

Groundwater resources, development and management in the largest tectonic sedimentary basin, Japan

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Abstract

The purpose of this paper is to show a typical example of excessive extraction of groundwater resources and their resulting problems suffered in the economic growth period in Japan from 1955 to 1972. In the case of the study basin, this problem has been remedied by the implementation of regulations over the past 50 years and the relatively high recharge rate due to the natural hydrologic conditions of the area. Environmental consequences according to the excessive groundwater development and strategies for groundwater resource management are discussed, based on the Japanese experiences during the past 50 years.

Keywords: tectonic sedimentary basin, groundwater resources, excessive extraction, land subsidence, countermeasures, regulation law, monitoring system.

1 Introduction

The Kanto Plain is the largest tectonic sedimentary basin in Japan as shown in fig. 1. The plain is underlain by Pliocene and Pleistocene sediments of the Kanto Tectonic Basin, consisting of unconsolidated layers of silt, sand and gravel which extend to a depth of more than 3,000 m. Figure 2 shows the east-west geologic cross section across the Tokyo Metropolitan area to a depth of around 500 m below the sea level. These sediments form the main confined groundwater aquifers in the Kanto Plain.



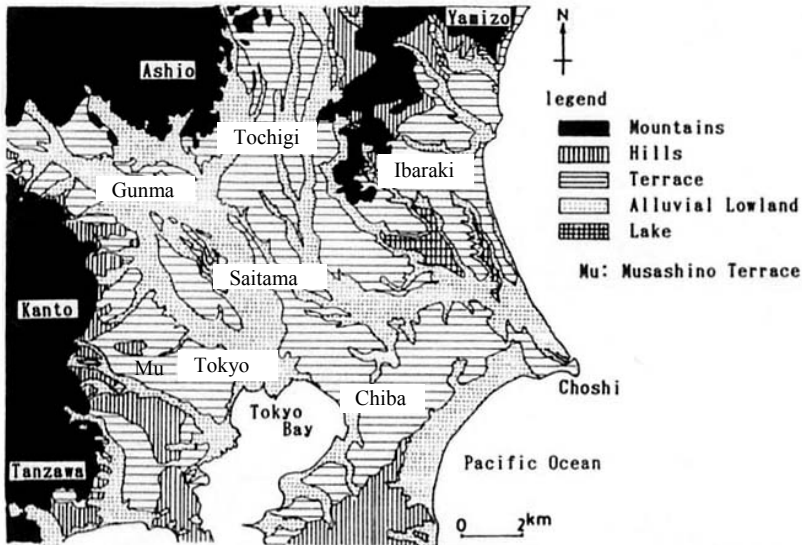


Figure 1: Topographic map of the Kanto Plain (Endo [1]).

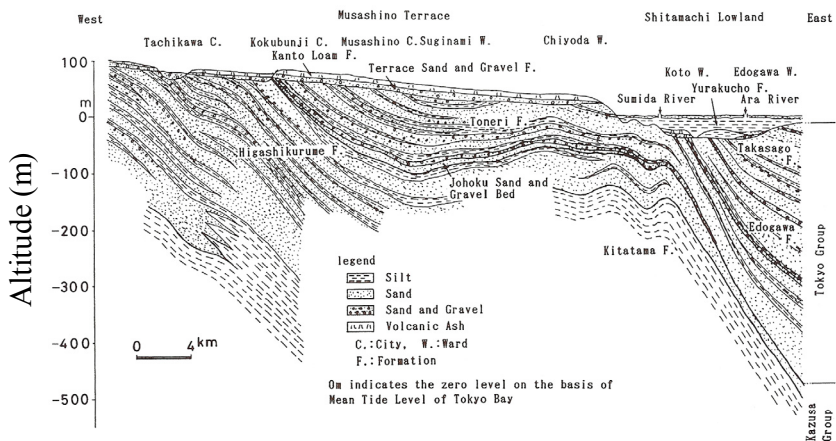


Figure 2: East-west geologic cross section across the Tokyo Metropolitan area (Endo [1]).

