GROUND WATER DEVELOPMENT AND ECONOMIC ASPECTS IN CHINA

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ABSTRACT

This paper provides the latest information concerning the development, utilization and economic aspects of groundwater in China. The drilling costs for one meter of cased well in different formation, with varied depth and diameters, China-made drilling rigs and drilling methods are given. Some drilling projects of cased wells in Africa and Asia countries are presented.

1 INTRODUCTION

China is a country with a long history in the development and utilization of groundwater, Goundwater, which combines with surface water as a source of water supply, has played an important role in development of national economy and upgrading of people's life. In the course of the development of utilization of groundwater, the exploitation departments in different regions have got a great deal of successful experience with regard to reducing water extraction costs and raising economic benefit. The government department has also put forward series of guiding policies on putting groundwater to rational exploitation. These have promoted the progress in groundwater utilization.

It is sure that with the development of the four modernization construction, the need of water resources, including groundwater, will increase with each passing day. Therefore, we should make and follow the technological and economic principles to raise the social, economic and environmental benefits in the utilization of groundwater.

2 DEVELOPMENT AND UTILIZATION OF GROUNDWATER IN CHINA

With the development of industry and agriculture, the expansion of urban area and upgrading of the living standards, the requirement of water has been increasing day by day. Continuous aridity in the last years has resulted in serious shortage and pollution of surface water and worsening of water quality. Therefore, the exploitation and utilization of groundwater should be integrated closely.

China has vast expansion of territory and its natural conditions vary from one place to another. Different regions differ greatly in climate, landform, plant, river system and gological structure. As far as distribution of groundwater is concerned, China could roughly be divided into two parts by Qinling mountains which traverses from east to west.

In North China, the main plain (including the interior basins and the piedmont plain in the west) with thick and loose deposits of Quternary sand and gravel has a series of water bearing formations. Because of shortage of surface water in this region now, groundwater exploitation and consumption are increasing year by year. At present, in a lot of big and medium cities in North China, such as Beijing, Shijiazhuang, groundwater became the main source of water supply. In other groundwater combined with surface water serves for the source of water supply. Pumping and use of groundwater is increasing in the South. In the southern China, where the hills and mountains are the most of landforms, the exploitation of groundwater from bedrocks is increased now. Because the yearly precipitation is very uneven, more over, surface water is contaminated in local places.

According to incomplete data in recent years the total ground water withdrawal in China is about 760×10^{8} m^3/yr. Among them water of 600×10^{8} m^3/yr is got by pumpage from exploited regions. Others are from large springs and underground rivers. The yield in plain regions is about 580×10^{8} m^3/yr., it makes up 76% of total withdrawal of groundwater in China. In mountainous region, the yield is 180×10^{8} m^3/yr., which makes up 24% of the total. The yield of groundwater of seventeen North provinces is about 660×10^{8} m^3/yr. It makes up 87% of the total yeild of groundwater in our country, and is about 42% of the recoverable reserves of groundwater of those provinces.

For rational and economic exploitation of groundwater, hydrogeological teams have been carrying out systematical exploration and mapping to find out hydrogeological conditions in different areas. Up to now, except Qinhai-Tibet plateau and some difficult regions, such as high mountains, deserts, forests, hydrogeological mapping of scale 1/200000-1/500000 has covered an area of 6,600,000 km^2 (two thirds of whole country's inland territory). In plain areas, mapping of scale 1/50000-1/100000 has covered an area of 69,000 km^2 (one tenth of the whole). This work is very useful for rural water supply and agricultural irrigation. In urban areas, more detailed explorations have been carried out. On the basis of these investigation " The Atlas of Hydrogeological Maps of the People's Republic of China" was published in 1979, which summaries the main results of regional hydrogeological investigation in China.

In 1981-1985, assessment of groundwater resources of the whole country had been done. The resources of pore water, fissure water and karst water were calculated as following (Table 1)

TABLE 1 Natural resources of groundwater in China ($\times 10 m^3$/yr.)

Areas	Types of groundwater	Natural resouces
Plains	Pore water	2503.90
Mountain areas	Fissure water	4250.81
	Karst water	2034.26
	Pore water in valleys and basins	458.72
	Total	6743.79
Superimposed		530.86
Total		8716.84

All of these works guide the development of groundwater. Determination of rational investment standard based on the exploiting conditions is an important thing to encourage the development of groundwater in arid or semi-arid areas (Table 2).

Groundwater plays very important role in rural water supply and irrigation. Besides drilling well, radiating wells (wells with horizontal collectors) are used for extracting groundwater from loess aquifer; karez is widely used in piedmont plains with arid zone. Large-diameter wells are popular in sand-gravel water bearing formation or fissure water in weathered zone. Sometimes cases are made of plastic, pig-iron, cement concrete and bamboo depending on the local condition. Thus, the cost of exploitation could be decreased.

