

# Analysis of Water Resources Status in Wuding River Basin in Shaanxi Province

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## Abstract

The quantity, quality and availability of water resources in the Wuding River Basin in Shaanxi Province were sorted out, and the existing water conservancy projects in the basin, the water supply and water consumption in 2018 were investigated and counted, and their water consumption indicators and water resources development and utilization rates were analyzed. This paper points out the characteristics and existing problems of water resources development and utilization in Wuding River Basin, and provides important support for the effective development and utilization of water resources, improving the water ecological environment quality in the Basin, and promoting the green, circular, and low-carbon development of the Basin economy.

## Keywords

Wuding River; water resources; development and utilization.

## 1. Introduction

The problem of water resources in China is particularly serious, which has prompted the continuous transformation of China's economic development mode, especially the recognition of the importance of the ecological environment to the development of human society<sup>[1]</sup>. In recent years, due to the influence of natural factors and human life factors, the solute sources and circulation patterns of natural water have gradually become more complicated<sup>[2]</sup>. The natural sources of solutes in rivers mainly include atmospheric deposition and rock weathering, while anthropogenic sources come from human production activities<sup>[3]</sup>. Factors such as continuous population growth, over-exploitation of water resources, and large-scale agricultural intensification have caused serious harm to water resources and the water environment, especially in semi-arid and arid regions<sup>[4,5]</sup>. For example, the proportion of groundwater water in the Wuding River Basin in northern Shaanxi is relatively high, and there is a shortage of renewable water resources, which restricts economic and social development and production and life<sup>[6]</sup>.

The Wuding River Basin (WRB) is located in the central part of the Loess Plateau in China. It is the largest tributary in the source area of sandy and coarse sand in the middle reaches of the Yellow River<sup>[7,8]</sup>. The river originates in northern Shaanxi Province, flows through Inner Mongolia Autonomous Region, and joins the Yellow River in Shaanxi Province<sup>[9]</sup>. The length of the main stream within the boundaries of Shaanxi Province is about 442.8 km, and the basin area is 21737.53 km<sup>2</sup>, accounting for 71.84% of the total basin area<sup>[10]</sup>. The Wuding River is a first-order tributary of the Yellow River and is the largest river in Yulin, which has an important impact on soil erosion in northern Shaanxi and the phenomenon of sediment entrainment in the Yellow River<sup>[11]</sup>. The basin is located in an area with fragile ecological environment, limited water resources, and vulnerable to climate change, which is characterized by sparse vegetation, large evapotranspiration, and serious soil erosion<sup>[12]</sup>. Although a number of soil and water conservation measures have been adopted to control sediment and restore the ecological

environment, these measures also changed the runoff environment<sup>[13]</sup>. Therefore, studying the characteristics and development and utilization of water resources in the Wuding River Basin provides theoretical basis and strategic guidance for evaluating the intensive and economical utilization of water resources in the Wuding River Basin.

This paper studies the quantity, quality and availability of water resources in the Wuding River Basin in Shaanxi Province, investigates and counts the existing water conservancy projects in the basin, and the water supply and water use in 2018, analyzes its water use indicators and water resources development and utilization rate, and analyzes the development and utilization of water resources. The characteristics and problems are sorted out to further evaluate the soil and water loss status of the Wuding River Basin in Shaanxi Province, and provide a reasonable basis for the comprehensive management and sustainable development and utilization of the Wuding River Basin.

## 2. Overview of water resources

### 2.1. Quantity of water resources

The theoretical hydropower capacity of the main stream of WRB is about 163 MW, and the technically developable installed capacity is about 43 MW. Therefore, hydropower resources are abundant and the development potential is huge<sup>[14]</sup>. The area of WRB accounts for 4.2% of the area of the Yellow River Basin, and the average annual runoff of WRB only accounts for 2.4% of the Yellow River Basin, so the internal runoff of WRB is very poor. WRB is one of the important energy and chemical bases in my country, occupies an important position in the national energy development strategy, and is of great significance to the sustainable and stable development of the energy economy in northern Shaanxi.

