

Research Article

Research on Carrying Capacity of Water Resource Based on Multi-reservoir Regulation

¹Liu Renyuan, ^{1,2}Li Lei, ³Li Hua and ¹Huang Qiang

¹Xi'an University of Technology Eco Water Northwest State Key

Laboratory Breeding Base, Xi'an 710048, China

²Shaanxi Institute of Engineering Survey, Xi'an 710068, China

³CongQing ChangAn Automobile Company Limited ChongQing 400023, China

Abstract: Analyze the level of Carrying Capacity of Water Resources; evaluate the condition of e region social, economic and ecological environment comprehensive and sustainable development. This study is based on analyzing the meaning of water resources carrying capacity, take water resources of the Midwest of Shenzhen City an example., by the way of the "Coordinated and sustainable development" theory, found the model of the Carrying Capacity of Water Resources, Calculated and analyzed. Water efficiency coefficients are different in different states, the Carrying Capacity of Water Resources is different too. the water resources in the Midwest of Shenzhen City can only meet now this stage (2010) Urban water demand, meanwhile people of over loading in there are also constantly increasing, In the future, Water requirement of Shenzhen Midwest cities must increase Dongjiang water and west diversion works of Shen Zhen, in order to enhance Carrying Capacity of Water Resources of the area.

Keywords: Carrying capacity of water resources, coordinated and sustainable development, reservoirs, the Midwest of Shenzhen, water resource

INTRODUCTION

Shenzhen city, of which another name is Peng city, is located in the south of Guangdong province and contiguous to Hong Kong. The total area of the city is 2020 km², the total land area is 1952.84 km² and the area of the special economic zone of Shenzhen is 327.5 km². Shenzhen has jurisdiction over six districts: Futian district, Luohu district, Nanshan district, Yantian district, Baoan district and Longgang district. Data shows till May 18th, 2010, the accumulative registered floating population of Shenzhen is 12005500 and plus the current 2460-thousand residential population, the current population of Shenzhen is 14 465 500. Shenzhen is one of the 7 cities of severe water shortage in China. The water resource is severely insufficient. The mean amount of water resource per capita is only a quarter of that of the nation and 1/5 of that of Guangdong province. Currently, 90% of water consumption of Shenzhen is supplied by the other cities. As one of the seven cities of severe water shortage in China, the water consumption of people in Shenzhen is wasteful. The data provided by relevant departments of Shenzhen shows compared with the mean integrated water consumption per capita in south big cities, in average, everyday there are more than 160 L of water used per capita in Shenzhen, which greatly exceeds the mean level of 261 L/d of the mean integrated water

consumption per capita in south big cities (Statistic of Chinese Total Water Consumption over the Years and Water Consumption for Living per Capita (EB/OL), <http://wenku.baidu.com/view/a38a6a235901020207409c4f.html>; (Du *et al.*, 2011). Thus, researching the bearing capacity of the water resource in the Midwest of Shenzhen city under the recent condition plays a significant theoretical significance and realistic significance.

CONSTRUCTION OF MODEL OF THE BEARING CAPACITY OF THE WATER RESOURCE BASED ON THE BALANCED AND SUSTAINABLE DEVELOPMENT

The bearing capacity of the water resource means the maximum capacities of the water resource (host water and guest water) in a region for bearing industrial and agricultural production, human survival, ecological environments, etc., (considering the regulation of reservoir and reasonable dispatch of the water resource).

Currently, there are many measures for studying the bearing capacity of the water resource, including the vague integrated evaluation method, the method of analysis on main ingredients (Lu *et al.*, 2013a, b), the conventional tendency method, the multi-target analysis method, the matter element model, the system

Corresponding Author: Liu Renyuan, Xi'an University of Technology Eco Water Northwest State Key Laboratory Breeding Base, Xi'an 710048, China, Tel.: 0086+13480661910

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dynamics model, the model of projection pursuit evaluation, etc., (Fu and Ji, 1999; Zhang and Guo, 2006). The thesis studies the problem of the bearing capacity of the water resource of Shenzhen based on the principle of balanced and sustainable development.

