

Brief Talk of Groundwater Resources in Role of Rural Drinking Water Safety and Construction of City Emergency Water Source

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Abstract: With respect to underground water as a component of water resources, this Paper, by analyzing the distribution, development and utilization of underground water resources in Zhejiang Province, brings forth the advices on setup of underground-water-based emergency water source in various cities in Zhejiang Province in accordance with the principle for selection of underground-water-based emergency water sources for the purpose of properly strengthen the protection of drinking water source (including underground water) in rural areas and properly setting up the emergency water sources in urban areas, so as to provide the scientific basis for protection of water supply security in rural and urban areas.

Keywords: Groundwater, Rural drinking water safety, City emergency water source, Zhejiang Province

Water is a foundational natural resource and strategic economic resource, the lifeline of national economy and biological environment. The water resource which could be continuously utilized is related to social security and comprehensive construction course of well-off society and is an important factor restricting social economic development.

Through 50-year survey, appraisal and monitoring, distribution and quantity, history and current status on development and utilization of groundwater in Zhejiang Province have been basically ascertained, and the groundwater's status and role in the water resources in the whole province have been confirmed. It is affirmed by "Overall Planning on Protection and Development and Utilization of Water Resources in Zhejiang Province": groundwater resource "type IV, type V groundwater are $119 \times 10^8 \text{ m}^3$, $54 \times 10^8 \text{ m}^3$ respectively, accounting for 53.7% and 24.5% of total quantity respectively", the groundwater in coastal plain area is excessively exploited, giving

rise to as series of geological environment problems, therefore that conclusion that development of groundwater resource has more harm than good is reached.

Affected by such natural factors as geography and weather as well as economic and social factors, in Zhejiang Province there is resource water shortage, pollution water shortage and engineering water shortage. It is the responsibility which could not be neglected by governments at different levels to reasonably develop and utilize, optimize allocation, save and protect, comprehensive treat the groundwater which is part of water resources, as well as surface water resource (Zong-gu Zhang et al., 2005).

It is an important task under the new situation to actually reinforce protection of drinking water including groundwater, construct urban emergency water source land and secure safety in drinking water in rural areas in accordance with such documents as the "Twelfth Five-year Planning Outline on National Economic and Social Development in Zhejiang Province", "Notice on Implementation of Important Work Division

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Program Decided by Reinforcement of Geological Disaster Prevention and Control Work of State Council in Zhejiang Province”, “Notice on Reinforcement of Safe Water Drinking in Cities and Countryside from the People’s Government of Zhejiang Province”, and “Opinions on Implementation of the Strictest Water Resources Management System and Comprehensive Promotion of Water-saving Social Construction by from the People’s Government of Zhejiang Province”.

Groundwater Resources in Zhejiang Province and Development and Utilization Status

Distribution of Groundwater Resources

The area of land territory in Zhejiang province is $10.18 \times 10^4 \text{ km}^2$. The abundant rainfall and overland runoff in Zhejiang province provides beneficial conditions for forming and gathering of groundwater, but resource quantity of different hydrogeological units or groundwater type have a wide difference. On the basis of groundwater storage conditions it could be classified as loose rock pore water (pore water), carbonate rock acid fissure cave water (karstic water), red clastic rock pore water (red stratum water) and bedrock fissure water (Shu-juan Yu et al., 2009). The groundwater is classified as some sub-categories and water-inclusive rock groups (Table 1).

Table 1 Partion Table of Groundwater Types in Zhejiang Province

Type	Subclass	Name of Rock Characteristic of Water-bearing Rock Formation	Grading of Water Quantity	Water Quality	Distribution
Loose rock pore water	Phreatic water	1. Holocene series of alluvial sand gravel water-bearing stratum (alQ ₄)	Medium-abundant	Fresh	River valley zone, intermountain basin
		2. Alluvial and proluvial sand gravel water-bearing stratum	Medium	Fresh	
		3. Alluvial and slope proluvial cohesive soil mixed with crushed gravel water-bearing stratum (plQ ₃ , dl-plQ ₂₋₃ etc)	Poor	Fresh	Piedmont belt
		4. Lake, sea silt or cohesive soil water-bearing stratum (al-lQ ₄ , al-mQ ₄)	Poor~ Extremely poor	Fresh-salty	Binhai-Hekou Plain
	Shallow stratum	Alluvial sand gravel water-bearing formation (alQ ₃ , alQ ₄)	Medium~ abundant	Fresh~ salty	
	Confined groundwater	1. Blanket sand, sand gravel water-bearing formation (I)		Fresh~ salty	Binhai-Hekou plain
		2. Blanket sand, sand gravel water-bearing formation (II)	Medium~ abundant	Fresh~ salty	
		3. Alluvial and proluvial sand gravel including cohesive soil water-bearing stratum (III)		Fresh	Hangjiahu plain

Table 1 (continued)