According to the results of "Survey and Evaluation of Water Resources and Its Development and Utilization in Shaanxi Province (2008)", the results of the evaluation of water resources in the Wuding River Basin in Shaanxi Province using the hydrological series from 1956 to 2000 are shown in Table 1. The average annual runoff of Wuding River is 1.151 billion m<sup>3</sup>, including 997 million m<sup>3</sup> of self-produced runoff in Shaanxi and 1.036 billion m<sup>3</sup> of self-produced groundwater resources. After deducting the duplication of the two, 597 million m<sup>3</sup>, the total amount of self-produced water resources in Shaanxi is 1.436 billion m<sup>3</sup>. The average modulus of water resources in the basin is 65,700 m<sup>3</sup>/km<sup>2</sup>.

Table 1 Water resources scale of Wuding River Basin in Shaanxi Province

The 4th grade area	The total area (km <sup>2</sup> )	Surface water resources (10 <sup>4</sup> m <sup>3</sup> )	Groundwater resources (10 <sup>4</sup> m <sup>3</sup> )	Double counting of groundwater and surface water resources (10 <sup>4</sup> m <sup>3</sup> )	The total water resources (10 <sup>4</sup> m <sup>3</sup> )	Water production modulus (10 <sup>4</sup> m <sup>3</sup> /km <sup>2</sup> )
Wuding River	21859	99700	103600	59700	143600	6.57

### 2.2. Water Quality

The water body of WRB is weakly alkaline as a whole, and there is no significant seasonal difference in hydrochemical types. The water quality of the main stream in the middle and upper reaches is relatively good, and the water quality gradually deteriorates from west to east along the river. The super-III water is mainly distributed in the tributaries during the dry season and the downstream during the flood season. The water quality is highly mineralized and unfit for human consumption<sup>[15]</sup>.

According to the “2018 Shaanxi Provincial Water Resources Bulletin”, the assessed river length of the main and tributaries of Wuding River is 578.4 km, and the annual average: the water quality of Class I-III accounted for 64.7% of the evaluated river length; the water quality of Class IV-V was 64.7%. River lengths accounted for 25.6% of the assessed river lengths; rivers with inferior water quality accounted for 9.7% of the assessed river lengths. The main items exceeding the standard are chemical oxygen demand, total phosphorus, and petroleum. The water quality of the Wuding River Basin in Shaanxi Province in 2018 is shown in Table 2.

Table 2 Water quality of Wuding River Basin in Shaanxi Province in 2018

River system name	Evaluate the river chief (km)	Proportion of classified river lengths in the whole year to the assessed river lengths(%)						
		Class I	Class II	Class III	Class IV	Class V	Inferior Class V	Class I - III
Wuding River	578.4	0	58.6	6.1	19.9	5.7	9.7	64.7

### 2.3. Availability of water resources

According to the “Survey and Evaluation Report on Water Resources and Its Development and Utilization in Shaanxi Province”, the average available surface water resources in the Wuding River Basin in Shaanxi Province for many years is 563 million m<sup>3</sup>, and the available groundwater resources are 364 million m<sup>3</sup>, and the duplication of the two is 2.46 m<sup>3</sup>. The total amount of water resources available in the Wuding River Basin in Shaanxi Province is 681 million m<sup>3</sup>. See Table 3 for the total available amount of the Wuding River Basin in Shaanxi Province.

Table 3 The total availability of water resources in the Wuding River Basin in Shaanxi Province

Watershed	Surface water availability (10 <sup>4</sup> m <sup>3</sup> )	Extractable groundwater (10 <sup>4</sup> m <sup>3</sup> )	Amount of repetition (10 <sup>4</sup> m <sup>3</sup> )	Total available (10 <sup>4</sup> m <sup>3</sup> )
Wuding River Basin, Shaanxi Province	5.63	3.64	2.46	6.81

## 3. Development and utilization analysis

### 3.1. Water conservancy projects

The social development history of Wuding River Basin is also a history of water conservancy project construction. Many water conservancy projects on the Wuding River have promoted production and construction and ecological protection in the basin, improved soil erosion, and ensured the balance of water supply in the basin<sup>[16]</sup>. By the end of 2018, a total of 73 small and medium-sized reservoirs had been built in the Wuding River Basin of Shaanxi Province, with a total storage capacity of 820 million m<sup>3</sup>, 405 large and small water diversion projects, 1,475 pumping stations, and 17,697 electromechanical wells. The current water supply capacity is

about 554 million m<sup>3</sup>. The main water storage projects in the Wuding River Basin in Shaanxi Province in 2018 are shown in Table 4.

