# Groundwater of the North China Plain

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**Abstract**

This paper briefly introduces basic hydrogeological conditions, recent result of its groundwater resource evaluation, all suggested measures to solve the water resource shortage problem. In order to make all necessary measures a reality, the most important problem is to strengthen infrastructure construction and capability construction.

## 1. Introduction

It is known to many people both at home and in abroad that the total water resource of the North China Plain is insufficient and its groundwater is under overexploitation. A lot of studies have been carried out in order to solve the water shortage problem. Generally speaking, as a fruitful result, such studies have promoted the progress of strengthening water saving measures, preventing water pollution, and limiting groundwater overexploitation. However, to thoroughly solve the water shortage problem and to reach the goal of rationally utilizing groundwater and effectively protecting the environment, is an extremely complicated and difficult system task, and needs long term tremendous efforts. On the basis of briefly introducing its basic hydrogeological conditions and some other problems, this author wishes to state his view on how to solve the problem of sustainable utilization groundwater resource as well as the whole water shortage problem.

## 2. Basic hydrogeological conditions

Speaking of North China Plain, there are two geographical concepts, the first one denotes the plain to the north of Huaihe river, the east of Taihang-Funiu-Dabie Mountains, the south of Yan Mountains, and the west of Bohai and Yellow Seas, the other concept denotes the part of above mentioned plain, located on the north of Yellow River. Because of its worse hydrogeological conditions and groundwater overexploitation, hydrogeologists usually use the later concept, and so does this paper. This plain has an area of about 260,000 km$^2$, a very dense population of about 70,000,000. Economically this plain is important for its relatively developed industrial and agricultural production, and of course its enormous population. Politically and culturally, this plain is significant due to its long history and the location of such important cities as the capital of China – Beijing, the other from the 4 municipalities under the direct jurisdiction of the central government – Tianjing, and the Hebei provincial capital – Shijiazhuang. The normal annual precipitation in the plain ranges generally from 500 to 600 mm. The monthly distribution of annual precipitation is uneven, with about 70% occurring within three months – from June to August. The yearly changes in annual precipitation are significant with the difference of precipitation during dry and wet years as much as three to four times.