Type	Subclass	Name of Rock Characteristic of Water-bearing Rock Formation	Grading of Water Quantity	Water Quality	Distribution
Red clastic rock pore water	Fissure water	Water-bearing formation mainly composed of calcareous siltstone (mainly K ₂)	Medium- abundant	Fresh, salty, partial salty	Cretaceous basin, such as Jinqu
	Interlayer water	Water-bearing formation mainly composed of sandstones and basic rocks (mainly K _{1c})	Poor- abundant	Fresh	
	Weathered water	Water-bearing formation mainly composed of sandy conglomerates and pelites (K)	Poor	Fresh	
Carbonate rock karstic water	Bare-typed	Water-bearing rock formation mainly composed of carbonate rocks (C-P)	Medium- abundant	Fresh	Western Zhejiang
	Covered-typed	Water-bearing formation of carbonate rocks and fragment rocks and fissure rocks (Z-O)	Poor- abundant		
Bedrock fissure water	Bedded rock structure fissure water	Water-bearing rock formation mainly composed of deposition fragment rocks	Poor~ Extremely poor Water-storing structure: Medium~ abundant	Fresh	Hilly and mountain areas of Western Zhejiang
	Bulk rock structure fissure water	Water-bearing rock formation mainly composed of volcanic rocks and intrusive rocks			Hilly and mountain areas of Eastern and Southern Zhejiang
	Weathered zone network fissure water	Water-bearing rock formation mainly composed of granide and metamorphic rocks			Altiplanation surface and denuded low-lying land in hilly and mountain area

Evaluation on Groundwater Resources

“Groundwater resources” refer to gravity water in various forms buried below the earth surface, their burial, water abundance, water quality, etc could be developed and utilized under current or future technical and economic conditions, and have realistic or potential economic meaning. The groundwater resources are featured with flow and recoverability; it is a mineral resource as well as an important part of water resources. The groundwater resources are composed of replenishing resources and stored resources.

According to *Standards on Classification and Grading of Groundwater Resources* (GB15218-94), the groundwater resources are divided into resources allowed to be exploited and resources still hard to be utilized. The quantity of

groundwater resources depends on replenishing conditions and storing conditions, but the groundwater system is a complicated dynamic system which has four-dimensional nature and functions in time distribution, controlled by various kinds of natural factors and human factors, with different grading, interrelation and mutual impact. Its appraisal results are usually much different on the basis of different appraisal methods.

The regional groundwater resource appraisal based on types of groundwater resources, groundwater dynamic monitoring fruits, survey and exploitation practice generally reflects the status of groundwater resources in Zhejiang province. The exploitable resources in the whole Zhejiang province is 28.62×10^8 m³/a (Table 2), including river valley pore phreatic water

$20.83 \times 10^8 \text{ m}^3/\text{a}$, accounting for 72.8%; red stratum pore fissure water $2.75 \times 10^8 \text{ m}^3/\text{a}$, accounting for 9.6%; confined fresh water in deep and shallow

stratum in plain area $2.01 \times 10^8 \text{ m}^3/\text{a}$, accounting for 7.0%; karstic water $3.04 \times 10^8 \text{ m}^3/\text{a}$, accounting for 10.6%.

Table 2 Evaluation Results Table of Recoverable and Difficult to Make Use of Groundwater Resources in Zhejiang Province

Classification of Resources	Exploitable Resource Quantity ($10^4 \text{ m}^3/\text{a}$)					Quantity of Resources still Hard to be Utilized ($10^4 \text{ m}^3/\text{a}$)			Total ($10^4 \text{ m}^3/\text{a}$)
	River valley phreatic water	Shallow stratum confined water	Karstic water	Deep stratum confined fresh water	Red stratum pore fissure water	Shallow stratum phreatic water in plain areas	Deep stratum confined slightly salty water	Bed rock fissure water	
	208,294.6	13,383.8	30,391.4	6,706.2	27,457.5	44,603.5	9,497.4	143,708.3	484,042.7
Total			286,233.5				197,809.2		

History and Current Status of Groundwater Development and Utilization

Zhejiang has had a long history in development of groundwater, the "wooden well" excavated in Hemudu neolithic cultural site which is 6,000 years old, is confirmed to be the earliest water supply well in China. Later the well of the same type is again discovered in Liangzhu cultural site which is 4,000 years old, the groundwater which has been more than some thousands old is one of main water resources on which citizens live.

At the demand of city construction and social economic development, large-scale groundwater exploitation started in the 1960s, first it was centrally in plain areas such as Hangjiahu, Ningbo, besides growing quantity demanded, blood fluke epidemic is also an important factor for groundwater exploitation as it needs a safe source of drinking water in life. In the end of 1960s, there was no severe draught. It is a golden age of hydrogeological investigation in the 1970s, groundwater was developed in the whole province and most of cities and counties, in the 1980s the groundwater exploitation in coastal plains was growing continuously, and spread from cities and towns to the countryside; with breakthrough of exploring and finding water from groundwater in red stratum basin, rapid advance of development in red stratum water; maturity of large-caliber caisson-well process, and river valley phreatic water was widely utilized. The water level in the coastal plain region was lowered in the 1990s, the

ground sinking intensified, with ground collapse in many karstic areas, arousing attentions of the government and the public and it started to enter an orderly management stage, on which groundwater resource protection and development and utilization planning were prepared by main counties (cities) (Jian-kang Zhao et al., 2006).

