Thirty Years of the Yellow River Water Allocation Scheme and future Prospect

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Abstract. Yellow River is an important source of water for northwest and north China, and an important strategic guarantee for the sustainable economic and social development of the Yellow River basin and its related regions. The Yellow River water allocation scheme (Scheme 1987 in short) was approved in 1987 by the State Council, which was the first river water allocation scheme in China. It allocates a total volume of 58 billion m^3 of water to the 11 provinces along the river and its ecosystem. However, with the deepening impact of climate change and human activities, the Yellow River water resource and its development situations have some changes and the water resource of the drainage basin faces new situations, so it is urgent to carry out the optimization and adjustment study of Scheme 1987 under the new situation. The background and promulgation process of Scheme 1987 was reviewed comprehensively, and its implementation effect for 30 years was analyzed from two periods before and after unified dispatching. The new situation of the development of the Yellow River basin in the future was analyzed, and the work to be carried out to optimize and adjust the Scheme 1987 was prospected.

1 Introduction

The Yellow River is an important water resource of the northwestern and northern China. As it contains 2% of volume of runoff of the country, the Yellow River feeds both 15% cultivated land and 12% of water requirements of people of China, while carrying the responsibility of long-distance water transferring. The per capita river runoff in the Yellow River is 473 cubic meters which is less than 1/4 of the average number of the country and is one of the areas which face the most significant water resource shortage problems. The Yellow River drainage basin supports some important energy sources and major grain producing areas, the demand of water keeps increasing since 1970s while sharpening the imbalance between supply and demand, and down-streams of the Yellow River also face frequent cutoffs since that time. In 1987 China State Council announced the first Chinese major rivers diversion plan — The Yellow River Water Diversion Scheme (Scheme 1987)[1-2], which clarifies different amounts of available water supplies in and out the river-way and between administrative regions, has a positive impact on rational utilization of the Yellow River water resources and water conservation as the basis of water resource management and dispatch. Nowadays, the situation of water resource and the new pattern of the development of the economic society will be significantly changed due to impacts of climate changes and human activities, thus there should be new requirements for water diversion. This essay will firstly conclude the process of the Yellow River diversion, then study results brought by the new scheme during the past 30 years, based on analyze the situation of the Yellow River drainage basin water resource faces and make basis for scientific managing the Yellow River water resource and protecting the sustainable development of drainage basin area and other related areas.

2 Water diversion process

2.1 Background

In 1970s the economy of the Yellow River drainage basin boosted rapidly, and the water consumption was also increased sharply from 6-8 trillion cubic meters in early years of the country to 25-28 trillion cubic meters in 1980s, came with the deficiency of enough management and plan, provinces located on the upstream derivative the river aimlessly, downstream of The Yellow River suffered frequent cutoffs since 1972[2]. From 1972-1986, cutoffs occurred ten times and the total time of cutoff was 165 days, with an average cutoff distance of 260 km per year (Fig.1). Frequent cutoff of the river, on one hand, caused difficulties for downstream provinces on water deficiency on all aspects and delayed the normal development of the economic society, on the other hand, it caused channel siltation, water environment pollution, marsh shrinkage and biodiversity decrease, it caused threats to flood production destroyed the biodiversity of downstream

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areas badly[3]. Thus, under the arrangement of State Planning Commission and Ministry of Electricity and Water, the Yellow River Conservancy Commission of the Ministry of Water Resources (YRCC) worked with provinces the river pass through, published pre-South-to-North water diversion the Yellow River Water Diversion Scheme, which set 1987 as current year and 2000 as target year. In the end, China State Council endorsed and requested to implement in 1987 which represented the birth of the first major river diversion scheme.

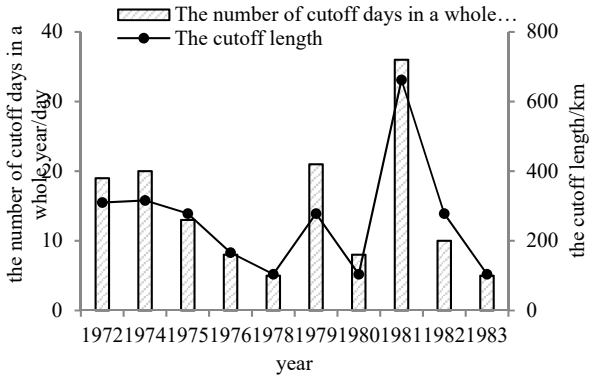

Figure 1. The cutoff situation in the Yellow River from year 1972 to year 1986

2.2 Promulgation and development

2.2.1 The process of promulgation

In November 1982, the No.1021 document from the State Planning Commission requested the planning of the Yellow River water resources utilization in every province along the Yellow River and proposed that the annual water supply in the Yellow River was 69.6 billion cubic meters and exceeded the multi-year average (1919-1975) natural runoff (58 billion cubic meters) for about 12 billion cubic meters. The contradiction between water supply and water demand was extremely prominent.