TABLE 2 Capital costs of drilling and irrigation

Well depth (m)	Drilling and pump costs (US$)			Rates of one well (m^3/hr)	Areas irrigated (ha)	irrigation costs ($/ha)
	Drilling	Equipment	Total			
10–50	8	18 (manual vacuum pump)	24	3–5	0.2–0.3	80
100–200	53	80 (vacuum pump)	133	10–20	1.3–1.5	100
300–400	2681	536 (Deep motor pump)	3217	150–200	10–13	241
400–500	3485	670 (Deep motor pump)	4155	150–200	10–13	311

In plains, location of ancient river courses, boudary of salty and fresh groundwater, depth of water bearing formation are determined by geophysical methods. In Hebei province, each county has got its own small geophysical group. In mountainous regions, the geologic structures and rock fractures are very complicated, so geophysical methods would be key factor to determine the proper well field. Some cheap but efficient geophysical instruments made by local factories are applied widely. Reduction of drywell, enlargement of yield in well, lower the total expenses for drilling and pumping. In areas, where water is buried deeply and quite difficult to pump, the costs of irrigation could be higher than the income of local people. Therefore the development and utilization of groundwater have been rather limited in these areas. Overexploitation of groundwater is another serious problem on development of ground water, which results in the water depression in area, land subsidence, ground collapse, deterioration of water quality and so on. Since some departments pay little attention to waste disposal, in many areas, groundwater, even deep ground water is polluted to various extent.

3 ECONOMIC ASPECTS OF GROUNDWATER IN CHINA

In China, groundwater abstraction is realized mainly by manual or mechanical machines to dig the large-diameter wells (including radiation wells and karez) and by drilling rig to drill cased wells. The large-diameter wells are generally dug by the experienced peasants. Casedwells are mainly constructed by the professional hydrogeological units or the water conservancy departments. Different rigs and construction methods have been adopted according to the different depth, diameter and formation.

After many years exploitation the capital costs of drilling and irrigation are rather clear. Drilling costs per one meter of cased wells by rigs, made in China are shown in Table 3.

TABLE 3 Comprehensive Drilling Costs E_o per one meter(US$)

Expense items	Types of rigs		
	DDP-100	SPC-300, SPJ-300H	SDY-600
Personnel	5.1	8.52	12.89
Materials	9.4	13.10	16.91
Amortization	0.66	2.08	1.00
Pipe amortization	0.28	2.61	6.25
Repairing	2.20	2.17	2.96
Transport	2.32	2.63	4.88
Management	3.98	6.31	9.00
Total	23.94	37.42	53.89

Explanation for Table 3:

1. All drilling costs E_o are made for rock category V (drilling efficient of 1.0m/hr.) Well diameter of 152 mm and depth of less than 100m.

2 The month drilling efficiency per one rig is 750m for DDP-100, 400m for SPC-300, SPJ-300H and 300m for SDY-600.

3. The rig amortization of 6% per year is considered.

For other rock categories, well diameters, well depth it is necessary to calculate the other drilling costs E_i through E_o using special coefficients.

$$E = f_r \cdot f_d \cdot f_i \cdot E_o$$

E_i — Drilling costs for special well.

f_r . f_d . f_i . — Rock category coefficient, depth coefficient and diameter coefficient, respectively. (see Table 4, 5, 6)

Rock category coefficient (f_r) is given in Table 4.

TABLE 4 Rock coefficients

Rock category	I	II	III	IV	V
formation	soil	Artificial soil, sand	sandgravel sandstone	Semi-consolidated sand-gravel pelite	pebble gravel limestone
fr	0.18	0.26	0.53	0.67	1.0

VI	VII	VIII	IX	X
Gravel-pebble, dolomite, basalt	Pebble, silicified dolomite	Boulder-pebble, granite	Boulder, silicolites	Strong silicolites
1.25	1.67	2.86	4.0	5.88

TABLE 5 Depth coefficients

Depth (m)	<100	100--200	200--300	300--400	400--500	500--600
fd	1	1.09	1.19	1.29	1.40	1.53

TABLE 6 Diameter coefficients

Diameter	152 mm	7 3/4 inch	9 3/4 inch	280—350 mm	350—450 mm	450—500 mm
fi	1	1.29	1.45	1.89	1.89	2.15