At the arrival of 2000s, the groundwater development and utilization enters the stage of taking prevention of deterioration of geological environment such as ground sinking, ground collapse as target, i.e. sticking to the principle of coordinating environmental protection and resource development. The provincial government office printed and issued such documents as Notice Concerning Opinions on Delimiting Prohibited and Restricted Exploitation Zones in Hangjiahu Areas and Confirming Control Target, and Notices Concerning Opinions on Delimiting Prohibited and Restricted Exploitation Zones in Yongtaiwen Areas in 2004 and 2005, and Provincial government issued Opinions on Reinforcing Prevention and Treatment of Ground Subsidence in 2006, delimiting the scope for prohibited and restricted exploitation zones in Hangjiahu areas and Yongtaiwen areas and the exploitation of urban groundwater was effectively controlled.

On the basis of statistics of Communiqué on Water Resources in Zhejiang Province in 1999-2012, the total exploitation quantity of groundwater in the whole province is in the range of 4×10^8 - $7 \times 10^8 \text{ m}^3/\text{a}$ (Fig.1-Fig.2), including exploitation quantity of groundwater in dispersed

civil wells in plain areas and river valley phreatic water, and displays the tendency of decrease of groundwater exploitation quantity year by year in

recent years, the supply quantity of groundwater accounts for only 2% of total water supply quantity in the whole province.

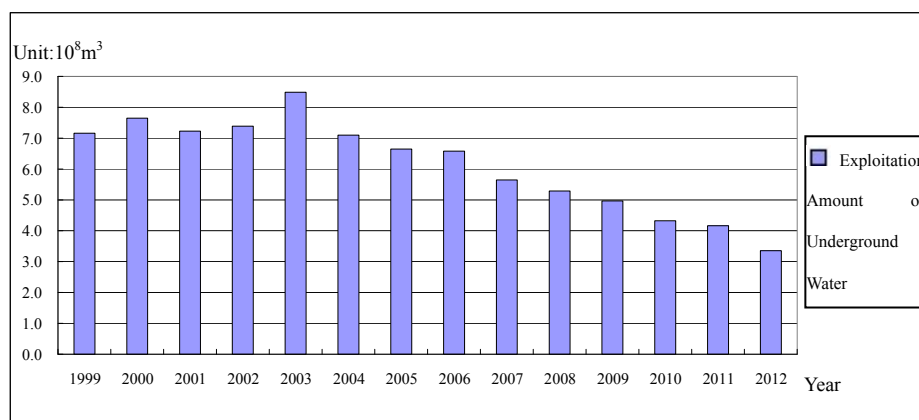


Fig.1 Statistical Figure of Groundwater Resources in Zhejiang Province

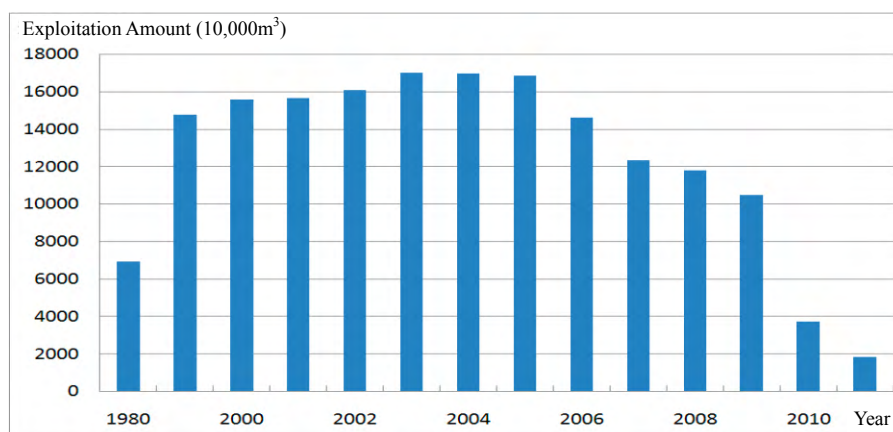


Fig.2 Calendar Year Production Figure of Pore Confined Groundwater in Zhejiang Coastal Plains

The groundwater in Zhejiang Province is mainly used for domestic drinking and industry in cities and countryside. According to the statistics in 2000, the domestic water consumption in cities and countryside accounts for 51.9% of total exploitation quantity of groundwater, industrial water consumption accounts for 31.3%, water for agricultural irrigation accounts for 16.8%. The water quantity of domestic drinking water is estimated to be over 60% in 2010, and the industrial water consumption to be reduced.