Table 4 The main water storage projects in the Wuding River Basin in Shaanxi Province in 2018

Number	Reservoir name	Total storage capacity (10 <sup>4</sup> m <sup>3</sup> )	Hin Lee Kurong (10 <sup>4</sup> m <sup>3</sup> )	Water supply capacity (10 <sup>4</sup> m <sup>3</sup> )	Water supply range
1	Wangge Dua Reservoir	389	110	156	Yumeng Industrial Zone and Yumi Sui Industrial Zone, Yulin City
2	Hongshixia Reservoir	19	11	3	Yulin urban area, facility irrigation area of 4.0×10 <sup>6</sup> m <sup>2</sup>
3	Youjiamao Reservoir	16	9	15	Irrigation and replenishment of Yulin High-tech Zone, Sanchawan Canal and Yugao Canal
4	Zhongyingpan Reservoir	19	17	15	Design irrigation of 7.3×10 <sup>6</sup> m <sup>2</sup> of Yudong Canal irrigation area, supplementary irrigation of 8.67×10 <sup>6</sup> m <sup>2</sup> of downstream old irrigation area, Yushuwan Coal Chemical Industry Zone
5	Hekou Temple Reservoir	61	21	3	Agricultural irrigation
6	Shimao Reservoir	8.45	8.45	6	Yulin City
7	Lijialiang Reservoir	21.4	16.9	31.17	Agricultural irrigation, industry and life
8	Zhouwan Reservoir	96.51	50.8	5.8	Agricultural irrigation
Total		630.36	244.15	234.97	

### 3.2. Water supply

In 2018, the total water supply of the Wuding River Basin in Shaanxi Province was 502.76 million m<sup>3</sup>, and the surface water supply was 325.46 million m<sup>3</sup>, accounting for 64.73% of the total water supply, of which the water storage, water diversion and water lifting projects were 8,623, 15,701, and 8,222 respectively. 10,000 m<sup>3</sup>, accounting for 26.49%, 48.24% and 25.27% of the surface water supply respectively. The groundwater water supply is 169.52 million m<sup>3</sup>, accounting for 33.72% of the total water supply; the unconventional water supply is 7.78 million m<sup>3</sup>, accounting for 1.55% of the total water supply. The water supply situation in the Wuding River Basin in Shaanxi Province in 2018 is shown in Table 5.

Table 5 Statistical table of the total water supply in the Wuding River Basin in Shaanxi Province in 2018

Municipal administrative district	Surface water supply (m <sup>3</sup> )	地下水源供水量 (10 <sup>4</sup> m <sup>3</sup> )	其他水源供水量 (10 <sup>4</sup> m <sup>3</sup> )	Total water supply

	Water storage	water diversion	water lift	Artificial water carrying capacity	Total	Deep water	shallow water	Total	Sewage treatment and reuse	Rainwater utilization	Brackish water	Total	
Yulin City	8585	15668	8135	0	32388	0	16674	16674	6	85	687	778	49840
Yan'an City	38	33	87	0	158	9	269	278	0	0	0	0	436
Total	8623	15701	8222	0	32546	9	16943	16952	6	85	687	778	50276

### 3.3. Water consumption

The total water consumption of the Wuding River Basin in Shaanxi Province in 2018 was 502.76 million m<sup>3</sup>, of which 50.89 million m<sup>3</sup> was used for domestic water use (including 24.62 million m<sup>3</sup> for urban residents and 26.27 million m<sup>3</sup> for rural residents), accounting for 10.12% of the total water consumption; agricultural water consumption ( Including farmland irrigation and forest, animal husbandry and fishery) 336.07 million m<sup>3</sup>, accounting for 66.85% of the total water consumption; industrial water consumption is 100.9 million m<sup>3</sup>, accounting for 20.06% of the total water consumption; urban public water consumption is 10.34 million m<sup>3</sup> (construction industry 4.72 million m<sup>3</sup>, service industry 4.72 million m<sup>3</sup> 5.62 million m<sup>3</sup>), accounting for 2.06% of the total water consumption; ecological water consumption is 4.56 million m<sup>3</sup>, accounting for 0.91% of the total water consumption. The water consumption in the Wuding River Basin in Shaanxi Province in 2018 is shown in Table 6.

