ground water

Foreword/

Special Section on Ground Water Research in China Featured in This Issue of *Ground Water*

by Xun Zhou[1], Jiu J. Jiao[2], and Mary P. Anderson[3]

Contained in this issue of *Ground Water* are three research papers by authors from China, as well as an overview on ground water resources in China by Jiao and Wen, which begins on this page at the right. The three research papers are part of a series focusing on ground water research being conducted in China. The rest of the papers in this series will appear in future issues of the journal.

In this issue, Liu et al. (pp. 491–499) evaluate the hydrochemistry of flow in the famous Guilin karst aquifer in the Guangxi Zhuang Autonomous Region, using high resolution measurements of carbonate chemistry and flow at two adjacent locations. They find that flow and hydrochemical responses at the two locations are significantly different in timing and magnitude. These data will help provide insights into landscape evolution in this spectacular karst region.

Mao and Ren (pp. 500–508) investigate the nonequilibrium transport characteristics of atrazine, a herbicide widely used for selective control of grassy weeds in China, by conducting column displacement experiments. They conclude that the retardation factor is the most sensitive parameter in controlling the transport of atrazine in Beijing sandy loam.

Zhang et al. (pp. 509–515) propose a new method for calculating the principal values of the permeability tensors of jointed rock masses, using probabilistic simulations of rock joint distributions based on statistical data from field surveys. Applications consider weathered rock at the Xiaowan hydropower project in Yunnan Province and fractured sandstone in Henan Province.

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Perspectives on Chinese Ground Water Resources

by Jiu J. Jiao[4] and Dongguang Wen[5]

The huge territory of the People's Republic of China dominates East Asia. With its eastern border washed by the Pacific Ocean, its southern provinces abutting India, Burma, and Vietnam, and its western and northern provinces thrusting deep into Central Asia and North Asia, respectively (Figure 1), China has a land area of ~9.6 million km^2 and a population of 1.2 billion. The landmass of China is characterized by dramatic geographical, geological, and hydrogeological diversity. Its land surface ascends from east to west in three distinct steps, like a three-step staircase. The plains and lowlands in the east and southeast constitute the first step, with an elevation < 1000 m and an extension out into the Pacific Ocean. The second step includes the Inner Mongolia, Loess, and Yunnan-Guizhou plateaus, and the Tarim, Junggar, and Sichuan basins, with an average elevation between 1000 and 2000 m. The third step is represented by the Qinghai-Tibet Plateau, with an average height > 4000 m above sea level.

The northern regions of China are separated from the southern regions by the Qingling mountain range, which roughly runs through the center of the country in an east-west direction. Chinese hydrogeologists divide the country into six hydrogeological regions (M. Chen and Z. Cai, 2000, *Groundwater Resources and the Related Environ-Hydrogeologic Problems in China*, Beijing: Seismological Press). In the north, from east to west, they are (1) the Great East Plain, including the Songliao Plain and Huang-Huai-Hai Plain, which are mainly Mesozoic or Cenozoic down-faulted basins with good aquifers consisting of very thick unconsolidated sediments; (2) the Inner Mongolia Plateau and the Loess Plateau; and (3) the western inland basin, an extremely dry Gobi desert region, mainly consisting of the Hexi Corridor, Junggar Basin, Tarim Basin, and Chaidam Basin. This region has ample ground water in the piedmont plains. In the south, the hydrogeological regions are, from east to west, (4) the southeastern and southern central hilly uplands, which are dominated by fractured aquifers; (5) the southwestern karst uplands with well karstified aquifers;