The principle of the balanced and sustainable development is: try best to increase the utilization rate of the water resource, reduce the loss of the water resource and realize the development mode of unification of economy, society and ecology. Thus, the thesis discusses the concept of the coefficient of water utilizing efficacy. The coefficient of water utilizing efficacy reflects the utilizing degree of the water resource used by a region or a water utilizing department and also can reflect the economic level of the region.

The model of balanced and sustainable development is divided into five steps:

- Confirm the capacity of reservoir V/m^3
- Confirm the available amount or water supplying amount $W(g)/m^3$ of the water resource of the city.
- Confirm the integrated quantity of demand of the city r/m^3 .
- Solve the integrated water-utilization efficacy coefficient $U^{[7]}$ of the city.
- Solve the GDP of the city G/RMB
- Establish the model of balanced and sustainable development:

Target function:

$$\text{Min } W_g = \sum_{m=1}^n \sum_{t=1}^n (W_x(U(m,t), G(m,t), V(m,t))) \quad (1)$$

$$\frac{W_1 U_1}{r_1} = \frac{W_2 U_2}{r_2} = \dots = \frac{W_n U_n}{r_n} \quad (2)$$

$$\frac{G}{W} = \frac{G_1}{W_1} = \frac{G_2}{W_2} = \dots = \frac{G_n}{W_n} \quad (3)$$

Transfer equation of the status of reservoir:

$$V_m(t+1) = V_m(t) + W_{\text{In-warehouse}}(t) - W_{\text{Ex-warehouse}}(t) \quad (4)$$

Constraint conditions:

$$\sum_{m=1}^n W_g(m) \leq \sum_{m=1}^n W_{\text{Ex-warehouse}}(m)$$

$$\sum_{m=1}^n Q_g(m) \leq \sum_{m=1}^n Q_{\text{Ex-warehouse}}(m)$$

$$V_m^{\min}(t) \leq V_m(t) \leq V_m^{\max}(t)$$

$$W = W_1 + W_2 + \dots + W_n \quad (5)$$

In the equation,

$r_j(j = 1, 2, \dots, n)$: The amount/ m^3 of water demanded by the city of the j aspect under a level of living

$W_j(j = 1, 2, \dots, n)$: The water supplying amount/ m^3 corresponding to the j demand of every area of the city

$U_j(j = 1, 2, \dots, n)$: The maximum production capacity of the unit water resource amount on a water utilizing target j (such as GDP), i.e., the water-utilization efficacy coefficient, U decides the water-utilization efficiency, the higher the U value is, the higher the water-utilization level is

$G_j(j = 1, 2, \dots, n)$: The total output value/RMB and the level of economic development of the area can be shown by the total output value

$W_{\text{EX-warehouse}}(m)$, $Q_g(m)$, $Q_{\text{EX-warehouse}}(m)$, respectively represents the inlet flow, outlet water amount, water supplying flow, outlet flow/ m^3 of the reservoir m ; $W_g()$, $W_x()$ represents the supplied water of reservoir and the demanded water of city/ m^3 .

$V_m^{\min}(t)$, $V_m^{\max}(t)$ are the limitations of the maximum and minimum reservoir storage of the reservoir m at t time.

ESTIMATION AND EVALUATION OF THE BEARING CAPACITY OF THE WATER RESOURCE IN THE MIDWEST OF SHENZHEN

Overview of the research area: The thesis takes the Midwest of Shenzhen as the target, wherein it includes Baoan, Nanshan and Futian districts, of which the areas

Table 1: Rainfall of Shi Yan hydrological station from 1970 to 2005 unit: mm

Year	1970	1971	1972	1973	1974	1975	1976	1977
Rainfall	1666.5	1810.1	1836.0	2000.6	1576.8	2382.4	1872.1	1151.9
Year	1978	1979	1980	1981	1982	1983	1984	1985
Rainfall	1575.8	1518.1	1488.9	1520.7	1376.8	1810.9	1060.7	1608.5
Year	1986	1987	1988	1989	1990	1991	1992	1993
Rainfall	1563.2	1828.4	1272.3	1250.4	1021.0	1021.4	1643.1	1930.7
Year	1994	1995	1996	1997	1998	1999	2000	2001
Rainfall	1903.0	1463.2	1662.0	1739.0	1548.9	1495.8	2160.2	2308.7
Year	2002	2003	2004	2005	Multi-year mean value 1615.57			
Rainfall	1417.5	1419.1	1431.5	1824.4				