In March 1983, the No. 285 document from the State Planning Commission requested Ministry of Electricity and Water to start editing the plan of the Yellow River overall development and consumption; in June, Ministry of Electricity and Water held the Yellow River water resources evaluation and overall consumption meeting, during that meeting YRCC made a presentation named Primary advisement of the Yellow River water resources consumption, generally pointed out the consumption of the Yellow River of the planning year 2000 (The available amount of water of the Yellow River was 37.4 billion cubic meters); provinces and regions the Yellow River passed through also gave their water consumption requirements and plan of development, and exchanged their thoughts about the advisement. In the end the then minister Qian Zhengying concluded the meeting and asked each province to make development plan and water consumption predict, and he asked YRCC to absorb good advisements to generate 2000 the Yellow River amount of water prediction for each part report[4].

In 1984, YRCC finished the Yellow River water resources development and consumption precast report and generated General advisement of the Yellow River runoff precast and distribution. Sent to State Planning Commission by Ministry of Electricity and Water. In August of the same year, during national planned meeting, State Planning Commission discussed with related provinces and regions about the advisement, adjusted and published the Yellow River water distribution method, the total amount of water the method considered is 58 billion cubic meters, 37 billion of them was distributed to 9 providences and regions inside the drainage basin and nearby water-deficient areas including Hebei province and (Table 1); 21 billion of them was for ecological water likes sediment transport.

In September 1987, the State Council published No.61 document endorsed the Yellow River water distribution scheme [1] and request related provinces and reigns to implement.

2.2.2 Improvement and development

There have been relative actions to improve the Yellow River water distribution method since the State Council approved the method to ensure the implement of the method. Approved by the State Council, State Planning Commission and Ministry of Water Resources announced Plan for annual water diversion of the Yellow River and mainstream amount of water dispatch plan and the Yellow River amount of water dispatch controlling solution (1998 No.2050 document), which made a clear evidence for overall dispatch of the Yellow River water. On Mar.1st, 1999 YRCC officially implemented overall dispatch of the Yellow River mainstream water and generate Water Resources Governing and Dispatching Bureau.

On Aug. 1st, 2006, the State Council announced and implemented the Yellow River water dispatch rules which authorized overall dispatch period that YRCC could control from non-flood period (From November to June) of the year to whole year.

On Nov. 20th, 2007, Ministry of Water Resources announced and implemented The Yellow River water dispatch rules and examination standard (trail implementation), stated the minimal water flow of critical cross section of The Yellow River tributaries and the assurance rate.

In 2008, The Yellow River Flood Control and Drought Relief Headquarters announced and implemented The Yellow River drainage basin drought resisting precast (trail implementation), and had a general instruction for The Yellow River under certain drought conditions; YRCC announced notification about strengthen the work of detailing of controlling the amount of water diversion from The Yellow River (The Yellow River Water Diversion 2008 No.8), finished the work of distributing the water consumption limitation of each province to prefecture-level division, clarified the mainstream and tributary dispatching of water consumption limitation of each providence or region.

Table 1. The Yellow River water distribution method before south-to-north water diversion project (Unit：0.1 billion m^3)

Provinces (Regions)	Qinghai	Sichuan	Gansu	Ningxia	Inner Mongolia	Shaanxi	Shanxi	Henan	Shandong	Hebei and Tianjin	Total
Annual water consumption	14.1	0.4	30.4	40.0	58.6	38.0	43.1	55.4	70.0	20.0	370

In Oct. 2012, YRCC started The Yellow River drainage basin total water consumption controlling standards planning program, based on Scheme 1987 YRCC confirmed total amount of water consumption standards for provinces The Yellow River passed through for year 2015, 2020 and 2030, which provided evidences for implementing the strictest water resource management.

On Mar. 2nd, 2013, the State Council replied The Yellow River drainage basin overall program, based on changes from The Yellow River water resources and facts of water diversion in between different drainage basins, according to Scheme 1987, set up three The Yellow River water reign resources distribution plans for three periods, which were before the effectiveness of east and central line of South-to-North Water Transfer Project, between the time after the effectiveness of east and central line of South-to-North Water Transfer Project and before the effectiveness the first-stage project of west line of South-to-North Water Transfer Project and after the effectiveness the first-stage project of west line of South-to-North Water Transfer Project. The process of developing Scheme 1987 is shown in Figure 2.

3 The effects of implement the yellow river water diversion scheme

The essay divides the total time into two parts: 1987-1998 and 1999-2016, according to the time YRCC started The Yellow River Water Unified Schedule, to discuss the effect of the implementation of the scheme from inside the channel and outside the channel.