The area for groundwater development in the Kanto Plain is about 13,300 km² and estimated total storage volume of groundwater resources reaches 500×10^9 m³. These confined groundwater resources have been mainly exploited for household water supplies and industrial, air-conditioning uses and irrigation and drainage in the Kanto region for nearly eight decades. Total amounts of

groundwater use in the Kanto Plain in 1999 were estimated as about $1.2 \times 10^9 \text{ m}^3/\text{year}$. Heavy utilization of confined groundwater in the past decades, especially the period of high economic growth in Japan of 1960s, serious problems related groundwater development such as land subsidence, groundwater salinization, oxygen-deficient air accident have appeared over the alluvial low lands and a part of terraces within the plain. Figure 3 shows the Japanese experience of environmental consequences according to the excessive groundwater development.

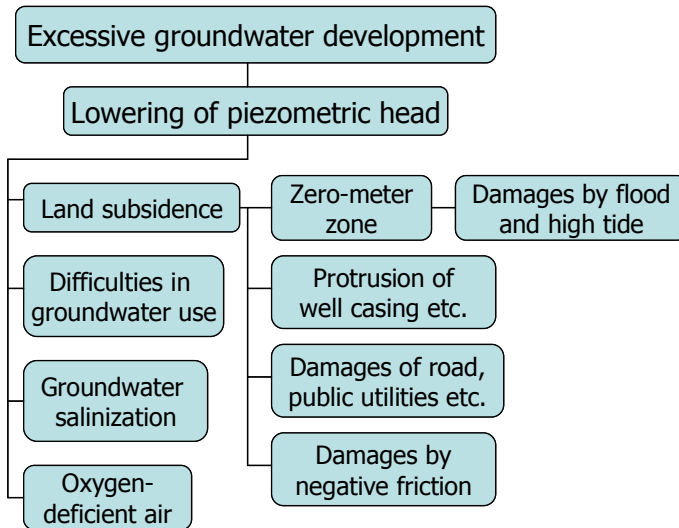


Figure 3: Japanese experience of environmental consequences according to the excessive groundwater development (Kayane [2]).

Figure 4 shows the cumulative land subsidence at main benchmarks in the Tokyo area. Land subsidence has resumed in the middle of 1950s when industries began pumping up large quantities of groundwater to support increased production activity. The cumulative land subsidence at the benchmark of No.9832 amounted to over 4.5 m from 1918 to 2000. Land subsidence in the Tokyo area has been rapidly reduced since about 1973 due to the restrictions for extraction of groundwater by means of the laws and the ordinance mentioned below.

Because of the serious problems related to the excessive groundwater use, the National Government has restricted extraction of groundwater for industrial use by the Industrial Water Law since 1956, and for air-conditioning use by the Law on Regulating the Extraction of Groundwater for Use in Buildings since 1962. The areas regulated by the laws are surround Tokyo Bay, the eastern part of the Tokyo Metropolis, the southern part of Saitama Prefecture, and the western part of Chiba Prefecture, respectively. In addition, local governments such as Tokyo's and each prefecture within the plain have also restricted the drilling of

new wells in the area not covered by the national laws applying the each prefecture’s ordinance. By the recognition of the local governments that these control regulations are highly effective, the area subjected the implementation has been gradually increased.