Suggestions on Safe Groundwater Drinking in Rural Areas

The safe water drinking in rural areas is related to normal life and physical health of the mass in

rural area, as well as economic development and social stability in rural area (Qiu-ping Cui et al., 2010; Qi-qing Yang et al., 2009; Chang-lei Dai et al., 2008). The Party Central Committee and the State Council attach importance to the issue of security of rural drinking water. Since 2003, Zhejiang Province implemented the plan “Drinking Water Engineering for Ten Millions of Farmers”, which made important progress.

In the Report on “*Investigation and Appraisal of Current Status of Rural Drinking Water in Zhejiang Province*” (Table 3) prepared by three departments such as Water Conservancy Department of Zhejiang province in 2005, the total rural population in the whole population is 35,587,100. According to the water supply quantity at water supply point 20 m³/d, the water supply is composed of central water supply and

disperse water supply, then the population of central water supply from the water resources on the earth surface in the whole province is 20,951,900, accounting for 81.9% of total population of central water supply, the population of central water supply from groundwater water is 4,528,100, accounting for 18.1%.

The water of dispersed water supply is obtained from well, diverted springs, and rainwater harvesting, the population benefiting on dispersed water supply from wells is 5,903,300, accounting for 58.4%, which explains that the phreatic water in shallow stratum is still generally used as the source for domestic drinking water in rural area. There is a rural population of 1,313,500 who directly drinks on water resources such as spring, stream, river, pit mineral water, etc.

The rural water drinking problem in Jiaying is very noticeable. Its rural population is 2,509,400, 86.1% of the people of central water supply use groundwater. 98.5% of the people of disperse water supply drink well water, and the remaining 1.5% drink rainwater harvesting, and none drink surface water, which has sufficiently explained the pollution of surface water is serious. The rural citizens' dependence on groundwater especially confined water in deep stratum as well as fundamental reasons for ceaseless repeated prohibition and restriction. It is pointed out in Report on "*Investigation and Appraisal of Current Status of Rural Drinking Water in Zhejiang Province*" that, "with implementation of well sealing plan, the local water drinking problem in Jiaying would be more noticeable."

Table 3 Summary Table of Basic Situation of Rural Water Supply in Zhejiang Province

Name of City	Total Rural Population (10,000)	Population of Central Water Supply (10,000)					Population of Dispersed Water Supply (10,000)				
		Subtotal	Classified on the basis of water supply methods		Classified on the basis of water sources		Subtotal	With facilities			Without facilities
			Water supply to household	Points of central water supply	Surface water	Ground water		Wells	Diverted springs	Rainwater harvesting	
Hangzhou	420.77	321.72	312.32	9.40	304.00	17.72	99.05	34.00	44.21	2.88	17.97
Ningbo	422.89	402.44	402.32	0.12	384.76	17.68	20.45	9.01	6.42	1.32	3.69
Wenzhou	630.84	497.27	487.53	9.74	462.21	35.06	133.58	26.87	65.05	6.20	35.46
Shaoxing	333.26	243.02	240.67	2.35	198.47	44.55	90.25	59.88	15.82	3.01	11.54
Huzhou	193.98	115.84	115.84	0.00	115.23	0.60	78.14	40.14	23.16	0.43	14.41
Jiaying	250.94	228.38	228.38	0.00	31.68	196.70	22.55	22.21	0.00	0.00	0.34
Jinhua	366.94	183.34	181.55	1.79	121.64	61.69	183.61	162.59	16.04	1.15	3.83
Quzhou	196.99	38.03	36.40	1.64	25.81	12.23	158.96	117.79	29.82	2.23	9.12
Taizhou	477.94	361.73	344.36	17.37	303.42	58.31	116.22	77.00	21.44	5.15	12.61
Lishui	194.70	108.41	98.74	9.67	101.33	7.09	86.28	22.28	38.22	3.49	22.28
Zhoushan	69.46	47.83	47.51	0.32	46.65	1.18	21.63	18.55	0.84	2.14	0.09
Total of the province	3558.71	2548.00	2495.63	52.38	2095.19	452.81	1010.71	590.33	261.02	28.02	131.35

Note: 1. The rural water drinking problems have been solved in the districts under administration of Hangzhou, except Yuhang district;

2. The rural water drinking problems have been solved in the districts under administration of Ningbo;
3. The rural water drinking problems have been solved in the districts under administration of Shaoxing;
4. The above municipal districts haven't had survey on rural water drinking problems, but the total population has been counted by relevant data;
5. This table is quoted from Report on Investigation and Appraisal of Current Status of Rural Drinking Water in Zhejiang Province.

The population of central water supply in Jinhua is 1,833,400, and with 616,900 drinking on the groundwater, accounting for 33.6%, the population of dispersed water supply is 1,625,900 accounting for 88.6%, i.e. among the rural population of 3,669,400 in Jinhua, the population drinking groundwater accounts for 61.1%.

Besides, the population benefiting on groundwater in Quzhou, Taizhou, Shaoxing, etc. accounts for a large ratio, the "digging well and drinking water" age hasn't come to an end.