3.1. Before Unified Schedule (1987-1998)

3.1.1 Outside of the channel

From year 1987 to 1998, since the Unified Schedule was not applied, water allocation and related work was not applied in normal years neither, regulation scheme was only applied in extreme dry year (1997). To do contrastive analysis for planned water consumption and actual water consumption for each year, the planned water consumption should be generated by converting from the runoff from Huayuankou. The water consumption of The Yellow River drainage basin (including outside of basin areas) increased rapidly in that period of time, the total water consumption grown from 41.6 billion cubic meters in 1985 to 50.4 billion cubic meters in 1998, the amount of increase in 13 years was 8.8 billion cubic meters, but the actual water consumption never excess the planned value; (Fig.3) (Data starts from 1988) however, Inner Mongolia and Shandong province still had big issues on passing consumption limitation. Inner Mongolia past the consumption limitation 8 times in this 11 years, in 1991 the water consumption in Inner Mongolia reached 7.16 billion cubic meters and excess the consumption limitation for 1.7 billion, the average number for annual excess water consumption was 0.58 billion cubic meters; Shandong province past the consumption limitation each year and in 1989 the largest water consumption was 13.48 billion which excess the limitation for 5.25 billion, and the average number for annual excess water consumption was 1.46 billion(Fig.4).

3.1.2 Inside of the channel

During 1987-1998, cutoffs often appeared at downstream of The Yellow River which, according to data, showed up 61 times and 905 days in total. The average cutoff distance was 377 kilometers. Compared with situations during 1972-1986, the first cutoff time for each year was earlier, cutoff date was longer, cutoff date at major flood period was longer, total cutoff date was longer, average cutoff distance was longer, etc. (Table 2). During this period, although total water consumption of the Yellow River did not pass the limitation, cutoff situations at downstream were more serious. There are two main reasons behind this, firstly, volume of runoff declined from 55.67 billion cubic meters in year 1972-1986 to 47.21 billion cubic meters in 1988-1998; secondly, Inner Mongolia water consumption and Shandong Province water consumption was way more than the planned value by irrigation from April to June, which had influence on water flow into the sea.

Table 2. Cutoff situation comparison in The Yellow River in Year 1987—1998 and Year 1972—1986

Period	The first day of cutoff	The total number of cutoff times	The total number of cutoff days from July to September	The number of cutoff days in one year			Average cutoff length (km)
				All-day	Intermittent	Total	
1972—1986	April 23rd	24	21	110	35	145	260
1987—1998	January 1st	61	176	792	113	905	377