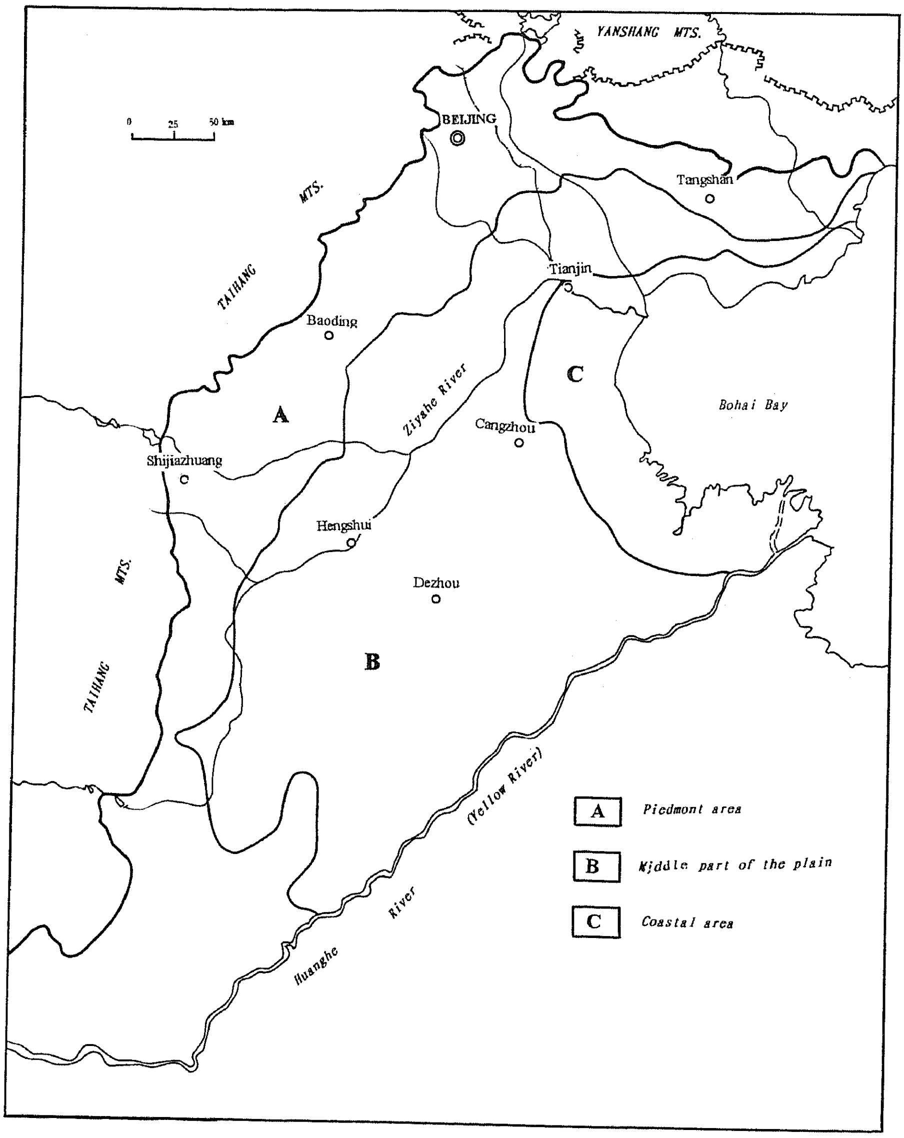


**Fig. 1** Hydrogeological zones of the North China Plain

The groundwater in the plain is mainly from Quaternary aquifers from depths down to 400 meters. Quaternary formations range in thickness from 200 to 600 m, however,

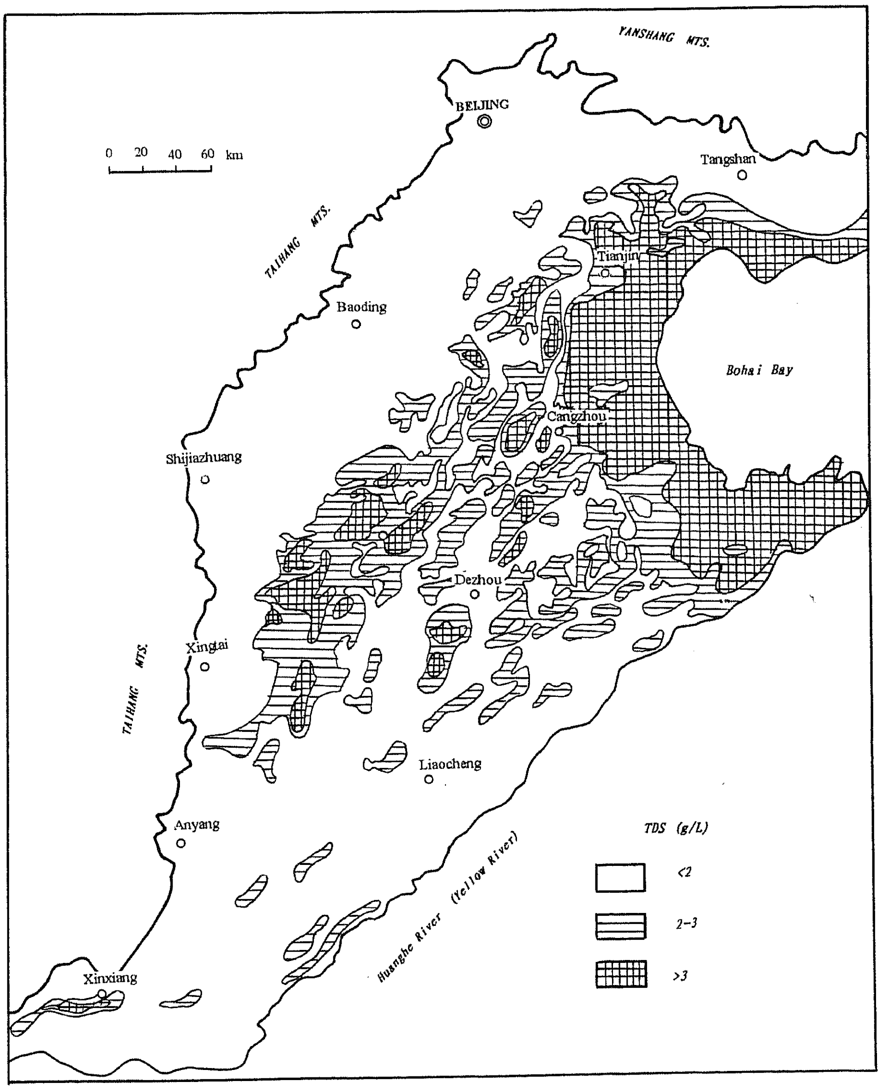


**Fig. 2** Distribution of shallow groundwater of different TDS in the North China Plain

the greatest thickness is more than 1,000 m. The aquifers are composed of unconsolidated pebble, pebble and gravel, sand and gravel, coarse sand, medium to coarse sand, fine sand, fine sand and silt, as well as silt. From west to east, the particles of quaternary aquifers become finer, and the thickness of individual aquifers decreases.