On the basis of standard of rural safe drinking water health appraisal system, the water is safe, if the water source guarantee degree is not lower than 95%, the water is basically safe if not lower than 90%; when it comes to convenience it is safe if the round-trip time to get water is not more than 10 minutes by human power, and basically safe if not more than 20 minutes, when it comes to domestic water consumption it is safe if the water quantity available for each person each day is not less than 60 L, and basically safe if not less than 40 L. By this standard, it is easy to understand the groundwater could become the reasons for important water source for rural domestic water: convenient to get water, exploiting water locally; simple engineering, low cost; stable water temperature, rather good water quality, little pollution; rather stably dynamic, with a higher assurance than surface water.

In 2004, the population of central water supply from rural groundwater in the whole Jinhua is 616,900, and the population of dispersed (well) water supply with facilities is 1,625,900, calculated on the basis of water consumption per capita 0.1 m³/d (annual per capita is 36.5 m³/a, equivalent to average water consumption in rural areas in the whole province), the total water consumption in the whole year is about $8,186 \times 10^4$ m³/a, accounting for about 49.9% of 1.64×10^8 m³/a which is total groundwater consumption in the whole city in 2004, equivalent to 48.8% of 1.68×10^8 m³/a which is domestic water consumption in cities and countryside in Jinhua. In Jinhua, such counties

(cities) as Yiwu, Lanxi, Yongkang, Dongyang have rather high ratio.

According to statistical data of "Report on Investigation and Appraisal of Current Status of Rural Drinking Water in Zhejiang Province", the rural population in Yiwu is 491,000, the population drinking unsafe water is 137,300, the population drinking unsafe water resulting from the water quality of groundwater including brackish water is 1,900, the population drinking unsafe water from seriously polluted and untreated groundwater is 23,900, besides, the population drinking unsafe water with fluorine which exceeds the standard is about 10,000 (totaling 20,400, from either surface water or groundwater), totaling 36,000, accounting for 26.3% of the population drinking unsafe water, accounting for 11.1% of the population 324,500 drinking on rural groundwater in Yiwu, which is sufficient to prove the safety of groundwater in the economically developed, population central and severely polluted areas still have an irreplaceable place in water supply in rural areas and cities and towns.

The groundwater in Jinqiu area mainly comes from red stratum pore fissure water and river valley pore phreatic water. The red stratum water is exploited by tube well, generally 60-80 m deep, with strong anti-pollution and penetration capability. It is shown by long-term observation that, except there is dotted pollution of "3-nitrogen" due to bad protection of well mouth, the water quality is still kept in an original status, and generally reach standard II above according to the water quality standard and part of metasilicic acid and strontium meet requirements of drinking mineral water. Because the groundwater is characterized with vertical zoning, few of wells are too deep, so there is SO₄-Ca type brackish water. The water inflow of most single wells is 100-500 m³/d, the well digging expense including water intake facility is less than RMB 3,000, so nearly all households have wells themselves if the conditions permit, and there are thousands of wells.

Much of rural groundwater comes from river

valley phreatic water, river valley pore phreatic water is stored sand gravel water-bearing stratum, if the water-bearing stratum is thick over 5-6 m and water is exploited by heavy-caliber caisson well, the water inflow of single wells may exceed 1,000 m³/d, some may exceed 5,000 m³/d even to 10,000 m³/d and become water source of central water supply. No seriously faceted pollution or heavy metal pollution has been found from monitoring until now. but the protective layer of unsaturated zone at upper part is rather thick and pollutants easily penetrates and has weak anti-pollution capability, it is needed to establish health protective belt in the countryside especially in the water sources of central water supply, necessary preventive measures shall be adopted and the quality of water intake engineering shall be improved.

In the construction of rural water supply engineering, reinforcement of combined use of surface water and groundwater is an important way to solve the problem of water source shortage, in which, it is a method generally applied at home abroad building an "underground reservoir" in river valley area so as to regulate runoff volume of groundwater and surface water, and obtain a remarkable result of "three-water storage", i.e. undercurrent, rain and surface water are obtained. Actually the barrages for lifting water constructed by Water Conservation Department in Zhejiang province in the 1960s and 1970s had the characteristics of "underground reservoir", according to the statistics from Zhejiang province agricultural hydrogeology zoning survey in 1982, there are more than 45,000, annual water consumption is 6.00×10^8 m³, which plays an important role in the rural domestic water drinking in small scope to the extent of water used for agricultural irrigation, now some part of the barrages are still in use, but most are gradually abandoned in lack of maintenance and protection. Therefore, it is needed to draw on experience, fully control and select geological and hydrological conditions in the areas on which the underground reservoirs are planned to be constructed, design underground barrage engineering according to circumstances, and give play to their benefit of society, economy and eco-environment.