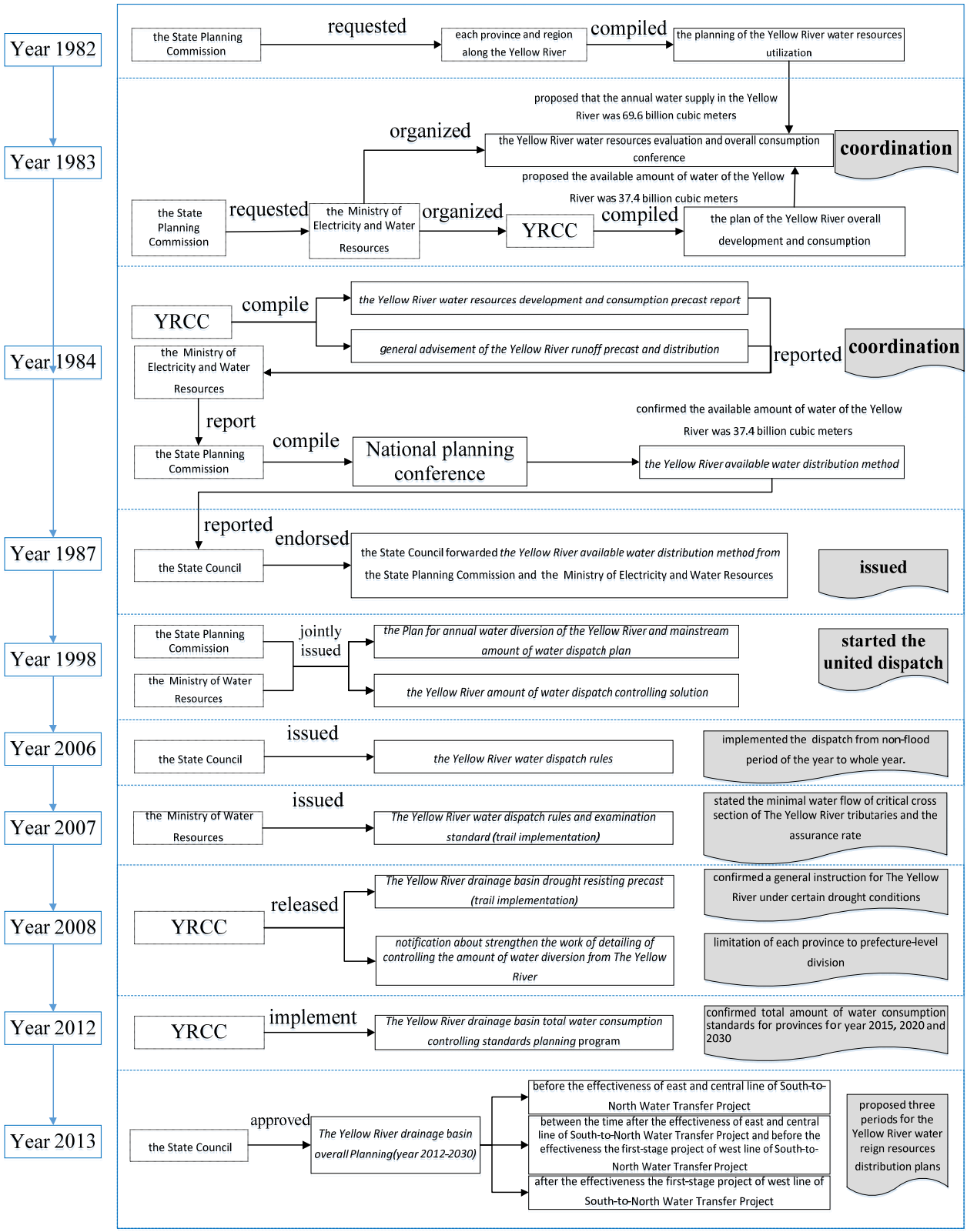

Figure 2. The promulgation and development process of The Yellow River Scheme 1987

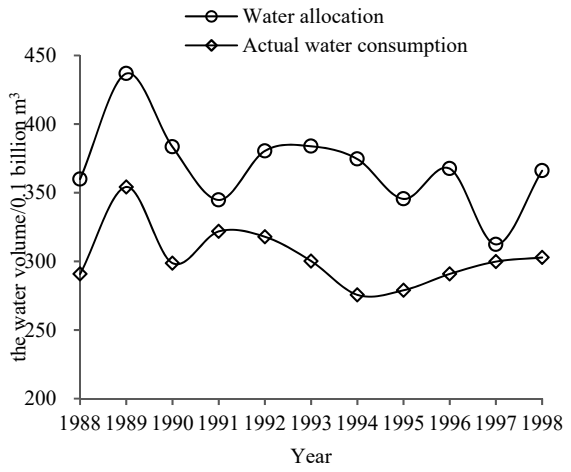

Figure 3. The water allocation and actual water consumption from year 1988 to 1998

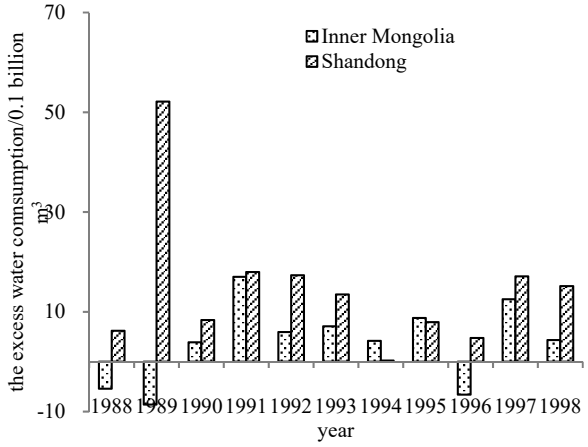

Figure 4. The situation of excess water consumption in Inner Mongolia and Shandong from Year 1988 to 1998

3.2 After Unified Schedule (Year 1999-2016)

3.2.1 Outside of the channel

To make sure the 87 The Yellow River Water Diversion Scheme implemented effectively, YRCC started running a system called mainstream water consumption unified schedule authorized by State Development Planning Commission and Ministry of Water Resources. By coordinating water consumption for each province, the Yellow River pass through, the total water consumption plateaued and differences between years became tiny. Average annual water consumption kept around 50 billion cubic meters for years. Compare planned water consumption and actual water consumption (table 3), we can see that in 1999-2013, the 87 The Yellow River Water Diversion Scheme implemented satisfyingly. Actual water consumptions for provinces were less than planned value ignoring extreme dry year; the overusing situation still occurred in Gansu, Ningxia, Inner Mongolia and Shandong Provinces (Reigns), but the overused part was decreasing and became stabilized; from 2014 to 2016 overusing behavior occurred in mentioned provinces and regions again and overused part kept increasing (Fig.5).