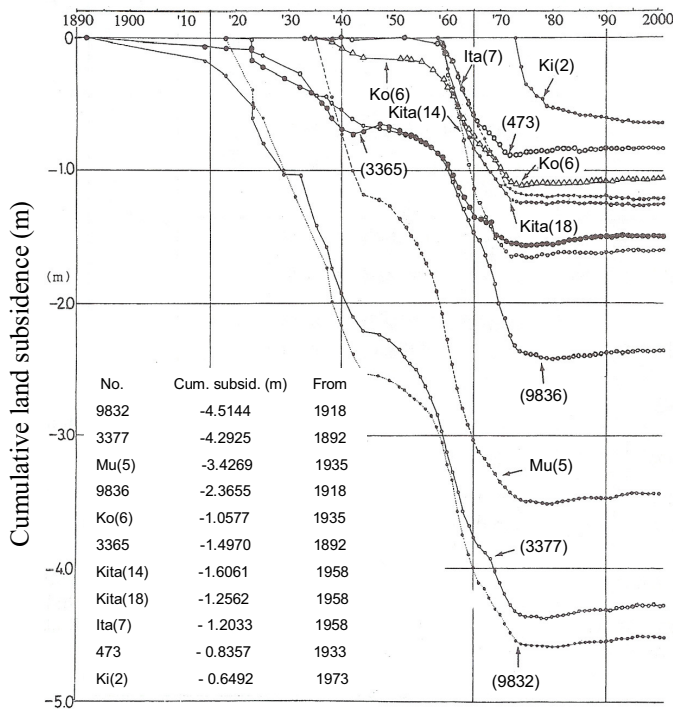


Figure 4: Cumulative land subsidence at main benchmarks in the Tokyo Metropolitan area (Imai [3]).

2 Change of piezometric heads of confined aquifers due to the groundwater development in the Kanto Plain

Figure 5 shows change of the piezometric heads of confined aquifers in the Tokyo area from 1954 to 1999. History of groundwater development in the Kanto Plain is typically shown in this figure. Water demand in the Tokyo and its surrounds had increased after the World War II. The extra demand was fuelled by Japan’s high economic growth resulting in over-extraction of the groundwater resource.

In the early 1970s, piezometric heads in several observation wells had declined to more than 40 m below the ground surface.

The groundwater potential distribution of the confined aquifer in the Kanto Plain in 1975 is shown in fig. 6. This figure clearly shows that the large declined piezometric heads centred surround the Tokyo area in the year.



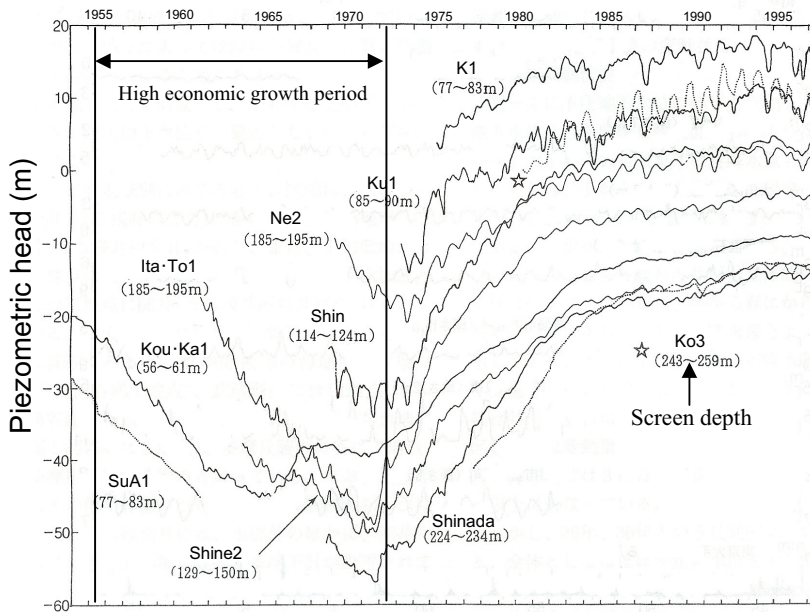


Figure 5: Changes of piezometric heads of confined aquifers in the Tokyo Metropolitan area (corrected Kawashima [4]).