Aquifers at depths from 0 to 400 m can be divided into two groups. The first group is called shallow groundwater and ranges from 0 to 80 m deep. The second aquifer group is called deep confined groundwater, or simply deep groundwater. It ranges from 80 to 400 m in depth. (Depth of 400 m is taken as the lower line for dividing the two groups, but this is not a hydrogeological boundary, it only shows the maximal depth of most available hydrogeological data and the maximal exploitation depth. Again the depth of 80 m as the dividing line between the shallow and deep aquifer groups is an approximate or an average figure, for concrete places, it should be decided according to hydrogeological data).

In the piedmont area (area A, fig. 1) to the west and the north of the plain, the two groups of aquifers are taken as an hydraulically unified group. They are of coarse grain aquifers, well recharged, more permeable (transmissivities range from 100 to 2000 $m^2/d$), and have good water quality(bicarbonate type, TDS less than 1 g/l). The depth of water table or pressure head over there used to be 3 –5 m before 1950's, but now it is 10 – 30 m.

In the middle part of the plain (area B, fig. 1), the shallow fresh water aquifers are, primarily, fine sand, and, secondarily, fine - medium sand and silt - fine sand. The cumulative thickness of shallow fresh water aquifers is 5 to 30 m, and the hydrochemical types of water are bicarbonate, bicarbonate - sulphate, bicarbonate - chloride, and sulphate - chloride waters with TDS less than 2 g/l. The transmissivities are 50 - 300 $m^2/d$. In some places of the area B, the shallow groundwater is brackish water with TDS of 2 - 5 g/l and hydrochemical types of sulphate -chloride or chloride - sulphate waters (fig. 2). Deep groundwater over there is fresh water and distributed evenly throughout the area, its aquifers consist primarily of medium-fine and fine sands, generally with a cumulative thickness about 40 m and buried to a depth greater than 100m. In most places these deep aquifers have transmissivities from 100 to 500 $m^2/d$. The hydrochemical types of water are bicarbonate, bicarbonate-chloride, sulphate-chloride, chloride-sulphate waters with TDS less than 1g/l.

In the coast area (area C, fig. 1), the widely distributed shallow groundwater is salt water with TDS greater than 5 g/l(fig. 2), only in a few places are there isolated thin lenses of shallow fresh or brackish water. The deep groundwater in coastal area can be found at the depth greater than 150 m, and the aquifer's accumulative thickness is 50-70 m. the hydrochemical types of deep fresh water are bicarbonate-sulphate, bicarbonate-chloride, sulphate-chloride, or chloride-sulphate waters with TDS less than 1 g/l. In the river mouth area of the Yellow River, both shallow and deep aquifers contain only salt water (Fei, 1988; Zhu, 1990).

## 3. Groundwater resource evaluation results, overexploitation

From 1960 to 1991, many authors have carried out different kinds of groundwater resource evaluation studies. The latest large scale groundwater resource evaluation for the whole plain and its adjacent mountainous areas was accomplished jointly by this institute and relevant institutions from the Ministry of Water Conservancy in 1990 and published in 1991. The result of this evaluation was accepted unanimously by the Ministry of Geology and Mineral Resources and the Ministry of Water Conservancy as an official figure. According to the evaluation, the exploitable shallow fresh

