level of three monitoring wells (PZ-05, PZ-09, PZ-10) was difficult to find a direct relationship with precipitation. One monitoring well (PZ-01) shows a groundwater level change pattern reflecting multiple reasons including precipitation. A plot of groundwater level as well as precipitation against time is shown in Fig. 2.

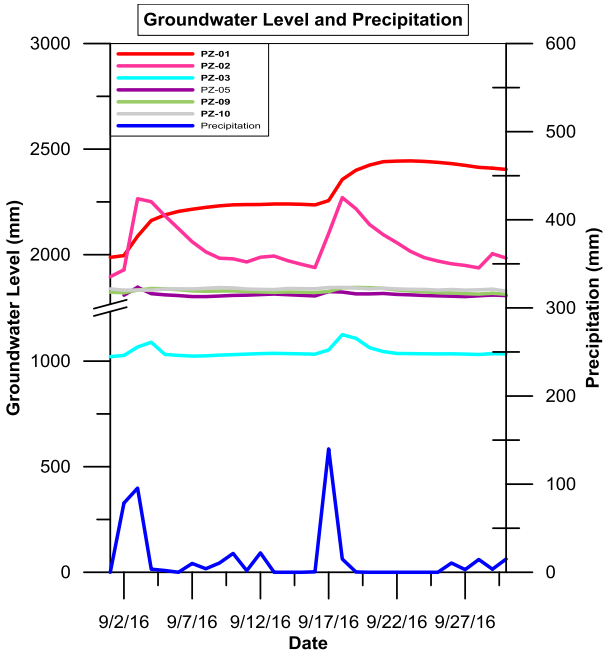

Fig. 2. Groundwater level fluctuation and precipitation

Earthquakes are known to be one of the factors affecting the change of groundwater level. However, the groundwater level data of Shin-Wolsung 1 and 2 sites used in this study did not seem to have any effect on the groundwater level change. The groundwater level data measured nearest to the time of the earthquake (Sep.12, 2016 8:32 pm) did not greatly change from the values before the earthquake.

3. Conclusions

To review and maintain structural integrity of structures, systems, and components in NPPs, it is necessary to analyze the groundwater level changes due to the effect of earthquakes. In this study, we attempted to characterize the groundwater level changes after the Gyeongju earthquake, with the objective of understanding the groundwater level changes at the Shin-Wolsung NPP. The results is that the Gyeongju earthquake did not affect the groundwater level changes measured at the NPP site. However, we need more detailed data to check the effect of Gyeongju earthquake. It is difficult to grasp the variation of the groundwater level due to the effect of earthquake with the data observed at 1 hour intervals. In order to understand the groundwater level changes more clearly due to the effect of earthquakes in the future, it is necessary to reduce the observation interval at intervals of perhaps one minute.

REFERENCES

[1] R.M. Leggette and G.H. Taylor, Earthquakes instrumentally recorded in artesian wells, Bulletin of Seismological Society of America, Vol. 25, pp. 169-175, 1935.
[2] KEPCO-E&C and KHNP, Shin-wolsung 1-2 site groundwater level measurement facility installation and groundwater level measurement service report, pp. 22, 2011.
[3] S.I. Ok, S.Y. Hamm, B.S. Kim, J.Y. Cheong, N.C. Woo, S.H. Lee, G.W. Koh and Y.S. Park, Characteristics of Aquifer System and Change of Groundwater Level due to Earthquake in the Western Half of Jeju Island, Econ. Environ. Geol., Vol. 43, No. 4, pp. 359-369, 2010.