H-3.3 Environmental Degradation in Northern and Northeastern Parts of China due to Excessive Land Use

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Abstract Northern and northeastern parts of China are those of the most important grain crop producing areas. These regions belong to semi-arid climate region. Those are also the areas of limitless grassland and forest. Therefore, in the near future it is expected that vast farmlands is utilized to the limit and the grassland is converted to cropland. Water resources are the key for agricultural development and the demand for groundwater will increase in the areas. This environmental pressure may cause serious environmental problems related to water resources issues in the areas.

We have focused on groundwater issues choosing Hebei. We evaluated the groundwater resources of the Plain, using agricultural statistics and spatial and temporal data on groundwater and natural conditions. Then, a hydraulic model of the flow of unconfined and confined groundwater is constructed with the objective of predicting the future groundwater distribution of the Plain.

Key Words Hebei Plain, China; Groundwater Flow Model; Land Use; Environment

1. Introduction

The National Institute of Hydrogeology & Engineering Geology, China conducted a geological survey including boring for the Huang-Huai-Hai Plain (lat 32° N - 41° N, long 113° E - 121° 30′ E) in 1982 - 1984. The survey results show that the Quaternary Formation in the Hebei Plain is deep, generally reaching 400-600m in depth, and is divided into four aquifers. The thickness of the each aquifer is 20 - 40 m, 60 - 130 m, 80 - 220 m, and 50 - 350 m as shown in Fig.-1[1)].

The Hebei Plain is one of the large agricultural areas in China, belonging to Haihe River drainage area in the eastern China. The water resources of the Hebei Plain are not abundant; the amount of usable unconfined and confined groundwater resources are 7.986 billion m^3/y and 0.985 billion m^3/y, respectively. The amount of surface water is strongly affected by the fluctuation of annual precipitation and varies widely, thus, the surface water cannot become a stable source of water supply.

Before 1970s, pumping of groundwater was low and neither unconfined nor confined groundwater was affected by human activities. Thus, the groundwater level kept fluctuating within a specific range in accordance with the annual precipitation. After the 1970s, the increase of pumping groundwater began to result in the fall of the groundwater level (table), land subsidence and other environmental problems. The fall of the unconfined groundwater level during the past 30 years in the Hebei Plain was greatest at the foot of the western mountains and the average value of the fall reached 12-25 m, and the fall was smaller in the central part and near the coast than at the foot area, with average values of 2-10 m. For example, the falling rates at Shijiazhuang, Hengshui and Cangzhou were 0.67m/y, 0.17m/y, and 0.11m/y, respectively (Fig.-2).