The safety of rural water drinking from groundwater has different characteristics from

surface water:

(1) First, on the basis of regional hydrogeological conditions, doing research on structure, water quantity, water chemistry distribution of underground system as well as replenishment, runoff and discharge characteristics of groundwater, seek for water source whose water quantity meets demand, quality is good, and which would not give rise to or suffer from various environmental geological problems or harms in the course of exploitation and which would guarantee sustainable utilization.

(2) The work of safe water drinking in rural areas is launched for the users at most basic level-villages and towns, country, single village, combined households to dispersed farmer household, and directly for farmer. The construction of water intake engineering requires correct design, reasonable layout, and it shall be practical and simple. Currently investigation, survey and monitoring have been launched in the areas with difficulties in water shortage, surface water supply or areas with bad distribution of water quality such as fluorine, arsenic and brackish water, and actual effect and demonstration have been achieved. Therefore the water conservancy, health, environmental protection and state-owned resource departments shall be equipped with experienced professional technicians, who go deep into the countryside, to seek for, develop and protect rural drinking water source, improve the farmers' life quality and actually strengthen their service functions.

(3) The utilization of groundwater resources shall not taken into the rural safe drinking water security system and rural water supply engineering construction system, to assure the plan "Drinking Water Engineering for Millions of Farmers" is realized.

Construction of Emergency Water Resources Land for Urban Groundwater

In the 1970s and 1980s, as part of urban water supply source, groundwater still has a certain ratio in water supply and mainly used for urban domestic drinking and industry (Table 4).

Table 4 Major Urban Water Supply List in Zhejiang Province in 1986

Name of city		Hangzhou	Ningbo	Wenzhou	Jiaxing	Jinhua	Taizhou
Groundwater ($10^4\text{m}^3/\text{a}$)	Water Supply Capability	3,234	5,000		5,265		520
	Water Supply Quantity	1,069	687	200	1,821	71	392
Surface water ($10^4\text{m}^3/\text{a}$)	Water Supply Capability (central)	17,630	7,300	3,650	1,820	3,468	360
	Water Supply Quantity	17,894	7,024	3,240	6,284	3,468	440

With the advance of urbanization, rapid growth of water demand, reinforced water supply capability of surface water, restriction of water quantity from groundwater source as well as such incurred geological environmental problems as ground subsidence, surface collapse; naturally the exploitation of urban groundwater plays a minor role. The groundwater supply quantity of such county (city)-level towns as urban area of Jiaxing, Pinghu, Haiyan reached the peak of $5,849 \times 10^4 \text{ m}^3/\text{a}$, accounting for 50.1% of total exploitation quantity of deep stratum pore confined water in Hangjiahuh plain, and decreased to be $2088 \times 10^4 \text{ m}^3/\text{a}$ in 2000, only accounting for 18.3% of total exploitation quantity; in 2004, according to request on prohibited and restricted exploitation on

groundwater from the provincial government, the government at different levels and relevant departments continuously make more efforts to prohibited and restricted exploitation on groundwater, and the groundwater-exploiting wells were decreased from 794 in 2004 to 44 in 2010, currently the deep stratum groundwater exploitation has been basically stopped in main cities and towns as well as countryside in Hangjiahuh plain, the exploitation quantity in 2012 was only about $200 \times 10^4 \text{ m}^3$, in comparison with the largest annual groundwater exploitation quantity $11,645 \times 10^4 \text{ m}^3$ in 2004, the decreased groundwater exploitation quantity reaches above $1 \times 10^8 \text{ m}$, and the groundwater exploitation and replenishment is balanced (Fig. 3).

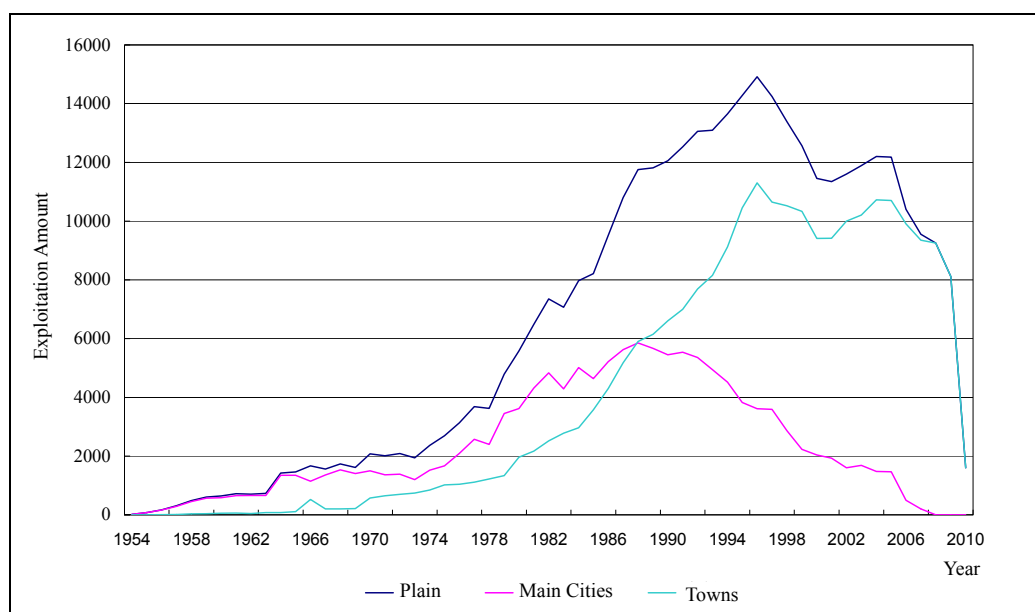


Fig. 3 Dynamic Curves of Pore Confined Groundwater Production in Hangjiahuh Plain