The total water consumption in Yulin City is 498.4 million m<sup>3</sup>, of which agricultural water accounts for the largest 67%, followed by industrial water accounting for 20%. The total water consumption in Yan'an City is 4.36 million m<sup>3</sup>, of which agricultural water consumption accounts for the largest 65%, followed by industrial water accounting for 20%.

Table 6 Survey and Statistics of Total Water Consumption in Wuding River Basin, Shaanxi Province in 2018

Municipal administrative district	Life (10 <sup>4</sup> m <sup>3</sup> )		Production (10 <sup>4</sup> m <sup>3</sup> )				Ecology (10 <sup>4</sup> m <sup>3</sup> )	Total water consumption (10 <sup>4</sup> m <sup>3</sup> )		
	Town	Rural	Agriculture	Industry	Urban public service			unconventional water source	surface water	Total
					construction industry	Tertiary Industry				
Yulin City	2444	2549	33325	10033	472	561	456	778	32388	49840
Yan'an City	18	78	282	57	0	1	0	0	158	436
Total	2462	2627	33607	10090	472	562	456	778	32546	50276

### 3.4. Analysis of water use indicators in 2018

In 2018, the per capita water consumption of Yulin City was 248.9 m<sup>3</sup>/person, and that of Yan'an City was 115.3 m<sup>3</sup>/person. Yulin City was higher than the provincial average of 242.5 m<sup>3</sup>/person, but both cities were lower than the per capita water consumption of the national survey and statistical analysis from 1980 to 2000. The reasonable range of quota (430-450 m<sup>3</sup>); the water consumption per 10,000 yuan of GDP in Yulin City and Yan'an City is 22.1 and 17.6 m<sup>3</sup>/10<sup>4</sup> yuan respectively, which are lower than the provincial average of 38.3 m<sup>3</sup>/10<sup>4</sup> yuan; The water consumption of the industrial added value was 11.1 and 9.6 m<sup>3</sup>/10<sup>4</sup> yuan respectively, which were lower than the provincial average of 15.5 m<sup>3</sup>/10<sup>4</sup> yuan; the agricultural irrigation water consumption in each city was lower than the provincial average of 4516.5 m<sup>3</sup>/hm<sup>2</sup>. See Table 7 for the analysis of water use indicators of cities in the Wuding River Basin in Shaanxi Province in 2018.

Table 7 Analysis of water use indicators for cities in the Wuding River Basin in Shaanxi Province in 2018

Project municipal administrative district	per capita water consumption(m <sup>3</sup> /人)	GDP water consumption (m <sup>3</sup> /10 <sup>4</sup> yuan)	Industrial value added water consumption (m <sup>3</sup> /10 <sup>4</sup> yuan)	农田灌溉亩均用水量 (m <sup>3</sup> /hm <sup>2</sup> )
Yulin City	248.9	22.1	11.1	3621
Yan'an City	115.3	17.6	9.6	2265
watershed average	244.8	33.0	13.0	2928
Provincial average	242.5	38.3	15.5	4516.5

### 3.5. Development and utilization of water resources

The annual average self-produced runoff in the Wuding River Basin in Shaanxi Province is 997 million m<sup>3</sup>. According to the results of the "Comprehensive Planning Report on the Wuding River Basin in Shaanxi Province" in 2011, the total water supply of the Wuding River Basin in Shaanxi Province in 2010 was 477 million m<sup>3</sup>, and the surface water supply was 327 million m<sup>3</sup>, accounting for 69% of the total water supply. The development rate of surface water resources is 33%. The water volume supplied by the water storage project, water diversion project and water lifting project is 65 million m<sup>3</sup>, 211 million m<sup>3</sup> and 51 million m<sup>3</sup> respectively. The water storage project only accounts for 19.8% of the surface water supply, and more than four-fifths of the water supply Provided for import and lift projects without storage capacity.