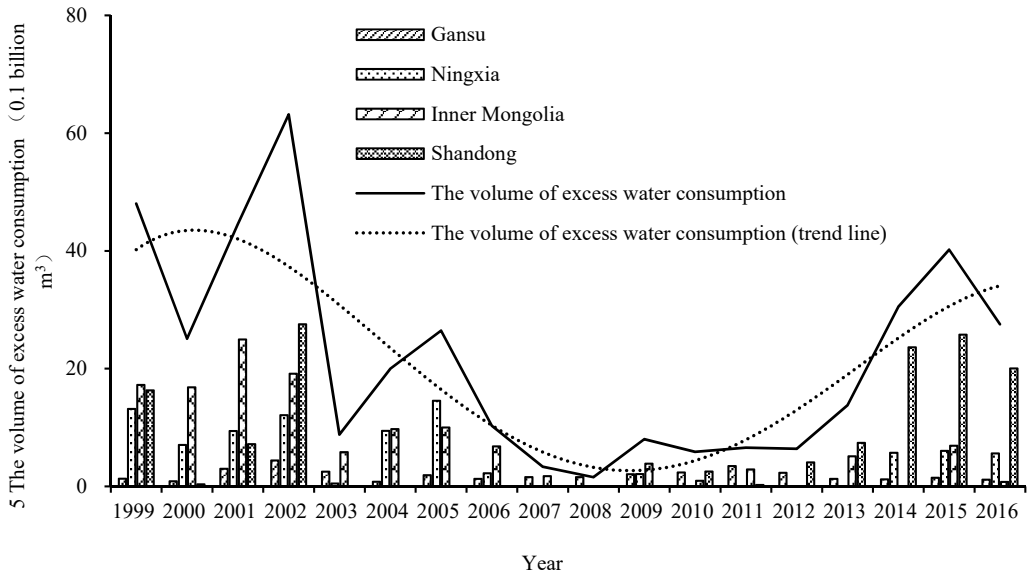

Figure 5. The volume of excess water consumption in the main stream of The Yellow River of each year in Gansu, Ningxia, Inner Mongolia and Shandong which are the provinces (regions) of regular excess water (assign 0 for non-excess water consumption)

Table 3. Results of applying of 87 The Yellow River diversion schemes and discharge into sea from Lijin in Year 1999—2016（0.1 billion m^3）

Year	planned water consumption of allocation	Actual water consumption	Excess water consumption *	Discharge into sea at Lijin cross section (whole year)	Discharge into sea at Lijin cross section (non-flood season)
1999	310	299	-11	62	17
2000	293	272	-21	42	31
2001	258	265	8	41	33
2002	237	286	49	35	12
2003	271	244	-27	190	69
2004	308	249	-59	196	90
2005	328	268	-60	204	93
2006	343	305	-38	187	115
2007	324	289	-35	200	78
2008	340	296	-44	142	87
2009	335	307	-29	128	70
2010	320	309	-11	188	61
2011	348	334	-14	179	88
2012	366	323	-43	277	128
2013	347	332	-15	232	106
2014	321	339	18	109	71
2015	314	340	27	127	84
2016	322	296	-16	81	37
average	316	297	-18	146	71

*positive value stands for the actual water consumption is higher than the planned water consumption of allocation, and negative value stands for the actual water consumption is lower than the planned water consumption of allocation.

3.2.2 Inside of the channel

By executing primary controlling cross section warning and the smallest flow standards of inflow cross-section of the Yellow River strictly, the frequent cutoff phenomenon during 1970s-1990s was ended. Cutoff was never show up again under continuous dry year situation from August 11th, 1999 for 18 years, and the water amount warning was not appeared for 12 years. The mainstream cross section water amount at each province was generally acceptable, although in some years the actual situation still did not match the objective of 5 billion cubic meters of water amount in non-flood seasons, 18.7 billion cubic meters for annually average of water amount emptying into the sea and no existence of functionally cutoff [5]. The data for water amount of emptying into the sea at Lijin cross section from 1999-2016 is in table 3.

4 New situations the water resources of drainage basin face

Nowadays, 87 Yellow River Water Diversion Scheme has been applying for thirty years, it played a huge role in relieving conflicts from supplying and demanding of the Yellow River water resource and protecting the safety of providing water resource along the drainage basin; at the same time, The Yellow River water resource and its development situations have some changes and the water resource of the drainage basin faces new situations:

(1) The economy development and water consumption of the drainage basin has changed a lot.

Comparing with year the 87 the Yellow River Water Diversion Scheme studied at (1980), nowadays (2016) the economic society development, amount of water consumption and water consumption structure of each province (region) has changed a lot. GDP of The Yellow River drainage basin has risen from 33 trillion Yuan in

1980 to 6294.6 trillion Yuan; ratios of GDP of each province or region in total drainage basin GDP have differences too, compare with them in 1980, ratios of GDPs of Gansu, Shanxi, Qinghai province decline 8.5%, 6.9% and 1.4% respectively; ratios of GDPs of Inner Mongolia, Henan, Shaanxi, Shandong and Ningxia province (region) incline 11.5%, 2.1%, 1.9%, 1.2% and 0.2% (Fig. 6a). The total water consumption of The Yellow River drainage basin increase from 34.3 billion cubic meters in 1980 to 39.8 billion cubic meters in 2016, ratios of water consumption of each province or region in total drainage basin water consumption have differences too, compare with them in 1980, ratios of amount of water consumption of Ningxia, Shandong, Henan and Qinghai province (region) decline 5.0%, 1.8%, 0.5% and 0.4% respectively; ratios of amount of water consumption of Inner Mongolia, Shanxi, Gansu and Shaanxi province incline 39%, 2.1%, 1.6% and 0.1% (Fig. 6b). Comparing from changes in water consumption categories, the ratio of agricultural water declines from 87.0% in 1980 to 70.0% in 2016, the ratio of manufactural water inclines from 7.9% in 1980 to 14.2% in 2016 and the ratio of domestic water inclines from 5.1% in 1980 to 15.8% in 2016. The structure of water consumption in each province (region) is also changed, the ratios of agricultural water of all provinces (regions) decline, specific numbers for Shandong, Henan, Shaanxi province, to be specific, are 33.1%, 31.4% and 26.3% and numbers for other provinces (regions) are about 10% respectively; as we look at the ratio of manufactural water take into total water consumption, most provinces (regions) boost the percentage, for example, ratios for Henan, Shandong ad Shaanxi province are 17.9%, 12.4% and 9.2%; Qinghai province and Gansu province are the only exceptions, the ratio of manufactural water take into total water consumption decline 2.2% and 0.6% respectively; the percentage domestic water take into total water consumption for all provinces (regions) incline respectively, the number for Shandong province is 20.7% and 17.1% for Shaanxi province, Henan, Shanxi, Qinghai and Gansu province incline the percentage for about 10% and Ningxia and Inner Mongolia incline the ratio for about 5% (Fig.7).

