

# Long-term groundwater level changes on the focal region of the 1999 Chi-Chi earthquake, Taiwan

# Naoji Koizumi[1], Wen-Chi Lai[2], Chjeng-Lun Shieh[2], Kuo-Chyng Chang[3] and Toshiharu Yamada[4]

[1] Geological Survey of Japan, AIST; [2] Disaster Prevention Research Center, National Cheng-Kung University; [3] Water Resource Agency, Taiwan; [4] Katsujima Co. Ltd.

## 1. Introduction

Japan and Taiwan are situated in plate boundary zones and repeatedly attacked by gigantic earthquakes. Therefore, for evaluation of long-term groundwater stability in Japan and Taiwan, groundwater changes caused by the gigantic earthquakes in the plate boundary zones should be fully considered.

On September 21, 1999, the Chi-Chi Earthquake (Mw 7.6) occurred in central Taiwan and made significant damage with many groundwater changes. Then Taiwan began a five-year's program named "Program on Earthquake and Active fault Research (PEAR)" in 2001. The project for research of earthquake-related groundwater changes, which was carried out by DPRC (Disaster Prevention Research Center), NCKU (National Cheng-Kung University) and WRA (Water Resource Agency), was included in the PEAR and still continues after the five-year's program.

Geological Survey of Japan, AIST has been making much contribution to the project since beginning of it as an international cooperative research. By the end of 2005, the project made 16 observation wells where the resolution of water level meter is 1mm. In addition, WRA has more than 550 wells for monitoring groundwater resources although the resolution of water level meter is 1-2 cm in those wells. Since hydro-geological structures of the wells are well investigated by DPRC and WRA and Taiwan is seismically active like Japan, groundwater data obtained from those wells are worth for evaluation of long-term groundwater stability although most of WRA's wells have some pumping effects.

## 2. Groundwater level changes on the focal region of the 1999 Chi-Chi earthquake

On and around the focal region of the 1999 Chi-Chi earthquake, groundwater level were recorded at 66 groundwater observation stations or 168 wells of WRA before and after the earthquake. Since WRA's groundwater observation stations usually have 2 or 3 wells, whose depths are different, number of the wells is larger than that of the stations. The depths of the wells range between 15m and 306m. Most of the wells are situated in and around the Choshui River alluvial fan. There are five aquifers named Layer 1, Layer 2-1, Layer 2-2, Layer 3 and Layer 4. Only Layer 1 is unconfined and the others are confined.

Many coseismic groundwater level changes were observed at those wells. These coseismic groundwater level changes can be explained not by coseismic volumetric strain changes but by liquefaction and permeability enhancement (Wang et al., 2001; Koizumi et al., 2004), whose degrees depend on the geological setting and seismic ground motion (Lai et al., 2004). Although the 1999 Chi-Chi earthquake occurred in the boundary zone of the plate, the depth of it was shallow. Therefore seismic intensity was very large on and around the focal region. In addition most of the wells are situated in the alluvial fan. Therefore it seems that the effects of liquefaction and permeability enhancement on the groundwater levels were larger than those of coseismic strain changes.

Analysis of the coseismic groundwater level changes shows that confined groundwater level tends to change more easily than the unconfined groundwater level. It is also shown that deeper more confined groundwater tends to change more easily. Generally unconfined groundwater is less sensitive to crustal strain changes and moves more easily than confined groundwater. Pressure of unconfined groundwater is usually controlled more by water levels of the neighboring sea, rivers and lakes or ponds. Therefore it seems that unconfined groundwater is generally less sensitive to earthquakes.

We also investigated water level changes in the 168 wells during the period from 1993 to 2000. All of the wells do not have the water level records from 1993 because observation at the different wells did not start in the same time. Most of the well water levels which changed coseismically recovered by December 2000. The possible reasons are as follows; (1) Permeabilities of the aquifers are relatively large, (2) Levels of neighboring sea, rivers and lakes or ponds, which are important boundary conditions controlling groundwater pressures, did not largely change after the 1999 Chi-Chi earthquake.

## References

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