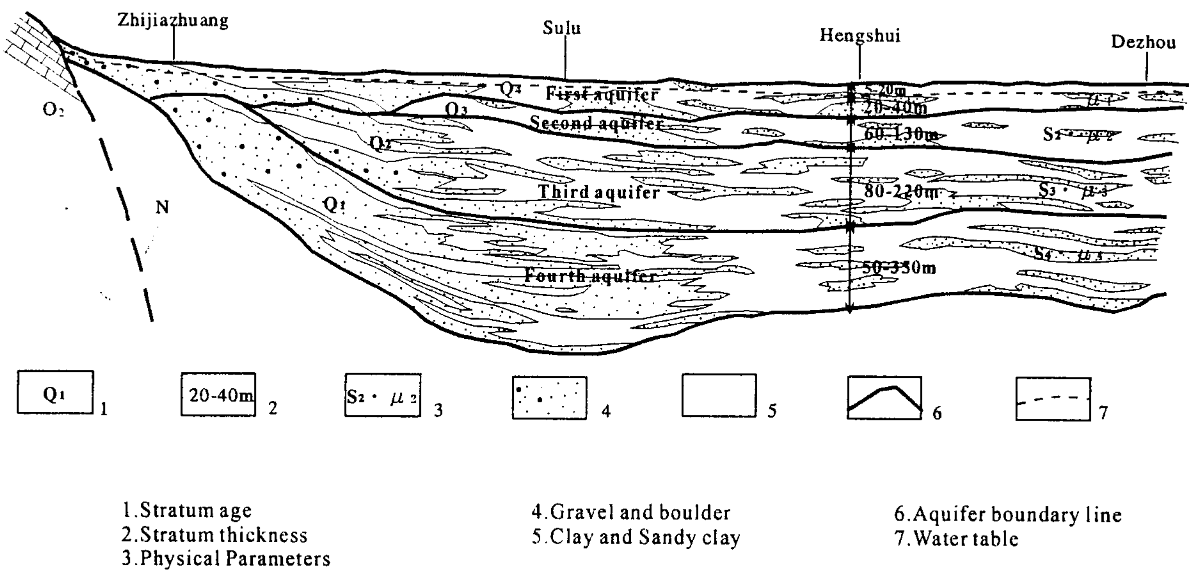

Fig.-1 Hydrogeology profile between Shijiazhwang (Lat. 38.07 N, Long. 114.55° E) and Dezhow (Lat. 37.5° N, Long. 116.3° E)

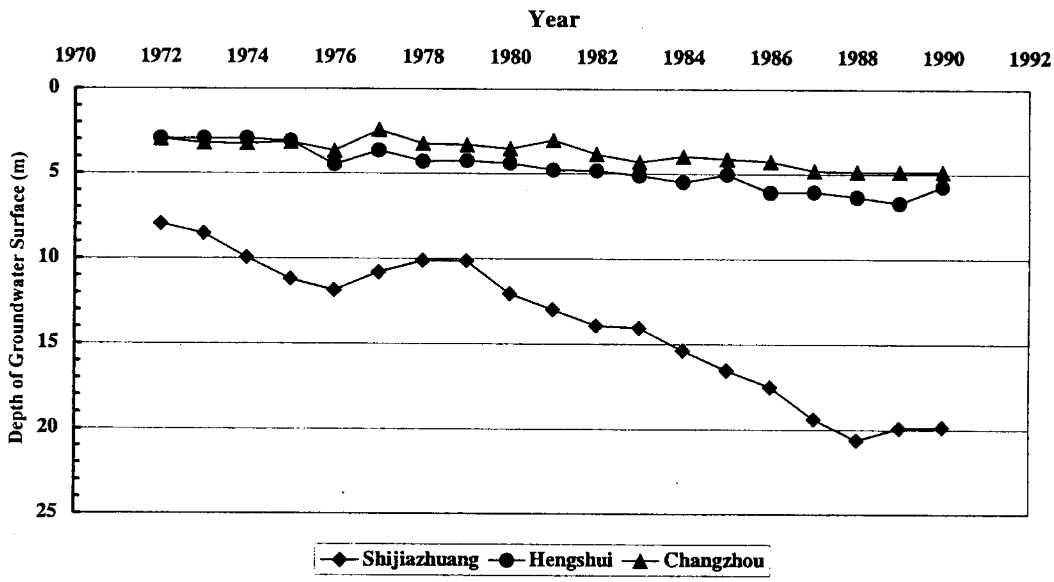

Fig.-2 Change of groundwater table of unconfined aquifer in the Hebei Plain

Through the routing monitoring of groundwater level for hundreds wells, we found that the flow of unconfined groundwater has changed, that is, it used to flow naturally in the SEE direction; however, it now flows toward urban areas because of a funnel-shaped curved surface of groundwater table.

2. Research Objectives

The objectives of our research are to evaluate the groundwater resources of the Plain, by the use of agricultural statistics and spatial and temporal data on groundwater and natural conditions, and to predict future groundwater distributions of the Plain by developing a hydraulic model in unconfined and confined aquifers and giving future groundwater use scenarios.

3. Research Method

We evaluated the groundwater resources of the Plain, using agricultural statistics and spatial and temporal data on groundwater and natural conditions[2]. Then, a hydraulic model of the flow of unconfined and confined groundwater is constructed with the objective of predicting the future groundwater distribution of the Plain. In order to check the adequacy of this model, the changes of the groundwater table during the 11 years from 1985 were simulated and compared with the observed data.[3]

We simulated future temporal change in groundwater table for given groundwater usage scenarios. Three scenarios of groundwater pumping were given for simulation[4].

1) Scinario1: The amount of groundwater pumping is none for each cell up to 2030.
2) Scinario2: The amount of groundwater pumping is the same as that at 1994 for each cell up to 2030.
3) Scinario3: The amount of groundwater pumping for irrigation is the same as that at 1994 for each cell up to 2030. While, the amount for industrial usage keeps increasing at the rate of 6%/y (past trend), and, that for domestic usage, at the rate of 2%/y up to 2030.

The initial conditions of unconfined confined groundwater tables are given by observed data at 1994.