Table 2: The local average years input water and the scale of water supply unit: 108 m³

Name	Local self-production water	Scale of the corresponding waterworks for water supply
Gongming reservoir	0	0
Ejing reservoir	0.0260	0.546
Shiyan reservoir	0.1674	2.179
Xikeng reservoir	0.0198	0.988
Total	0.2132	3.713

are respectively 79, 151 and 733 km², the total area is 963 km². Till 2010, the total population of Futian, Baoan and Nanshan districts is 7183300 (Bulletin of Statistic of National Economy and Social Development of Shenzhen City in 2000, 2005 and 2010, http://news.sznews.com/content/2011-04/25/content_5565662.htm). Main water resources of the Midwest of Shenzhen are self-production water and water supplied from other places. The proportion of the water supplied from other places is about 90% of the total amount of the fresh water used in the special area.

Local water: To the local water, it mainly takes the rainfall data from 1970 to 2005 of the Shiyan hydrologic station, Shenzhen (Xu and Chen, 2008) as the rainfall of the whole region: the multi-year mean rainfall is 1615.57 mm; the mean value per month is 133.1 mm; it is shown in Table 1. According to the multi-year rainfall data, the self-production water of all reservoirs in the Midwest of Shenzhen city is obtained and it is shown in Table 2.

The self-production water of the Gongming reservoir and the loss of pervaporation are basically cancelled out and the Gongming reservoir is a spare reservoir without the corresponding waterworks, thus, the scale of water supply of the self-production water and the corresponding waterworks is calculated as zero.

Water from other areas: Recently, the water supplying project of the northern line is mainly used for supplying the water from other areas to the Midwest of Shenzhen. Under the 97% guarantee rate of water supply, the water supplying amount of the northern line is 350-million m³/year. In future, the amount of the water supplied by the northern line should be increased and the water supplying project in the western line should be combined for water supply.

Amount of water demand of the city: To the sum of the amount of current (2010 year) water demand of all departments of cities in the Midwest of Shenzhen, it should take the water supply scale of the waterworks corresponding to each reservoir as the final and the sum is 371.3-million m³/year (Table 2). According to the current demand of water consumption, carry out the long-series united optimal dispatch calculation to the reservoir group through the Eq. (4) and (5) in the model of balanced and sustainable development, they are multi-year reservoirs which store the residual water in the ample flow year and supply water to the city in the dry year. The balance relationship between supply and demand of the water resource is obtained and results are shown in Table 3.

The multi-year mean total amount of water supply of the Midwest of Shenzhen from 1970 to 2005 is 37.13-million m³. As the water demand amount of 37.13-million m³ of the city in 2010, the actual multi-year mean amount of water supply is 37.13-million m³. It can be concluded that the current amount of water supply can satisfy the demand of water consumption of 2010. The result is shown in Table 3.

U vale means the local total production value/corresponding water consumption. The higher the

Table 3: The calculated results of long series water resources supply and requirement balance of the Midwest of ShenZhen city unit: 108m³

Serial number	Year	Self-production water	Total volume of water supply	Sequence (increase)	Corresponding year	Water demand	Amount of water supply	Surplus and deficiency	V capacity of reservoir
1	1970	0.215	3.715	3.778	1999	3.713	3.713	0.065	0.065
2	1971	0.222	3.722	3.776	1982	3.713	3.713	0.063	0.128
3	1972	0.226	3.726	3.764	1977	3.713	3.713	0.051	0.179
4	1973	0.225	3.725	3.761	1991	3.713	3.713	0.048	0.227
5	1974	0.219	3.719	3.745	1986	3.713	3.713	0.032	0.259
...
31	2000	0.167	3.667	3.679	1998	3.713	3.713	-0.034	0.260
32	2001	0.204	3.704	3.678	1980	3.713	3.713	-0.035	0.225
33	2002	0.230	3.730	3.674	1985	3.713	3.713	-0.039	0.186
34	2003	0.235	3.735	3.667	2000	3.713	3.713	-0.046	0.140
35	2004	0.188	3.688	3.657	1983	3.713	3.713	-0.056	0.084
36	2005	0.193	3.693	3.635	1990	3.713	3.713	-0.078	0.006
Average		0.213	3.713	3.713		3.713	3.713	0.000	0.006