In recent years groundwater in other cities is rarely used as the source of domestic water, its restricted exploitation mainly based on self-provided wells is used for industrial production, air-conditioner cooling. Except some famous springs and wells like Tiger Spring which is still in the memory of the public, the groundwater resources are forgotten and usually linked with geological disasters, and prohibited and restricted exploitation of groundwater has become an incontrovertible established policy.

In 2005 serious water pollution emergencies occurred in the places like Jihua, in 2007 “blue-green algae” event occurred in Taihu Wuxi Jiangsu province, the severe situations which water resources and water environment face give rise to new knowledge and new requirements, so a new task on water drinking safety security and urban emergency water resources and reserved water resources construction is brought up which displays the “human-orientated” spirits.

Groundwater source may become urban reserved water source in emergent status (Yong Ye et al., 2010; Yue-ping Zhang et al., 2010; Xiang-Qian Dai et al., 2007; Jing Li et al., 2006 ; Yi Fan et al., 2012), take the groundwater source of Yinjiang Bridge of Zhenhai Power Plant in Ningbo town Zhejiang province for example, in 1975, in order the meet boiler water of Zhenhai Power Plant, groundwater exploration appraisal was made on river valley pore phreatic water area in Yinjiang Bridge of Yinzhou District Ningbo, the exploitable quantity in the engineering I was 7,000 m³/d, in 1984 the engineering II provided 16,800 m³/d, which were both rated as level I according to Groundwater Quality Standard, and all indicators meet Domestic Drinking Water Health Standard. The length of fresh water waterline is 46 km, which is the longest in the electric power system in the whole nation. Upon a 40-year exploitation, the daily exploitation quantity is about 2×10^4 m³/d on average, and its water level, water quantity and

water quality have stable dynamic, providing secure guarantee for safe operation of Zhenhai Power Plant.

There are a number of water sources with similar hydrogeological conditions which could be used as urban emergency water sources. There are mainly three considerations: first is abundant water, the exploitable quantity of water sources in emergency state shall be 3,000-5,000 m³/d; second are good exploitation conditions, convenient water taking and speedy water transportation; third is the water quality shall be fresh water, which meets or after simple treatment meets Domestic Drinking Water Health Standard (GB5749-2006). Due to excessive exploitation of pore confined water in coastal plain in Zhejiang province at early stage, the ground subsidence is rather severe, currently most of exploitation wells have been basically closed, exploitation quantity is decreased considerably, but their water quantity is large and water quality rather good; the river valley phreatic water is mainly distributed in larger ravines, lithology is mainly composed of sand gravels, water inflow of single well is 1,000-3,000 m³/a, water quantity is large and water quality is good; the water quality of part of covered karst water and pedestal rock fissure water is also rather good, which could be considered as groundwater emergency water sources.

After hydrogeological conditions have been ascertained and groundwater resources are appraisal, the following places could be taken as emergency water resources to provide scientific basis for urban water supply safety: West Lake in Hangzhou, Liuxia, Yuanpu, Downtown of Ningbo, Yinjiang Bridge, Hangzhouwan New District of Cixi, Shabu-Yuanqiao, Gaoqiao-Yuanqiao, Luqiao-Jinqing in Taizhou, Xiqiu Pingshui Shaoxing, Xiahuizao Lanting, Pinghu-Haiyan in Jiaxing, as well as Zhoushan Dazhan plain and Baiquan, Ganlan, Xiaosha, Cengang, Beichan, etc. (Table 5).