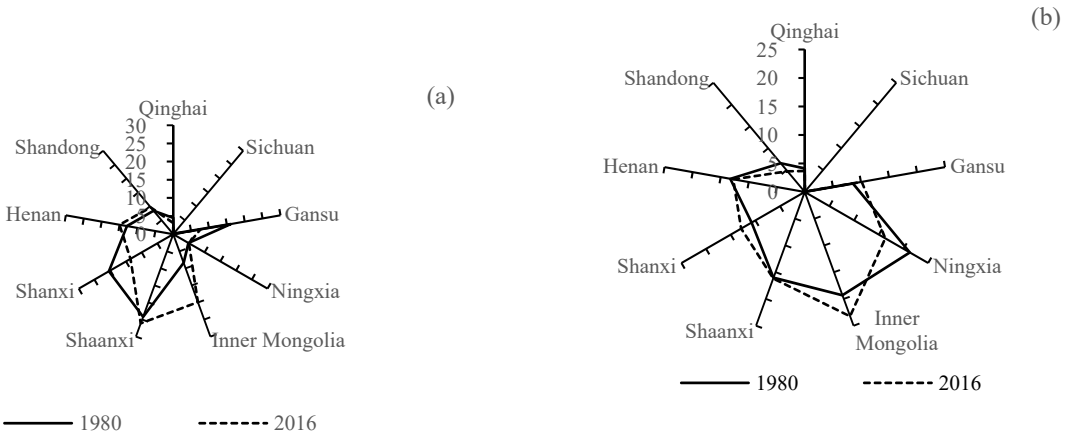

Figure 6. The comparison of GDP and water consumption situation in each provinces and regions for year 1980 and year unit：%. (a) The GDP ratio of each provinces and regions to The Yellow River Drainage Basin; (b) The water consumption of each provinces and regions to The Yellow River Drainage Basin.

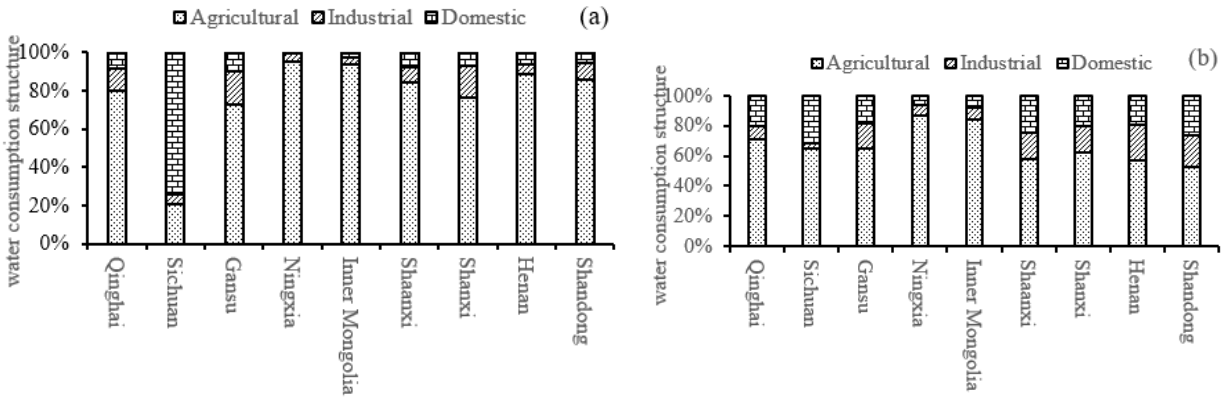

Figure 7. The comparison of water consumption structure for year 1980 and year 2016. (a)year 1980; (b)year 2016

(2) The water-and-sand situation of the drainage basin has significantly changed.

Effecting by climate changes and human activities, the water-and-sand situation of the drainage basin has changed significantly. The Yellow River Water Diversion Scheme is enacted based on an average runoff

water of 58 billion cubic meters (1919-1975) for years. In these years, the situation of The Yellow River water resources has significantly changed. During 1956-2000 and 1956-2010 the average natural runoff decreased to 53.5 billion cubic meters and 48.2 billion cubic meters respectively, the ratio of decreasing is 8% and 17% respectively. At the same time the Yellow River primary cross section sediment discharge decreased significantly too, sediment discharge at Xiaolandi decreased from 790 million tons at the period of 1987-1998 to 90 million tons at the period of 1999-2015, sediment discharge at Lijin cross section decreased from 430 million tons at the period of 1987-1998 to 130 million tons at the period of 1999-2015 decreasing rate was 89% and 70% respectively (Fig.8).