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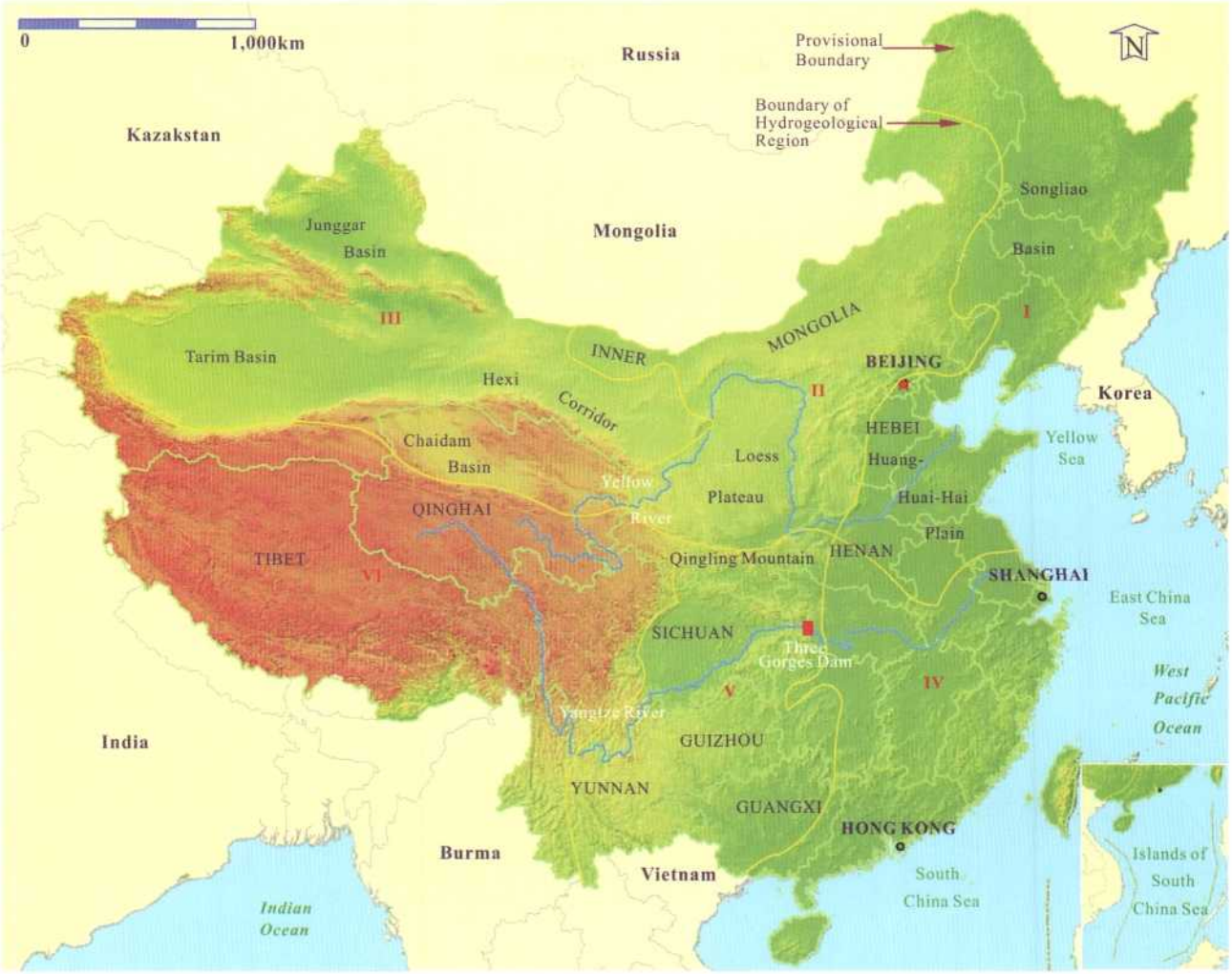

Figure 1. Topography of China with hydrogeological regions indicated.

and (6) the Qinghai-Tibet Plateau, which is dominated by permafrost aquifers of glacial sediments (Figure 1).

The annual precipitation ranges from < 25 mm in the dry Gobi desert areas in the northwest to 2500 mm in south China. The average annual precipitation in China is ~640 mm, which leads to a total annual precipitation of 6200 billion m^3. China has a total of 2800 billion m^3 of annually renewed fresh water. It is the world's most populous country and ranks fourth in the world in terms of total water resources. However, with water resources per capita of only 2400 m^3, China has the second lowest per capita water resources in the world—less than one-third the world average. The annual ground water recharge amounts to 870 billion m^3, of which 290 billion m^3 is exploitable.

Water resources are unevenly distributed in China. The northern parts of the country are deficient in water, while the south is water-rich. The areas south of the Yangtze River, which account for only 37% of the country's total territory, have 81% of its total water resources. However, the areas north of the Yangtze, which make up 63% of China's territory, possess only 19% of the country's total water resources. As a result of this uneven distribution, more than 300 of the 640 major cities in China face water shortages, and 100 of these face severe scarcities. The distribution of ground water is similarly skewed—average ground water resources in the south are more than four times greater than in the north. To ease the water shortage in the North China Plain and the cities of Beijing and Tianjin, a south-to-north water diversion project involving the construction of three manmade rivers, all > 1000 km in length, was started in 2002. The three diversion lines will link together four of China's major rivers, including the Yangtze and Yellow rivers. A marked environmental impact on water cycle and ground water flow systems is expected.

Ground water in China has been exploited for more than 3000 years, but large-scale ground water extraction started in the 1950s and has been significantly increased in the past 20 years. The annual volume of extracted ground water grew from 61.9 billion m^3 in 1980 to 106.9 billion m^3 in 2000. Accordingly, ground water use as a percentage of the total water supply also increased from 14% in 1980 to 20% in 2001. Ground water is a major source of water for agriculture in north China, where 85% of the annual exploitation occurs, while only 15% of the annual exploitation occurs in the south. More than 30% of the water supply of China's 11 northern provinces comes from ground water. In Hebei Province, which relies mostly on ground water, ground water accounts for 78% of its total water supply. Most major cities in north China rely heavily on ground water for water supply; ground water usage as a percentage of total water for domestic and industrial purposes is ~90%. Due to rapid urbanization, ground water usage in south

China has also steadily increased. Overall, 70% of Chinese drink ground water.