With downhole hammer drilling method in hard rocks (the rock category) the efficiency is increased quite a lot, though the downhole hammer method consumes too much oil fuel and high cost compressor. So, generally speaking, the drilling cost is reduced, particularly in mountain areas lacking of water. In case of SPC-300 rig the coefficient adjusting to increase of equipment and fuel (f_e) is considered to be 5.0, and at same time rock category coefficient——0.25 for all categories more than V (drilling efficiency——4m/hr.) According to all above adjustment the expense for drilling one meter formation in particular case is

$$E = f_r \cdot f_d \cdot f_i \cdot f_e \cdot E_0$$

Example, Drill water well with depth of 100m (0-20m is sand gravel, dia. 300 mm; 20-100 m is granite, dia. 3/4"). Using the conventional drilling method (rotary method with core bits) the total expense is,

$B = 0.53\times1\times1.89\times37.42\times20+2.86\times1\times1.45\times37.42\times80(m)$
$= 131.64$

Comprehensive cost for one meter (E_o) is 131.64 US$

Using the downhole hammer drilling method the total expenses is:

$B = 0.53\times1\times1.89\times37.42\times20+0.25\times1\times1.45\times37.42\times5.0\times80$
$= 749.67 + 5425.90$
$= 61.76$

Comprehensive cost for one meter (E_1) is 61.76 US$

Comprehensive hydrogeological work costs per one month are shown in Table 7

TABLE 7 (US $)

Items	Geology investigation		Water analyses	soil engineering analyses		long-term observation work
	in field	in office		disturbuted sample	undisturbuted sample	
1. Personnel	62.2	54.7	0.04	2.0	6.0	61.7
2. Material	8.0	8.0	0.09	0.4	1.0	10.7
3. Amortization	5.4	5.4	0.04	0.2	0.6	11.8
4. Repairing	6.4	6.4	0.02	0.1	0.4	10.7
5. Transport	13.4	4.3	0.01	0.1	0.3	25.2
6. Other direct expenses	15.5	15.5	0.01	0.4	1.3	10.7
7. Management	27.9	23.6	0.05	0.8	2.4	32.7
Total	138.8	113.9	0.26	4.0	12.0	163.5

China Geo-Engineering Corporation (CGC), whose previous name is China Geo-Exploration and Water well Engineering Corporation, is a large professional state-owned enterprise which has been registered as economical and legal entity. In the past thirty years, CGC has constructed about 100 water well drilling, water supply and mineral exploration projects in thirty more countries of Asia, Africa and Latin America, such as Mali, Somalia, Sanegal, Mozambique, Nigeria, Bukkin, Faso, Ethiopia, Pakistan, Sri Lanka, Peru and so on.

1. Drilling of 450 water wells in rural areas (Fana, Kamtiala and Sikasso) in Mali.

It is financed by the World Bank. The average depth is 60m and the total drilling footage 27000m (9000m is sediment with diameter 9 7/8-12 1/4 inch, and rotary drilling method; 18000m in sandshale with diameter 1/2 inch and downhole hammer method). The project began in November 1985. Because of high drilling efficiency (speed, about 10 m/hr. with utilizatin of downhole—hammer), the project was completed in December 1987. the total price of the contract (including pipe, but not pump) is847,833,400 FCFA or 2,874,011.5 US$ The cost per one meter is 106.45US$.

2. The Construction of 485 Tubewells in South Rohri (Pakistan) Project

It has been financed by the Asia Bank. Average depth of wells is 47.5m with installation of 8"—12" pipes and screens. Total drilling footage is 23239.3m and total price of contract (including pipes and pumps is 58,788,643 PRs or 3,359,351 US$. The cost per each meter is 144.5 US$. This project began in September 1987 and will be ending in two years.

3. The Construction of 300 Tubewells in North and Extreme-North Provinces in Cameroon.

This project is financed by the World Bank. CGC began the project in September 1987 with total drillings of 21342m and total price of contract (including pipe) of 804,815,000 FCFA or 2,728,186 US$. The cost per each meter is 127,83 US$.

4. The Water Resource Exploration and Well Drilling in Puttalam and Chilaw towns, Sri Lanka.

The project was commenced in October 10, 1985 and completed in June, 1987. The exploratory wells of 53 and production wells of 21 with tube dia. of 24.7–32.5cm were drilled. The total drilling footage is 3048.28m. The total water flowrate is 2895m³/d and allowable exploitative amount of underground water in both towns is 17992m³/d (in Puttalam the main aquifer is limestone and in Chilaw-sand and gravel). Total cost of the project is 375,300 US$ (including 15% of equipments and machinary cost). The cost of each meter is 123.11 US$.

Note: Karez

A kind of irrigation construction in XinJian Region, Northwest China. First, a series of wells from the hill slope to the fields are dug, then, dig through in the bottom of wells, make a connection into the hidden channel to draw the melted snow in the mountain and underground to irrigate the field.