Land subsidence and other environmental impacts due to groundwater extraction from fractured hard rocks in Sri Lanka

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Abstract: Groundwater extraction and distribution for the general public from two borehole wells which have been drilled through metamorphic rocks at Ampitiya, Kandy, was started in 1991. After two years the paddy fields and dug wells began to dry up and land subsidence was observed in the surrounding. In addition, the formation of cracks in the was seen in some houses in the neighbourhood. People in the area explained the other possible environmental effects. Land subsidence was greater close to the production wells. The dewatering cone extending along a linear rock fracture is related to the drying out of surface water resources. This situation indicates the extraction of groundwater from metamorphic hard rocky terrains also creates environmental problems for the people who utilize this groundwater for domestic purposes. To avoid this situation the average annual groundwater withdrawal should be kept constant, below the estimated recharge volume.

INTRODUCTION

General

Land subsidence is not a common geo-related hazard in Sri Lanka. It sometimes occurs in gem mining areas where horizontal tunnels or adits are made to remove gem bearing gravels. The first event on the Island of land subsidence due to groundwater extraction has been recorded from the Ampitiya production intake in Kandy. It was a very rare event because most of the boreholes have been drilled in metamorphic rocky terrains where the overburden thicknesses are comparatively low. Since there was an absence of environmental impacts, groundwater is being extracted from deep fractured rocks continuously without considering its effects on the overburden. After many complaints from the people living within the affected area, even though these same people benefit from the groundwater supply, a survey was carried out to assess the damage and other environmental impacts which are seriously affecting them. This paper shows the land subsidence and other environmental impacts due to groundwater extraction from hard rocky areas. The survey was carried out in 1993.
The project

After introducing the deep well concept to Sri Lanka in 1978, a number of foreign organizations have started to tap the deep groundwater resources in the crystalline hard rocks. Under this programme, hydrogeological investigations were carried out by "Kandy District Water Supply and Sanitation Project (KDWSSP)" for locating groundwater resources and for the determination of their properties for the realization of water supply in the area.

After feasibility investigations, deep boreholes were drilled at selected suitable locations. Groundwater from higher yielding wells was supplied for distribution through delivery pipes. Ampitiya scheme is one of the major groundwater supply schemes under KDWSSP.

Ampitiya is located southeast of Kandy city (Fig. 1). The area is a small, broad valley surrounded by gentle sloping hills. The elevation of the valley bottom is around 500 m above mean sea level. The wells have been drilled in the paddy fields. A narrow stream is flowing nearby. The mean annual precipitation at the closest station is 1959 mm. The population density of the area is 966 persons per km\(^2\) (Plancenter Limited, Finland, 1981).

HYDROGEOLOGICAL SETTING

Geology

Geologically the intake is situated in the eastern limb of the Uduwela anticline, within a lineament along the northeast direction and also in a band of crystalline limestone (marble). The major rock types in the area are crystalline limestone, quartzite, quartz-feldspathic gneiss and interbanded charnockitic gneiss. The rocks dip towards the northeast.

Groundwater system

The lithological data of two boreholes indicate that the maximum thickness of soil overburden is 8 m. Highly fractured rocks have been noted between 20 and 25 m below the surface level. One interesting feature is the variable penetration rates of drilling through this marble. Penetration rates of highly weathered overburdens are about 20 minutes per metre. Slower rates are usually encountered when drilling through unfractured crystalline rocks. At some depths the penetration rates during the drilling of the boreholes was about 3 minutes per metre. This faster penetration rate, together with the samples collected, indicated the occurrence of highly fractured rocks in the marble. As faster penetration rates are found through fractured rocks than through the overburden, this points to the occurrence of narrow sinkholes within the marble. And also there were no samples at some depths. Lithological data indicate that this is an unconfined aquifer system and the principal aquifers in fractured rocks vary from 25 m to 40 m in thickness down to 60 m depth from the surface. Recharge to the principal aquifers is primarily from the hilly areas. Water may enter from all directions to this unconfined aquifer system.
Fig. 1 The location of the project area, water level contours and flow lines around the intake and the boundaries of effected and non-effected areas due to groundwater withdrawal.
Groundwater pumping

Borehole drilling was completed in June 1990. In April 1991 the distribution of water for the public commenced. The collected data indicated that the average pumping rate in 1991 was 75.1 m$^3$ h$^{-1}$ for a 17 h daily pumping period. In 1992, the groundwater withdrawal rate was 85.2 m$^3$ h$^{-1}$ for 17 hours daily. This shows an increase of annual withdrawal in the second year. But the actual recharge amount per year has not been calculated. Therefore the higher extraction in the second year was purely in response to an increase in water demand.

Water level declines

Monitoring of dug wells and observation boreholes were carried out in 1993. Based on a study of water levels during this short period, water level contours were drawn for the peak drought at the beginning of April 1993. The level of water in boreholes have declined as much as 5 m in the first year and it has further declined by about another 5 m within the second year after pumping began. This is due to the higher withdrawal from the aquifer.

Dynamic water level contours and flow lines around the intake are shown in Fig. 1. It also indicates the situation of water levels along the lineament during pumping. The cone of depression is elongating and extending along the lineament which lies along the northeast direction. The dewatering cone along the lineament was related to the drying out of surface water sources. The difference between dynamic water level and static water level is about 19 m. The cone of depression extends along the lineament and covers an area of approximately 20 000 m$^2$ (Fig. 1).

ENVIRONMENTAL IMPACTS

Subsidence

As mentioned earlier, groundwater level monitoring was not undertaken in the areas due to the lack of experience of similar events in Sri Lanka. While the test pumping programme was going on before distribution started, about 100 m$^2$ of the land surface around the borehole suddenly collapsed and the surface level dropped by about 1 m. This was the first subsidence event recorded in this well field. After the commencement of continuous pumping changes of ground surface spread further away from the borehole. Some cracks and holes were seen on the public road which crosses the area. About one year later some cracks on the walls and foundations of nearby buildings and gardens were noticed. Many complaints were forwarded after the appearance of these cracks. A detailed survey of the environmentally affected areas due to pumping of groundwater was undertaken for the benefit of the people living there. Figure 2 indicates the adversely affected areas where the buildings and gardens have been damaged due to groundwater withdrawal. These areas lie along the lineament and cone of depression. In general, about 1.5 m of land has subsided close to the pumping well and no subsidence was noticed in non-affected areas. But changes of the surface levels were not
monitored and therefore the actual amount of subsidence is not known. The badly affected areas were subsequently filled by compacted layers of soils. The project is still in operation. Structural damage related to land subsidence has been a common occurrence since this project was started.

Other impacts

The other major environmental impacts in the area were drying out of paddy fields and dug wells and lower crop yields from homestead plots. The local people reported their experiences of the situation in the paddy fields before and after groundwater extraction from the boreholes. The normally wet muddy paddy fields have dried up completely and it is difficult to work on the hard dry surfaces. Most of the dug wells have completely dried up. The crop yields in the homestead cultivation plots have decreased and they are comparatively very low after the commissioning of production pumping.
CONCLUSION

Land subsidence and the other environmental effects of the Ampitiya area in Kandy district, Sri Lanka, are directly related to the groundwater withdrawal from the deep boreholes. This groundwater mainly occurs in the fractured hard rocks and possible sinkholes in crystalline limestone. This is an unconfined aquifer system. To minimize the environmental damage and the future effects, the average annual groundwater withdrawal must be kept constant and should be less than the estimated average annual recharge. Still there is no system to find the changes of land surface. Therefore a proper technical management system to maintain the scheme is needed. This situation should be considered for the future projects to minimize the environmental hazards.

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REFERENCE