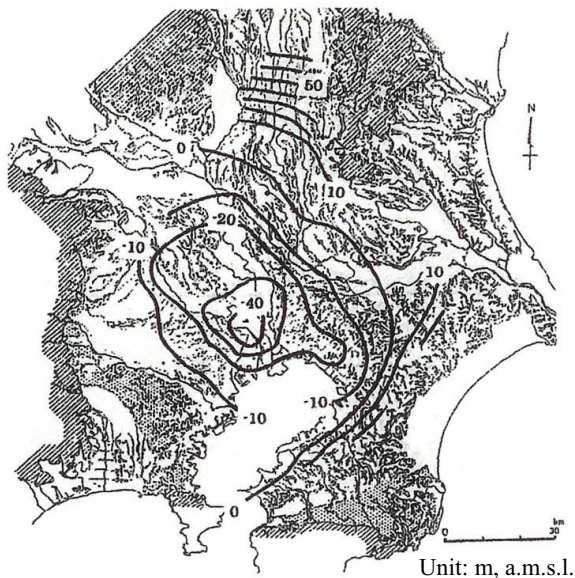


Figure 6: Groundwater potential distribution of the confined aquifer in the Kanto Plain in 1975 (Prefectures Governor's Association of the Kanto Region [5]).

After implementing regulations mentioned above groundwater potentials have recovered so quickly as shown in fig. 5 for better than was expected. Annual precipitation of the Kanto Plain is about 1,300 to 1,600 mm, while the potential evapotranspiration is estimated as 700 to 800 mm/year. Therefore, the residual 500 to 900 mm/year of water can be expected as the potential recharge rate in this region. These values correspond to the daily recharge rates of 1.4 to 2.5 mm. It is believed that because of this high potential recharge rate, the piezometric heads of the confined aquifers have recovered so quickly.

3 Countermeasures to prevent the land subsidence

Two groundwater laws are effective in whole Japan, but practical application of laws to a specific area is decided by the local government. The Tokyo Metropolitan Government has succeeded in reduce the rate of land subsidence by converting water resources from groundwater to surface water and by making legislative guidance in order to save groundwater resources in factories and buildings. However, bordering prefectures such as Saitama, Chiba and Ibaraki in the same Kanto Plain are still suffering from the land subsidence as shown in fig. 7.

This figure shows cumulative land subsidence during the 10-year period from 1988 to 1997 in the Kanto Plain. The center of the land subsidence in the period exists in the northern part of the plain. In 1950s, the land subsidence in the Kanto Plain was most severe in the southern part of Saitama Prefecture, and gradually spread over for areas such as the northern part in Saitama Prefecture, the western part in Ibaraki Prefecture, the north-western part in Chiba Prefecture and the southern part in both Gunma and Tochigi Prefectures. In 2004, a total area of about 26 km² subsided 2 cm or more/year in the northern part of the Kanto Plain. The maximum land subsidence recorded in 2004 was 4.7 cm in the southern part of the area (Ministry of Environment [7]).

According to the situation of the land subsidence in the northern part of the Kanto Plain, the National Government has decided to formulate the Guideline for Measures to Prevent Land Subsidence in the Northern Part of the Kanto Plain in November 1991. The purpose of the Guideline is to prevent the land subsidence through comprehensive promotion of policies related to prevent the land subsidence in that area. In the Guideline, the target extraction quantity of groundwater in the prevention area is formulated as 0.48×10^9 m³/year. The total extraction of groundwater in the area in 2002 was 0.51×10^9 m³/year (Ministry of Land, Infrastructure and Transport [8]), and exceeded the quantity than that of the target volume. The target year of the present Guideline was set in the fiscal year of 2000. The National Government has been setting up in the work to improve the contents of the Guideline.