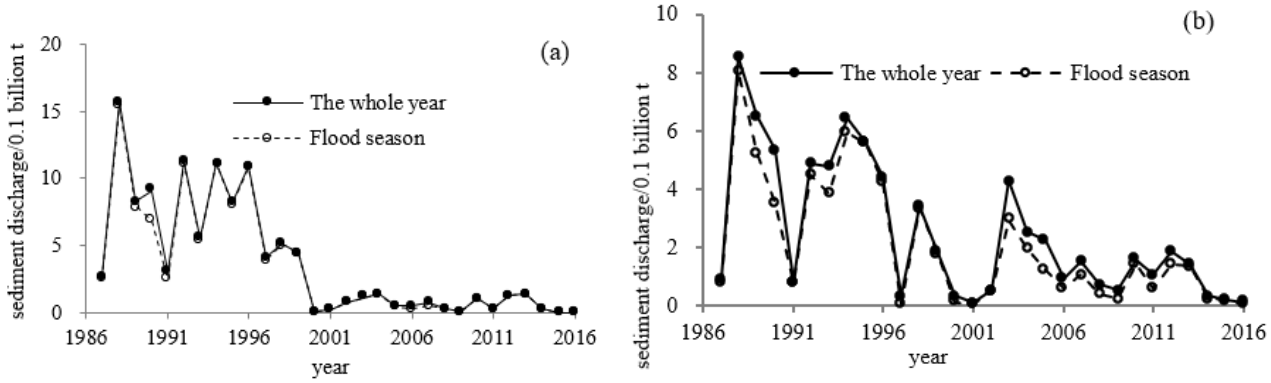

Figure 8. The sediment discharge of main cross section in The Yellow River from 1987-2016. (a)Xiaolangdi; (b)Lijin

(3) The increasing of water demanding will be sharper in the future.

The water demanding of The Yellow River drainage basin, caused by economic society development, in the future will have increase with no doubt. In these years the State Council published Plan for main functional area nationwide and Plan of new type urbanization, generated some strategies like synergetic development of Beijing-Tianjin-Hebei region and One Belt and One Road programs, had new strategies on energy safety, grain safety, urbanization, ecological civilization construction and reginal synergetic development, and will cause direct impacts on The Yellow River economic society water demanding, including these following points, firstly, country develop blueprint have more requirements on manufactural water of The Yellow River drainage basin, the predicting manufactural water will be 11 billion cubic meters in 2030; secondly, high-standard new type urbanization and major cities along the Silk Road Economic Belt will cause more water demand on domestic water, the predicting number in 2030 will be 6.5 billion cubic meters; thirdly, grain safety will have more requirement on agricultural water. There are three major agricultural production areas in The Yellow River drainage basin out of seven in the country, the predicting agricultural water will be 34.7 billion cubic meters in 2030; fourth, construction of water ecological civilization will have more requirements on keeping a healthy river and lake function and a balance between human activities and water system. The Yellow River drainage basin involve 5 out of 25 premium ecological function areas across the country, the predicting ecological water out of the channel will be 2.5 billion cubic meters in 2030. To sum up, the water demand of The Yellow River drainage basin economic society will increase with time.

(4) Changes on drainage basin water conservancy project layout.

To ease the restrict bring by deficiency of water in the Yellow River to economic society development and ecological civilization construction, the country and related provinces (regions) pushed plan and construction of relative works positively, thus the water supply and drought conditions can be ease at part of the drainage basin. The Yellow River drainage basin construction arrangement has changed significantly, east line and first-stage project of central line of South-to-North water diversion project become active one by one, dams like Xiaolangdi dam, Guxian dam and Luhun dam are put into work one by one and the total reservoir storage for all built dams on mainstream of The Yellow River reaches more than 90 billion cubic meters; Shaanxi province appealed Hanshui River to fill Weihe River project has finished; medium and large size irrigated areas continuous constructions and water saving transform projects keep constructing, Lanzhou water source project is under construction in Gansu province; huge water net plan and Bailongjiang River water diversion project is actively working.

(5) New requirement of national water resource governing.

On Jan. 12th, 2012, the State Council published The State Council's Idea on Running the Strictest Governing Policies on Water Resources (2012 No.3 document), clearly mentioned the guidance idea, the fundamental principle, the target, governing measures and guarantee measures of executing the strictest water resource governing policies, including making sure three limitations: water recourses development and consumption limitation, water consumption efficiency limitation and water functional area pollution limitation, and four policies: total water consumption controlling policy, water consumption efficiency controlling policy, water functional areas pollution controlling policy and water resources governing responsibility and examination policy, which is a file of guidance for water

resource work at present and in the future. During 18th Party Congress of China, Xi Jinping mentioned Water saving is a priority work, spatial equilibrium, governing systematically and government should improve the ability of governing water resource, clear the target of new era water governing; base on the development concepts, clear pointed out total requirements: Executing the strictest water resources governing policy, society economic development must meet water resource capability and city development must meet water resource capability to build a water saving society.