China has virtually all the problems related to ground water faced by the world as a whole. China's rapid economic growth, industrialization, and urbanization have outpaced infrastructural investment and management capacity, and have created widespread problems of ground water scarcity and pollution. Degradation of ground water resources and deterioration of ground water quality have become a striking environmental problem in half the cities of northern China.

Desertification is a major environmental issue in China. According to the monitoring results of China's State Forestry Administration in 1999, the desert areas are still expanding, at an average rate of ~10,400 km^2/year, and China has 2.67 million km^2 of desert land, accounting for 27.9% of its total land area. Overexploitation of ground water is a factor, among many others, responsible for desertification. Marked falls in the water table have resulted in vegetation diminution, followed by soil desertification in many areas. In other areas, however, irrigation has led to a rise in the water table and soil salinization. For example, in the upper reach of the Tarim River, the biggest continental river in China, 267 km^2 of previously cultivated land has been abandoned due to salinization caused by inappropriate irrigation.

Despite growing international concern over the efficacy of dams, China remains one of the most active dam-building countries today. The ecological and environmental impact of damming is not always well understood. The major Three Gorges dam project involved studies on the impact on the environment and ecology in the area immediately near the riverbanks, but the reservoir construction will significantly modify the ground water flow system over a huge area, and the indirect impact due to such modification on regional environment and ecology has yet to be studied. The Yellow River flows past numerous cities, including eight provincial capitals; both it and other major rivers are drying up due to dam construction. Consequently, aquifers, which now have much less recharge due to reduced streamflow, are increasingly being overexploited.

Ground water overexploitation has caused a marked and continuous drawdown of ground water levels in some cities of north China. In all of China, there are more than 50 large cones of depression with an area greater than 100 km^2. The intense exploitation of ground water by industrial enterprises in Cangzhou, Hebei Province, has caused the water level to drop 60 m, causing a regional cone of depression over an area of 2225 km^2. As a result, 38% of irrigation wells in the cone have been abandoned and half of the remainder pump at < 50% of their capacity. Deeper wells have to be installed from time to time. A recent survey indicates that the cones of depression in the deep aquifers have joined together to form a huge interprovincial cone of depression in the North China Plain. Competition for water between communities, sectors of the economy, and individual provinces is growing.

With the formation of cones of depression, many cities, especially the coastal cities with thick unconsolidated soft soil layers, are suffering from land subsidence caused by the withdrawal of ground water in deep aquifers. Shanghai and Tianjin, with maximum subsidence of ~3 m, are the most severe cases. Ground subsidence has caused a series of problems, such as sinking and splitting of railway bases, buildings, and underground pipelines, and an emerging flood crisis in areas near major rivers or the sea. For example, embankments have had to be constructed to prevent flooding of sea water into some areas of Tianjin City after significant ground subsidence.

Sea water intrusion occurs in most of the coastal cities in north China, and also in some southern coastal cities such as Laizhou, Longkou, Yantai, and Qinhuangdao. Sea water intrusion has resulted in the severe corrosion of industrial-cooling equipment. Surface collapses have appeared in some cities with karst aquifers after significant falls in the water level. For example, in Tangshan, an important city in northern China rebuilt after an earthquake of 7.8 on the Richter scale in 1976, karst collapses have occurred in 20 places in the downtown area. In addition, 400 ground fissures have opened in 49 cities of north China and are believed to be related to ground water overexploitation.

Some major karst springs from aquifers of Ordovician and Cambrian limestone and dolomite systems in Shanxi and Shandong provinces have reduced discharge or stopped flowing as a result of the lowered potentiometric surface due to ground water overexploitation. Jinan City in Shandong Province has been known as the "City of Springs" for thousands of years because of its cluster of 72 springs. When water bursts through the outlets, the springs give thunderous sounds, and water columns surge upward. However, some of the springs have dried up because of the overdevelopment of ground water. This has had an adverse effect on the traditional spring tourist influx to Jinan.

The Chinese government has recognized the vital need to address ground water shortage issues in China in order to maintain the nation's development. Since 1988, a number of pieces of legislation regulating the exploration and protection of ground water have been introduced. These specify how the quantity and quality of ground water resources should be evaluated, and how accurate the evaluation should be at different survey stages. They require possible pollution sources to be identified, and the risk of pollution to be assessed. They require arrangements to be made to monitor the level and quality of ground water, so that the findings can be used for further ground water study and management. This legislation offers hope for better protection and optimum use of ground water resources, provided that it is rigorously enforced.