4. Results and Discussion

The simulated results for Scenario 1 are as follows:

1) The central and eastern parts of the plain would recover their groundwater table within 5 years from the beginning of the simulation.
2) The recovering groundwater table is around 3m below the surface. The capillary height of the plain is around 5m, therefore, if the groundwater table recovers such level, the salinization problem would happen.
3) Proper amount of groundwater pumping would be desirable at the central and eastern parts for sustainable agriculture.

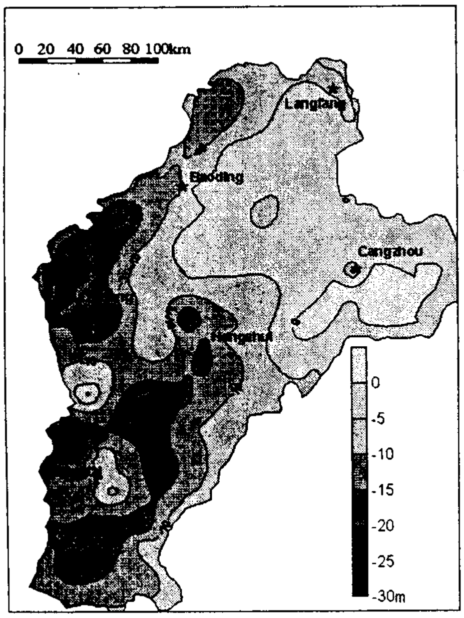

Fig.-3 Simulated result of water level fall of unconfined aquifer at 2030 (based on 2-km grid scale result, Scenario 3)

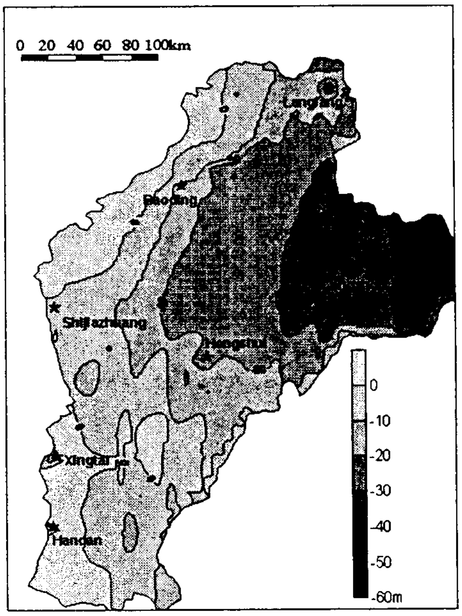

Fig.-4 Simulated result of water head fall of confined aquifer at 2030 (based on 2-km grid scale result, Scenario 3)

The simulated results for Scenario 3 are shown in Fig.-3 and Fig.-4. Fig.-3 shows a map of the fall of unconfined groundwater table at 2030. We can see more than 20m fall of the level at the western part of the plain where several cities (population: 1-2 millions) are located along the foothill of western mountains. According to the simulation, the unconfined groundwater may be used up by 2030 in those areas. Fig.-4 shows a map of the fall of confined groundwater head at 2030. We can see more than 40m fall of the head at the eastern part of the plain. According to the simulation, the head would fall to below the sea surface at most parts of the plain except for the western foothill region.

The concerned issues about groundwater resources and environment in the Hebei Plain are shown in Table-1. We divided the plain into four regions and describe issues of unconfined aquifer, confined aquifer and possible countermeasures, respectively, for each region.

Table-1 Consemed issues in groundwater resources and environment and countermeasures for them in the Hebei plain

	Western Region	Central Region	Eastern Region	Coastal Region
Unconfined Aquifer	·serious fall of water table ·funnel-sapped hollows of water table around big cities ·out of order of shallow wells ·high risk of dried up of water several decades later ·serious water pollution	·slow fall of water table ·requirement of proper amount of pump-up to avoid salinization ·no water pollution ·soil pollution(?) ·soil degradation(?)	·unusable water due to high salinity ·requirement of distillation by confined groundwater	·saline soil
Confined Aquifer	·funnel-sapped hollows of water head around big cities ·water pollution	·slow fall of water head	·very serious fall of water head table ·land subsidence at cities ·very high risk of invasion of seawater ·heavy metal pollution due to land subsidence	·Invasion of seawater
Counter-measures	·intensive action for save water ·improvement of irrigation ·recycling of water ·conduction of surface water from other river basin	·no requirement unless arable land is used as paddy field	·intensive action for save water ·improvement of irrigation ·recycling water ·condition of surface water from other river basin	·development of salt-proof plants ·desalinization of soil ·conduction of river water

Simulated temporal changes of unconfined groundwater level at three cities are shown in Fig.- 5 for the three scenarios. The fall of groundwater level for scenario 2 is less than that for scenario 3; however, the amount of fall itself is still serious. Unless strong counteractions are taken to conserve groundwater resources, the future groundwater pumping would be between Scenarios 2 and 3 in the plain, which means that the groundwater resources and environment would confront serious deterioration in the future.