According to the results of the "2015 Shaanxi Provincial Water Resources Bulletin" and related data, the surface water supply in the Wuding River Basin in Shaanxi Province in 2015 was 263 million m<sup>3</sup>, accounting for 56.85% of the total water supply in the basin, and the development and utilization rate of surface water resources was 26.41%.

The self-produced surface water resources in the Wuding River Basin of Shaanxi Province are 997 million m<sup>3</sup>, according to the results of surface water supply and total water supply in the Wuding River Basin in Shaanxi Province in 2018. According to the formula  $WRU=WU/WR$ , where WRU represents the development and utilization rate of surface water resources, WU represents the surface water intake in the river and lake basins, and WR represents the total surface water resources in the river and lake basins. The development and utilization rate of surface water resources is 32.60%. This shows that the Wuding River Basin in Shaanxi Province still has great development potential, which may be related to the fact that 63.2% of the Wuding River Basin is hilly and gully landform, with undulating beams and ridges, and vertical and horizontal ravines, which are not conducive to the construction of water conservancy projects.

## 4. Development and utilization characteristics and existing problems

### 4.1. Development and utilization characteristics

(1) The annual average rainfall in the Wuding River Basin is between 350 and 500 mm, decreasing from southeast to northwest, with large inter-annual variation, with a maximum ratio of about 6 times; the annual rainfall distribution is uneven, and 65% of the rainfall is concentrated in the From July to September, there are many rainstorms with high intensity. The changes of runoff and precipitation in the Wuding River Basin are basically the same, and the coefficient of variation is between 0.27 and 0.40. There are distinct seasons of high and dry during the year. Generally, summer and autumn are high-water periods, and the average flow

can account for 75-86% of the annual average flow. Winter is the dry season, and the average flow accounts for 1.4%-24.4% of the annual average flow.

(2) The degree of water resources development and utilization is high. The amount of water resources in the Wuding River Basin in Shaanxi Province is 1.436 billion m<sup>3</sup>. In 2018, the local water consumption in the basin was 499 million m<sup>3</sup>. The development and utilization rate of water resources in the basin was 32.60%, indicating a high degree of resource development and utilization.

(3) The development potential of water resources in the basin is limited, and water saving is an inevitable choice. The total amount of water resources available in the basin is 681 million m<sup>3</sup>. In 2018, the water consumption in the basin was 499 million m<sup>3</sup>, accounting for 73.27% of the total available water. The development and utilization of water resources in the basin is inversely proportional to its development potential.

## 4.2. Existing problems

(1) The proportion of local groundwater water consumption is relatively high. There is a general over-exploitation area of Jingbian groundwater in the Wuding River Basin. In 2018, the groundwater consumption in Jingbian County was 76.07 million m<sup>3</sup>, accounting for 75.5% of the total water supply in 2018, and the proportion of groundwater water consumption was relatively high;

(2) Insufficient utilization of reclaimed water. In 2018, the utilization of reclaimed water in the Wuding River Basin was 60,000 m<sup>3</sup>, and the utilization rate was 0.3%, of which Yulin City was 0.3%.

## 5. Conclusion

This paper summarizes the general situation of water resources in the Wuding River Basin, the development and utilization of water resources, the characteristics of water resources development and utilization, and existing problems, and further understands the current situation of water resources in the Wuding River Basin, which provides comprehensive water quality management in the basin and effective guidance for water resources in the later stage. The assignment provides theoretical guidance. The analysis shows that although the groundwater resources in the Wuding River Basin are very rich, the decrease of precipitation and the increase of groundwater exploitation have led to the continuous reduction of groundwater resources and serious soil erosion. Therefore, under the condition of total water consumption control, in order to meet the growth of water use in various industries, water conservation must be taken as the premise of water resource development, utilization, protection, allocation, and scheduling, and effective governance measures must be taken to reduce watershed evapotranspiration and control groundwater exploitation. , such as adding surface water storage projects (such as reservoirs) to further limit groundwater extraction or replacement by surface water. In the future river basin management, it is necessary to adhere to and implement the priority policy of water conservation, actively explore new mechanisms and new paths for innovative water conservation in the new era, and effectively promote the transformation of water use to conservation and intensive use, in order to achieve ecological protection in Wuding River Basin and green, low-carbon, high-efficiency Quality development provides an important guarantee.

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