groundwater resource for the whole plain is 17,415,000,000 $m^3/a$, the exploitable deep confined fresh groundwater resource is 1,598,000,000 $m^3/a$, and the present average overexploitation rate of the deep confined fresh groundwater is about 1,500,000,000 $m^3/a$. The present exploitation rate of shallow fresh groundwater for the whole plain is about 16,000,000,000 $m^3/a$, i.e. slightly less than the exploitable resource. However such exploitation rate is not evenly distributed from place to place in the plain. In the piedmont area of the Taihang Mountains, especially in places surrounding the medium and bigger municipalities along the railway from Beijing to Guangzhou, the shallow fresh groundwater is being seriously overexploited, for example: in the central district of Beijing municipality, the shallow fresh groundwater is being overexploited by 200,000,000 to 300,000,000 $m^3/a$ averagely, in the area from Shijiazhuang to Hangdan, the overexploitation rate is about 600,000,000 $m^3/a$. In the middle part of the plain, the exploitation rate of shallow fresh groundwater is approximately equal to the exploitable resource, and in its southern places close to the Yellow River, the shallow fresh groundwater is not exploited fully (Zhu, 1990).
The environmental problems caused by the overexploitation is as the following:

3.1 The water table or pressure head of groundwater in the piedmont areas of the Taihang Mountains is withdrawing seriously, for instance the maximum depth of groundwater table and pressure head in the central district of Beijing is over 30m, and that of Shijiazhuang is over 37m.

3.2 The long time overexploitation of deep confined groundwater in the middle part of the plain caused in landsubsidence in Tianjing, Changzhou, Dezhou etc., for example: the pressure head withdrawing rate of the deep confined fresh water in Tianjing is 0.9 - 2.1 m/a averagely, the landsubsidence rate is about 83 mm/a, and the total landsubsidence has reached 2.7m as the maximum.

## 4. Suggestions to solve the water shortage and groundwater overexploitation problems

To solve the groundwater overexploitation problem is an organic part of the whole solution of the water shortage problem. Starting from 1970, many learners have been studying on this problem and put forward a lot of suggestions (Liu,1989; Zhu, 1990; Cheng, 1996). To sum up, those suggestions are as the following:

4.1 Eastern line and middle line projects of diverting water from the south to the north. Eastern line project can provide 6.5 billion $m^3/a$ of water for the middle and east parts of the plain. Middle line project can provide about 8 billion $m^3/a$ of water for the piedmont area along the Taihang Mountains and the other parts of the plain (Xie, 1995). Naturally, it is significant for solving the water shortage problem of the plain, if such projects can be made a reality. At present time, the feasibility studies for those two line projects have accomplished, and the initial design stage work for the middle line project has started. However, there are so many technical and environmental problems that need to be considered carefully, and on the other hand, such projects require tremendous financial investment, therefore, most likely those projects will not be made a reality in near future.

4.2 Saving water and rational utilization of water. Such factors as the natural condition and dense population caused in the water shortage problem of the plain. In despite of whether the diverting water from the south to the north can be made a reality, the most essential and important measures to solve the water insufficiency problem are saving water all the time and every where.

4.3 Preventing pollution, protecting environment, protecting fresh water resource, that is already extremely valuable, against any kind of deterioration. Since 1980, along with the rapid development of economy, a lot of country-side and small town enterprises have build up, and due to their poor technical condition, they caused in serious pollution problems. At the same time, such publicly beneficial work as groundwater monitoring network has been weakened due to insufficient financial support. Starting from 1990, the work of preventing pollution has been strengthened by legislation and administrative measures, and many achievements have gained. However, it is still a big job and most existing environmental problems are still to be solved urgently, requiring much more efforts to strengthen the work.

4.4 The economy development allocation should be rational in accordance with local water availability. Industry and agriculture production of water saving type should be encouraged, and the high water consuming production should be restricted. Also, the municipality size and the inevitable citifying process should be controlled, and the city or town allocation planning should be made in accordance with water resource possibility.

4.5 Enhance the repeat utilization rate of water, encourage and develop waste water treatment and purification work. Encourage sea water purification work while it is feasible.

4.6 Realize conjunctive management of surface and ground waters. The piedmont area of Taihang Mountains should be constructed as a groundwater intensive exploitation and artificial recharge area in order to fully utilize the aquifer's natural water resource regulating ability as well as the excess water, during raining season and winter time, from all reservoirs and the middle line project of diverting water from the south to the north.

4.7 A big, well designed and managed draining system for the middle and east parts of the plain must be constructed in order to control the depth of shallow groundwater while irrigating and diverting water from the south to this area. The shallow fresh groundwater, even brackish water, should be used as much as possible together with the diverted surface water. The deep groundwater overexploitation situation should be eliminated as soon as possible, and while the condition permits, the artificial recharge to deep confined aquifers should be carried out, Deep groundwater system should be constructed and treated as an emergency water source for dry years.