5 The future of water diversion

Nowadays the Yellow River faces new challenges brought by situations like the change of water-sand condition, economic society development, built up major water construction and new requirements for water resource management. To solve the problem of The Yellow River drainage basin development and protection, improving The Yellow River drainage basin and sustainable development of related areas economic society and ecological systems, listed The Yellow River water diversion questions need to be solved:

(1) Dynamic evaluate water resource of The Yellow River drainage basin under changing environment and water demand evolution; reveal the fact behind drainage basin water resource supply and demand under changing environment; improve the technique of changing conditions drainage basin water resource evolution and water demand precisely precast, raise the precise prediction of The Yellow River drainage basin generalized water resource amount, its tendency of changing and the drainage basin water demands under changing conditions, decide the tendency of demands and supplies of The Yellow River drainage basin water resource. Main ideas are:

• Using distributed model and changing the pace of time method, coupling natural circulation system and artificial collateral system to simulate all kinds of runoff field and the process of conflux of runoff yield like excess infiltration, filling up and mixing; achieving the transition and unified dynamic analysis of meteoric water, surface water, soil water and ground water; building up the water balance relationship in close drainage basin and replying on generalized The Yellow River drainage basin water resource under frequent human activities.

• Dividing water resource requirements into domestic usage, manufactural usage and agricultural usage, and dividing the influence of demanding water into two elements, the first is positive element which increase the water demand such as economic target, living condition and urbanization, the second is negative element which decrease the water demand such as technology advancement, the price of using water, pollution governing; building up water demand trigger elements model and issuing The Yellow River drainage basin water demanding precisely predict under multi influence elements.

• By stimulating water transition system and balance relationships of rainfall in all forms, the change in available amount of water can be concluded; by filtering the main influential elements of water demand, generating controlling factors of water demand model to predict the change of economic society water demand, considering both water demand and water supply, the rule and tendency of water supply and demand relation of The Yellow River can be determined.

(2) Get adept to water resources dynamic balance; create water resources dynamic balanced configuration for water lacking areas in the drainage basin; improve the technique of water resource balance control and dynamic configuration for water lacking areas, raise the plan of water resources dynamitic balanced configuration which is well-adapting to the changing circumstance, one step further, raise the modification adjustment of Yellow River Scheme 1987. Main ideas are:

• Unify the economic value, social value and ecological value as a general value by using energy theory as the efficient driving force of water resource configuration; apply Gini coefficient to measure the space-time balance the harmony of supplying water as the control variable of water resource configuration, to generate a theory of water-lacking water resource dynamic balanced configuration with both efficiency and fairness.

• Use the water resources dynamic balanced configuration as guidance, adopting approximate ideal point method to do normalization processing and linear weight ensemble to two repealing targets to construct generalized value driving and regional balanced coordinating and controlling drainage basin dynamic balanced model.

• Facing 30 to 50 years in the future, study the regulation such as irregular water resource usage and water-sand replacement from the supplying side, analyze its effect on increasing effective supply of Yellow River water resource; study the regulation such as research on effective water saving, industrial structure modification and scale modification from demanding side, analyze its effect on decreasing potential demand on water resource; base on all of these to generate a analyze method of drainage basin water resource supply and demand bilateral linkage and construct sets of solution of drainage water resource regulation.

• Use the dynamitic balanced model to analyze all kinds of regulations, then generate the Yellow River Scheme 1987 optimize advisement to provide more resources for Yellow River medium-and-long-period regulation.

(3) Multi-dimensional coordinated dispatch of cascade reservoirs in the Yellow River. With revealing the ecological coupling mechanism and synergistic control principle of water, sediment and electricity in complex cascade reservoirs, this paper constructs a multi-dimensional coordinated scheduling platform for cascade reservoirs of the Yellow River and proposes a multi-dimensional coordinated dispatch optimization scheme for the Yellow River cascade reservoirs in response to different water and sediment conditions. The main ideas are:

• Considering different needs such as water supply in the drainage basin (minimum water shortage), river

sediment transport (maximum river sediment transport), system electricity generation (maximum electricity generation), river ecology (flow within the river channel to meet ecological flow demand)，the dispatch process of coordinated cascade reservoirs achieves the optimal utility of the river system.

• In the coupled river system, watershed water supply, river sediment transport, system electricity generation, river ecology and other targets， for the reservoir discharge process, establish a multi-dimensional collaborative dispatch model of cascaded reservoirs, using time-space dimensionality reduction technology to solve the multi-objective problem, using length nesting method to have the process control quantity of electricity generation, sediment and ecological dispatching using the total amount of water in the year, and refine the process to the day. Finally connect the total amount of water quantity dispatching in the river section with the section and node process to achieve nested conversion and multi-process coordination in different time and space scales.

Acknowledgments

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