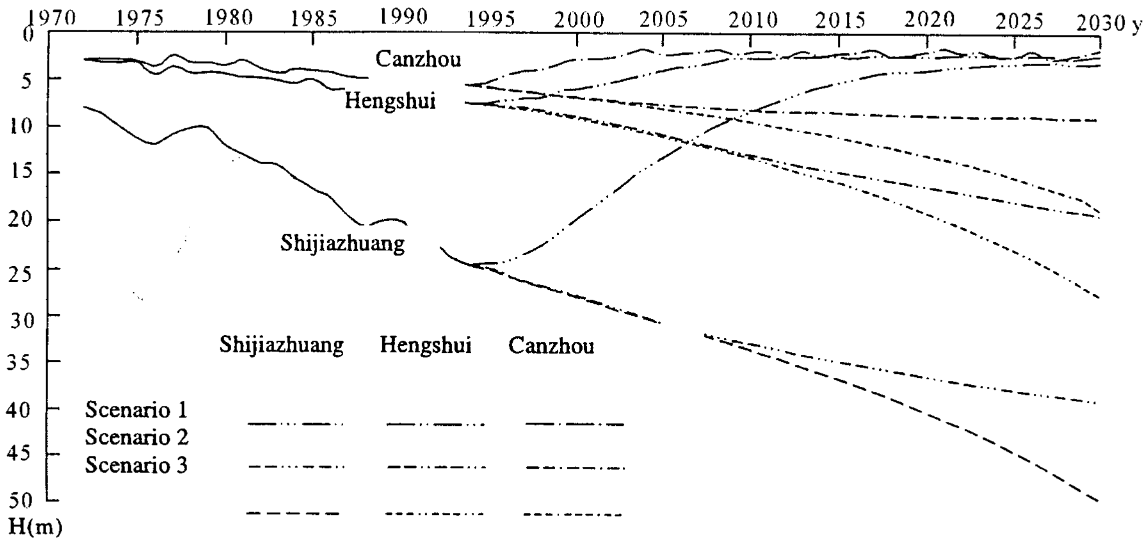

Fig.-5 Simulated temporal changes in water level of unconfined aquifer at three cities (Shijiazhuang, Henghsui and Cangzhuo) for different scenarios

4. Conclusions

1) Unconfined groundwater level and confined groundwater head have kept falling at cities and their surrounding areas in the western part of the Hebei Plain.
2) Confined groundwater head has kept falling at the eastern part of the plain faster than the western part.
3) According to the simulation for given groundwater pumping scenarios, the western part would confront serious shortage of unconfined groundwater and the eastern part would confront very serious sanitization problem in confined aquifer owing to the fall of groundwater head to be 30 or 40m below the sea surface.

References

1) ZHANG, Z., OTSUBO, K., ZHU, Y. and ISHII, T. (2000): Groundwater Resource and Related Environmental Deterioration in the Hebei Plain, China, LU/GEC Report VI, CGER-REPORT, CGER-I042-2000, pp.215-226.
2) OTSUBO, K. (1999): Outline of the LU/GEC Project, Proceedings of 1999 NIES Workshop on Information Bases and Modeling for Land-use and Land-cover Changes Studies in East Asia, CGER-REPORT, CGER-I036-'99, pp.1-12.
3) OTSUBO, K., ZHANG, Z. and ISHII, T.(2000): Influence of Intensive Land Use on Groundwater Resources in the Hebei Plain, China, Land Use and Cover Change, Oxford &IBH Publishing Co. Pvt. Ltd., pp225-237.
4) ZHANG, Z., OTSUBO, K. and ISHII, T. : Recent and Future State of Groundwater Resources in the Hebei Plain, China, Annual Journal of Hydraulic Engineering, JSCE, vol.44, pp. 361-366 (in Japanese)