4.8 In places where brackish shallow groundwater are distributed, special measures of draining brackish water and strengthening recharge with fresh water are wishful for the purpose to improve the environment and to increase regulatable water resource.

4.9 Strengthen the unified management of water resources. The existing institutional situation – multiple water management institutions, each acts on their own, difficult to adjust their activities, some time regard the department's benefit even higher than the country's, and so forth – must be solved properly. Present urgent task is to change the water management situation from a "rough" type into a scientific type so as to well control, well utilize, and well protect limited water resource (Cheng, 1996).

4.10 Strengthen the scientific research on water resource problems. To solve the water resource problem of the North China plain is a very complicated system problem. Although a lot of researches have been carried out during recent 30 years, there are much more studies that need to be done either from the view point of learning the natural conditions and rules or from the point of developing different technical measures as well as the way of their systematic and comprehensive application.

## 5. Essential barrier for solving the water resource problems

Above mentioned 10 suggestions are stated as a brief summing-up of the results from different studies. Obviously, all researches have promoted the progress of the water resource management work and many of those suggestions have been realized to different degree, improving the water shortage situation and the environment quite a lot. However, as a whole the water resource shortage problem is far from its reasonable solution. The reason for that is firstly because of the complexity of the problem itself, and on the other hand, the fact that the country can not afford to realize such tremendous engineering projects like diverting water from the south to the north sooner. All of those factors are understandable, but they are not the essential barrier. People can do much better than what it is now, if such barrier did not exist. Recently, many learners both at home or in abroad start discussing the utmost importance of paying enough attention to the capability and infrastructural constructions of most areas where the water problems are serious. In the author's view, right this is the essential barrier or weakness for the plain and many other areas in China. It is true that many contents of the capability and infrastructural constructions have already been put forward in the above mentioned suggestions under different terminology. But we must be clearly aware that the capability and infrastructural constructions as a whole is a system work and scientific study itself. Only if relevant scientists of different specialties, including social scientists and economists, would jointly work out a realistic program and consciously do their best efforts to promote the program and to strengthen and enhance the constructions, the existing difficult water problem of the plain would not be solved (Fei, 1996).

Capability construction includes: conversation between scientists and decision makers in order to exchange views and to enhance the awareness on how to deal with the given problem; public education for the purpose to enhance the public consciousness in saving water and protecting environment; education and training for water problem related personnel in order to enhance their working ability.

Infrastructure construction includes: institutional construction, what mentioned above in suggestion 10 is some of its major contents, what is more is: such institutions should be of management character, and be separated from running relevant enterprises, it should be given enough administrative power to solve water problems without any interference from any other authorities, and so forth; legal constructions in the context of water related and environment related legislation constructions, which has already started not long ago, yet needs to be much more strengthened; hardware constructions, which should be regarded as a long accumulative process and be perfected step by step, depending upon the available sources and technology.

Obviously, the groundwater overexploitation problem and as a more general problem – water resource management problem of the North China Plain is a very difficult problem not only due to its technical difficulties, but mainly due to the complexity of involvement of social, economical, technical, scientific, and even political components. However, it is believed that final finally this problem will be solved, if we could start paying much more attention to the capability and infrastructural constructions together with developing all other possible scientific and technical progress.

## 6. References


1. CHEN, Zhikai, “To well manage, well utilize, and to well protect the limited water resource”, The forum of water problems, Vol. 2, 1996, pp. 2-7 (In Chinese).
2. FEI, Jin, “Groundwater resources in the North China Plain”, Environmental geology and water sciences, Vol. 12, 1988, pp. 63-67.
3. FEI, Jin, “The direction for futher study on fresh groundwater resource management”, The frontier of geological sciences, Vol. 3.2, 1996, pp.156-160 (In Chinese with English abstract).
4. LIU, Changming et al., “The agriculture hydrology and water resource in the North China Plain”, The publishing house of “Science”, 1989, pp. 195-223 (In Chinese).
5. XIE, Jingrong, “Some words on the justification, engineering projects, and major scientific problems for diverting water from the south to the north”, the forum of water problems, Vol. 3,1995, pp. 12-17 (In Chinese).
6. ZHU, Yanhua et al., “Groundwater resource evaluation for the North China Plain”, Thematic report for the project 75-57-01-03 by the Institute of Hydrogeology and Engineering Geology , 1990, pp. 8-118 (In Chinese).