Table 5 Emergency Groundwater Source List in Main Cities of Zhejiang Province

Name of City	Name of Emergency Water Source	Exploitable Quantity		Maximum Exploitable Quantity in History (10 ⁴ m ³ /a)	Quality Level
		10 ⁴ m ³ /a	10 ⁴ m ³ /d		
Hangzhou	Karstic Water around West Lake	367	1.0	315	Level I- II
	Yuanpu-Zhoupu Shallow Stratum Pore Confined Water	2,000	5.5	203	Level II (part of Fe, Mn exceeding standard)
	Zhuantang Pingfeng Mountain-Ling Mountain Karstic Water	146	0.4	87	Level II
	Deep Stratum Pore Confined Water in Xiangfuqiao	221 (including slightly salty water)	0.6	300	Level II-IV (part of solid maters, Fe, Mn exceeding standard)
	River Valley Pore Phreatic Water				
	Longwu	226	0.6	154	Level I- II
	Jiuxi	73	0.2	64	Level- II
Ningbo	Liuxia	272	0.7	210	Level I- II
	River Valley Pore Phreatic Water in Yinjiangqiao	770	2.1	800	Level I- II
	Hengjietou River Valley Pore Phreatic water - shallow Stratum Confined Water	560	1.5		Level I- II
	Deep stratum confined water in Duantang and Sanguantang	150	0.4	520	Level II-IV (part of Fe, Mn exceeding standard)
	Basalt Structure Fissure Water in Wuxiang, Baozhuang Anshan			60	Level I- II (HSiO ₃ , Sr, Br drinkable mineral water)
Huzhou	River Valley Pore Phreatic Water				
	Miaoxi	228	0.6		Level I- II
	Gujia	629	1.7		Level I- II
Wenzhou	Karstic Water in Baiqiao (Including Huangzhishan, Santianmen, Yangjiapu, Zhaowan)	222	0.6	202	Level I- II
	Deep Stratum Pore Confined Water in Yongqiang	537	1.5	2,341	Level II (part of Fe, Mn exceeding standard)
	Red Stratum Pore Fissure Water in Downtown	738	2.0		Level I- II (part meeting drinkable mineral water standard)
Jinhua	River Valley Pore Phreatic Water in Bailongqiao	5,691	15.6		Level I- II
	River Valley Pore Phreatic Water in Wuxi River, Qu River	3,209	8.8		Level I- II
Quzhou	River Valley Pore Phreatic Water in Wuxi River, Qu River	3,209	8.8		Level I- II
Taizhou	Baihe – Luiao - Huanglang Deep Stratum Pore Confined Water	697	1.9	1,843	Level II-IV (part of Fe, Mn exceeding standard)
Jiaxing	Deep Stratum Pore Confined Water in Downtown				
	Urban area	1,188	3.3	2,364	Level II (part of Fe, Mn exceeding standard)
	Suburbs			2,582	

Table 5 (continued)

Name of City	Name of Emergency Water Source		Exploitable Quantity		Maximum Exploitable Quantity in History (10 ⁴ m ³ /a)	Quality Level
			10 ⁴ m ³ /a	10 ⁴ m ³ /d		
Shaoxing	River Valley Pore Phreatic Water in Pingshuijiang		144	0.4	About 400	Level I- II
	Karstic Water in Lanting		164	0.4		Level I- II
Lishui	River Valley Pore Phreatic Water in Lishui basin		3,587	9.8		Level I- II
	River Valley Pore Phreatic Water in Bihu					Level I- II
Zhoushan	River Valley Pore	Dazhan	137	0.4		Level I-II (part of Fe, Mn exceeding standard)
	Phreatic Water -	Baiquan	126	0.3		
	Confined Water in	Baqiao	47	0.1		
	Shallow Stratum	Dinghai	36	0.1		

Note: The water at level I mainly reflects natural low background contents of chemical components of groundwater, applicable to various usages; the water at level II mainly reflects natural background contents of chemical components of groundwater, applicable to various usages; the water at level III is based on health reference value of human body, mainly applicable to central domestic water source and industrial and agricultural water; the water at level IV is based on requirements of agricultural and industrial water, besides applicable to agricultural and part of industrial usage, still used as domestic water after proper treatment; the water at level V is not suitable for drinking, and other water may be selected according to their purposes.

Conclusions and Suggestions

The ultimate purpose of protection of groundwater resources is to utilize the groundwater resources. Besides deep stratum pore confined water lacks replenishment, the atmospheric precipitation permeates into the ground, is stored in the groundwater runoff inside holes, fissures and caverns, and most of it is lost with water circulation, a reasonable and full utilization of this part of water resources, not only in arid cities deficient of water, either short-term or long-term, needs to be taken into water resources planning, water saving planning, water drinking safety security planning, and become one factor in building a saving and harmonious society.

During the “Eleventh Five-year Plan” period, measures for prohibited and restricted exploitation have been adopted to prevent such geological disasters as ground subsidence, land collapse in the areas with fragile geological environmental conditions, it is necessary to implement filling the wells exploited for groundwater. At the same time, during the “Twelfth Five-year Plan” period, part of water supply wells shall be preserved as

monitoring wells planned and on purposed, monitoring on water level and water quality shall be continuously launched and reinforced; to guarantee a timely initiation of safe groundwater sources in emergency state, exploitation wells and its water intake facilities (well pumps, pipelines, power supply, etc.) with large water quantity and good water quality shall be reserved and maintained according to plan, they should not be abandoned totally. Therefore, during the “Twelfth Five-year Plan” period, special investigation on groundwater resources and water intake engineering shall be launched for the purpose of rural water drinking safety and construction of urban groundwater emergency resources, to improve the capability of water drinking safety in rural, urban and key engineering construction projects.

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