Table 4: The efficiency coefficient of water in Midwest of Shenzhen city

Type	2000-subsistence type			2005-full well-off type			2010-initial rich type		
	First industry	Second industry	Third industry	First industry	Second industry	Third industry	First industry	Second industry	Third industry
Baoan	0.632	20.388	10.5890	0.511	73.5670	46.3020	0.051	96.4410	51.6780
Nanshan	0.079	23.606	7.3250	0.250	66.2800	29.4900	0.085	102.2900	59.6870
Futian	0.006	13.375	15.1200	0.001	20.5750	44.5610	0.071	20.2670	169.2740
Total	0.717	57.369	33.0340	0.759	160.4190	120.3510	0.208	218.9980	280.6390

Table 5: Carrying capacity of water resources in Shenzhen^[7,10] unit: E-10⁸ Yuan, P-10⁴ (Jiao, 2007; Liu *et al.*, 2008)

Name	2000-subsistence type		2005-full well-off type		2010-initial rich type	
	Economy	Population	Economy	Population	Economy	Population
Baoan	305.490	165.69	1163.45	204.17	2329.84	362.01
Nanshan	364.080	123.72	1124.66	152.45	1990.05	270.31
Futian	448.070	101.85	1027.03	125.50	1832.63	222.52
Total	1117.640	391.25	3315.14	482.11	6152.52	854.84

U value is, the richer the city is and it is shown in Table 4. Table 5 is the result of the analysis on the loading capacity of the water resource in Shenzhen. Under the subsistence condition, basically, Baoan district, Futian district and Nanshan district are in the status of loading insufficiency. Under the condition of the full well-off type, Futian district and Nanshan district are little overload and Baoan district is highly overload and the overload value is about 1278600 persons. Under the condition of initial rich type, Futian and Nanshan are basically little overloading, Baoan district is highly overload and the overload value is about 1380000 persons.

CONCLUSION AND DISCUSSION

The model of balanced and sustainable development established by the thesis analyzes and calculates out the conditions of the bearing capacity of water resources of subsistence type, full well-off type and initial rich type in Futian district, Nanshan district and Baoan district in the Midwest of Shenzhen. Results show the following: in the target year, the amount of the water resource in the Midwest of Shenzhen at most can satisfy the requirements of water consumption of initial rich type at present (2010 year) and the status of balance of supply and demand can be satisfied without water insufficiency and meanwhile, the overload population of each district also continuously increases. In the dry year, the population of the bearing capacity in the Midwest of Shenzhen will be definitely smaller than that of the target year, thus, the stability of the water consumption in the Midwest of Shenzhen is conserved. The thesis proposes the following advices:

- Creating the city of water saving type, try best to develop and utilize the new water resource and develop the water saving technology, establish the well running system of water supply, recycling of intermediate water and sewage processing and increase the utilization ratio of the water resource.
- Establish and perfect the management system of the development and utilization of the water resource, get the sustainable development of the water resource and provide sustainable and reliable water resource for the economic development and people's living of Shenzhen.
- The water used by the Midwest of Shenzhen mainly depends on the water of the Dongjiang River, so to

prevent emergency incidents in Shenzhen; Shenzhen should prepare well form the emergent water supply plan of the reserve reservoir.

- To satisfy the requirement of long-term (2020) water supply, it must increase the supplying amount of the water from the Dongjiang River and be combined with the water supplying project in the western line for water supply.
- For the data is limited, the thesis does not consider the problem of the bearing capacity of the water resource from the aspect of the water environment pollution, thus, this should be improved.

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