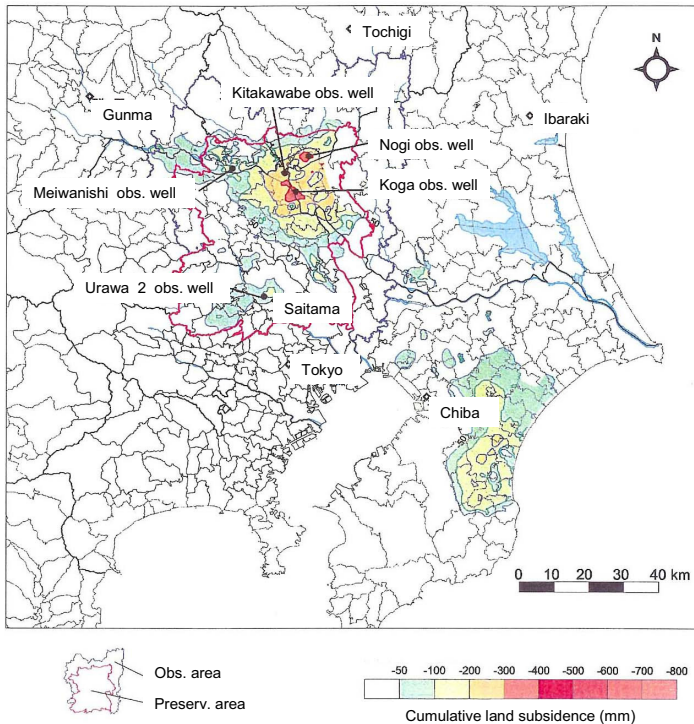


Figure 7: Areal distribution of cumulative land subsidence in the Kanto Plain during the 10-year period from 1988 to 1997 (Ministry of Land, Infrastructure and Transport [6]).

4 Concluding remarks

This paper showed a typical example of excessive extraction of groundwater resources and their resulting problems suffered in the Kanto Plain, the largest tectonic sedimentary basin in Japan. In the case of the Kanto Plain, this problem has been remedied by the implementation of regulations over past 50 years and the relatively high recharge rate due to the natural hydrologic conditions of the area.

For sound groundwater management, the information on pumping amounts in time and space, hydrologic parameters, aquifer characteristics, quantities of irrigation and drainage and so on should be unified so as to make the groundwater resource management effectively. Appropriate legislative and administrative measures are essential for providing background for acting the proper groundwater management. It requires the knowledge of hydrologic balance between the quantity of recharge rate and the extraction of groundwater for the sustainable management of groundwater resources. A balanced budget is the goal for all groundwater managers.



Furthermore, to maintain the continual social and economic growth of the area and to minimize the enlargement of the environmental problems related to the groundwater development, it should establish the continuous monitoring systems such as groundwater levels, quantities of extraction, and the land subsidence as well as monitoring the groundwater pollution.

References

- [1] Endo, T., Confined groundwater system in Tokyo. *Environ. Geol. Water Sci.*, **20**, pp. 21-34, 1992.
- [2] Kayane, I., Personal communication, 1989.
- [3] Imai, T., New policy for groundwater preservation in Tokyo Metropolitan area. *Groundwater Technology*, **44**(3), pp. 14-21, 2002. (in Japanese)
- [4] Kawashima, S., Groundwater environment in Tokyo. *Ground-water Technology*, **43**(3), pp. 6-19, 2001. (in Japanese)
- [5] Prefectural Governor's Association of the Kanto Region, *Research Report of the Distribution of Groundwater Level in the Kanto Groundwater Basin*. pp. 1-65, 1991. (in Japanese)
- [6] Ministry of Land, Infrastructure and Transport, *Evaluation of the Guideline for Measures to Prevent Land Subsidence in the Northern Part of the Kanto Plain*. pp. 1-36, 2002. (in Japanese)
- [7] Ministry of Environment, *Outline of Land Subsidence Area in Japan in the FY 2005*, pp. 1-30, 2006. (in Japanese)
- [8] Ministry of Land, Infrastructure and Transport, *On the Measures to Prevent Land Subsidence in the Northern Part of the Kanto Plain*. pp. 1-148, 2005. (in Japanese)

